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قـائـمـة الـمـحـتـويـات

القسم العربي:

Influence of Aging Time on Asphalt Pavement Performance

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ABSTRACT

Aging of asphalt pavements typically occurs through oxidation of the asphalt and evaporation of the lighter maltenes from the binder. The main objective of this study is to evaluate influence of aging on performance of asphalt paving materials.

Asphalt concrete mixtures, were prepared, and subjected to short term aging (STA) procedure which involved heating the loose mixtures in an oven for two aging period of (4 and 8) hours at a temperature of 135 ^{o} C. Then it was subject to Long term aging (LTA) procedure using (2 and 5) days aging periods at 85 ^{o} C for Marshall compacted specimens.

The effect of aging periods on properties of asphalt concrete at optimum asphalt content such as Marshall Properties, indirect tensile strength at 25 ^{o} C, Resilient Modulus and resistance to permanent deformation were evaluated.

The impact of Short-term and long-term aging on asphalt concrete properties was evaluated. The stiffness of the mixture increases by increasing aging period that lead to increase of Marshall Stability, indirect tensile strength, and the resilient modulus, which leads to increases the resistance of mixtures against permanent deformation. The 8 hr. short term aging causes the Marshall stability, indirect tensile strength at 25 ^{o} C and resilient modulus to be increased by 52%, 34 % , 20% respectively as compared with control mixture while, the permanent deformation decreased by (33 %) as compared with control mixture.

Key words: Marshall Properties, indirect tensile strength, permanent deformation, short-term ageing, long-term aging.

تأثير زمن التقادم على اداء الرصفة الإسفلتية

الاستاذ سعد عيسى سرسم **سامر مؤيد عبد المجيد**
قسم الهندسة المدنية، كلية الهندسة-جامعة بغداد

الخلاصة

تقادم التبليط الاسفلتي عادة ما يحدث من خلال أكسدة الإسفلت وتبخر المواد المتطايرة من الاسفلت الإسمنتي. الهدف الرئيسي من هذه الدراسة هو تقييم تأثير التقادم الزمني على اداء الاسفلت الاسمنتي ومواد الرصفة الإسفلتية. تم تحضير الخلطات الإسفلتية باستخدام أنواع الاسفلت المختلفة حيث عرضت هذه الخلطات للتقادم القصير الامد والذي يتضمن تسخينها في الفرن لفترات زمنية (4, 8) ساعة عند درجة حرارة 135 درجة مئوية (وهي مفككه) ثم عرضت هذه الخلطات للتقادم الطويل الامد خلال فترات زمنية مختلفة (2 , 5) يوم عند درجة حرارة 85 درجة مئوية بعد رصها الى نماذج. تم دراسة تأثير زمن التقادم على خواص الخلطات (خصائص مارشال , قوة الشد غير المباشر عند 25 درجة مئوية, ومعامل المرونة ومقاومة التشوه الدائم) التي تم تحضيرها عند المحتوى الاسفلتي الامثل .تم تقييم تأثير التقادم قصير الامد وطويل الامد على خصائص الخرسانة الإسفلتية. ان صلابة الخلطة تزداد بزيادة زمن التقادم الذي يؤدي إلى زيادة ثبات مارشال، والشد غير المباشر، ومعامل المرونة، الأمر الذي يؤدي إلى زيادة مقاومة الخلطة ضد التشوه الدائم. ان زمن التقادم بمقدار 8 ساعات يؤدي الى

زيادة كل من قيم ثبات مارشال ومقاومة الشد غير المباشر عند درجة حرارة 25 مئوية ومعامل المرونة الحركي بمقدار 25%, 34%, 20% على التوالي عند المقارنة مع الخلطة المرجعية بينما قل التخدد بمقدار 33% عند مقارنته بالخلطة المرجغية.

الكلمات الرئيسية : خصائص مارشال, قوة الشد غير المباشر, الانفعال الدائم, التقادم قصير الامد, التقادم طويل الامد

1. INTRODUCTION

One of the major problems facing asphalt during its service life is the "aging" process, Aging causes the asphalt to stiffen and become brittle which leads to a higher potential for fatigue and thermal cracking.

Asphalt paving mixtures are used as surface or base layers in a pavement structure to distribute stresses caused by loading and to protect the underlying unbound layers from the effects of water. To adequately perform both of these functions over the pavement design life (age), the mixture must also withstand the effects of air (oxygen) and water, resist permanent deformation, and resist cracking caused by loading and the environment, **Bordea et al., 2002**.

Aging is one of most and important factors that affect performance of asphalt pavement because other factors of failure (moisture damage , thermal cracking ,rutting , and fatigue) affect certain mode of pavement performance while aging factor enters as cause of failure for each mode. It is necessary to study aging effects on asphalt and asphalt aggregate mixture separately for two reasons .First, during mixing and laydown process, asphalt properties are most affected by aging than aggregate; therefore performing aging tests on asphalt only gives ideal about performance of asphalt mixture. Second, the presence of aggregate mixed with asphalt render asphalt behaves in another mode under aging effects, **Sarsam and Lafta, 2014.**

Ageing is primarily associated with the loss of volatile components and oxidation of the bitumen during asphalt mixture construction (short-term ageing) and progressive oxidation during service life in the field (long-term ageing). Bitumen slowly oxidizes when in contact with air (oxygen) increasing the viscosity and making the bitumen harder and less flexible. The degree of viscosity is highly dependent on the temperature, time and the bitumen film thickness. Excessive age hardening can result in brittle bitumen with significantly reduced flow capabilities, reducing the ability of the bituminous mixture to support the traffic and thermally induced stresses and strains, which contribute to various forms of cracking in the asphalt mixture, **Brown et al., 1995**.

2. BACKGROUND

Ageing of bituminous binders in asphalt mixtures is well studied because of its effect on the mechanical performance of the binder and the durability of the asphalt pavement. Since some of the most important rheological properties of bitumen depend on the chemical constitution, **Simpson et al., 1961**, and the ageing mechanism affects the chemical composition it is clear that also the rheological properties of the binder will change. **Jamieson and Bell, 1995**, found a good correlation with aged road mixtures from 14 to 19 years old pavements, when the long-term step was extended from 4 to 8 days. They concluded that the short-term oven aging (STOA) method showed an equivalence of 0-2 years and the long-term oven aging (LTOA) method up to 5-15 years, depending on the climate.

Harvey and Tsai, 1997, conducted a laboratory study to investigate the influence of long-term oven aging on the fatigue of asphalt concrete beam specimens using controlled-strain loading. They used two sources of asphalt AR-4000 and one type of aggregate. Their results show that aging is sensitive to the type of asphalt used and that stiffness increase associated with aging does not necessarily reduce the beam fatigue life. The application of the beam fatigue and stiffness results in the analysis of thin and thick pavement sections indicated that aging

prolonged the fatigue life of the pavement structure, **Korsgaard et al., 1996**. Oxidized compacted mix specimens (5% bitumen, 1.1-5.8% air voids) using the pressure ageing vessel (PAV) test developed under the SHRP research program for oxidizing bitumen. They oxidized the mix specimens at 100°C and 2.1 MPa of air for up to 72 hours. The penetration and softening point of the extracted bitumen were measured. They reported that the rate of oxidation of pure bitumen (presumably as 3.2 mm films) was 4 times faster than that of bitumen in the mix.
Hachiya et a.,l 2003, prepared compacted slabs of dense mix and cut them into 20x40x250 mm beams. They oxidized these in an oven at 70°C for up to eight hours and measured the flexural strength, strain at failure and stiffness of the mix at –10° to 30°C. They also carried out oxidation experiments at 60°C in a pure oxygen atmosphere for up to 20 days. The laboratory results were compared with data from samples exposed outdoors for up to five years, showing similar trends (though with quantitative differences); and conclude that a combination of the two oxidation methods would be most suitable. Their data seem to show that measured flexural properties were relatively insensitive to oxidation time (as opposed to test temperature). Though the authors do not correlate laboratory oxidation time to field ageing period, their data suggest that five days' exposure to pure oxygen at 60°C is approximately equivalent to 3 years' field ageing, based on flexural properties over 0°C.

3. MATERIAL CHARACTERIZATION

The materials used in this work, namely asphalt cement, aggregate, and fillers were characterized using routine type of tests and results were compared with State Corporation for Roads and Bridges Specifications (**SCRB, R/9 2003**).

3.1 Asphalt Cement

The asphalt cement used in this work is a 40-50 penetration grade. It was obtained from the Dora refinery, south-west of Baghdad. The asphalt properties are shown in **Table 1.**

3.2 Aggregate

The aggregate used in this work was obtained from Al-Nibaie quarry; it consists of crushed quartz, hard, tough, grains, free of injurious amount of clay, loam or other deleterious substances. This aggregate is widely used in Baghdad city for asphalt concrete mixes. The coarse and fine aggregates used in this work were sieved, and recombined in the proper proportions to meet the wearing course gradation as required by specification (**SCRB, R/9 2003**). The physical properties and selected gradation curve for the aggregate are presented in **Table 2.** and **Fig. 1.**

3.3 Filler

The filler is a non-plastic material that passing sieve No.200 (0.075mm). In this work, the control mixes were prepared using ordinary Portland cement (from Tasluga factory) as a mineral filler at a content of 7 percent, this content represent the mid-range set by the **SCRB, 2003** specification for the type IIIA mixes of wearing course. The physical properties of the filler are presented in **Table 3.**

4. PREPARATION OF MIXTURES

Three types of mixtures have been prepared in the study using Marshall Method, control mixture; short and long- term aged mixtures.

4.1 Preparation of Control Mixture

The efficiency of mixing procedure depends on providing homogenous mix and uniform coating of aggregate with asphalt. Asphalt mixtures were prepared in this investigation as follows: The aggregates are washed, dried to a constant weight at 110 ºC, and then sieved. The combined aggregate was heated to a temperature of (160 ºC) before mixing with asphalt cement. The asphalt cement was heated to a temperature of (150 ºC) to produce a kinematic viscosity of (170±20) centistokes. Then, asphalt cement was added to the heated aggregate to achieve the desired amount, and mixed thoroughly by hand for 2 minute until all aggregate particles are coated with asphalt cement. The Marshall Mold assembly were (101.6 mm) in diameter and (63.5 ±1.27 mm) in height. Spatula and compaction hammer were heated on a hot plate to a temperature between (90-150 ^{o} C). The asphalt mixture was placed in the preheated mold and it was then spaded vigorously with the heated spatula 15 times around the perimeter and 10 times in the interior. The temperature of the mixture immediately prior to compaction was between (140-150^{o} C). Then, 75 blows on the top and bottom of the specimen were applied with a compaction hammer of 4.535-kg sliding weight, and a free fall of (457.2 mm). The specimen in mold was left to cool at room temperature for 24 hours and then it was removed from mold by using sample extractor. The asphalt concrete was prepared as per **AASHTO, 1994** procedure.

4.2 Preparation of Aged Mixture

Aging of mixture was conducted in accordance to **AASHTO**, **SP2 2002**. The short-term mixture conditioning for the mechanical property testing procedure is designed to simulate the plant-mixing and construction effects on the mixture. The long-term mixture conditioning for the mechanical property testing procedure is designed to simulate the aging the compacted mixture will undergo during seven to ten years of service.

4.2.1 Short-term aging

The same procedure to prepare the control mixture was adopted; but after preparation of the mixture, the loose mix was placed in a pan, and spread to an even thickness ranging between 25 and 50 mm. the mixture in pan was placed in the conditioning oven for (4, 8) hr. at a temperature of 135 °C and Stir the loose mix every 60 minutes to maintain uniform conditioning. After aging process, the loose mix was removed from the forced-draft oven. The conditioned mixture is compact by Marshall Hammer in the same procedure as that of virgin sample.

4.2.2 Long-term aging

In order to simulate long-term aging of HMA that occurs during the pavement service life, Marshall sized compacted specimens prepared from mixtures exposed to short-term aging were placed in a forced-draft oven at 85°C for (48,120) h. At the end of the aging periods, the oven is switched off and left to cool to room temperature before removing the specimens. The specimens were not tested until at least 24 h after removal from the oven.

5. EXPERIMENTAL WORK

The experimental work was started by determining the optimum asphalt content for all the asphalt concrete mixes using the Marshall mix design method .**Table 4** shows that the optimum asphalt content (O.A.C) for asphalt concrete mixture of 4.7% and the performance properties.

5.1 Marshall Test Method

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of the Marshall apparatus according to **ASTM (D 1559).** Marshall Stability and flow tests were performed on each specimen. The cylindrical specimen was placed in water bath at 60 ˚C for 30 minutes, then

inserted into the testing device and then compressed on the lateral surface at constant rate of (50.8mm/min) until the maximum load (failure) was reached. The maximum load resistance and the corresponding flow value were recorded. The bulk specific gravity and density **ASTM (D 2726),** theoretical (maximum) specific gravity of void-less mixture were determined in accordance with **ASTM (D 2041).** The percent of air voids was then calculated.

5.2 Indirect Tensile Strength Test

Specimens were prepared by Marshall Method and tested for indirect tensile strength according to **ASTM (D 4123).** The prepared specimens were cooled at room temperature for 24 hours, immersed in a water bath at different testing temperatures (25 and 40 ˚C) for 30 minutes. Then they were tested by Versa-Tester using a 1/2 in. (12.5 mm) wide curved, stainless steel loading strip on both the top and bottom, running parallel to the axis of the cylindrical specimen which was loaded diametrically at a constant rate of 2 in/min. (50.8 mm/min.) until reaching the ultimate loading resistance. The indirect tensile strength (ITS) was calculated, as follows:

$$\mathbf{ITS} = \frac{2P}{\pi t D} \quad (1)$$

where:

ITS = indirect Tensile Strength, MPa

P = ultimate applied load (N).

t = thickness of specimen (mm),

D = diameter of specimen (mm).

5.3 Indirect Tension Repeated Load Test

The Indirect Tension repeated loading tests were conducted for cylindrical specimens, 101.6 mm in diameter and 63.5 mm (2.5 inch) in height, using the pneumatic repeated load. In these tests, repetitive compressive loading with a stress level of 20 psi was applied in the form of rectangular wave with a constant loading frequency of 1 Hz (0.1 sec. load duration and 0.9 sec. rest period) and the axial permanent deformation was measured under the different loading repetitions. All the uniaxial repeated loading tests were conducted at 40°C (104°F). The specimen preparation method for this test can be found elsewhere, **Albayati, 2006**. The permanent strain (εp) is calculated by applying the following equation:

$$\varepsilon p = \frac{pd * 10^6}{h} \quad (2)$$

where

εp= axial permanent microstrain

pd= axial permanent deformation

h= specimen height

Also, throughout this test the resilient deflection is measured at the load repetition of 50 to 100, and the resilient strain (ε_r) and resilient modulus (Mr) are calculated as follows:

$$\varepsilon_r = \frac{rd}{h} \quad (3)$$

$$Mr = \frac{\sigma}{\varepsilon_r} \quad (4)$$

where
εr= axial resilient microstrain
rd= axial resilient deflection
h= specimen height
Mr= Resilient modulus
σ = repeated axial stress
εr= axial resilient strain

The permanent deformation test results for this study are represented by the linear log-log relationship between the number of load repetitions and the permanent micro-strain with the form shown in Eq.6 below which is originally suggested by **Monismith et. al., 1994, and Barksdale 1972.**

$$\varepsilon p = aN^b \quad (5)$$

where
εp= permanent strain
N=number of stress applications
a= intercept coefficient
b= slope coefficient

6. RESULTS AND DISCUSSION

6.1 Effects of Aging Time on Marshall Properties

The variation of Marshall Properties with aging time is shown in **Fig.2** which is based on the data presented in **Table 5.** Marshall Stability gives the indication about the resistance of asphalt mixture to permanent deformation; a High value of Marshall Stability indicates increased Marshall Stiffness. Figure (2-a) shows the effect of short and long term aging periods on Marshall Stability of asphalt mixture, and it can be observed that the short and long term aging of asphalt mixture increase the Marshall Stability values. The Marshall stability after 8 hr short aging is higher than that of control mixture by 52.2%. In the case of long term aging of 5 day, the stability increase by 66% as compared to control mixture. This may be attributed to the loss of volatiles which makes the asphalt concrete more stiff and can resist the deformation. From fig (2-a) it found that Marshall stability for mix that exposed to 8 hr short aging is equivalent to that at 2 day long aging. Figure (2-b) shows the effect of short and long term aging periods on Marshall Flow asphalt mixture. It can be observed that the short term aging of asphalt mixture reduced the Marshall Flow values, and also the flow value for long term aging reduced more than short term aging. these reduction may be related to that the aging process make the mixture more stiffer than control mixture and also may be related to the good interlocking offered by asphalt binder and coarse aggregate particles and the reduction in fluidity of the binder.
Air void in the mixture is an important parameter because it permits the properties and performance of the mixture to be predicted for the service life of the pavement and percentage of air voids is related to durability of asphalt mixture. Figure (2-d) shows the effect of short and long term aging on voids in total mix (VTM) percent's for asphalt mixture investigated .It is clear from Figure that the air void is increased with increased aging time and the 8 hr. short term aging have VTM more than 2 day long term aging but less than 5 day aging. This may be related to the loss of volatiles and reduction in asphalt volume. Test results agrees well with **Sarsam, 2007**.

6.2 Effect of Aging Time on Indirect Tensile Strength Test

The indirect tensile strength test is used to determine the tensile properties of the asphalt concrete, which can be further related to the cracking properties of the pavement. **Fig. 3** shows Effect of aging times on ITS @25 ^{0}C for asphalt mixture. Results indicated that indirect tensile strength

was 1471 KPa, these value increased during short term aging process. For 8 hr. aging, the ITS shows (34.1%) increment more than that of control mixture. While After 2 day aging the ITS give lower value than 8 hr. aging by 3.5% ,this indicate that 8 hr. aging have more severity than 2 day aging ,ITS was increased by (13.4%) at 5 days aging when compared to 2 days aging . Results agrees well with **Sarsam, 2007,** and **Sarsam and Lafta 2014** work.

6.3 Effect of Aging on Resilient Modulus Test

Table 6 shows Resilient Modulus value for mixture with asphalt cement. It was observed that the resilient modulus increased with increased aging period , such increment may be related to increase in stiffness. Higher resilient modulus results will generate great rutting resistance development in the asphalt pavements.

6.4 Effect of Aging on Resistance to Permanent Deformation

The result of permanent deformation tests is shown in **Fig.4** which is based on the data presented in **Table 7.** The analysis of permanent deformation in this study is based on intercept, slope parameters. The slope of control mixture was higher than that of mix with 8 hr. short term aging by approximately 3.3%, and higher than 5 day long term aging by approximately 9.3% as compared with control mix. From the table below, the intercept value is decreased as the aging time increases for various type of asphalt, this mean that the aging have lower micro-strain at first load cycles. Results are in agreement with, **Sarsam and AL-Zubaidi, 2014** findings.

7- CONCLUSIONS

1. The aging of asphalt concrete mixture lead to changes in the mixture properties, the 8 hr. short term aging causes the Marshall stability, indirect tensile strength at 25 ^{o}C and resilient modulus to be increased by 52.2%, 34.1%, and 20.6% respectively as compared with control mixture. The permanent deformation decreased by (33.4%) as compared with control mixture.

2. The 5 day long term aging causes, the Marshall stability, indirect tensile strength at 25^{o}C, and resilient modulus to be increased by 66%, 46.7%, and 40% respectively as compared with control mixture while, permanent deformation decreased by(53.6%) as compared with control mixture.

3.The 8 hr. short term aging period has an equivalent effect on the properties of asphalt concrete as compared to that of 2 day long term aging.

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Table 1. Physical properties of asphalt cement.

Property	Unit	ASTM Designation	Test Result	SCRB, 2003 Specifications
Penetration (25˚C, 100 gm, 5sec)	0.1 mm	D 5	41	40-50
Softening point (ring & ball).	^{o}C	D 36	49.4	--------
Ductility (25˚C, 5 cm/min).	cm	D 113	>100	>100
Flash point (cleave land open cup)	^{o}C	D 92	275	>232
Residue from thin film oven test		D-1754		
Retained Penetration of Residue	%	D 5	66	>55%
Ductility of Residue	cm	D 113	87	>25%
Loss on Weight %	%	D 1754	0.3	< 0.75

Table 2. Physical properties of aggregates.

Property	Value	ASTM Designation No.
Coarse aggregate		
Bulk specific gravity	2.584	ASTM C 127
Apparent specific gravity	2.608	ASTM C 127
water absorption %	0.57%	ASTM C 127
Wear % (Los Angeles abrasion)	13.08%	ASTM C 131
Fine aggregate		
Bulk specific gravity	2.604	ASTM C 128
Apparent specific gravity	2.664	ASTM C 128
% water absorption	1.419%	ASTM C 128

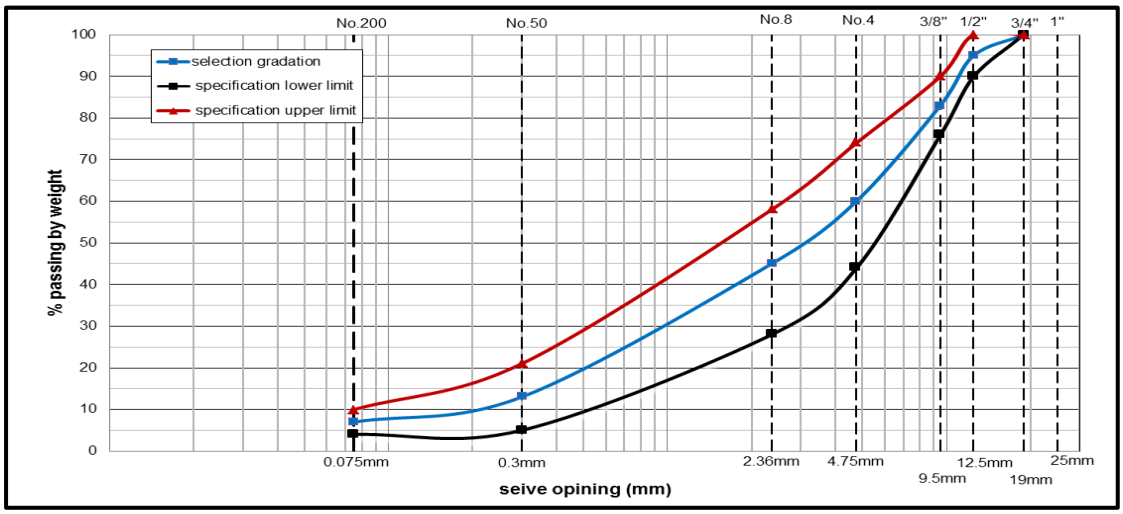


Figure 1. Selected aggregate gradation and specification limits.

Table 3. Physical properties of portland cement.

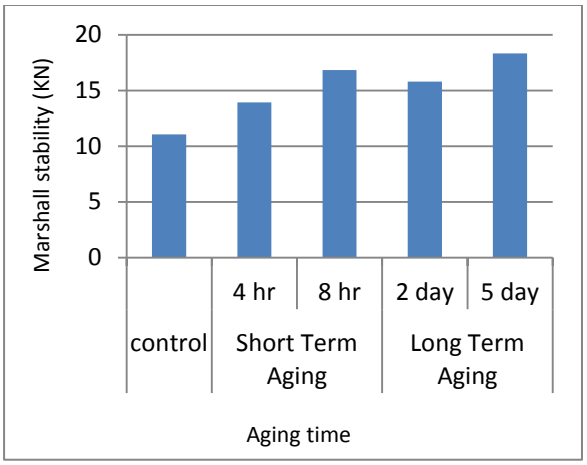
Property	Physical properties
% Passing Sieve No. 200	96%
Specific Gravity	3.14

Table 4. Properties of asphalt mixture with the optimum asphalt content.

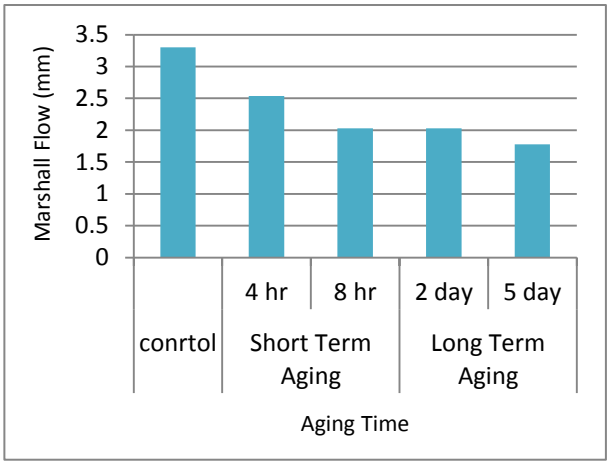
Marshall properties	value	SCRB, 2003 Specification limit
Optimum asphalt content %	4.7	----
Stability KN	10.87	8 KN min.
Flow mm	3.21	2-4 mm
Bulk density gm/cm^3	2.351	-----
Air void in total mix %	3.549	3-5%
VMA %	14.724	14 % min.
VFA %	73.88	----

Table 5. Summary of the Marshall Properties of asphalt concrete mixes at optimum asphalt content.

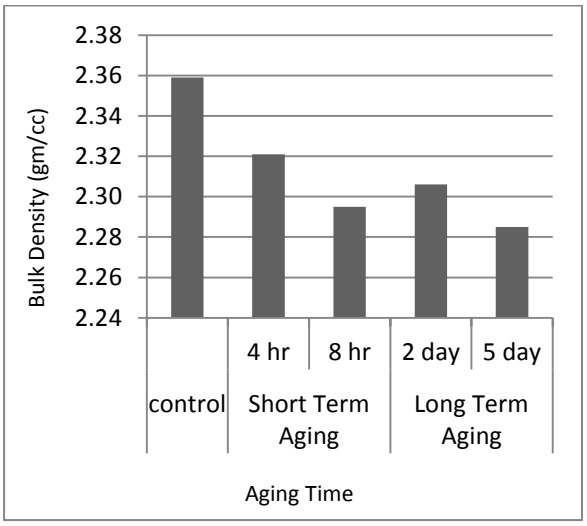
Aging Type	Aging Time	Marshall Stability KN	Marshall (mm)	Bulk Density (gm/cm^3)	VTM (%)	VFA (%)	VMA (%)
Control		11.05	3.302	2.359	3.8	73.3	14.4
Short term a time (hours)	4 hr.	13.93	2.54	2.321	4.4	72.0	15.8
	8 hr.	16.82	2.032	2.295	5.6	66.3	16.7
Long term a Time (days)	2 day	15.79	2.032	2.306	5.21	68.1	16.3
	5 day	18.31	1.778	2.285	5.8	65.7	17.1



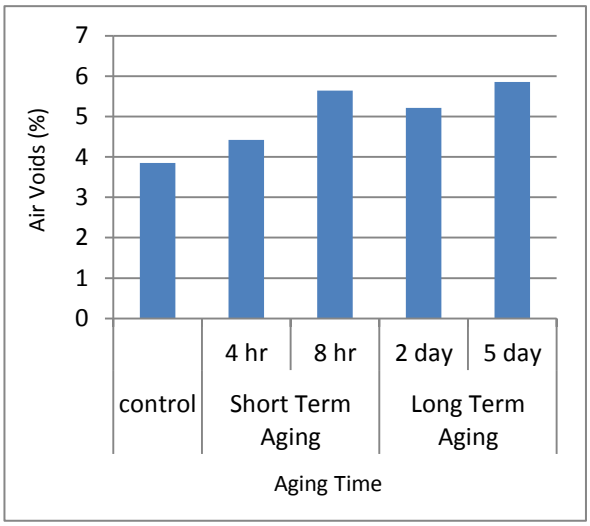
A-Marshall Stability



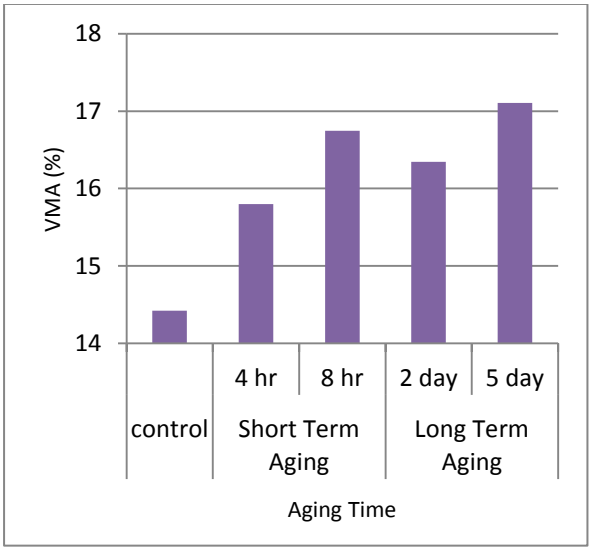
B- Marshall Flow



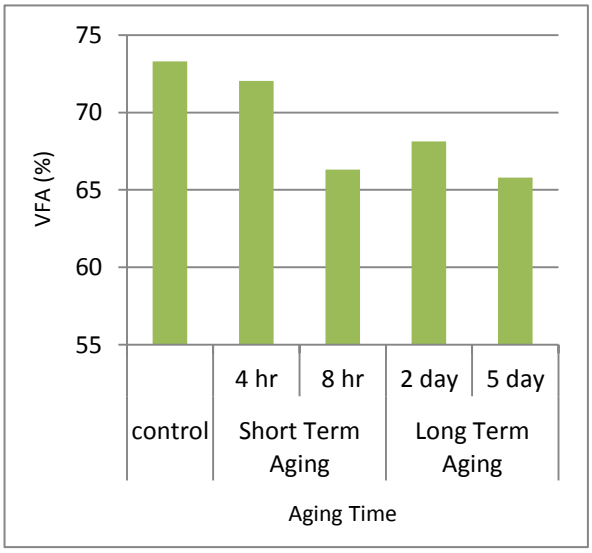
C – Bulk Density



D- Air Void



E – VMA



F – VFA

Figure 2. Effect of aging time on Marshall Properties.

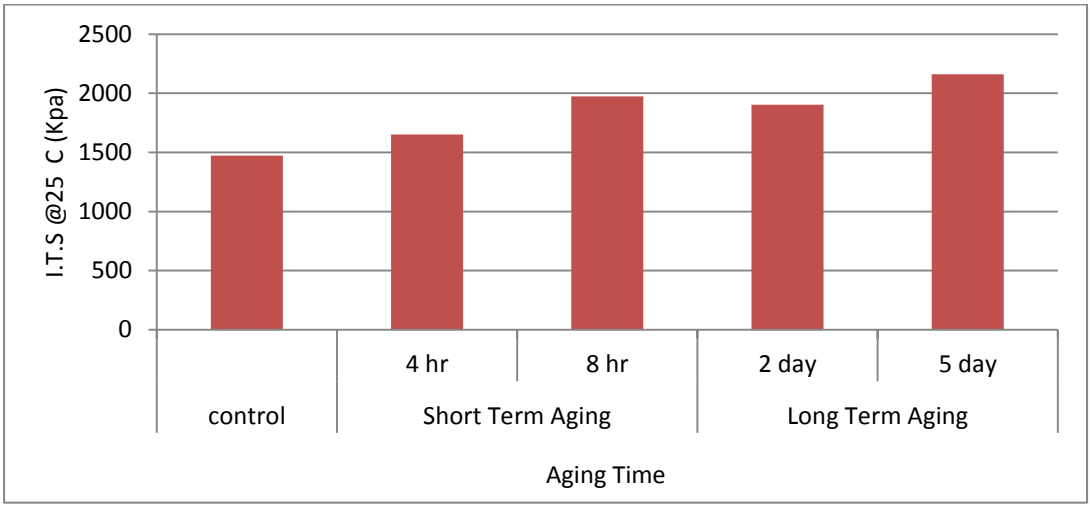


Figure 3. Effect of aging times on ITS @25 ^{0}C for asphalt mixture.

Table 6. Effect of aging time on resilient modulus value.

Aging time	Control mixture	Short term aging		Long term aging	
		4 hr.	8 hr.	2 day	5 day
Mr (psi)	31373	32653	33823	34043	37209

Table 7. Effect of aging time on permanent deformation test results.

Aging time	Control mixture	Short term aging		Long term aging	
	0 hr.	4 hr.	8 hr.	2 day	5 day
Intercept	268.15	241.77	198.31	190.55	167.22
Slope	0.4617	0.4571	0.4465	0.4369	0.4188

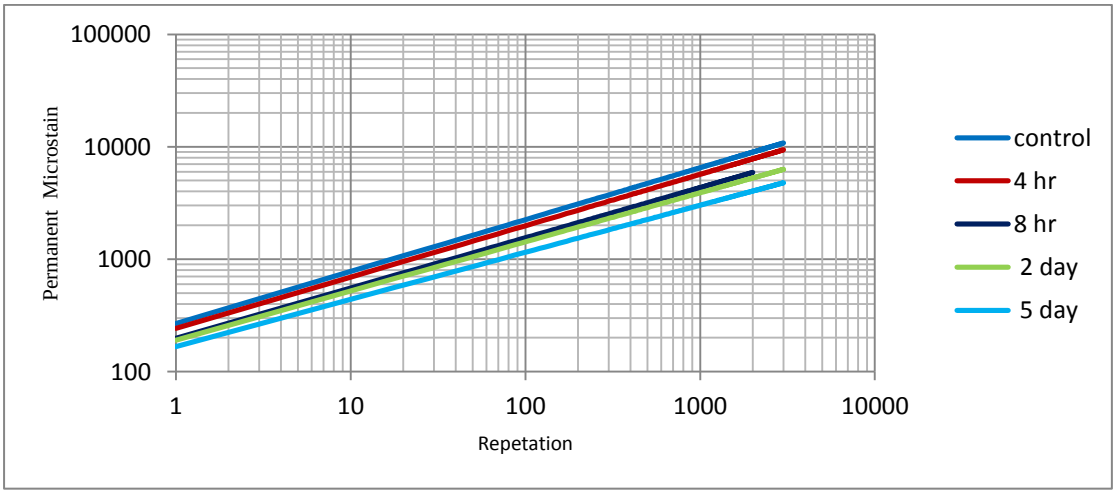


Figure 4. Effect of aging time on permanent deformation.

Effect of Allowable Vertical Load and Length/Diameter Ratio (L/D) on Behavior of Pile Group Subjected to Torsion

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ABSTRACT

Some structures such as tall buildings, offshore platforms, and bridge bents are subjected to lateral loads of considerable magnitude due to wind and wave actions, ship impacts, or high-speed vehicles. Significant torsional forces can be transferred to the foundation piles by virtue of eccentric lateral loading. The testing program of this study includes one group consists of 3 piles, four percentages of allowable vertical load were used (0%, 25%, 50%, and 100%) with two L/D ratios 20 and 30, vertical allowable load 110 N for L/D = 20 and 156 N for L/D = 30. The results obtained indicate that the torsional capacity for pile group increases with increasing the percentage of allowable vertical load, when the percentage of allowable vertical load was 100% and L/D ratio (20) the torsional capacity for pile group increases about 42% if compared with the torsional capacity when the percentage of allowable vertical load was 0% for the same L/D ratio. Also increasing L/D ratio leads to increasing the torsional capacity of pile group, when the percentage of allowable vertical load is 100% and L/D ratio (30), the torsional capacity for pile group increased about 51% if compared with torsional capacity when L/D ratio was (20) for the same groups and the same percentage of allowable vertical load. At failure the twist angle for pile group remain constant 3° when the percentage of allowable load change from 0% to 100 and L/D ratio 20, while it decreases from 2.9° to 2.7° when the percentage of allowable load change from 0% to 100% respectively and L/D ratio 30.

Key words: torsional load, twist angle, percentage of allowable vertical load, pile group

تأثير الحمل العمودي المسموح به ونسبه طول الركيزه الى قطرها على سلوك مجموعة الركائز المتعرضه الى الالتواء

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الخلاصه

تتعرض بعض الهياكل مثل المباني العالية ، المنصات البحرية ،و الجسور، إلى أحمال جانبية بسبب الرياح ،الأمواج ، و ألآثار الناتجه عن اصطدام السفن بجسور ، أو المركبات عالية السرعة. ينتج عن ذالك انتقال أحمال كبيرة إلى مجموعة الركائز بحكم التحميل الجانبي. .يتضمن برنامج الفحص لهذه الدراسه مجموعة واحدة تتكون من 3 ركائز ، استخدمت أربعة نسب من الحمل العمودي المسموح به (0 ٪، 25 ٪ ، 50 ٪ ، و 100 ٪) مع نسبتان من طول الركيزه الى قطرها 20 و 30 ، (الحمل العمودي المسموح به 110 N عندما تكون نسبة طول الركيزه الى قطرها 20 و 156 N عندما تكون نسبة طول الركيزه الى قطرها 30)

النتائج التي تم الحصول عليها تشير إلى أن قابلية مقامة الالتواء لمجموعة الركائز تزيد مع زيادة نسبة الحمل العمودي المسموح به، فعندما كانت نسبة الحمل العمودي المسموح به 100 ٪ و نسبة طول الركيزه الى قطرها (20) زادت قابلية مقاومة الالتواء لمجموعة الركائز 42% إذا ما قورنت مع قابلية مقاومة الالتواء لنفس مجموعة الركائز عندما كانت نسبة الحمل العمودي المسموح به 0 ٪ لنفس نسبة طول الركيزه الى قطرها. أيضا زيادة نسبة طول الركيزه الى قطرها يؤدي إلى زيادة قابلية مقاومة الالتواء لمجموعة الركائز ، فعندما بلغت نسبة الحمل العمودي المسموح به 100 ٪ و نسبة طول الركيزه الى قطرها 30، زادت قابلية مقاومة الالتواء لمجموعة الركائز حوالي 51 ٪ إذا ما قورنت مع قابلية مقاومة الالتواء لنفس مجموعة الركائز عندما كانت نسبة طول الركيزه الى قطرها 20 لنفس نسبة الحمل العمودي المسموح به. وجد ان زاوية الالتواء لمجموعة الركائزعند الفشل هي 3° عندما كانت نسب التحميل العمودي المسموح به من 0٪ و 100٪ و نسبة طول الركيزه الى قطرها 20 ، بينما قلت من 2.9° الى 2.7° عند تغير نسبة الحمل العمودي المسموح به من 0٪ الى 100٪ و نسبة طول الركيزه الى قطرها 30 .

الكلمات الرئيسية : قوة الالتواء، زاوية الالتواء، نسبة الحمل العمودي المسموح به، مجموعة الركائز

1. INTRODUCTION

Pile foundations of some structures, such as tall buildings, bridge piers, offshore platforms and electric transmission towers, can be subjected to significant torsional forces due to eccentric lateral loading from ship impacts, high-speed vehicles, wind and wave actions, and other sources of loading. Inadequate design of the piles against torsional loads may seriously affect the serviceability and safety of these structures with catastrophic consequences. The literature reported two cases of tall buildings in Miami and in Lubbock (Texas) which had suffered serious damage due to wind action and exhibited marked permanent deformations from torsion **Vickery, 1979**. Another case, described by **Barker and Puckett 1997**, reported the collapse of a support pier of the 6.82km long Sunshine Skyway Bridge in Florida caused by the eccentric impact of a bulk carrier. About 395m of the bridge fell into the sea, resulting in thirty-five deaths. Therefore, it is important that the strength and deformation characteristics of the foundation piles are properly addressed in design in order to ensure safety and cost-effectiveness.

2. MATERIALS

2.1 Model of Pile Groups

The models of pile groups used in this research study includes one group consists of 3 circular piles connected with Aluminum pile cap of (11.5×11.5×3) cm. The pile is modeled as Aluminum closed end tube and fixed head with (15 mm) outer diameter and (2mm) thickness. Two pile lengths were used (30, and 45 mm), the spacing between piles is 3d, see **Fig.1**. The determination of the mechanical behavior of the pile material used is very important. The sample was tested in accordance with the ASTM (2003) specifications. The results of the mechanical properties of aluminum tube used under tensile test are listed in **Table 1**.

2.2 Soil

A series of tests was performed on Karbala sand according to ASTM D 422-2001 procedures. In this study, the sand soil can be classified (SP-SM) according to the Unified Soil Classification System. The grain size distribution curves of sand are shown in Figures (2). The minimum and maximum unit weight of sand soil tested was determined according to ASTM D 4253-2000, The results of the maximum and minimum unit weights of sand soils are (17.64) kN/m^3 and (14.53) kN/m^3 respectively. The physical properties of the Karbala sand in the **Table 2**. The density of the sand soil used through the experiments was controlled by means of the raining technique. This technique includes raining the soil by different heights of drop that give different placing densities. Many

investigators such as **Lee, et al., 1973** and **Sanjeev, 2007** used this technique. It was decided to employ unit weight (16.5) kN/m3 of sand soils, which corresponds to the height of drop of (50) cm. The relations between heights of drop, density, void ratio and relative density of sand soil shown in **Fig. 3.**

3. SETUP FORMULATION

Tests were carried out in a steel box with inside dimensions of (800) mm width (800) mm length and (800) mm height. The sides and bottom were made of (6) mm thickness plate. Front face of the box was includes get with dimensions (400) mm width and (400) mm length. The test box was placed over (1000) mm width and (2000) mm length of strong steel base, which was connected to a stiff frame of vertical hydraulic jack. Steel loading frame was manufactured to support the piston that is used for subjecting vertical load and insert the pile group in the soil. Steel loading frame consists of two beams in horizontal direction have (U-section) to allow the piston to move horizontally along the beam and two column in vertical direction have (square-section), at the sides of columns found holes that are used to help in controlling vertically the distance between the piston and the container surface. The soil is prepared in steel box by raining frame. This frame includes Two columns with changeable height were designed and manufactured to achieve any desired elevation. The change of the frame height is done by holes, from top and bottom. The column was connected with two valves to join 4 beams together. These beams are bolted at their ends. Two beams in the longitudinal direction have (U-section) and the other beams are used to support the U-section beams. Another beam was designed as a roller; it rests on the longitudinal beams to move along these beams. This (rolled-beam) is connected from the bottom with another beam, it is provided with screw and it can be horizontally moved along the beam; this beam was made to carry the cone that is used to pour the sand. This configuration of raining frame helps get a uniform density by controlling the height of fall. The rolled beam and the screw that connected with the cone ensure that each particle drops in equal height and uniform intensity.The torsional load applied by horizontal hydraulic jack, the horizontal hydraulic jack connected with steel plate contain many holes for applied load in any point, this plated support on the side edge of box, the load measured by load cell of 5 KN capacity. The corner and center displacement measured by two dial gauges (0.01) mm fixed on the middle and corner of the pile cap by two magnetic holders. **Fig. 4** and **Fig.5** show the general view of testing equipment.

4. TEST PROCEDURE

The steps followed for performing torsion test on model pile group are summarized as follows:

1. Soil Preparation:
   a) Prepare the soil by raining technique at the chosen density and the corresponding relative density (RD=70% for dense state),
   b) Level the sand surface at final depth when the raining is completed, the level of sand layers is checked by leveling tool,

2. Pile Group Installation:
   a) Fix the pile group in the head of vertical hydraulic jack,
   b) The group are instilled in sand by pre jacking method,

3. Testing preparation:
   a) Support the allowable vertical load (if any) on the pile group,
   b) Fit the dial gages in the horizontal direction at the corner, at the middle of the pile cap while at the vertical direction in the right and left side of the pile cap
   c) Fit the load cell with the horizontal jack and connect it with the digital indicator,
   d) Fix the horizontal jack in the upper edge of the right side of the container to be ready to subject the torsion load on the pile cap.

4. Testing:
   a) Now apply the torsion and record the readings of all the dial gages used,
   b) At the end of the test, remove all the dial gages, load cell, horizontal jack, allowable vertical load, pile group, and open the gate for removing the sand to prepare the model for another test; and

5. Repeat all the above steps in the next test.

6. Criteria of Failure

Many references indicate some of the recognized criteria for defining failure loads of piles under compressive loads or lateral loads, but no criteria were found in literature to define the failure load of torsionally loaded pile or pile group. Therefore we depend on the criteria of failure for lateral loads to determine the failure of pile group subjected to torsional load. Some of the failure criteria of laterally load pile are stated as follows:

Mc Nulty, 1956 stated that the pile head deflection under the effect of lateral load depends on the soil characteristics and the size of the pile, the suggested allowable design load was taken as the load required to produce ¼ inch (6.35 mm) deflection divided by a factor of safety of 3.

Hopkins, 1956, considerd the allowable deflection for laterally loaded pile can be assumed as only 1/16 inch (1.6 mm).

Bowles, 1988, stated that the most lateral piles were usually designed for lateral displacement on the order of 6 to 10 mm at the ground line.

Rahman and Chowdhury, 2003, stated that the load displacement curves were non- linear. Lateral failure occurred at a pile head displacement from 4 to 8 mm (0.2D to 0.4D) for L/D ratio 20. However, for L/D ratio 30, the lateral failure occurred at a pile head displacement of 6 to 10 mm (0.3D to 0.5D).

In practice, of course, the pile will fail at some stage, normally by the formation of a plastic hinge at some point down the pile. Lateral movement of the pile to cause such failure to be generally in excess of 10% of the pile diameter, **Fleming and Randolph, 2009**.

Therefore to analyze the results of the present work, a load required to produce a horizontal displacement in the corner of the pile cap of pile group 0.3D (D=15mm) is considered as failure load.

5. RESULTS AND ANALYSIS

5.1 Effect of Applied Allowable Vertical Load on the Behavior of Pile Group Subjected to Torsion.

Fig. 6 and **7** show the effect of increase in the percentages of allowable vertical load on the variation of the torsion load with displacement (that has measured at corner of the pile cap) and twist angle for pile group PG3, when L/D ratio was 20, four percentages for the allowable vertical load (0%, 25%, 50%, and 100%) were used. The torsional capacity for the pile group increases when the percentage of allowable vertical load increases due to increase in vertical stress (σ_v) that leads to increase the frictional resistance of pile group and subsequently increase the lateral and torsional resistance of pile group correspondingly. At failure (0.3D) when the percentage of allowable vertical load is 100%, the torsional capacity increases about 42% if compared with 0% percentage for the allowable vertical load, and the twist angle at failure is unchanged (3º) if the percentage of allowable vertical load changes from 0% to 100%.

Fig. 8 and **9** illustrate the torque developed (Torsion Load ×0.0575m where 0.0575m is the distance from corner to center of pile cap) in pile group with displacement at corner and twist angle at different percentages of allowable vertical load.

Fig. 10 shows the effect of percentages of allowable vertical load on the torque capacity at failure for pile group when L/D ratio is 20.

Also **Fig. 11**and **12** show the variation of the torsion load and torque (Torsion Load×0.0575m) with displacement in corner and twist angle of pile group due to the increase in the percentage of allowable vertical load. Four percentages of allowable vertical load were used (0%, 25%, 50%, and 100%) and L/D ratio is 30. The torsional capacity for pile group increases with the increase in the percentage of allowable vertical load due to the increase in frictional resistance of pile group. In this case, at failure (0.3D) the torsional capacity when the percentage of allowable vertical load is 100% increases about (70%) if compared with percentage of allowable vertical load of 0%, also the twist angle when the percentage of allowable vertical load is 100% is (2.7°) while it is (2.9°) when the percentage of allowable vertical load is 0%.

Fig. 13 shows the effect of the percentages of allowable vertical load on the failur torsion load and failure torque of pile group when L/D ratio is (30).

5.2 Effect of L/D Ratio on the Behavior of Pile Group Subjected to Torsion

Increasing L/D ratio for piles in the pile group PG3 leads to increasing the vertical stress (σ_v) and frictional resistance for pile group, therefore the torsional capacity increases. **Figs. 14** and **15** show the effect of L/D ratio on the variation of torsion load with displacement at corner and twist angle of pile group when the percentages of allowable vertical load (0% and 100%). At failure (0.3D), when the percentage for allowable vertical load 0% the torsional resistance for L/D ratio (30) is 1.51 times that of the L/D ratio (20), also when the percentage for allowable vertical load 100% the torsional resistance for L/D ratio (30) is 1.78 times that of the L/D ratio (20). The twist angle when the percentage of allowable vertical load 0% is (3°) for L/D ratio is (20) and (2.9°) for L/D ratio (30), and when percentage of allowable vertical load 100% is (3°) for L/D 20 and (2.7°) for L/D ratio

(30), this means the increase in L/D ratio leads to increase the torsional capacity and rigidity of the pile group.

6. CONCLUSIONS

1. The torsional capacity of pile group increases when increasing the percentage of allowable vertical load.
2. The increase in number of piles and L/D ratio leads to increase the torsional capacity of pile group.
3. For all tests the maximum twist angle at failure is 3º for pile group PG3 when L/D ratio is (20) and the percentages of allowable vertical load are 0% and 100%,
4. The torque decreases when the torsion load approaches from center of pile cap and increases when the torsion load goes away from center of the pile cap

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8. NOMENCLATURE

C_c : coefficient of curvature

C_u : coefficient of uniformity

D_{10} : diameter of particle when percentage of passing is10%

D_{30}: diameter of particle when percentage of passing is 30%

D_{50}: mean grain size

D_{60}: diameter of particle when percentage of passing is 60%

Gs : specific gravity

L/D: length of pile / diameter of pile

PG3: pile group which consists of 3 piles

RD: relative density, %

σ_v : vertical stress

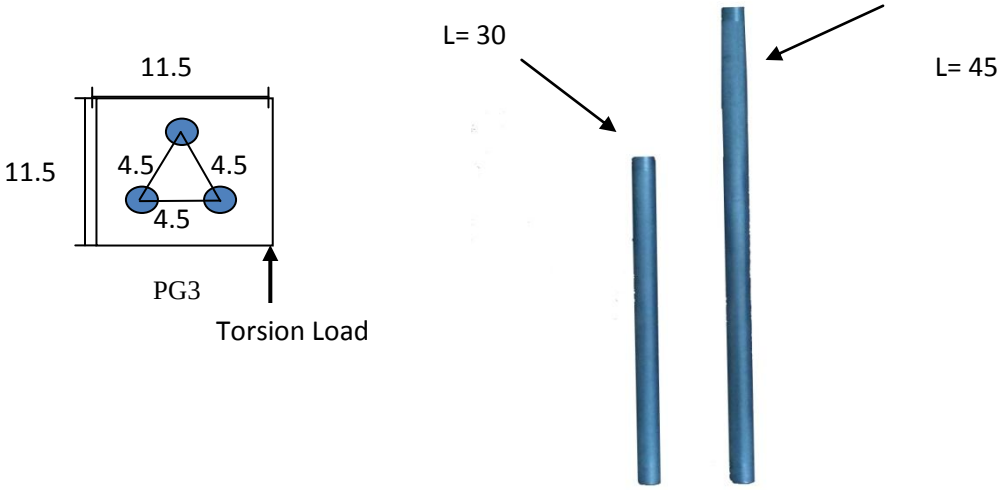


Figure 1. Pile groups pattern and piles of different lengths (all dimensions in cm).

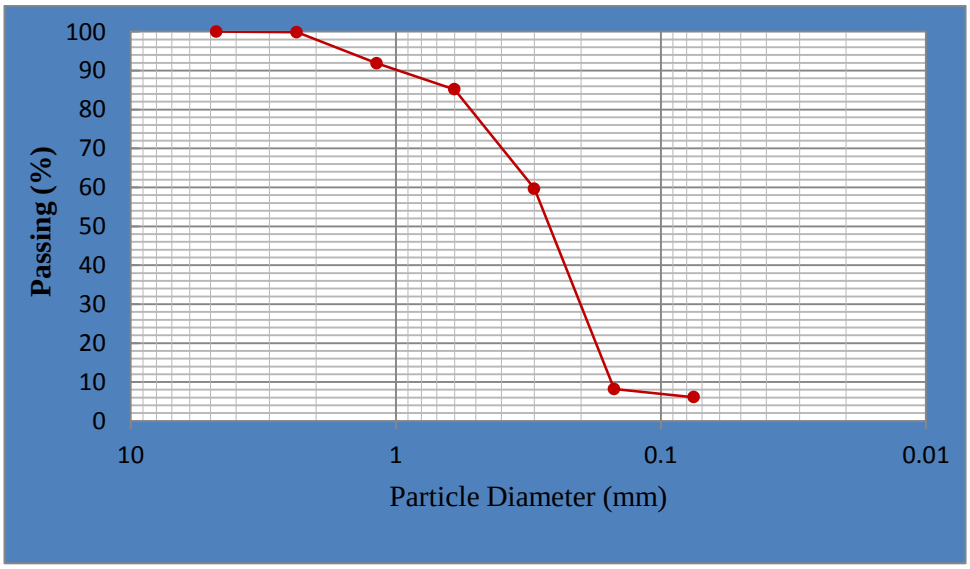


Figure 2. Grain size distribution curves of sand soil.

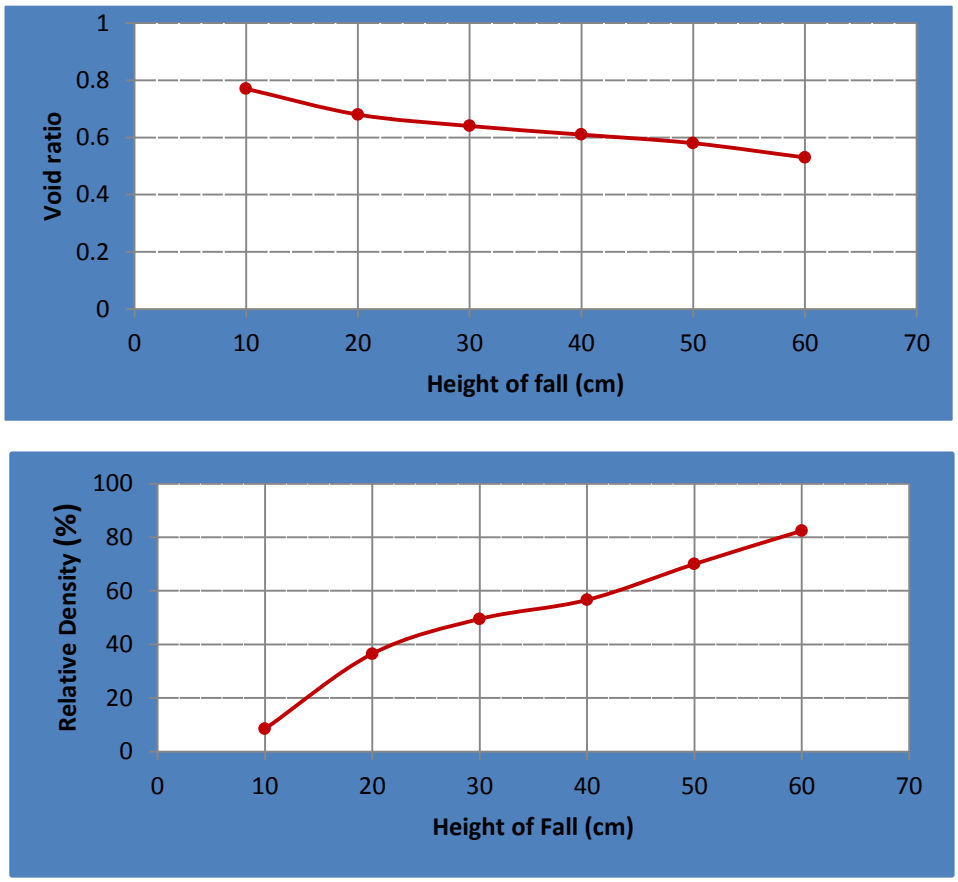


Figure 3. Relative density, and void ratio vs. height of fall relationship.

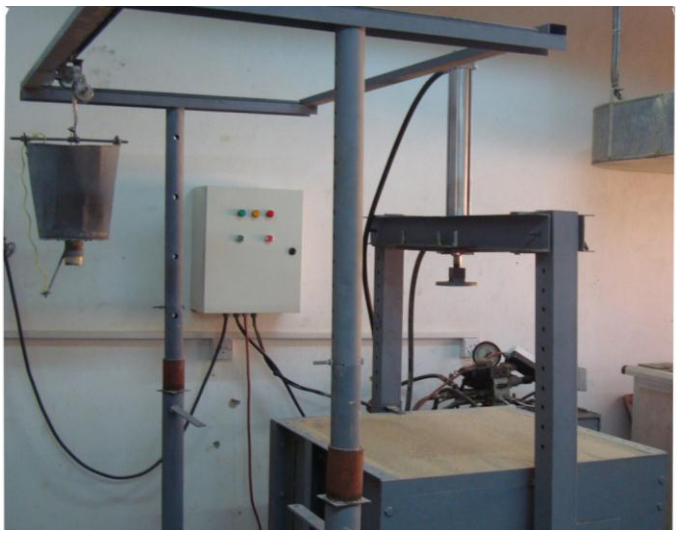


Figure 4. General view of testing equipment.

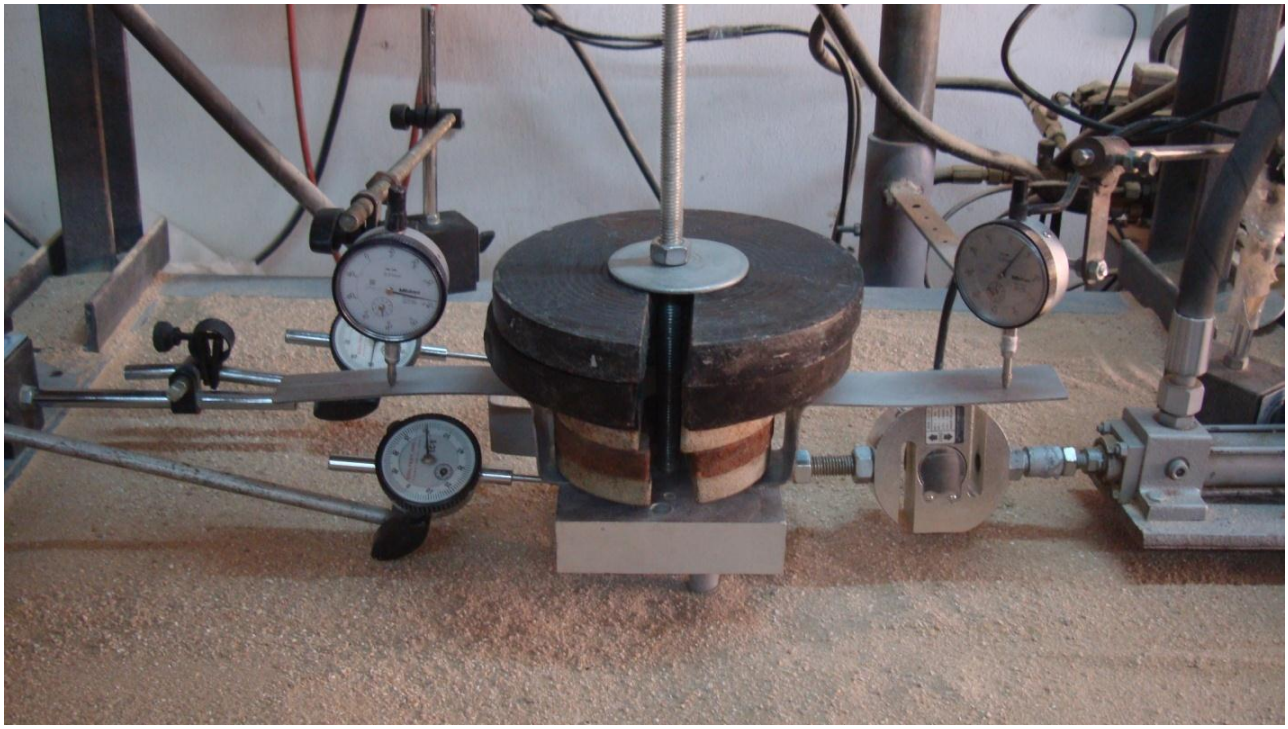


Figure 5. Pile group subjected to torsion load with allowable vertical load.

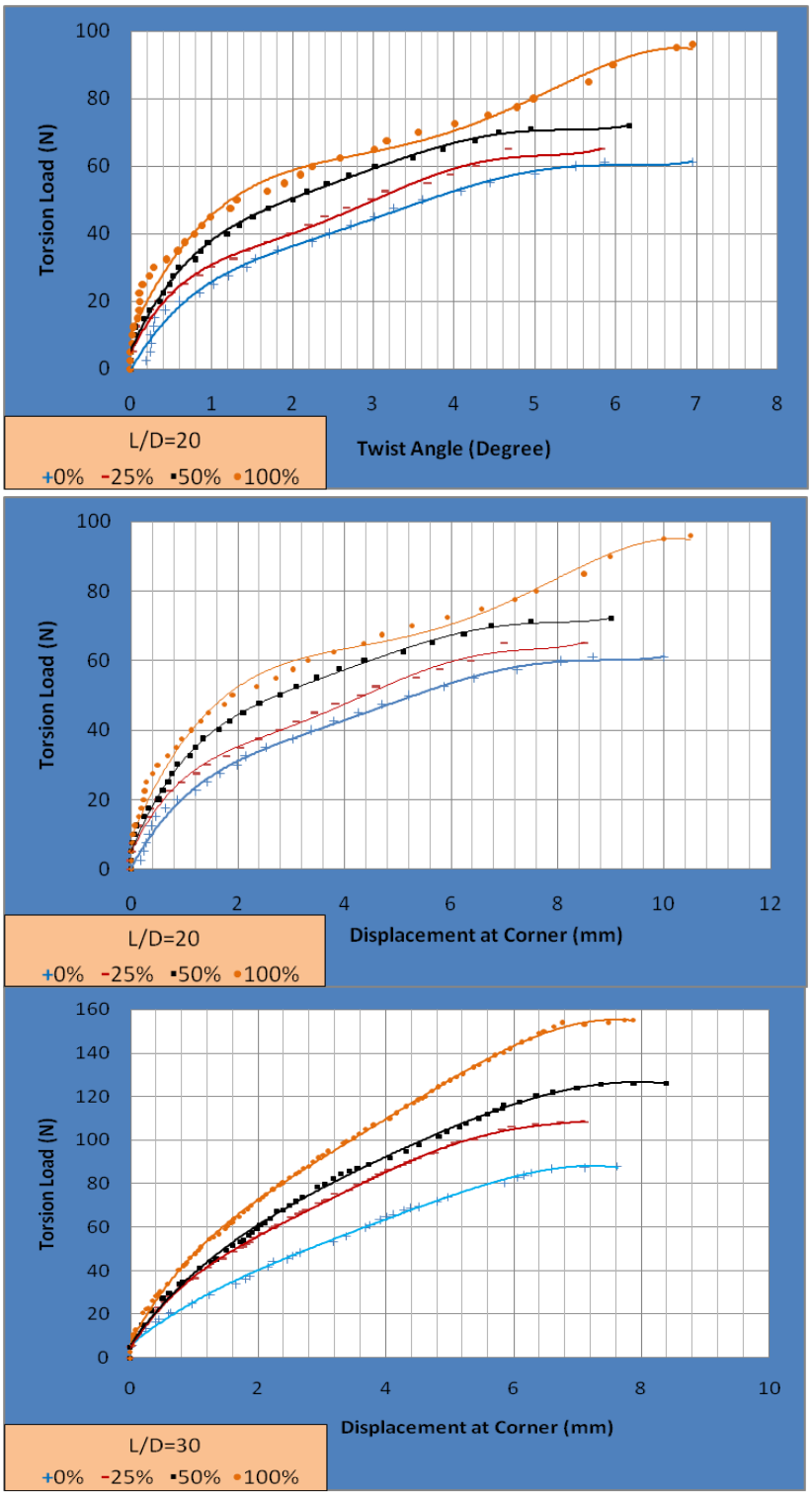


Figure 6. Effect of percentages of allowable vertical load on variation of torsion load with displacement at corner of pile group when L/D ratio is (20).

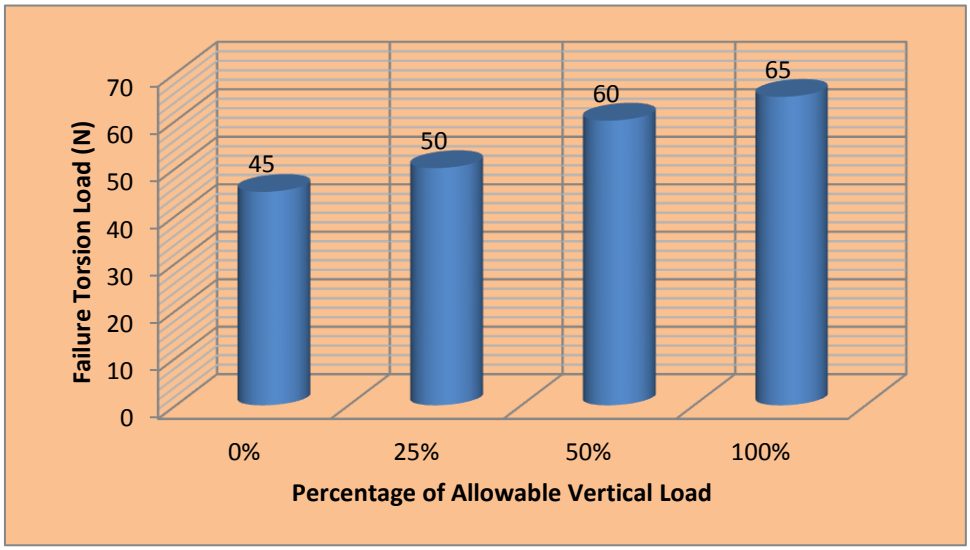


Figure 7. Effect of percentage of allowable vertical load on torsion capacity at failure of pile group when L/D ratio is (20).

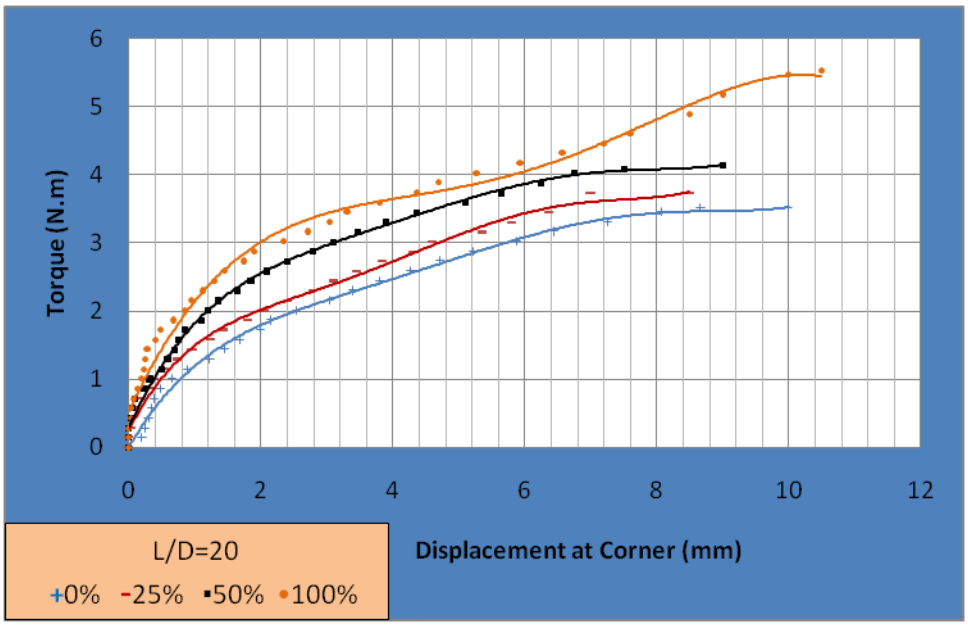


Figure 8. Effect of percentages of allowable vertical load on variation of torque with displacement at corner of pile group when L/D ratio is (20).

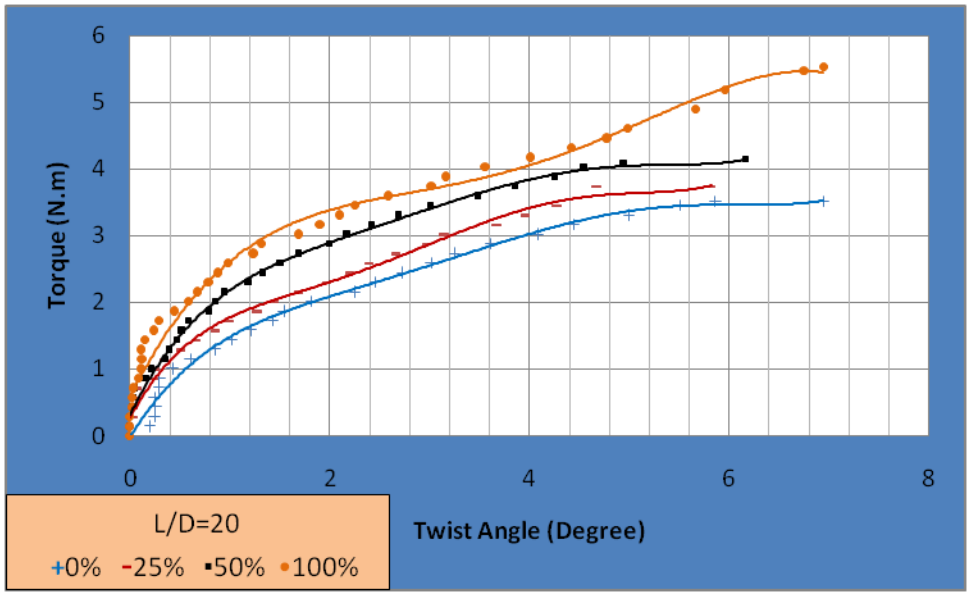


Figure 9. Effect of percentages of allowable vertical load on variation of torque with twist angle of pile group when L/D ratio is (20).

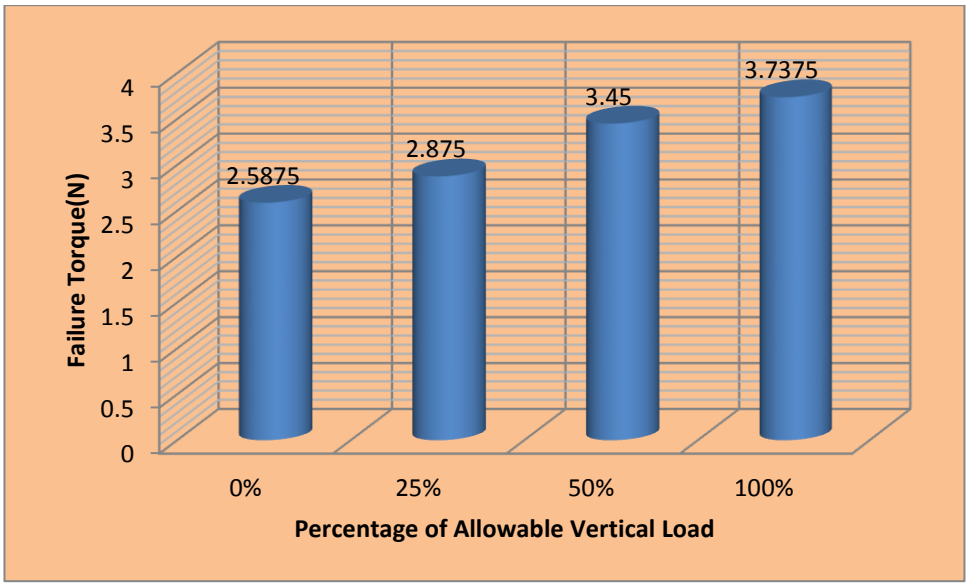


Figure 10. Effect of percentages of allowable vertical load on torque capacity at failure of pile group when L/D ratio is (20).

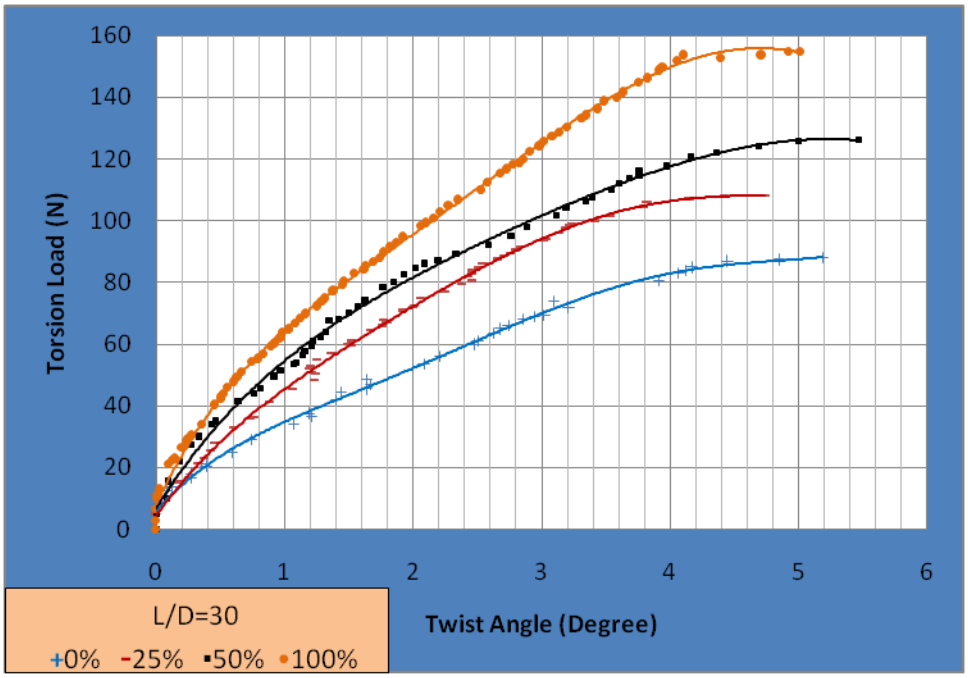
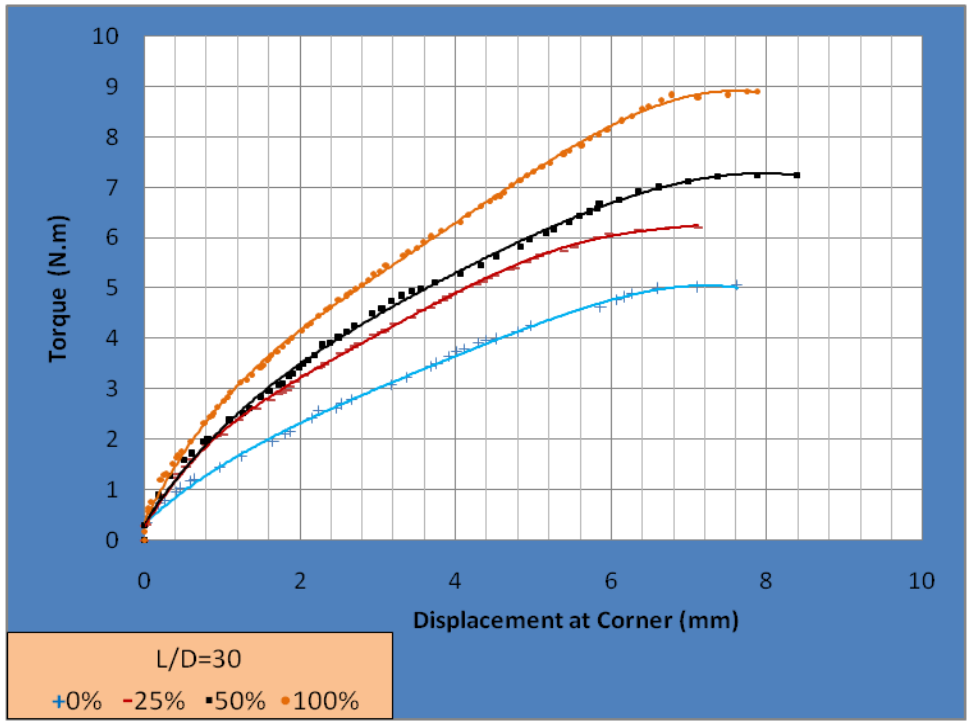


Figure 11. Effect of percentages of allowable vertical load on variation of torsion load with displacement at corner and twist angle of pile group when L/D ratio is (30).



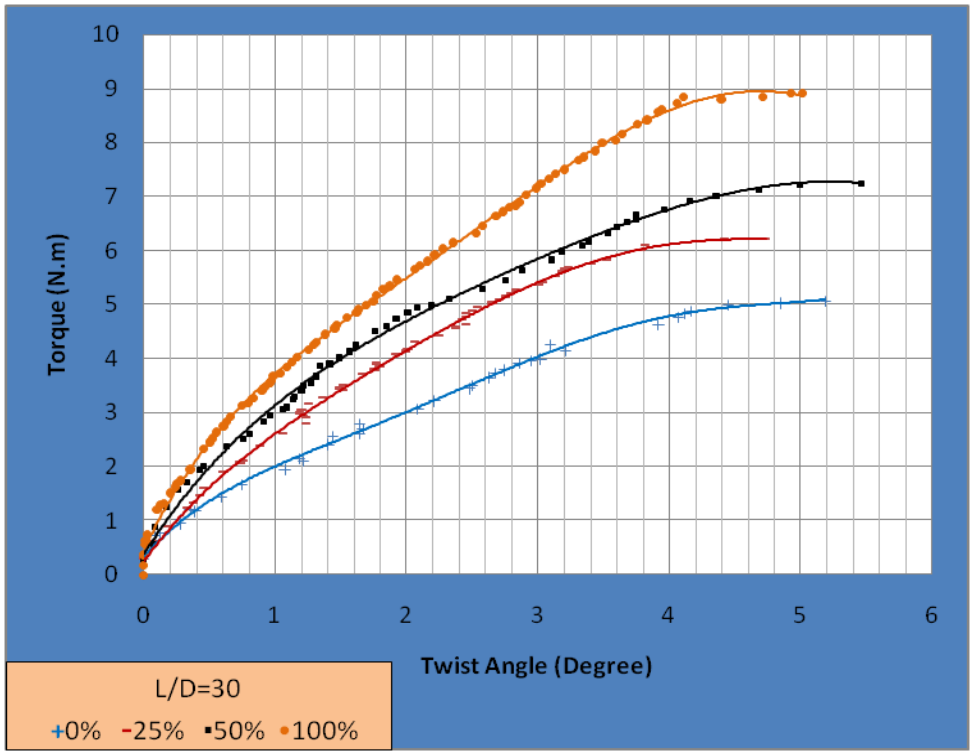


Figure 12. Effect of percentages of allowable vertical load on variation of torqe with displacement at corner and twist angle of pile group when L/D ratio is (30).

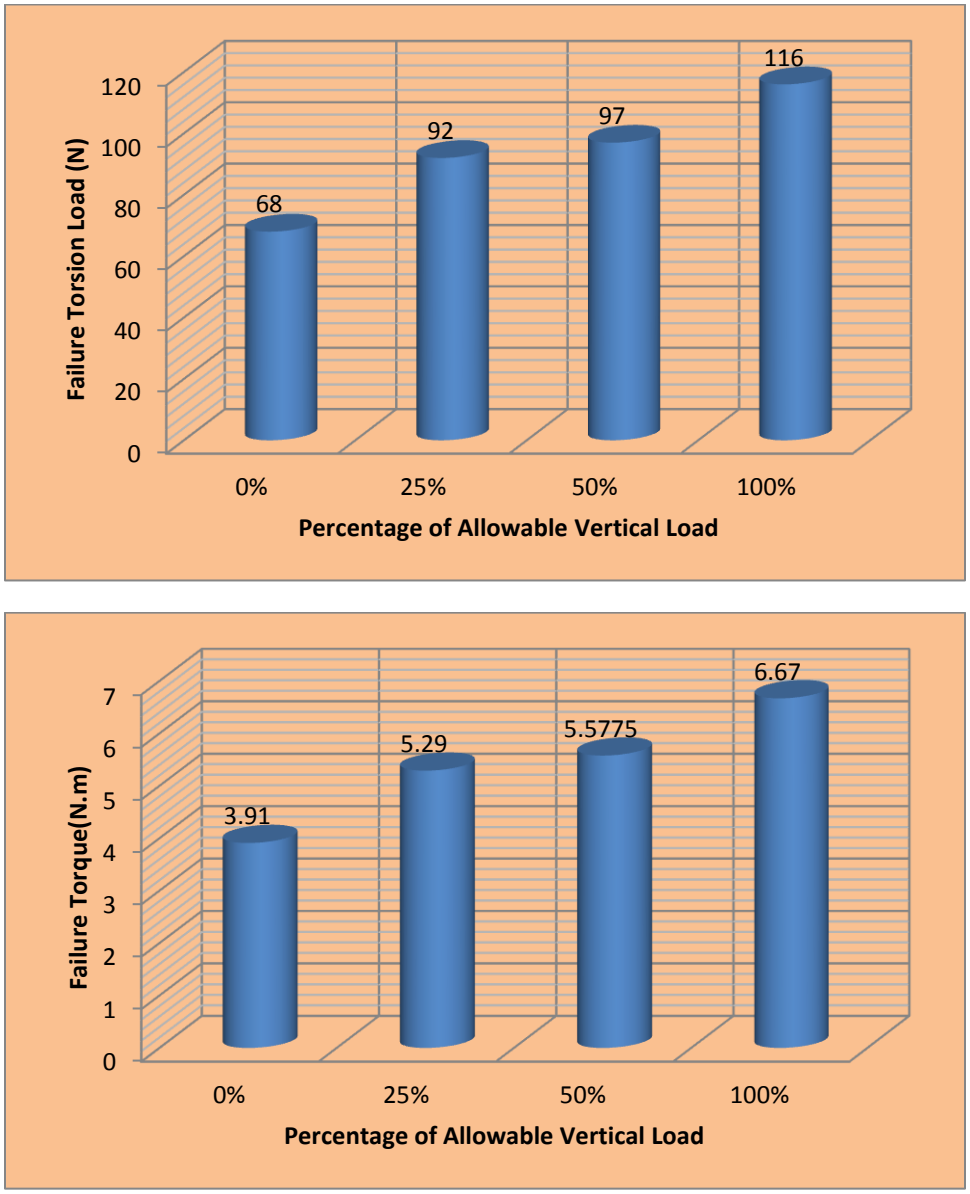
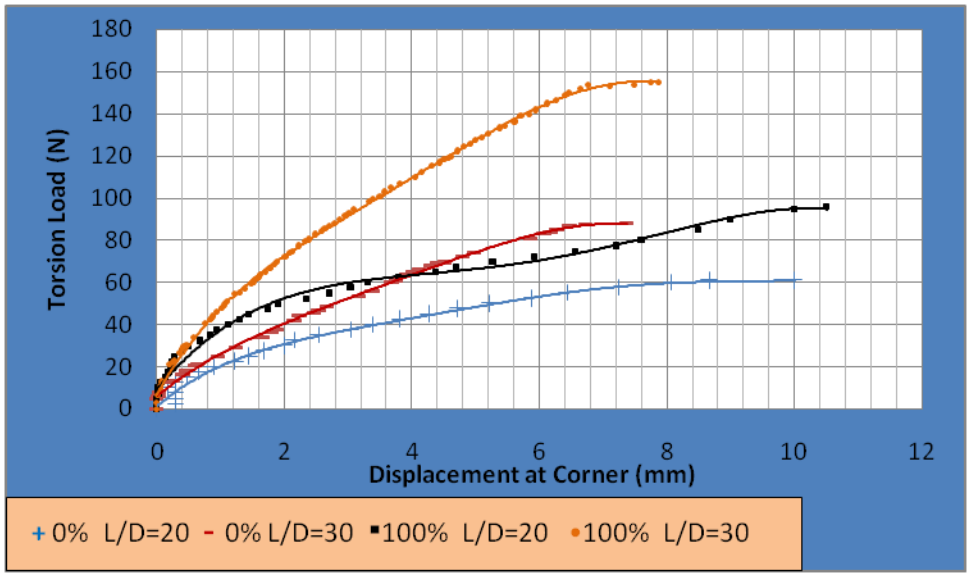


Figure 13. Effect of percentages of allowable vertical load on failure torsion load and failure torque of pile group when L/D ratio is (30).



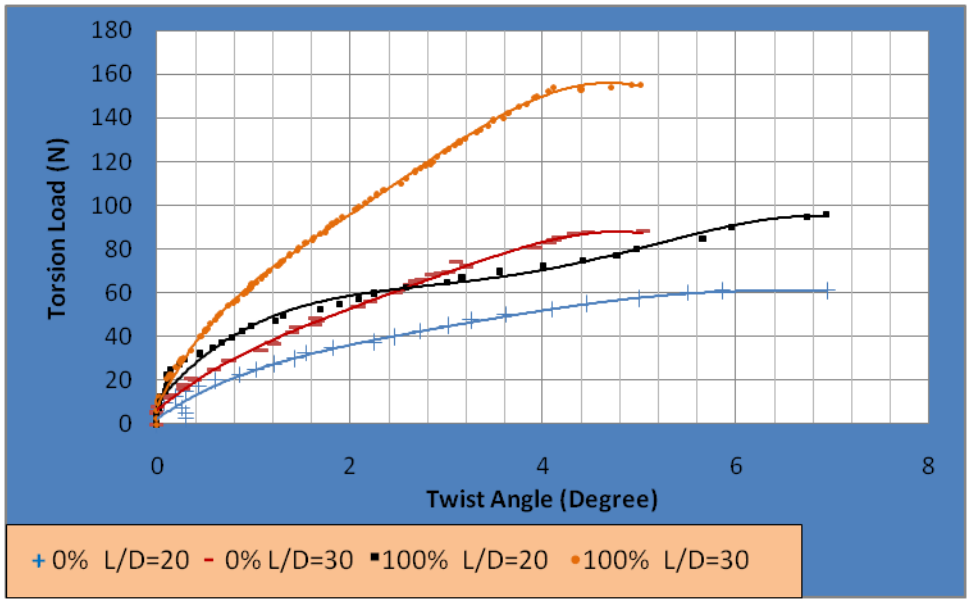


Figure 14. Effect of L/D ratio on the variation of torsion load with displacement at corner and angle of pile group when the percentages of allowable vertical load are (0% and 100%).

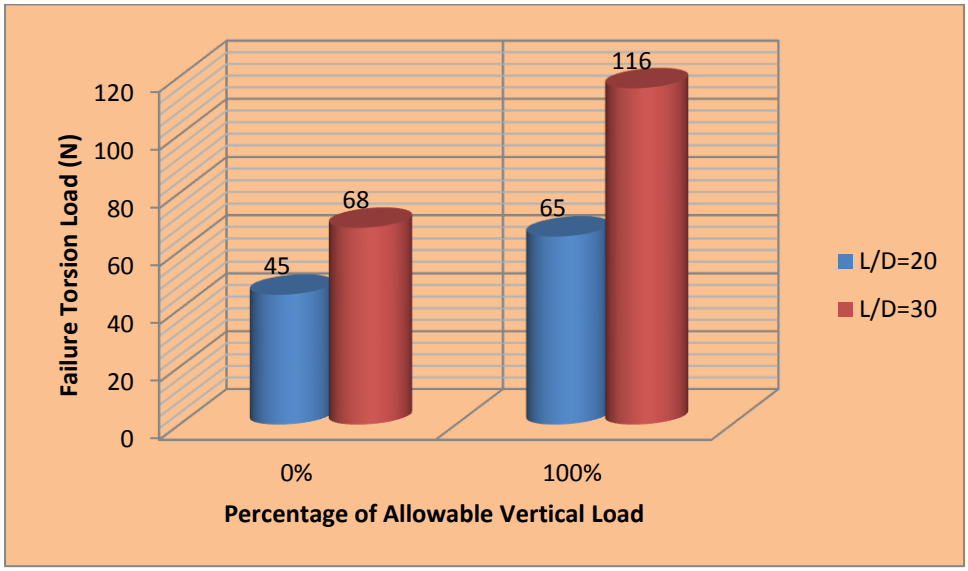


Figure 15. Effect of L/D ratio on the failure torsion load of pile group when the percentages for vertical allowable load are (0% and 100%).

Table 1. Mechanical properties of aluminum tube.

Properties	**Yield Strength Fy (N/mm^2)**	**Tensile Strength Fu (N/mm^2)**	**Poisson's Ratio v**
Value	150	212	0.3

Table 2. Soil properties.

Index Properties	Values
Specific Gravity (Gs)	2.61
D_{10} (mm)	0.17
D_{30} (mm)	0.2
D_{50} (mm)	0.27
D_{60} (mm)	0.3
Coefficient of uniformity (Cu)	1.76
Coefficient of curvature (Cc)	0.784
Maximum dry unit weight (kN/m^3)	17.64
Minimum dry unit weight (kN/m^3)	14.53
Maximum void ratio	0.79
Minimum void ratio	0.47
Dry unit weight at testing (KN/m^3)	16.5
Angle of internal fraction	43^o
Soil classification (USCS)	SP-SM

Paving the Way for PPP's to Infrastructure Projects in Iraq

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ABSTRACT

The political situation experienced by Iraq before the events of 2003 that led to the collapse of infrastructure. rebuilding costs were estimated after 2003 by187(million USD) according to the estimates of the basic needs as stated in Five-Year Plan 2010-2014. The difficult in financing projects and the continuous demands for maintenance and operating cost, and working by contemporary styles in different countries, the strategic option is to adopt the government entering the private sector as a partner in the development process. Since public _private partnership (PPP's) is at a germinating stage of development in Iraq, it has been studied the critical success factors(CSF's) in the experiences of countries that have implemented the style (PPP's) in infrastructure projects which can be ensured or controlled in some way and in the effective management of those already embarked upon . It should pave the way for enhanced decision making in the choice of suitable projects. The mainly aims of this paper are:

1- To highlight the importance and need of PPP's contracts in Iraq.
2- Establishing a model of CSF's for infrastructure projects in Iraq. collected (87)success factors which characterized by the state directly in PPP's projects consists of (8)main criteria(Privatization and investment Policy, Economical , Legal and political ,Financial and commercial, Administration and organizational ,Social and environmental ,Technical and Support , motives and guarantees of government) and found out (40) CSFs among them through questionnaire experienced in these projects to work to assess the standards and compare them and come to decisions by the decision maker, and therefore have a database of views experienced for use in other projects.

Keywords: public private partnerships (PPP's), infrastructure projects, investment tendencies critical success factors (CSF's), decision making

تمهيد الطريق لمشاركة القطاع الخاص للعام في مشاريع البنى التحتية في العراق

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الخلاصة

بسبب الاوضاع السياسية التي مر بها العراق قبل احداث 2003،والتي ألت الى انهيار البنى التحتية،تم تقدير تكاليف اعادة الاعمار بعد عام 2003 بـ187 مليار دولار, وفقا لتقديرات الاحتياجات الاساسية كما ماورد في الخطة الخمسية2010-2014.في ضوء هذه المتطلبات المتزايدة ومايصاحب ذلك من صعوبات في تمويل هذه المشاريع والتكاليف المستمرة للتشغيل والصيانة.وعملا بالاساليب الحديثة في مختلف بقاع العالم،فان الخيار الاستراتيجي هو تبني الحكومة دخول القطاع الخاص كشريك في عملية التنمية.تعتبر تجربة مشاركة القطاع الخاص للعام (PPP's) في العراق ضمن مرحلة النمو, فقد تمت دراسة عوامل النجاح الحرجة في تجارب الدول التي طبقت اسلوب PPP's في مشاريع البنى التحتيةو التي من الممكن ان توفر بصورة افضل تاثيرا اكبر على نجاح مشاريع الشراكة والتي من الممكن ان تضمن او تسيطر على الادارة الفعالة لنجاح هذه المشاريع لاجل تمهيد الطريق لتحسين اتخاذ القرارات المتخذة لاختيار المشاريع المناسبة التي من الممكن ان تنفذ بهذا الاسلوب ,تتضمن اهداف البحث بصورة رئيسية, مايلي:-

1- ابراز الاهمية المطلوبة لادخال مشاريع البنى التحتية تحت نمط مشاركة القطاع الخاص للعام(PPP's) في العراق.
2- تاسيس نموذج لعوامل النجاح الحرجة لمشاريع البنى التحتية في العراق.اذ تم جمع (87) عامل من العوامل الاساسية التي يجب ان تتميز بها الدولة للمباشرة في مشاريع المشاركة مقسمة الى (8) معايير رئيسية (سياسة الاستثماروالخصخصة، اقتصادية،قانونية وسياسية,مالية وتجارية,ادارية،اجتماعية وبيئية،تقنية وفنية ومعايير الدعم والحوافز الحكومية),واستنتاج(40)عامل من عوامل النجاح الحرجة من خلال معرفة مقدار الاهمية لهذة المعايير الرئيسية وترتيب اولوياتها من خلال استبيان ذوي الخبرة في هذه المشاريع لعمل التقييم والمقارنة بينها والخروج بالقرارات بواسطة متخذ القرار, وبالتالي يكون قاعدة معلوماتية لاراء ذوي الخبرة للاستفادة منها في مشاريع اخرى.

1. INTRODUCTION

The criticisms of the traditional method of procurement are known and documented in many literatures and researches. Such issues include delay in time, cost overrun, lack of single point responsibility, tendency to adversarial relationships, lack of utilization of construction knowledge, backwardness in innovation, among others. The private sector in the world is increasingly getting more involved in the provision of public infrastructure and services across a wide range of industries and sectors in order to alleviate the spending on governments' budgets.

Over recent years the interest in adopting public private partnerships (PPP's) has increased internationally. Many research studies have presented positive reasons for the governments and the private sector to welcome this form of procurement, rather than continue adopting the traditional options. A PPP's can provide a number of benefits to the public sector such as:

1. Speedy, efficient and cost-effective delivery of projects;
2. Creation of added value through synergies between public sector and private sector, in particular, through the integration and cross-transfer of public and private sector skills, knowledge and expertise;
3. Alleviation of capacity constraints and bottlenecks in the economy through higher productivity of labor and capital resources in the delivery of projects;
4. Competition and greater construction capacity;
5. Accountability for the provision and delivery of quality public services;
6. Innovation and diversity in the provision of public services; and
7. Effective utilization of state assets to the benefit of all users of public services.

2. IRAQ INVESTMENT TENDENCIES AFTER 2003

Encouraging private sector for the good deed in economical development will reduce the burden left on state shoulders and will contribute to attract more unemployed hands through achieving more economical bases variations. After the 2003 war, several laws went into effect improving Iraq's business environment and changed the legal regime attracting foreign investment and allowing foreign investors national compliant treatment. The following are the Iraqi investment tendencies after 2003.:-

2.1 Constitution of Iraq 2005(al-Waqā'i 'al-'Irāqiyah,2005)

The most important state investment tendencies in Iraqi new constitution(2005) which concerns with these issues that comes in the constitution articles with direct touching in organizing the economical affairs ,which concentrate on the investment issue especially in the following:

Article 112-second: Refers to (depending on new marketing technical principle encouragement of investment, because by changing the economical order from socializing to capitalizing and encourage the adventure towards marketing economics spontaneous stricter through the offer and demand ways).

Article 111: Oil and gas dominated by the Iraqi people to all regions and governments; the fortunes is owned by the government to people; the state view has changed in possessing the natural fortunes from the state possessing to people possessing.

Article 25: Iraqi state guarantees reforming its economic according the modern economical foundation, which ensure its full sources investment, varying its sources, encouraging special sector and developing it.
Article 26: Iraqi state guarantee encouraging investment in different sectors, and organized by law, the investment will be according to marketing economics, so that the state will take the investment supporting role which will complete through especial sector not the investor role.
Article 23: The special possessive reserved by low and the owner has the right to get benefit by his possessing and uses it and disposal it.
Article 23-second: It is impossible to take the property dispossess of the owner by force except in general benefit (public fair) benefits in opposite to fair compensation.
Article 23- third: Iraqi has the right to possess any thing every where in Iraqi land.
Article 24: Special and local education is guaranteed and organized by role.

2.2 Iraqi Investment law I.I.L(, al-Waqā'i 'al-'Irāqiyah,2006)

Iraqi parliament gives the agreement on the (I.I.L) NO.13 2006 on October, and becomes valid from January 17-2007, this law encourages both local and foreign private investors to invest in the country and which protects investors' property rights. The investments do not include investment less than 250 000 USD and awards fundamental privilege and guarantees include:

1. Exempts approved investment projects from certain taxes and fees for at least 10 years;
2. Allows investors to repatriate investments and profits from investments ;
3. Allows investors to rent or lease land for the whole period of an investment project,
4. Allows investors to insure projects with any national or foreign insurance company;
5. Permits investors to open accounts in Iraqi or foreign currency or both at Iraqi banks or at banks outside Iraq.

2.3 International convention action with Iraq(2007)

In May 3rd _2007 the prime minister (Noori Almaliki) has released and the united nation secretary general (Ban Q Mun), the international convention action with Iraq in Sharm Alsheikh, this convention is an action released by Iraqi government aims to hold new partnership between Iraq and international community, the purpose of this action to achieve national vision to Iraq aims to support peace and to achieve political, economic and social development through coming five years, it has been taken the investment and reformation program in details. the aims of the development of private sector and encouraging investment are:

1. To create a suitable environment for private investment and to find work chances.
2. To confirm sovereignty of law in financial and commercial fields.
3. To develop the justice system and law abilities in this field to ensure protection for private ownership and credibility of contracts.
4. To a plicate investment law and to issue and a plicate a new commercial law.
5. Improve and facilitate establishing commercial works, workers employment property registration, gaining loans, dealing with license and over boarders' trade, ,
6. Improving finance for private sectors, especially for small and medium companies. Including loans assurances, good aspects of finance including small and medium companies ,
7. Listing lawful texts within the legislation and instructions of general contracts to encourage public private partnership.
8. Joining the economical cooperation and investment organization for Middle East and North Africa which are interested in private sectors and encouraging investment.

2.4 National development strategy in Iraq (2010-2014)

It displayed the preferences strategies to rebuild and develop Iraq, we fixes the goal for the purpose of achieving the fundamental national view in regaining Iraq its suitable rank in the international community as continental economical flourish power, opened on all marketing economics. Under chapter 11, the Objectives and Means of Achieving the vision "An interactive, participatory, and competitive private sector that supports sustainable growth, are:-

Objective1: Enhancing the Private Sector's Developmental Role:

1. Increasing its percentage contribution in gross domestic product generation and capital formation.
2. Increasing its percentage contribution in job creation by the scope of the private sector.
3. As private sector savings are key sources for funding plan projects,
4. Making the private sector a source for diversification of commodity supply using the method of private integrated industrial Complexes.

Objective2: Partnership between the Private and Public Sectors:

1. Determining the forms of partnership and choosing the most appropriate,
2. Legislating and activating a privatization law.
3. Establishing support for technological projects and expanding their adoption.

Objective3: Promoting an Environment that Encourages Investment:

1. Adopting flexible policies that respond to local and international economic changes.
2. Expanding establishment of economically feasible shareholding companies
3. Completing the law and regulation system that supports the private sector and the economy
4. Developing banking systems, capital markets, and lending plans
5. Updating economic regulations that support a market economy,
6. Relying on transparency as the basic premise for building the investment relationship between the private sector and the state
7. Developing the government institutions' capabilities,

Objective4: Privatizing of Public Sector Projects

1. Developing the Iraqi stock market from an administrative, technical, and technological perspective.
2. Instituting a flexible and transparent privatization law that protects state and worker rights,
3. Offering stocks for public subscription ,
4. Providing workers with a portion of the shares of the companies sold

Objective5: Developing the Banking Systems and Supporting Financial Institutions

1. Liberating interest rates and exchange rates and reducing restrictions on the flow of capital
2. Developing financial risk management technologies and systems to mitigate the impacts of said financial risk
3. Revitalizing private banks to promote the effectiveness of the private sector's financial transactions
4. Strengthening banking systems' technical and guidance roles to provide support and financial advice to private sector investors.

Objective6: Developing the Private Sector's Competitive and Export Capabilities

1. Examining potential export markets and creating a database thereof
2. Completing the export infrastructure consisting of cold storage, cargo shipping…etc,
3. Focusing on quality, packaging, and marketing,
4. Orchestrating extensive marketing campaigns in regional and international markets,
5. Developing business partnerships with the various economic blocs to enhance trade,

Objective7: Strengthening the Private Sector's Role in Regional Development

1. Distributing roles between the state and province on the one hand, and the private sector on the other hand
2. Promoting decentralization in the management of development facilities,
3. Activating the private sector's role in developing slow-growing provinces,
4. Encouraging the private sector to participate in province development plans.

2.5 Infrastructure law in Iraq

The draft has been put in 2009 in order to do the strategic projects execution like (ports, hospital and rebuilding the establishment and substructure of vital projects) which effect on social and economical life .The costs of achieved projects must be paid for the execution companies during not more than five years from handing the project over date, or any agreed period not less than five years .in order not to bear debts of the execution projects the law limits of sum of the contracts by 70000 million dollars .establishing the infrastructure raise the projects economical value, which represent their production and their services an opening to infrastructure projects and to the projects stand its production on the services which supplied by the infrastructure.
Never the less this law does not appear for reasons for other side concerning:
1. Open the corruption and wasting funds.
2. Drowning Iraq into debts.

The international development studies center reveal (in London)that infrastructure law in Iraq will contribute to increase the Iraqi exhausted economy burdens with debts and interest without any guarantees protect Iraqi people development rights.

3. INVESTMENT ENVIRONMENT CHALLENGES IN IRAQ

In spite of present investment environment distinguished, especially by investment law (2006), containing many of necessary motives, but the challenges still face the investors are:-
1. inflexibility of administration state in required interaction and the absence of working by one window, in addition to that ,there are miscellaneous items approved represented by discovering administration
2. Weak commercial banks, which could by high flexibility fast responsibility for investment requirement in addition to weak of insurance companies presence.

These factors contribute to make the investment environment weak comparison with other countries. When we review to surveying have done by international bank 2014 (doing business in Iraq) see **Fig.1.**The World Bank ranks Iraq 166th out of 183 countries in its "Doing Business 2011" behind even Haiti and Zimbabwe to 151th out of 189 countries in its "Doing Business 2014", and thus still indicates a very serious situation.
In particular, survey of the ease of doing business around the world, the worst ranking of any country in the Middle East., Iraq ranked 128th globally in terms of "protecting investors" and 142th in "enforcing contracts". The World Bank scored it 4.3 out of 10 on its "strength of investor protection index". The survey notes that court proceedings to enforce contracts in Iraq require 51 procedures taking an average of 520 days. By contrast, Singapore, which topped the global ranking, requires 13 procedures, which take 150 days. So we found the survey solution reflects the high hard degree in using economical activities.
Table1.showing the ranking of Iraq according to mainly ten index about starting business, Where the government administration incapable to create a suitable and encouraging circumstances to bring qualified businessmen and contractors.
It is noteworthy to compare Iraqi investment environment and ranks relative to comparator economies and relative to the regional average, see **Fig. 2**, by using the economic survey data which presented by The International Bank for Reconstruction and Development, **international**

bank,2014.we found a big difference refers to that Iraq relatively represent a difficult investment environment.

4. SITUATION OF INFRASTRUCTURE FACTS IN IRAQ

In 2010, after the new investment law was passed the private finances including investment contracts in some major infrastructure and residential projects were estimated over $40 billion in all sectors see **Fig.3**. Since 2009 Iraq has attracted investments worth $23 billion, **National Investment Commission,2009.**

Dr. kamal (Iraq institute for economic reform) has revealed in practical study including public sector during 2007, the negative effective factors in retardation of execution, we found in **Table2**.schedule number of factors, for example 91%of state administrations think that the negative effective factor is the late to prepare the site for working commencement. Dr. kamal has perform two studies once in 2008,and the other 2011 ,which the images doesn't differs so much than 2008 but many details about worse execution matters embodied by the following:-

A- outer factors(the factors don't affect on foundation disability) : represented by

1.security circumstance influences
2.supervision foundations standard obstacles,
3.absence of infrastructure projects
4.general budget agreement delay
5.Inflexible rules and arrangement.
6.Law domination weaker because of exceptional circumstances of political operation faces.

B- Interior factors (specialized by productive foundation for services) ,this factors lead to project delay and in consistency. Represented by:

1.Good leader ship required weakness implementation (decision making transparency, Depending on adequate (qualified person), Remote planning etc).
2.The weakness leadership reflects on technical knowledge not being found in project administration, like tender opening and analysis commission, resident engineer's directorate, disability of technical as measuring devices and laboratories..
3.Responsibility inducement absence and complication of administration central systems.

C- Complementary working weakness factors between different foundations. Coordination factors between different estate administrations. Its include for example:

1.Weakness cooperation between government administrations concerning the land designation.
2.Weakness of financial allowances decisions (ministry of planning).
3.Weakness of paying government allowances(ministry of financial)
4.Opening LC(Central Bank and Iraqi commercial Bank)…..etc

Rebuilding costs were estimated after 2003 by 187 billion USD for the period 2010_2014 according to different economical sectors essential needs which represent maximum standard for required investment in rebuilding and saving citizen fundamental needs ,they distributed as they come according to fifth plan(2010-2014) in the following schedule, It is distributed in **Table 3**.

Through a historical look, and in light of government obligations toward inflated operating expenses, particularly in terms of the magnitude of salaries, pension payments, and expenses pertaining to security and price subsidies, the public budget can allocate what corresponds to 30 percent of these revenues to investment spending, i.e., 117,119 billion dinars or US$100 billion. See **Table 4**.

The magnitude of investment needed to achieve the plan's target growth rate of 9.38 percent annually is 217,637 trillion dinars, or US$186 billion. It is anticipated that development partners (the domestic and foreign private sector) will fund US $86 billion, which will be spent in the

various fields specified by the plan, as well as other activities not set forth in the plan such as insurance, banks, and other personal services. See **Table 5.**

Government investment as well as domestic and foreign private sector investment will contribute to executing the plan's aggregate and objectives. Specifically, the government will contribute 53.7% of investment, with the foreign and private sector contributing 46.2% of investment during the years of the plan.

According to what is presented and working by contemporary styles in different countries. the Strategically chosen for rebuilding and rehabilitating the infrastructure projects in Iraq is adapted by PPP's contracts to public sectors in accordance of it, the public sector partner (regulator) agreed with private sector partner (provider) to execute the infrastructure projects according specification and limited period of time. It is necessary to use this type of contracts to develop private and public sectors inside the form of harmony (twin) between local sector and foreign sector.

5. PPP's CONTRACTS

5.1 PPP's definition

No universally acknowledged and convincing definition of PPP's exists. One cause lies in the complexity, multi-dimensionality and changeability of the concept **, Ziekow,2008.** Accordingly, various definitions are very global and embrace all forms of co-operation between public and private actors**, Ulli Arnold,2011.**

According to International Monetary Fund, **IMF, 2004.** public-private partnerships (PPP's) refer to arrangements where the private sector shares the risks by supplying infrastructure assets and services that traditionally have been provided by the government, see **Fig.4** .Partnership is a means of mobilizing the energies and talents of diverse sector of society to bring about social and economic transformation. The inter-sectoral collaboration between government, the business sector and civil society is based on the premises that partners have distinctive assets that can be combined in a more productive manner to find long lasting solutions to complex problems, **Fourie, 2006.**

5.2 PPP's forms

The World Bank and PPIAF Private Participation in Infrastructure (PPI) Project database is divided into sectors as follows **,World Bank, 2012.**:

- Energy (electricity and natural gas)
- Telecommunications
- Transport (airports, seaports, railways, and toll roads)
- Water and sewerage (treatment plants and utilities).

Within these four sectors, the database identifies four types of projects: management and lease contracts, concessions, green field projects, and divestitures. and identifies sub-categories for each of the four types of projects- the World Bank classification is depicted in **Table 6**.

1-Management and Lease Contracts - A private entity takes over the management of a state-owned enterprise for a fixed period while ownership and investment decisions remain with the state. There are two subclasses of management and lease contracts:

- Management contract - The government pays a private operator to manage the facility. The operational risk remains with the government.
- Lease contract - The government leases the assets to a private operator for a fee. The private operator takes on the operational risk.

2-Concessions - A private entity takes over the management of a state-owned enterprise for a given period during which it also assumes significant investment risk. The database classifies concessions according to the following categories:

- Rehabilitate, operate, and transfer (ROT): A private sponsor rehabilitates an existing facility, then operates and maintains the facility at its own risk for the contract period.
- Rehabilitate, lease or rent, and transfer (RLT): A private sponsor rehabilitates an existing facility at its own risk, leases or rents the facility from the government owner, then operates and maintains the facility at its own risk for the contract period.
- Build, rehabilitate, operate, and transfer (BROT): A private developer builds an add-on to an existing facility or completes a partially built facility and rehabilitates existing assets, then operates and maintains the facility at its own risk for the contract period.

3-Greenfield Projects - A private entity or a public-private joint venture builds and operates a new facility for the period specified in the project contract. The facility may return to the public sector at the end of the concession period. The database classifies Greenfield projects under the following categories:

- Build, lease, and transfer (BLT): A private sponsor builds a new facility largely at its own risk, transfers ownership to the government, leases the facility from the government and operates it at its own risk up to the expiry of the lease. The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees.
- Build, operate, and transfer (BOT): A private sponsor builds a new facility at its own risk, operates the facility at its own risk, and then transfers the facility to the government at the end of the contract period. The private sponsor may or may not have the ownership of the assets during the contract period. The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees.
- Build, own, and operate (BOO): A private sponsor builds a new facility at its own risk, then owns and operates the facility at its own risk. The government usually provides revenue guarantees through long-term take-or-pay contracts for bulk supply facilities or minimum traffic revenue guarantees.
- Merchant: A private sponsor builds a new facility in a liberalized market in which the government provides no revenue guarantees. The private developer assumes construction, operating, and market risk for the project.
- Rental: Electricity utilities or governments rent mobile power plants from private sponsors for periods ranging from 1 year to 15 years. A private sponsor places a new facility at its own risk, owns and operates the facility at its own risk during the contract period. The government usually provides revenue guarantees through short term purchase agreements such as power purchase agreement for bulk supply facilities.

4- Divestitures - A private entity buys an equity stake in a state-owned enterprise through an asset sale, public offering, or mass privatization program. The database classifies divestitures in two categories:

- Full: The government transfers 100% of the equity in the state-owned company to private entities (operator, institutional investors, and the like).
- Partial: The government transfers part of the equity in the state-owned company to private entities (operator, institutional investors, and the like). The private stake may or may not imply private management of the facility. These would not be PPPs as defined in this paper.

6. JUSTIFICATION OF PPP's IN IRAQ

We may limit these justifications as following:

1.The accelerating technical and economic changes which provide an opportunity for the reduction of the costs of projects.
2.The increasing pressures of competition and the reduction in the rates of growth.
3.The limitations on the financial, human resources and technology available to the public sector, in view of the multiplicity of spheres and projects which are in need of implementation.
4.The limitation of the financial resources allocated for social development programs, and the demands of citizens for improving the services offered by governmental institutions.
5.To increase the effectiveness and capabilities through adopting the principle of comparative advantage and the rational division of labor.
6.To support the partners by affording they complete solutions required by the nature of the problems.
7.To enhance decision making in the service of the public interest.
8.To achieve a higher value on the invested capital .

7. REQUIREMENTS OF SUCCESSFUL PARTNERSHIP FOR INFRASTRUCTURE

For countries that are new at adopting PPP's, it is even more important for them to identify the success factors in order to maximize the advantages of this method and to reduce the risks for all parties. The concept of 'Critical Success Factors' (CSF's) was first introduced by Rockart 1979**, Dada,2012.**CSF's are 'those few key areas of activity in which favorable results are absolutely necessary for a particular manager to reach his or her own goals'. Critical success elements are significantly important to help firms or organizations to identify key factors that firms should focus on in order to be successful in a project **,Hardcastle ,2005.**

Some researchers have been conducted to identify CSF's for project success using quantitative measures of various factors. However, these factors are only confined to the project management efforts. The same approach also cannot be adopted to cover intangible factors or be used when hard performance data are not available. Alternatively, CSF's have also been identified using expert opinions. The impact of experience possessed by project key personnel toward project outcomes has been widely recognized. A comprehensive literature review to identify the CSF's of PPP's has been conducted. Relevant published literature including textbooks, research reports, journal articles, conference papers, and internet materials were reviewed thoroughly. **Table 7,** shows a summary of the analysis of these pieces of literature.

7.1 CSF's for infrastructure projects under PPP's model

To assessing CSF's for the viability of government component includes 87 significant decision factors shown in **Table 8**, grouped and classified according to relevance under eight main criteria including (Privatization and investment Policy **,**Economical **,**financial and commercial, legal and political, social and environmental, technical, administration and organizational and support and government incentives).

7.2 Identification CSF's for infrastructure projects under PPP's model in Iraq

A questionnaire was designed to acquire different views about the CSF's. The respondents (46) person, include government sector, private investors, and academic experts who have engaged in the PPP's projects. Experts' respondents were requested to rank these factors for success the implementing of PPP projects according to a five-point Likert scale (1 = Least Important and 5 = Most Important). By using statistical program **(IBM/SPSS,V20)**, the researcher analyzed the questionnaire answers within three steps:

1- Making arithmetic average for factors then arrange them according to their importance.
2- Having the general average for factors importance according to the analysis of the questionnaire.
3- Limited importance and Significance indexes for factors.

The evaluation results were shown as **Table 8**. Delete those factors whose significance indexes values are less than 60% and the factors left are critical success factors. For the particular study, The researcher taking the most important five ranking factors in order to inviting government obligation to fulfill these aims and discussing the briefing description of CSFs

7.3 Brief description of CSF's

This paper has attempted to summarize the main issues surrounding the development of PPP's initiatives for infrastructure projects, and has highlighted the necessary structuring principles to strengthen the identification and analysis of that type of projects. Basing on the characteristics of CSFs for infrastructure projects under PPP's model and the viewpoints of experts during the questionnaire of this study, the priorities of CSF's in PPP's model have ranked as a key issues in five ranking under eight main criteria, are:

1- Privatization and investment Policy criteria

The government must be clearly obliged to words PPP's in development of infrastructure services. The government controls many of necessary success factors of infrastructure projects under PPP's. Nobody can participate or investor or borrower unless it without depending on the inviting government which is fixed all the project period.

the most important five Privatization and investment Policy criteria factors which The inviting government obligation must fulfill these aims:

- The country need for private sector finance and technique.
- Obvious national political for development clearly obliged the private sector participation in financing substructure projects.
- A good national reputation.
- Participation notion of people acceptance
- The government obligation in compliance with substructure projects based on PPP's.

2- Economical criteria

According to the infrastructure investment importance of national development, the government must put a work scheme for economical evaluation to make sure that better decisions are made then achieve a value for finance by using the country local sources and the foreign investment with limitation of the government participation with the project profits. the most important five economical criteria obligation must fulfill these aims:

- Multi benefit objectives.
- Economical development flourish's contribution.
- Real demands promising (perspective).
- Level of economic development.
- Public debt problem salvation and lessen deficit

3- Legal and political criteria

Whether to assess the contracting authority has the legal ability to enter into a PPP contract. The legal viability assessment should also consider the legal implications of the project in relation to existing employees, assets and contracts.Attractiveness of any PPP's projects to private sector investor depends on the way which the government treats main legal cases like carrying out contracts and private ownership ,taxes, insurance, foreign sector finance, profits they are all critical things for all foreign investment in PPP's projects. The most important five legal and political critical factors which the government obligation must fulfill these aims:

- Legal framework for realization of PPP's projects.
- Political stability.
- Expropriation.
- Government skills in PPP's projects.
- National resources and services use.

4- Financial and commercial criteria

The Development in the financial market is a great importance in attracting local and foreign investments because they make it easier for the investor access to financial resources when needed and the ability to be employed when there are assets, and they are easier for the investor out of the market with minimal losses. The most important five Financial and commercial criteria factors which the government obligation must fulfill these aims:

- Contracts execution ability ;
- Availability of foreign currencies ;
- Sufficient rules for foreigner property and company establishment;
- Efficient capital market;
- Commercial banking jobs legislation and insurance.

5- Administration and organizational criteria:

The government should establish a framework to host administratively credible and effective implementation of the strategy for PPP's successfully so that the complex bureaucratic procedures and lack of decision-making authority to managers often referred to as a serious bottleneck for operations PPP's. the effective administrative framework will greatly accelerate private sector investment in projects of PPP's. There is no management framework and perfect single for the development of all PPP's projects so that each country has its own Special administrative and special culture administrative region. the most important five Administration and organizational criteria factors the government obligation must fulfill these aims:

- Legislation suggestion and putting administration systems to activate and watching projects.
- Penetrate the bureaucratic obstacle to secure the immediate ratification and auditor.
- Limit and put priority for PPP's projects in compliance with ministries and government organization and local executive corps.
- Training of administration person to understand and value the plans of PPP's.
- Using consultative corps to check, certification, development and PPP's projects executive.

6- Social and environmental criteria

the development and implementation of most PPP's projects is a customary in traditional infrastructure projects, take a survey of social , environmental ,social impact assessment , environmental standards and characterization of environmental performance standard is particularly important. The most important five social and environmental critical factors which the government must follow to make successful PPP's projects as appeared in analysis of questionnaire are:

- Job security and achieve development implementing
- The impact of Wars and terrorism
- Private sector participation activation
- Local support from the surrounding community to the project
- Existence of environmental policies.

7- Technical criteria

This refers to the availability expertise in terms of technology, management, material, equipment and human resources to undertake infrastructure projects in Iraq. The government is seeking projects in the PPP's to increase the benefits of the PPP's projects up to the maximum for each of

them, local capacity-building and technology transfer from the project sponsors , guarantors and contractors and so the PPP's projects can formulated to provides for the transfer of advanced technology and reduce the countries' dependence developing on foreign technology and improve the self-reliance of technology they have. The most important five Technical criteria factors which the government obligation must fulfill these aims :

- The applicable technology to infrastructure projects must be aligned with national available input and with the current and expected needs of the country.
- Training and the use of national elements trainees to transfer technology.
- Cooperation between local companies and project companies to manufacture equipment.
- The acquisition and transfer of technology from sponsors.
- The use of local goods and services to insure local participation as long as it is rival in (quality, service and time table for delivering and price)

8- Support and government motives and guarantees criteria

the governments should assess the need to provide incentives support both direct and indirect in all PPP's projects almost , and vary the degree and type of support varies greatly too , depending , among other things on the country risk and the feasibility of the project and the country's need for the project and the competitive position of the Government .The most important five Support and government motives and guarantees criteria factors which the government obligation must fulfill these aims:

- Currency exchange protection.
- The host government Contributions coming from the existing assets
- Land and Facilities for other logistic made by government.
- Providing incentive and tax guarantees.
- Financial support Subsidy.

7. CONCLOTION

According to what is presented in this paper about the facts of infrastructure projects in Iraq and the tendencies of investment after 2003. the Strategically chosen for rebuilding and rehabilitating the infrastructure projects in Iraq is adapted by PPP's contracts to public sectors in accordance of it, the public sector agreed with private sector to execute the infrastructure projects according specification and limited period of time.

This paper has presented the requirements of successful partnership in Iraq, depending on the basis of reviewing relevant researches of (CSF's) in PPP's projects and local factors in Iraq and findings from a questionnaire survey including looking at the 87 previously identified CSF's for PPP's models. The significances index technique was used to identify the ranking of CSF's. The findings showed that five underlying grouped factors accounting in responses were derived from the 87 success factors. All loadings for the CSF's were greater than 60% indicating a high absolute value for each.found out (40) CSF's. thus they are especially important CSF's based on our interpretative structural model. These findings will be of help to the successful scientific decision-making of infrastructure projects in their evaluation of CSF's for PPP's projects in Iraq.

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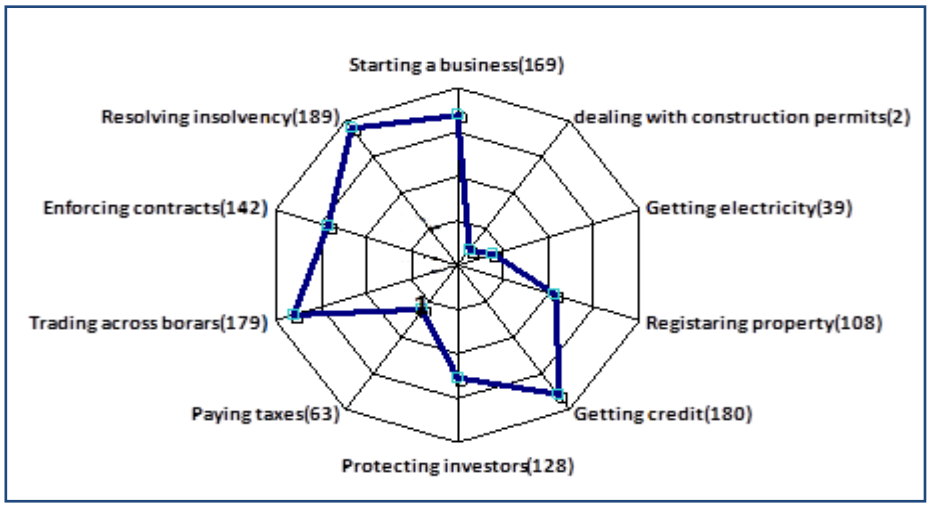

Figure 1. How Iraq ranks on Doing Business topics (doing business in Iraq 2014) .

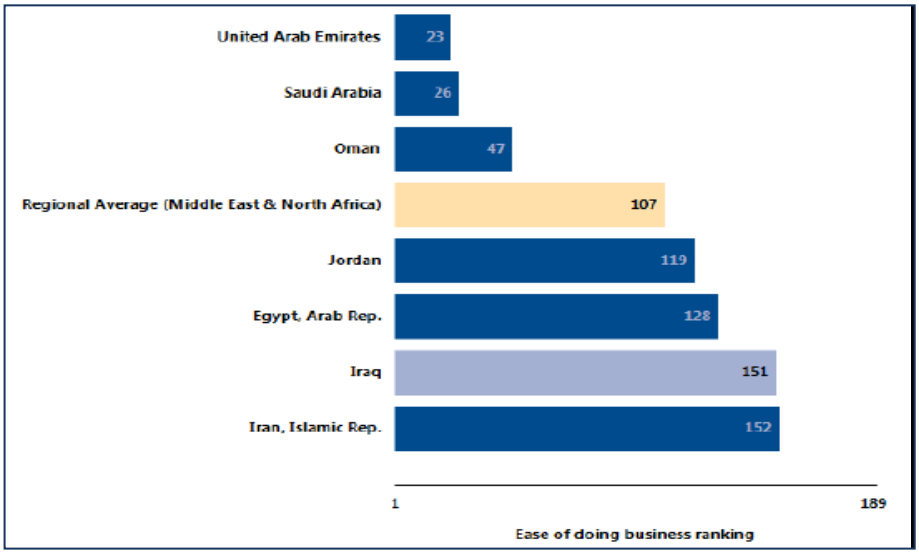

Figure 2. How Iraq and comparator economies rank on the ease of doing business.

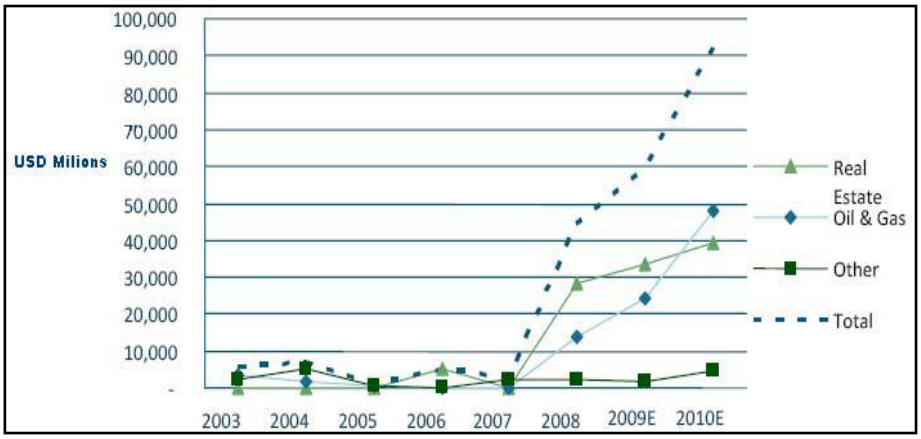

Figure 3. Investment in Iraq by sector **,Investment overview of Iraq, 2009.**

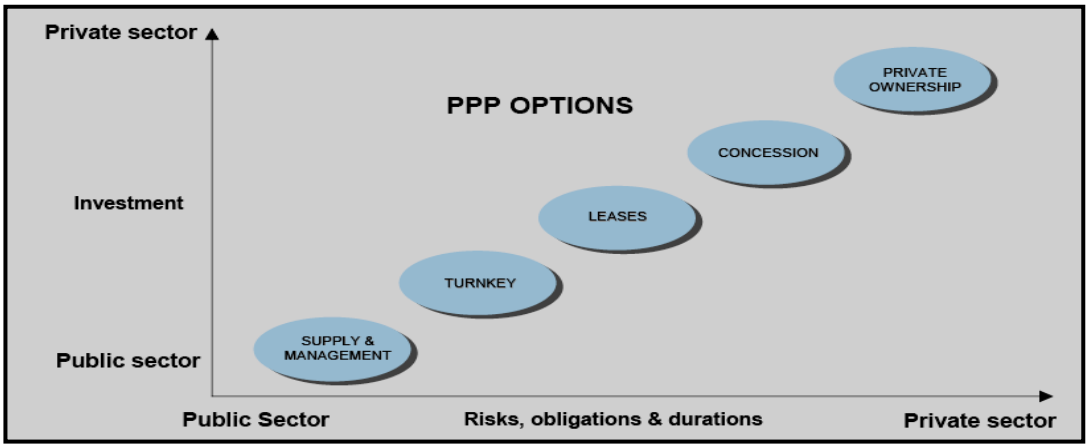

Figure 4. PPP models and assumption of risks by the private sector.

Table 1. How Iraq ranks on Doing Business topics (doing business in Iraq 2014).

TOPICS	DB 2014	DB 2013	Change in
Starting a Business	169	168	**-1**
Dealing with Construction	20	28	**+8**
Getting Electricity	39	49	**+10**
Registering Property	108	99	**-9**
Getting Credit	180	177	**-3**
Protecting Investors	128	127	**-1**
Paying Taxes	63	65	**+2**
Trading Across Borders	179	182	**+3**
Enforcing Contracts	142	143	**+1**
Resolving Insolvency	189	189	No change

Table 2. balanced sheet (2006-2010).

NO.	Effective factor	Ratio %
1	Working commencement delay because of preparing site.	91.30
2	Security absence	86.96
3	Unlimited of the period of opening and analyses and remits.	76.19
4	Un chosen apt contractor.	76.19
5	Complete working investigation not has been found.	73.91
6	Financial allowances delay transformation	69.57
7	Changing order taking decisions delay	68.18
8	Contractor advance payment delay	52.38
9	Incompatible observation and management	40.91
10	Site receiving delay of the contractor	38.10
11	Unavailable of gas oil and asphalt and others	36.48

Table 3. The investment Estimation of the economic sector.

the investment Estimation needs of the economic sector						Milliards of $
activities	2006(1)	2007	2008	2009	2010	total
Crude oil extraction	3.4	8.4	8.7	9.3	9.6	36.0
Electricity		6.0	4.4	3.5	2.6	16.5
Water Resources		1.0	1.5	1.5	1.2	5.2
Agriculture		1.1	1.0	1.0	1.0	4.1
Manufacturing		0.3	0.2	0.2	0.1	0.8
Transportation, transport		7.5	7.5	7.5	7.5	30.0
Building and construction		1.5	1.5	1.5	1.5	6.0
Home ownership		10.0	12.0	15.0	15.0	52.0
Health		2.5	3.3	4.4	4.5	14.7
Education		0.6	0.6	0.6	0.6	2.4
communications		0.3	0.3	0.2	0.2	1.0
Water and sanitation		1.4	1.9	2.5	2.7	8.0
Development of regions and provinces		205	2.5	3.0	4.0	11.0
tatal	14.9	43.1	45.4	49.7	49.5	187.7

Table 4. The budget of Iraq state.

Designated and paid investment spending for(2007-2012)					
year	2008	2009	2010	2011	2012
Operating spending	52.4	46.3	52.2	66.6	79.9
investment spending	21.7	12.8	20.2	30.1	37.2
% total budget	29%	22%	28%	31%	32%
Total budget	74.1	59.1	72.4	96.7	117.1

Table 5. Anticipated Financial Revenues for the Years 2010-2014 (Billions of Iraqi Dinars).

Table 3	Anticipated Financial Revenues for the Years 2010-2014 (Billions of Iraqi Dinar)				
Year	Committee Estimates for Oil Revenues	Non-Oil Revenues	Total (-1)	Alternative Oil Estimates	Total (-2)
2010	55,089.45	3,263.6	58,353.1	55,089.4	58,353.1
2011	61,880.13	5,628.2	67,507.7	61,880.1	67,507.7
2012	72,598.5	6,354	78,952.5	82,506.1	88,860.1
2013	81,310.32	6,846.9	88,157.2	99,006.6	105,853.5
2014	90,022.14	7404.4	97,426.5	118,808.8	126,213.2
Total			390,397		446,787.6
Plan Calculations					
Alternatives	30 percent of budget revenues targeted to investment spending		Portion funded by the domestic and foreign private sector		
	Billions of dinars	Billions of dollars	Billions of dinars	Billions of dollars	
Alternative One	117,119.1	100	152,345.9	130.2	
Alternative Two to be adopted after 2010	134,036.3	114.6	83,600.7	71.5	

Table 6. Classification of public- private partnership.

Ppp option /activities	Service contracts	Management contracts	Lease contracts	BOT contracts	Concession contracts
Financing investment	Puplic sector	Puplic sector	Puplic sector	Private sector	Private sector
Financing workings capital	Puplic sector	Puplic sector	Private sector	Private sector	Private sector
Contractual relations with customers	Puplic sector	Private sector(on behalve of Puplic sector)	Private sector	Puplic sector	Private sector
Private sector responsibility and autonomy	low	low	Low to medium	medium to high	high
Need of private capital	low	low	low	high	high
Financial risk for	low	low	Low to	high	high

private sector			medium		
Duration of contract license	6 months-2years	3-5 years	5-15 years	15-30 years	20-30 years
ownership	Puplic sector	Puplic sector	Puplic sector	Private then Puplic sector	Puplic sector
management	Mainly Puplic sector	Private sector	Private sector	Private sector	Private sector
Setting prices	Puplic sector	Puplic sector	Contract and regular	Public/Private sector	Contract and regular
Collecting bills	Puplic sector	Private sector	Private sector	Puplic/Private sector	Private sector
Main objective of ppp	Improve operating efficiency	Improve technical efficiency	Improve technical efficiency	Mobilize private capital and /or expertise	Mobilize private capital and /or expertise

Table 7 . Critical Success Factors for PPP Projects through Literature Review.

NO.	CSF's	Ppp type	Author
1-	Tiong identified six CSF's for private contractors in competitive tendering and negotiation in BOT contracts as: 1- entrepreneurship and leadership; 2- right project identification; 3- strength of the consortium; 4- technical solution advantage; 5- financial package differentiation; and 6- differentiation in guarantees	BOT	Tiong (1996)
2-	Tiong identified CSF's in winning BOT contracts, which include factors such as: o right project identification, o strength of consortium, o financial package differentiation' and o supportive and understanding community.	BOT	Tiong and Alum (1997), Gupta and Norasimham (1998
3-	Buksbaun describes Public Private Partnership as: 1- new institutional relationships , 2- effectively address critical socio-economic challenges. 3- developed by mobilizing the energies and talents of diverse sectors to bring about social and economic transformation. 4- result of mature democratic tradition	PPP general	Buksbaun (1999)
4-	Qiao established Eight independent CSF's ,were 1- appropriate project identification; 2- stable political and economic situation	BOT	Qiao (2001)

	3- attractive financial package; 4- acceptable toll/tariff levels; 5- reasonable risk allocation; 6- selection of suitable subcontractors; 7- management control; and 8- Technology transfer.		
5-	Jefferies explored CSF's to Stadium Australia. And identified and examined 15 success factors relevant to the project and the most significant CSF's include, 1-compatibility/complimentary skills among the key parties', 2-'technical innovation in overcoming project complexity' and 3-'efficient approval process'. 4-'environmental impact', 5-'developed legal/economic framework', 6-'political stability', 7-'selecting the right project', 8-'existing strategic alliances', 9-'good resource management', 10-'trust','community support', 11-'feasibility study', 12-'transfer of technology', 13-'financial capability', and 14-'consortium structure'.	BOOT	Jefferies et al. (2002)
6-	Solomon showed that 1- well organized and committed public agency; 2- social support; 3- project technical feasibility and multi-benefits objectives. are the CFSs that are most important to the private investors. On the other hand, factors such as: 1- transparency in the procurement process 2- shared authority between public and private sector; 3- thorough and realistic assessment of the cost and benefits; 4- commitment and responsibility of public and private sector and 5- strong and good private consortium are the CSFs that are most important to the public clients.	ppp	Solomon Olusola Babatunde 2002
7-	Akintoye investigated Factors that: 1- Contribute to the achievement of best value in PFI projects are detailed risk analysis and appropriate risk allocation, drive for faster project completion, curtailment in project cost	PFI	Akintoye et al. (2003)

	escalation, encouragement of innovation in project development, and maintenance cost being adequately accounted for. 2- impede the achievement of best value in PFI projects are: high cost of the PFI procurement process, lengthy and complex negotiations, difficulty in specifying the quality of service, pricing of facility management services, potential conflicts of interests among those involved in the procurement, and the public sector clients' inability to manage consultants.		
8-	Jamali investigated the CSF's for PPP implementation in the telecommunication industry in Lebanon. Using a case study approach, the findings indicate that 1-'trust', 2-'openness' and 3-'fairness' are basic foundational underpinnings of successful PPPs	Ppp general	Jamali (2004)
9-	Zhang advocated that PPP project procurement should be based on a public– private win–win principle. It is under this premise that he was able to identify five CSF's and a number of SSFs. These are: 1-favorable investment environment; 2- economic viability; 3- reliable concessionaire with technical strength; 4- sound financial package; and 5-appropriate risk allocation via reliable contractual arrangements	Ppp general	Zhang (2005)
10-	Hardcastle used factor analysis approach to identify CSF's in PPP/PFI projects in the United Kingdom construction industry: 1- effective procurement; 2- project implementability; 3- government guarantee; 4- favourable economic conditions; and 5- available financial market	PFI	Hardcastle, Edwards , Akintoye and Li (2005)
11-	A grounded theory research , Trafford discovered five key characteristics that are crucial in ensuring the success of PPP projects: 1- good communication, 2- openness, 3- effective planning, 4- ethos and 5-direction	ppp	Trafford and Proctor (2006)
12-	He research on factors like general government	ppp	Hammami et al.(2006)

	balance, total debt, Aid per capita, fuel exports, ethnic fractionalization, chief executive's party orientation, opposition parties in legislature, population, real GDP per capita, inflation, money supply, international reserves, control of corruption, composite country risk, rule of law and common law origin as determinants of PPPs in developing countries		
13-	Bing Li show that the three most important factors are: 'a strong and good private consortium', 'appropriate risk allocation' and 'available financial market'. Factor analysis revealed that appropriate factor groupings for the 18 CSF's are: effective procurement , project implement ability, government guarantee, favorable economic conditions and available financial market.	PFI	Bing Li, A. Akintoye, P. J. Edwards Corresponding author(2007)
14-	Wong proved the Successful PPP's implementation requires a stable political and social environment, which in turn relies on the stability and capability of the host government (Political and social issues that go beyond private sector's domain should be handled by the government. If unduly victimized, it is legitimate that the private sector participants should be adequately compensated	ppp	Wong, (2007).
15-	Wang proposed forty-five success factors of infrastructure projects under PPP mode in China are classified into eight main aspects, including 1-the own factors of PPP projects, 2-favorable investment environment, 3- project company competence, 4- project contractor and operator competence, 5-government support, 6- product quality, 7- project management and Regulation policy for PPP project. and found out twenty-one critical success factors ,among which, 1- reasonable risk-sharing mechanism, 2-financial system and policy for PPP projects, 3-the improvement of regulation and policy, 4-rational pricing mechanism and effective supervision mechanis:	ppp	Wang, LI Qi-ming, Deng Xiao-peng , LI Jing-hua (2007)
16-	Jacobson examined principal factors that contribute to successful PPP projects. Ten success factors were investigated: 1-specific plan/vision, 2-commitment, 3-open communication and trust,	ppp	Jacobson and Choi (2008)

	4-willingness to compromise/collaborate, 5- respect', 'community outreach, 6-political support, 7-expert advice and review, 8-risk awareness, 9-clear roles and 10-responsibilities. The results show that 'high degrees of commitment' and 'shared vision between the client, architect, and contractor' are the most important factors for construction success		
17-	Abdul Aziz examined the CSF's of ten PPP housing projects in Malaysia. The study identified 15 success factors for PPP housing projects: 1-action against errant developer', 2-robust and clear agreement', 3-reputable developer', 4-constant communication', 5-developer's profit sharing accountability', 6-developer's social accountability', 7-house buyer's demand', 8-negotiation skills', 9-adequate negotiation staff', 10-realistic projection', 11-competition', 12-ample time to evaluate proposal', 13-political influence', 14-consistent monitoring', and 15-compatibility between partners'. The results reveal that all 15 factors except 'political influence' contribute significantly to the success of a PPP housing project	PPP	Abdul Aziz (2010)
18-	Dulaimi, Concluded that political support was regarded as most critical factor, while lack of appropriate knowledge and skills of the consortia leads to project failure.	ppp	Dulaimi, Alhashemi, Ling and Kumaraswam (2010)
19-	Ahmadi find in the last experiences in developing countries and reaching a model for Iran Factors like GDP, macroeconomic stability, fuel export, budget deficit, trade deficit, business climate,	ppp	Ahmadi et al.(2010)
20-	Zhao investigated the factors contributing to the success of two PPP power projects – thermal power and wind power – that were developed using the Build Own Transfer (BOT) mode.the authors identified 31 success factors for the power projects and investigate the relative importance of the success factors specific to the individual thermal and wind power	BOT	Zhao et al. (2010)

21-	Chan Used 18 factors to investigate opinions on CSF's in PPP. The factors were decomposed into five underlying groups or factors: 1- stable macroeconomic environment, 2- shared responsibility between private and public sector, 3- transparent and efficient procurement process, 4-stable political and social environment, and 5- Judicious government control.		Chan, Lam, Chan, Cheung, and Ke (2010)
22-	Marques described a Successful PPP's projects are based on three pillars 1- all relevant criteria should be taken into account in the public tender phase (although the evaluation model should only contain the strictly necessary criteria to choose the best bidder); 2- the suitable risk management framework is determinant to protect the public interest; 3- the sound principles of contract management must be put into practice (including the definition of incentives and penalties,	PPP	Marques and Berg (2010)
23-	Akintoye achieving best value in private finance initiative (PFI) projects and the associated problems therein,find the Factors that contribute to the achievement of best value in PFI projects are 1.detailed risk analysis and appropriate risk allocation, 2.drive for faster project completion, 3.curtailment in project cost escalation, 4.encouragement of innovation in project development, and maintenance cost being adequately accounted for. Factors that impede the achievement of best value in PFI projects are: 1. high cost of the PFI procurement process, 2. lengthy and complex negotiations, 3. difficulty in specifying the quality of service, 4. pricing of facility management services, 5. potential conflicts of interests among those involved in the procurement, and 6. the public sector clients' inability to manage consultants	PFI	Akintoye, Cliff Hardcastle et al..2010
24-	Chan showed that the 18 CSF's could be grouped into five underlying factors including: 1—stable macroeconomic environment; 2—shared responsibility between public and private sector 3—transparent and efficient procurement process;		Chan, A., Lam, P., Chan, D., Cheung,2010

	4—stable political and social environment; and Factor 5—judicious government control.		
25-	Rosa presented PPP infrastructure construction projects can be evaluated according to financial, technical, private partner selection criteria as well as social, economic, and environmental factors by using model for effectiveness evaluation of PPP infrastructure construction projects suggested by the authors: **a-** sustainability performance indicator 1- economical aspects 2- Social aspects 3- Environmental aspects. **b-** PPP effectiveness indicator 1- Private sector partner evaluation **2-** Project evaluation	ppp	Rasa Apanavičienė , Rūta Rudžianskaitė Kvaraciejienė,2010
26-	Mohamed found that the most important factors in Kuwait can be grouped in five clusters. 1- Effective Procurement, 2- Project Implementability, 3- Government Guarantee, 4- Favorable Economic Conditions 5- Available Financial!Market	ppp	Mohamed Ahmed Helmy,2011
27-	The study has established for the Nigerian environment, Under favorable investment environment both the private and public sectors ranked **1-** Stable political **2-** sound financial package, **3**−appropriate risk allocation		Dada, M.O.a* and Oladokun, M.G.2012
28-	Basing on the overall respondentsof 18 factors' results, the top five most critical factors, in descending order of importance are: 1- good governance; 2- commitment and responsibility of public and private sectors; 3- favourable legal framework; 4- sound economic policy; and 5- available financial market. The two factors that were ranked as least important for project success are government involvement by providing guarantee and political support.	ppp	. Suhaiza Ismail, Shochrul Rohmatul Ajija 2013

28-	Ogunsanmi concluded that for successful implementation of PPP projects in Nigeria the contributive CSF's are: 1- transparent and sound regulatory framework, 2- comprehensive feasibility study, 3- appropriate risk allocation, 4- commitment, 5- responsibility of public and private sectors, 6- strong private consortium, 7- government guarantee, 8- realistic cost/benefit assessment, 9- stable macro-economic conditions and 10- sound economy policy that must	ppp	Ogunsanmi Olabode Emmanuel,2014

Table 8 .statistical analysis results for infrastructure projects under ppp model.

NO.	factors	mean	Chang level	St. deviation	% significance index	95% Confidence Interval for Mean		ranking
						Low ending	High ending	
1- Privatization and investment Policy criteria:								
1.	Participation notion of people acceptance	3.21	.176	1.138	64.200	2.86	3.57	4
2.	Obvious national political for development clearly obliged the private sector participation in financing substructure projects	3.5000	.14952	.96903	70.000	3.1980	3.8020	2
3.	The government obligation in compliance with substructure projects based on ppp	3.1905	.16778	1.08736	63.810	2.8516	3.5293	5
4.	The country need for private sector financial and technical resources.	3.7381	.14076	.91223	74.762	3.4538	4.0224	1
5.	The government has a logic base to support ppp projects,	3.1429	.15828	1.02580	62.858	2.8232	3.4625	6
6.	Private sector participation activation	2.9524	.14836	.96151	59.048	2.6528	3.2520	9
7.	Public awareness supportance and laboure unions for private sector participation.	2.4048	.12779	.82815	48.096	2.1467	2.6628	10
8.	Stable political situation	3.0952	.15916	1.03145	61.904	2.7738	3.4167	8
9.	Well international reputation	3.2143	.17883	1.15897	64.286	2.8531	3.5754	3
10.	International plan consistancy	3.1190	.18417	1.19353	62.380	2.7471	3.4910	7
2- Economical criteria;								
1.	Public debt problem salvation and lessen deficit	3.2143	.17883	1.15897	64.286	2.8531	3.5754	5
2.	Political and security stable	3.21	.176	1.138	64.200	2.86	3.57	7
3.	Country economical strength (economical development standard)	3.5000	.14952	.96903	70.000	3.1980	3.8020	4
4.	System and interest rate	3.1905	.16778	1.08736	63.810	2.8516	3.5293	8
5.	Project benefit of government participation rate	3.7381	.14076	.91223	74.762	3.4538	4.0224	1
6.	Interest achievement of sale price	3.1429	.15828	1.02580	62.858	2.8232	3.4625	9
7.	Market need for project	2.9524	.14836	.96151	59.048	2.6528	3.2520	13

8.	Demand progressive and buying assurances(warranty guaranties)	2.4048	.12779	.82815	48.096	2.1467	2.6628	14
9.	Investment attraction	3.0952	.15916	1.03145	61.904	2.7738	3.4167	10
10.	Joint – stock and local companies	3.2143	.17883	1.15897	64.286	2.8531	3.5754	6
11.	Economical development flourish's contribution	3.7351	.14076	.91223	74.702	3.4538	4.0224	2
12.	Real demands promising (perspective)	3.619	.17024	1.10326	72.380	3.2752	3.9628	3
13.	conventional and international society Interest	3.0476	.17361	1.12515	60.958	2.6970	3.3982	12
14.	Purchase orders for articles local equipment	3.0952	.14780	.95788	61.904	2.7967	3.3937	11
3- Legal and political criteria:								
1.	National merchandise and services use	3.1429	.15828	1.02580	62.858	2.8232	3.4625	5
2.	Resemblance of system and its stability	2.9514	.14836	.96151	59.028	2.6528	3.2520	9
3.	Privilege ending by government	2.4524	.11905	.77152	49.048	2.2120	2.6928	10
4.	Competition	2.9524	.14836	.96151	59.048	2.6528	3.2520	8
5.	The right for using land, roads and supporting establishments	2.4048	.12779	.82815	48.096	2.1467	2.6628	11
6.	Rarity of risks and argument	3.0952	.15916	1.03145	61.904	2.7738	3.4167	7
7.	Government skills in ppp projects	3.2143	.17883	1.15897	64.286	2.8531	3.5754	4
8.	Legal framework for realization of PPP's projects.	3.7381	.14076	.91223	74.762	3.4538	4.0224	1
9.	The rate of foreigner property in the projects	3.1420	.15828	1.02580	62.840	2.8232	3.4625	6
10.	Political stability	3.4524	.14540	.94230	69.048	3.1587	3.7460	2
11.	Expropriation	3.2857	.15723	1.01898	65.714	2.9682	3.6033	3
4- Financial and commercial criteria:								
1.	Legal frame work to protect personal thoughts	2.9524	.14836	.96151	59.048	2.6528	3.2520	8
2.	Rules project property rights	2.4762	.14150	.91700	48.080	2.1904	2.7619	10
3.	Property rights protection from appropriation and natnalization	3.0238	.17540	1.13671	61.900	2.6696	3.3780	6
4.	Contracts execution ability	3.7381	.14076	.91223	74.762	3.4538	4.0224	1
5.	Sufficient rules for foreigner property and company establishment	3.1429	.15828	1.02580	62.858	2.8232	3.4625	3
6.	Rent legislation and privilege giving	2.9524	.14836	.96151	59.048	2.6528	3.2520	7
7.	Environmental and labour rules	2.4048	.12779	.82815	48.096	2.1467	2.6628	9

8.	Commercial banking jobs legislation and insurance	3.0952	.15916	1.03145	61.904	2.7738	3.4167	5
9.	Efficient capital market	3.1429	.15828	1.02580	62.858	2.8232	3.4625	4
10.	Availability of foreign currencies	3.1667	.15955	1.03398	63.334	2.8445	3.4889	2
5- Administration and organizational criteria:								
1.	Framing the government politics and choosing suitable sectors' for ppp projects	3.0000	.13632	.88345	60.000	2.7247	3.2753	8
2.	Legislation suggestion and putting administration systems to activate and watching projects	3.7381	.14076	.91223	74.762	3.4538	4.0224	1
3.	Submitting systems for rationalization and coordination administrative arrangements with ministries and government organizations	2.9524	.14836	.96151	59.048	2.6528	3.2520	9
4.	Limit and put priority for ppp projects in compliance with ministries and government organization and local executive corps.	3.2143	.17883	1.15897	64.286	2.8531	3.5754	3
5.	Using consultative corps to check ,certification, development and ppp projects executive	3.1429	.15828	1.02580	62.858	2.8232	3.4625	5
6.	Penetrate the bureaucratic obstacle to secure the immediate ratification and auditor.	3.3095	.15798	1.02382	66.190	2.9905	3.6286	2
7.	Training of administration person to understand and value the plans of ppp.	3.2381	.15546	1.00752	64.762	2.9241	3.5521	4
8.	The experience of the contracts owner and negotiation of ppp projects	3.0952	.14780	.95788	61.904	2.7967	3.3937	6
9.	Speed credits and monitoring extracts credits and speed monitoring extracts	3.0714	.16483	1.06823	61.428	2.7385	3.4043	7
10.	Management flexibility and responsibility determination	2.9048	.15916	1.03145	58.096	2.5833	3.2262	10
11.	Government intervention in the projects	2.4048	.12779	.82815	48.096	2.1467	2.6628	11
6- Social and environmental criteria:								
1.	Private sector participation activation	3.0952	.15916	1.03145	61.904	2.7738	3.4167	3
2.	Job security and achieve development implementing	3.7381	.14076	.91223	74.762	3.4538	4.0224	1
3.	The impact of Wars and terrorism	3.1429	.15828	1.02580	62.858	2.8232	3.4625	2

4.	Local support from the surrounding community to the project	2.9524	.14836	.96151	59.048	2.6528	3.2520	4
5.	Existence of environmental policies	2.4048	.12779	.82815	48.096	2.1467	2.6628	5
7- Technical criteria:								
1.	The use of local goods and services to insure local participation as long as it is rival in (quality, service and time table for delivering and price)	3.0952	.15916	1.03145	61.904	2.7738	3.4167	5
2.	The applicable technology to infrastructure projects must be aligned with national available input and with the current and expected needs of the country.	4.0238	.12972	.84068	80.476	3.7618	4.2858	1
3.	The acquisition and transfer of technology from sponsors.	3.3333	.15113	.97946	66.666	3.0281	3.6386	4
4.	The adaption of the must appropriate technology to the local conditions.	2.9524	.14836	.96151	59.048	2.6528	3.2520	6
5.	The introduction of local contractor in request for quotation for minor contracts(building national capacity secondary contracting)	2.5952	.14483	.93859	51.904	2.3028	2.8877	7
6.	Training and the use of national elements trainees to transfer technology.	3.9286	.14616	.94721	78.572	3.6334	4.2237	2
7.	Cooperation between local companies and project companies to manufacture equipment.	3.381	.15223	.98655	67.620	3.0735	3.6884	3
8- Support and government motives and guarantees criteria:								
1.	Providing incentive and tax guarantees.	3.4762	.15706	1.01784	69.524	3.1590	3.7934	4
2.	Currency exchange protection.	4.0238	.12972	.84068	80.476	3.7618	4.2858	1
3.	Exemption from income tax for foreign project staff.	2.7857	.14271	.92488	55.714	2.4975	3.0739	17
4.	The process of tax exemption (the tax exemption of real state).	3.0952	.15916	1.03145	61.904	2.7738	3.4167	12
5.	Land and Facilities for other logistic made by government.	3.7381	.14076	.91223	74.762	3.4538	4.0224	3
6.	Franchise (privilege) of tax.	3.1429	.15828	1.02580	62.858	2.8232	3.4625	10
7.	Exemption from import duties on equipment, row materials and the components of the establishment and operating maintenance of the projects or divided.	3.1667	.13162	.85302	63.334	2.9008	3.4325	9
8.	Incentives and fines of achievement and performance	2.4048	.12779	.82815	48.096	2.1467	2.6628	19

9.	Government guarantees and financial reservation	3.0714	.16832	1.09082	61.428	2.7315	3.4114	13
10.	Reinforcement of petrol support.	3.2857	.15723	1.01898	65.714	2.9682	3.6033	8
11.	Indirect guarantees for operating income and stand by loans	3.0000	.16344	1.05922	60.000	2.6699	3.3301	14
12.	Corporation tax exemption to class commitment.	3.0952	.15916	1.03145	61.904	2.7738	3.4167	11
13.	Commercial freedom Guarantees.	3.3810	.17361	1.12515	67.620	3.0303	3.7316	7
14.	Rate interest compensation .	3.3333	.15113	.97946	66.666	3.0281	3.6386	6
15.	Reduction of incidents of unsecured force majeure	2.9524	.14836	.96151	59.048	2.6528	3.2520	15
16.	emphasis on non- rival projects	2.5952	.14483	.93859	51.904	2.3028	2.8877	18
17.	The host government Contributions coming from the exsisting assest	3.9286	.14616	.94721	78.572	3.6334	4.2237	2
18.	The government's commitment to the conclude of projects within a reasonable period of the government.	2.9286	.17837	1.15596	58.572	2.5683	3.2888	16
19.	Financial support Subsidy	3.4286	.18079	1.17167	68.572	3.0635	3.7937	5

Effect of Operating Conditions on Reverse Osmosis (RO) Membrane Performance

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ABSTRACT

The aim of this research is to study the effect of high concentrations of salts, pressure and temperature on the performance of the RO membrane with time. Four different (Na_2CO_3) concentrations (5000, 15000, 25000 and 35000) ppm and various pressures such as (1, 3 and 5) bars at different temperatures of the feed solution (i.e., 25, 35 and 45) $^{\circ}$C were used in this work. It was found that, as the concentration of salt and feed temperatures increase, the rejection of the salt decrease. While the salt rejection of the membranes increases with increase of transmembrane pressure.

Key words: reverse osmosis, membrane, permeation flux.

تأثير الظروف التشغيلية على أداء غشاء التناضح العكسي

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الخلاصة

في هذا البحث تم دراسة تأثير التراكيز العالية للمحلول الملحي الداخل والضغط ودرجة الحرارة للمحلول على أداء الاغشية التنافذية. حيث تم إعداد أربعة تراكيز مختلفة(35000,25000,15000,5000) جزء بالمليون وعند الضغوط (١ , ٣ و٥) بار وتغيير درجة حرارة الماء الداخل (٢٥، ٣٥ و ٤٥) °م باستخدام نوع واحد من الاغشية التنافذية RO مع استخدام ملح (Na_2CO_3) لتحضير المحلول الملحي . حيث وجد انه كلما زادت تراكيز الاملاح تقل كفاءة الفصل للاملاح بينما تزداد كفاءة الفصل للاغشية عند الضغوط العالية. عند ارتفاع درجة الحرارة وجد ان كفاءة الفصل تقل.

الكلمات الرئيسية: التناضح العكسي, غشاء, معدل التدفق النافذ.

1. INTRODUCTION

The scarce availability of clean water in certain areas has led to an increased need to fresh water production via desalination of brackish and seawater or, e.g., treated wastewater. Membrane technology has revolutionized the separation industry by providing a highly selective and low-cost alternative to separation processes. Pressure-driven membrane separation processes (especially reverse osmosis) are important and attractive technologies for desalination and wastewater treatment, and this is because of the advantages of RO compared to the thermal desalination techniques, **Fritzmann, et al., 2007**. Reverse osmosis membrane technology has developed over the past 40 years to a 44% share in world desalting production capacity, and an 80% share in the total number of desalination plants installed worldwide. Recently, the use of reverse osmosis (RO) as a separation process is the leading technology for new desalination installation, and it is applied to a variety of salt water resources, **Lauren, et al., 2009**. In the late 1950's the work of Reid showed that cellulose acetate RO membranes were suitable for water desalination, **Reid and Breton, 1959, Ferguson, 1980; Lonsdale, 1982** and **Applegate, 1984.** In 1960's, **Loeb** and **Sourirajan, 1962,** developed a method for fabricating asymmetric cellulose acetate membranes with high water permeation fluxes and solute rejection ,**Loeb and Sourirajan, 1962, Loeb, 1981 and Sourirajan and Matsuura, 1985.** The development of new membranes such as the thin-film, composite membrane that can be used for a wide pH ranges, temperatures. In addition, RO membranes have found uses in wastewater treatment, production of ultrapure water, water softening, and food processing,… etc., **Bhattacharyya et al., 1992.**

Water treatment processes employ several types of membranes; these types are classified according to pore diameter. The reverse osmosis process is characterized by a membrane pore size in the range of 0.0005 microns. Reverse osmosis membranes are effectively non-porous, and therefore exclude particles and even many low molar mass species such as salt ions, organics, etc. Reverse osmosis called as hyper filtration in the past, it is regarded as another pressure driven process. In this process a solvent of the solution is transferred through a membrane and this lead to change in the concentration of the solution. In such a way, the concentration of some solute with low molecular weights (up to 500 Daltons) or other solvents is decreased, **Sath, et al., 2012**. Reverse osmosis (RO) is a physical process that uses the osmosis phenomenon. Osmosis is a natural phenomenon in which a solvent (usually water) passes through a semi permeable barrier from the side with lower solute concentration to the higher solute concentration side. Water flow continues until chemical potential equilibrium of the solvent is established. At equilibrium, the pressure difference between the two sides of the membrane is equal to the osmotic pressure of the solution. To reverse the flow of water (solvent), a pressure difference greater than the osmotic pressure difference is applied; as a result, separation of water from the solution occurs as pure water flows from the high concentration side to the low concentration side, **Mousa,** and **Salem, 2010.**

In the RO process, the pressure projecting on the primarily treated water raising to the limit that suitable for the type of membranes and concentrations of total dissolved solids (TDS) in the water to be treated. That mean the amount of pressure required directly relates to the TDS concentration of the feed water. The RO process is effective for removing TDS concentrations of up to 45,000 mg/L, so the RO technique can be used to desalinate both brackish water and seawater. Reverse osmosis needs energy to operate the pumps that raise the hydraulic pressure of the feed water to the enough limits to exceed the natural osmosis pressure and produce the required quantity of treated water. The objective of this work was to investigate the separation of salt from different salinity water using the

RO process. The effect of Na_2CO_3 concentration of the feed stream, transmembrane pressure and feed temperature on salt rejection and permeate flux were determined.

2. EXPERIMENTAL WORK

A laboratory reverse osmosis unit is used and shown in **Fig.1**. The feed solution is pumped from the feed tank to the membrane module by using diaphragm pump. The Permeate solution was collected in a glass beaker placed on a electronic balance. The Permeate was periodically returned to the feed container to prevent change in the feed concentration. The operating conditions using RO membrane process were commenced with the following ranges:

1. Solute concentration (5000, 15000, 25000 and 35000) ppm.
2. Temperature of Feed (25, 35 and 45) °C.
3. Operating Pressure (1, 3 and 5) bar.

2.1 Materials

1-The RO membrane used in this work was (Hidrotek RO membrane model TW30-1812-50, NSF certified, technology USA). It is supplied from Hidrotek company.
2- Distilled water.
3- Na_2CO_3 as a solute.

3. RESULTS & DISCUSION

Different salinity water is treated by using reverse osmosis system. Performance of RO system is examined by performing experiments under different operating conditions. The resulting salt rejection and permeation flux are presented in **Figs. 2** to **7** under various operating conditions. The salt rejection can be found by the following equation:

$$R\ (\%) = (C_f - C_p / C_f)\ x\ 100 \quad (1)$$

Fig. 2 shows the effect of salt concentration in feed solution on salt rejection (R %). It can be noticed that increasing of salt concentration from 5000 ppm to 35000 ppm results to decrease of salt rejection from 88% to 65%. Moreover, using 15000 and 25000 ppm of salt concentration led to small decrease in salt rejection as shown in **Fig. 2**. This is because when the salt concentration increases in feed water, the salt passage through the membrane increase. The results obtained are in agreement with **Lingyung,** and **Shingjiang**. Effect of feed solution temperature (i.e., 25, 35 and 45) ^oC on the salt rejection is shown in **Fig. 3**. It can be seen that the salt rejection decrease with increase of feed temperature from 25 to 45 ^oC. The reason of this effect is attributed to the decrease of feed solution viscosity which is lead to decrease of fouling on the membrane surface. Furthermore, effect of transmembrane pressure on the salt rejection is shown in **Fig. 4**. Increase of transmembrane pressure from 1 to 5 bar results to increase of salt rejection from 82% to 94%. It is worthy to mention here that there is a significant effect of transmembrane pressure on the salt rejection. Because RO membranes are not completely retained dissolved salts in feed water, there is always some salt passage through the membrane. Therefore when increasing feed water pressure, this salt passage decrease as water is pushed through the membrane. So the permeate concentration was diluted by the higher rate of water flow through the membrane, resulting in an increase in salt rejection , **Abou Rayan,** and **Khaled, 2002**.

Regarding the permeation flux of the RO membrane, **Figs. 5** to **7** show the effect of feed solution temperature, transmembrane pressure and salt concentration in feed solution on the RO membrane permeation flux. It can be seen that the permeation flux of RO membrane increase with increase of feed temperature as shown in **Fig. 5**, this is due primarily to the decrease in both viscosity and density of water when increase the temperature of feed water, so the permeability coefficient of water increase, as reported in the work of **Al-Mutaz ,** and **Al-Ghunaimi, 2001.** Also, from **Fig. 5,** it can be conclude that the best permeation flux was at 35 ^{o}C especially after 70 min from operation and that for a given feed water temperature, the permeation flux decrease with progress in time. In **Fig. 6**, it is expected to find that the transmembrane pressure has the highest effect on permeation flux among the other operating parameters. The permeation flux of RO membrane increases with increasing of transmembrane pressure. This behavior can be attributed to the fact that when increase transmembrane pressure, apportion of the feed water is forced through the membrane to emerge as purified product water (i.e. permeation flux is increased). This is because when increase transmembrane pressure the net driving force is increased also, so the permeation flux is increased**,** **Lingyung,** and **Shingjiang**. The effect of salt concentration in feed solution on permeation flux is shown in **Fig. 7**. The permeation flux decreases with increasing of salt concentration. This is due to increase the osmotic pressure difference across the membrane. The osmotic pressure is a function of the type and concentration of salts or organics contained in feed water. Therefore if feed pressure remains constant, under higher salt concentration results in higher osmotic pressure and this leads to much higher driving force. The increasing in salt concentration in feed water also leads to surface cake or fouling phenomenon on the membrane surface. A similar behavior has been reported by **Marwan,** and **Owee, 2006**.

4. CONCLUSIONS

In this research, different salt solutions were treated by reverse osmosis system. The salt rejection and permeation flux are studied under different operating conditions. The permeation flux experiments are conducted by operating reverse osmosis system for 3 hrs. This study leads to the following conclusions:

- The permeation flux is reduced with increasing time of operation at different conditions.
- The operating pressure has the stronger effect in the reverse osmosis system.
- The permeation flux and salt rejection are enhanced with increasing operating pressure, where the salt rejection is reached to 94% at 5 bars.
- The rejection decrease when increasing feed temperature, while the permeation flux increase.
- Both salt rejection and permeation flux are decreased when increasing the salt (Na_2CO_3) concentration from 5000 to 35000 ppm in the feed solution.

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NOMENCLATURE

C_f = concentration of salt in the feed water, ppm.

C_p = concentration of salt in the permeate water, ppm.

R = rejection of salt, dimensionless.

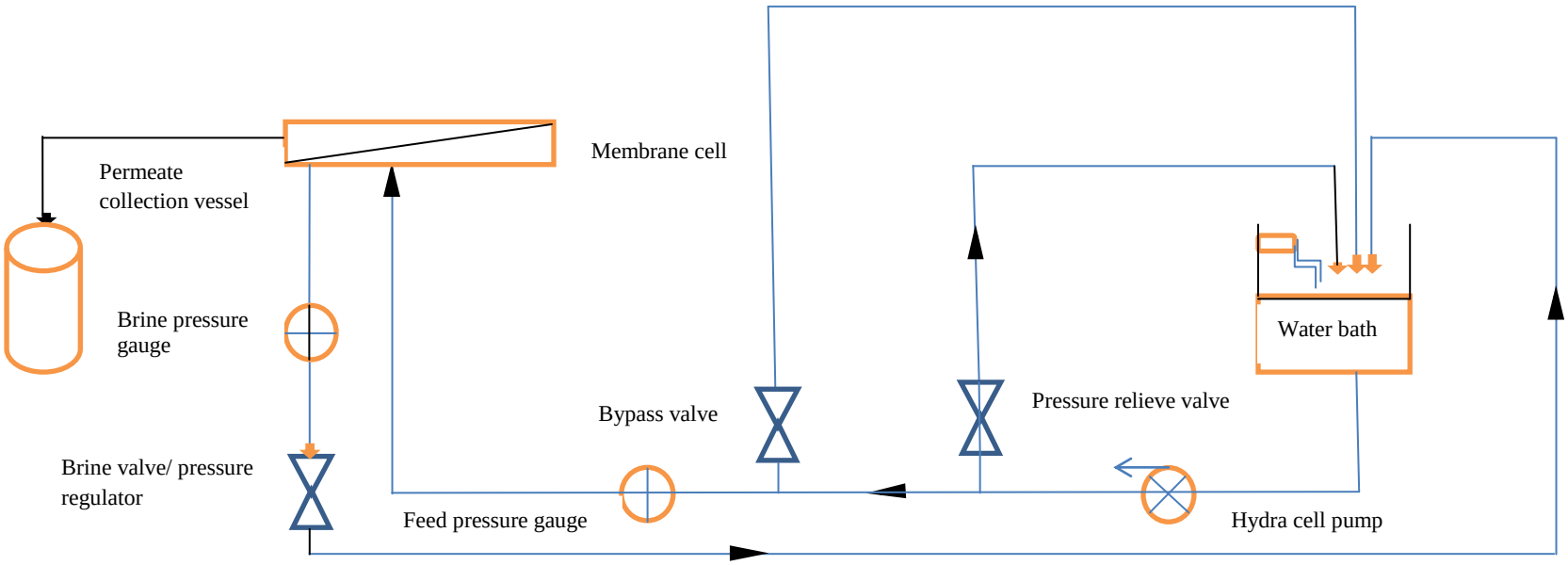

Figure 1. A schematic diagram of RO experimental system.

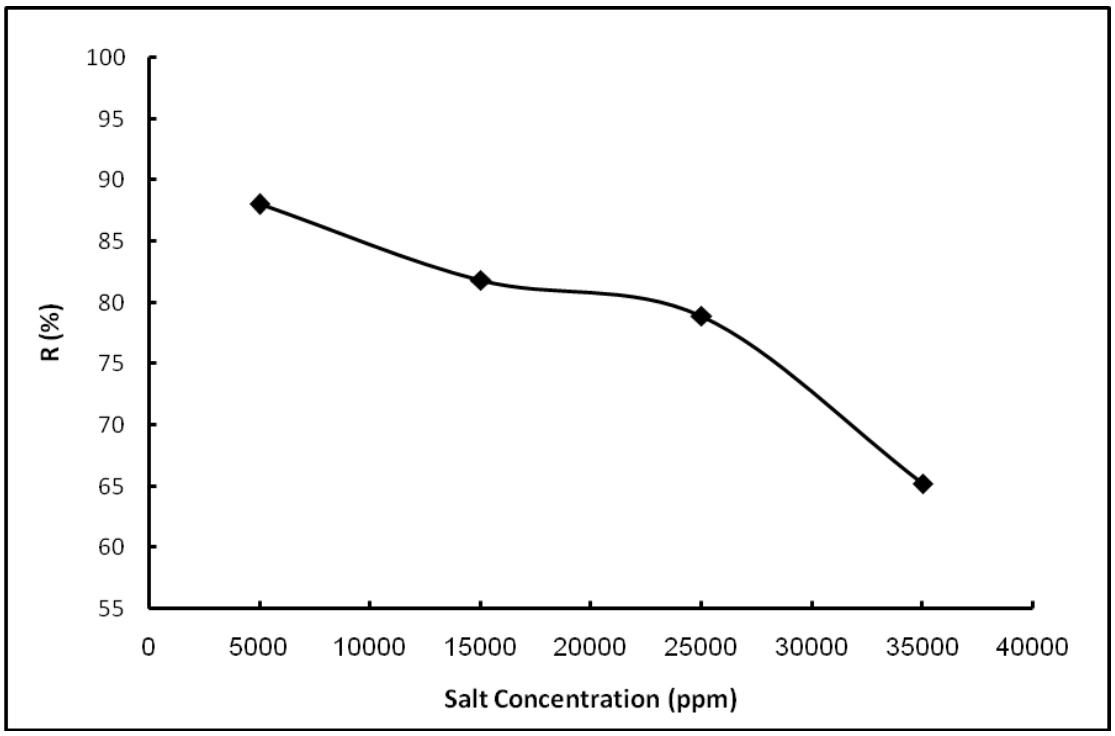

Figure 2. Effect of salt concentration on salt rejection (temp.: 25 °C; pressure: 1bar).

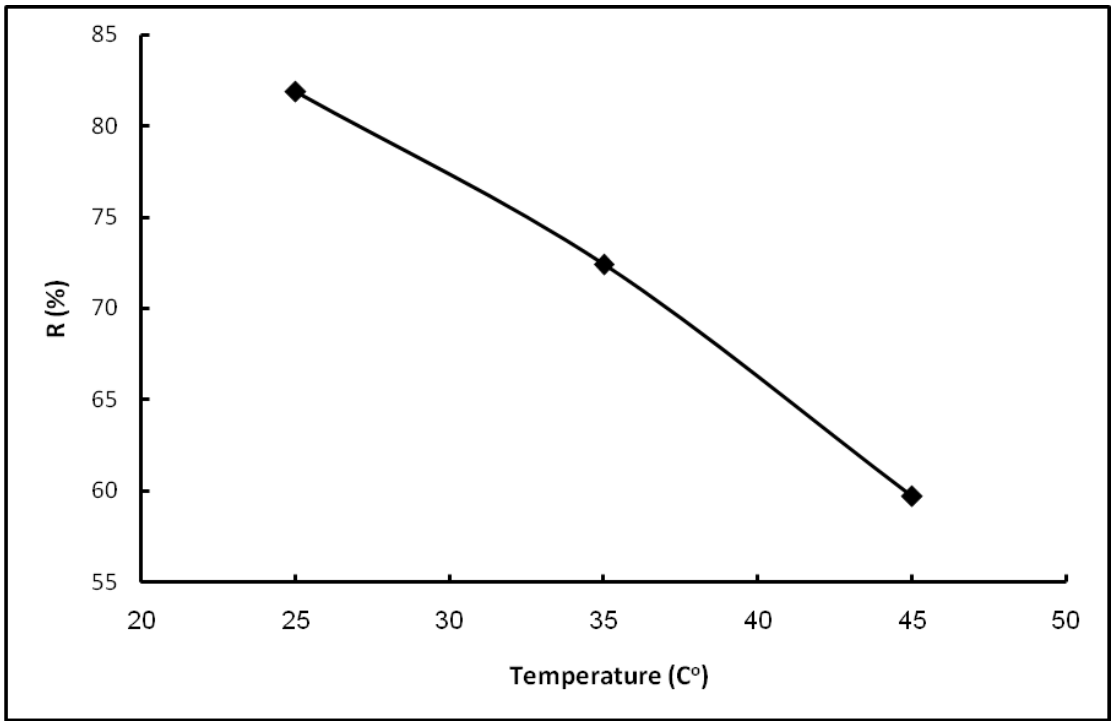

Figure 3. Effect of temperature on salt rejection (conc.: 15000 ppm; pressure: 1bar).

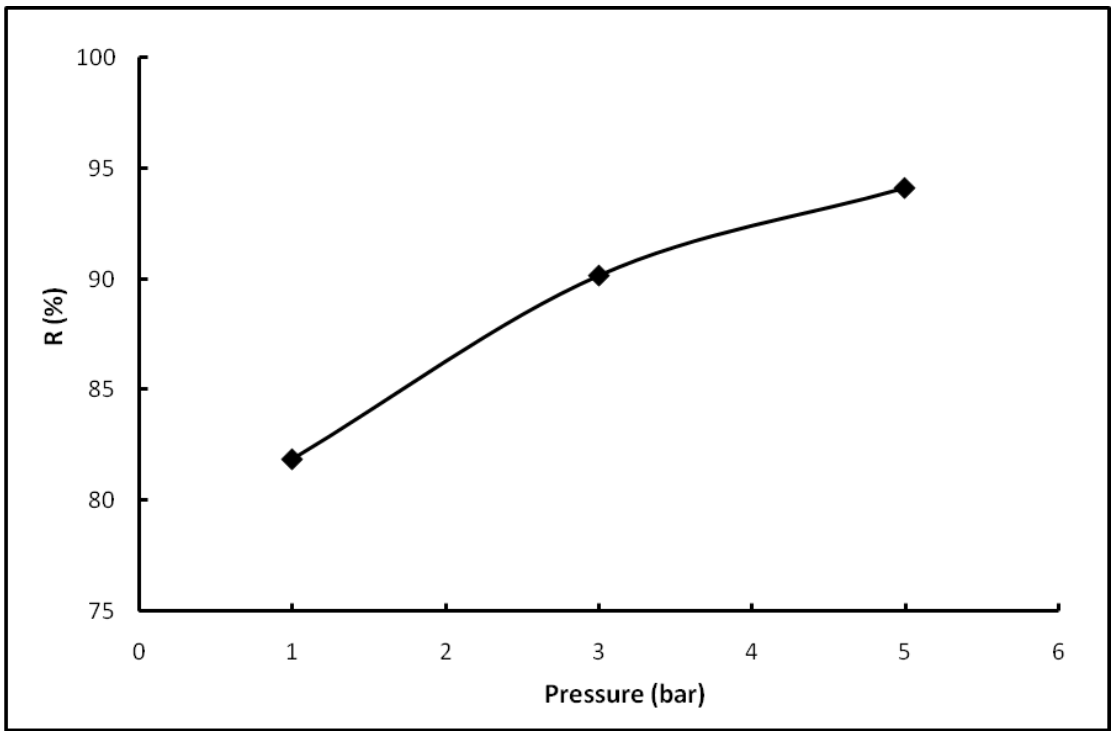

Figure 4. Effect of transmembrane pressure on salt rejection (temp.: 25°C; conc.: 15000 ppm).

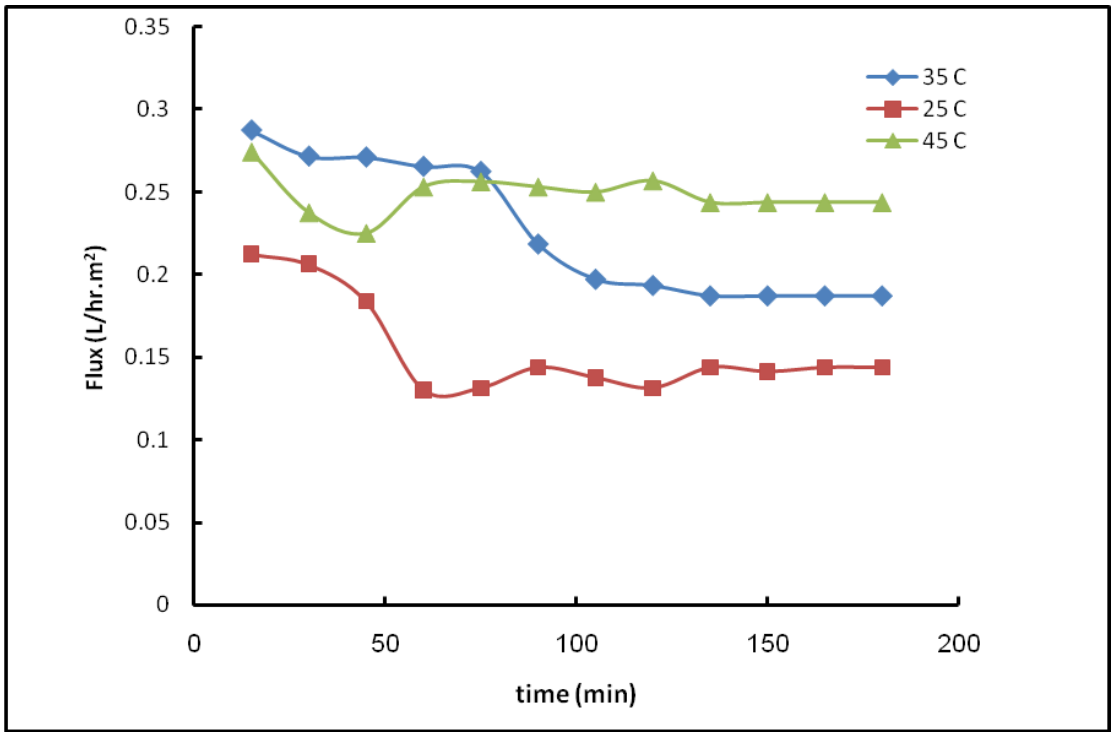

Figure 5. Effect of temperature on permeation flux (conc.: 15000 ppm; pressure: 1bar).

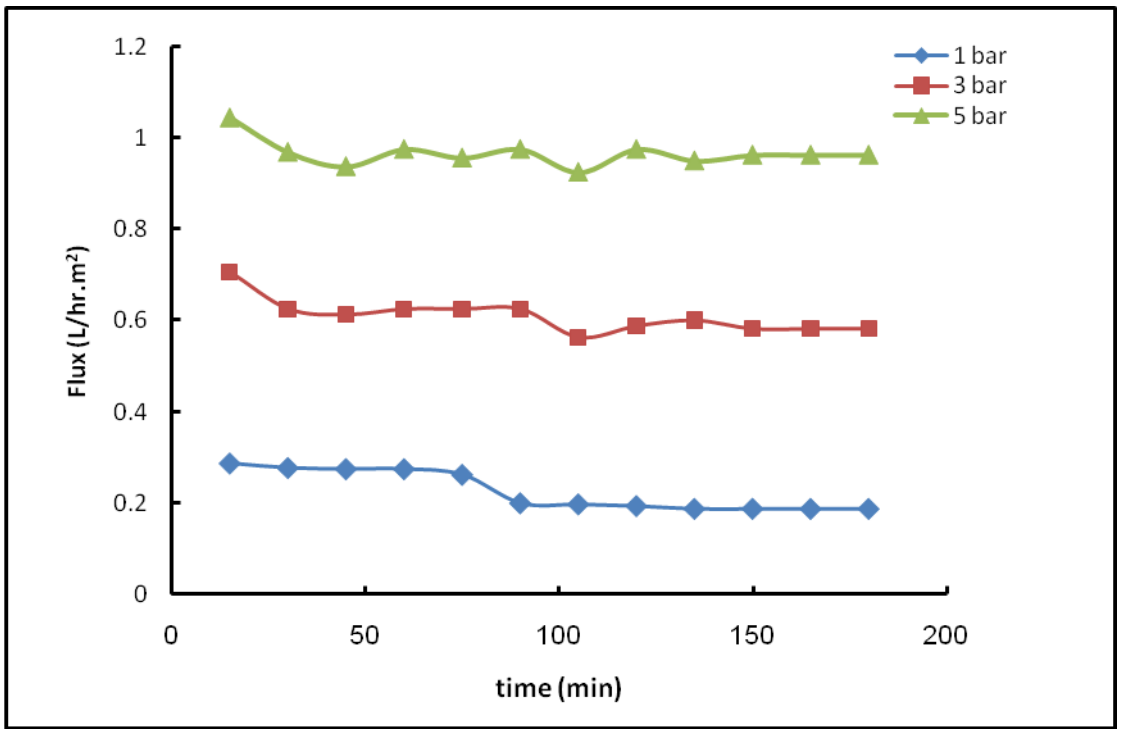

Figure 6. Effect of transmembrane pressure on permeation flux (conc.: 15000 ppm; temp.: 25°C).

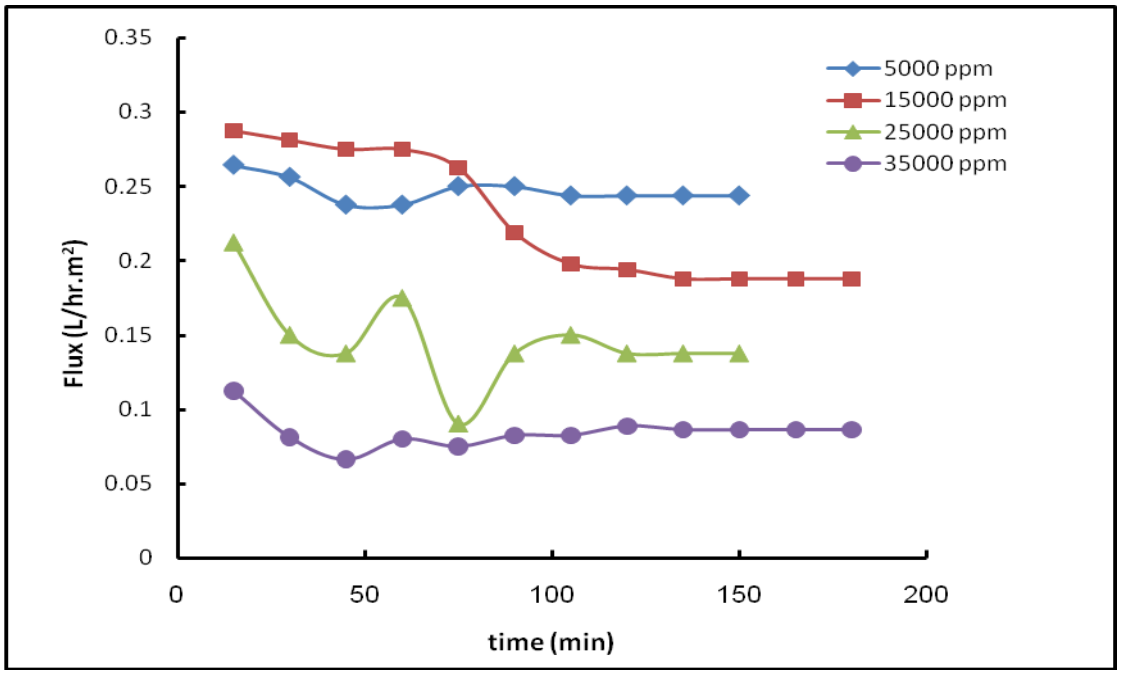

Figure 7. Effect of salt concentration on permeation flux (temp.: 25°C ; pressure: 1bar).

Table 1. Specification of RO membrane, Hidrotek RO Membrane.

Hidrotek RO membrane model	TW30-1812-50
Active area (ft^2 m^2	3.5(0.32)
Max pressure	300 psi (21 bar)
Max feed flow rate	2 gpm
Max operating temp	45°C
Max SDI (inlet)	5
Free chlorine tolerance	< 0.1 ppm
pH range (continuous operation)	3~10
pH range (chemical cleaning)	2~11

Reaction Kinetics of Tert-Butanol Esterification

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ABSTRACT

In this study, the kinetics for the reaction of tert-butanol esterification with acetic acid in the presence of Dowex 50Wx8 catalyst was investigated. The reaction kinetic experiments were conducted in 1000 milliliter vessel at temperatures ranged from 50 - 80 ^{o}C, catalyst loading 25-50 g/L, and the molar ratios of acetic acid to tert-butanol from 1/3 – 3/1. The reaction rate was found to increase with increasing temperature and catalyst loading. It was also found the conversion of the tert-butanol increases as the molar ratio of acid to alcohol increases from 1/3 – 3/1. The Non-ideality of the liquid phase was taken into account by using activities instead of molar fractions. The activity coefficients were calculated according to the group contribution UNIFAC method. The results show that the activation energy of tert-butanol esterification with acetic acid was found to be 1.09 kJ/mol.

Key words: esterification, reaction kinetic, tert-butanol, tert-butyl acetate, dowex 50wx8.

دراسة حركية تفاعل الاسترة المحفزه لكحول البيوتانول الرباعي

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الخلاصة

تم دراسة حركية تفاعل الاستره لحامض الخليك مع كحول البيوتانول الرباعي باستخدام عامل مساعد من نوع ديواكس 50. تم اجراء التجارب العمليه عند درجة حراره تتراوح بين (50-80) درجه مئويه وكميات من العامل المساعد تتراوح بين (25-50) غم ونسبه موليه (حامض/كحول) للمواد المتفاعله بين (1/3-3). تم التوصل الى ان زيادة درجة الحراره وكمية العامل المساعد تؤدي الى زيادة معدل التفاعل. وكذلك وجد ان نسبة التحول من كحول البيوتيل الرباعي تزداد مع زيادة النسبه الموليه (حامض/كحول) من (1/3-3). ولكون السائل غير مثالي تم حساب معامل التنشيط بطريقة اليونيفاك. من خلال النتائج العمليه في تفاعل الاستره لحامض الخليك مع كحول البيوتيل الرباعي تم التوصل الى ان طاقة التنشيط للتفاعل تساوي 1.09 كيلوجول/مول.

1. INTRODUCTION:

Esterification is a chemically reversible reaction producing ester and water from two reactants of acid and alcohol; it's an important reaction in the chemical engineering industry. The desired product (ester) plays a major role in the production of flavors and fragrances, solvents, plasticizers, pesticides and herbicides, medicinal and surface-active agents, **Ali, et al., 2007**.

Butyl acetates are used primarily as solvents in the lacquer and enamel industries. It is used in coatings, where its solvent capacity and its low relative volatility make it useful for adjustment of evaporation rate and viscosity. It is particularly useful as a solvent or thinner for acrylic polymers, vinyl resins, as reaction medium for adhesives, as solvent for leather dressings, and a process solvent in various applications and in cosmetic formulations **, Liu, et al., 2005**.

A general method is presented for the preparation of tert-butyl esters by the gentle warming of the carboxylic acid in the presence of excess of tert-butyl acetoacetate and a catalytic amount of acid. This method generates only low pressures, and is therefore suitable for laboratory scale pressure glassware **, Taber, et al., 2006**.

There are two catalysts to accelerate the rate of esterification reaction, that is, homogeneous and heterogeneous catalyst **, Lilja, et al., 2002**. Homogeneous catalysts provide distinguished performance in terms of reaction rate, the benefit of those catalysts is diminished since separation and recovery of catalyst are difficult due to the miscibility between liquid acid catalyst and reaction medium**, Ali, et al., 2007and Lilja, et al., 2002** . In addition, the homogeneous acid catalysts cause the occurrence of side reactions, corrosion of the equipment and the need to deal with acidic wastes, **Liu and Tan, 2001**.

Heterogeneous catalyst (ion-exchange resin) is a promising material for the replacement of the homogeneous acid catalysts. The solid type of material has good physical and chemical properties, and shows excellent performance as a heterogeneous catalyst in esterification reaction. The mechanical separation by filtering is possible, the ion exchange resin is reusable, guaranteeing the continuous operation, waste or disposal problems are eliminated, and isolation of reaction intermediates is possible **, Ali, et al., 2007** and **Sanz, et al., 2002**. Moreover, catalysts in the solid type preclude corrosion as well as pollution, and show both high selectivity and thermal stability**, Gangadwala, et al., 2003**.

The significance of external mass transfer limitation which is directly related to stirrer speed in batch systems depends on several factors such as the viscosity of the system, reactions conditions, in addition to the type and properties of catalyst used. The effect of internal diffusion on the rate of the reaction catalyzed by a solid catalyst (ion-exchange resin) is dependent on many parameters such as catalyst composition, particle size, reaction medium and temperature **, Ali, et al., 2007**.

Several works on esterification with heterogeneous catalyst have been studied with various reactants.

Nagasawa et al., 1994, used activated basic alumina for the esterification of tert-butanol by acid chlorides or acid bromides. They got a good yield for tert-butyl ester; the amount of catalyst relative to the reactants used by them was very large.

Altiokka and Çıtak 2003, studied the kinetics of esterification of acetic acid with isobutanol with and without catalyst. They found the initial reaction rate decreases with alcohol and water concentration as it linearly increases with that of acid.

Niasari et al., 2005, studied the esterification of tert-butanol by acetic anhydride to tert-butyl acetate over $InCl_3/Al_2O_3$, $GaCl_3/Al_2O_3$, $FeCl_3/Al_2O_3$, $MnCl_2/Al_2O_3$, $CoCl_2/Al_2O_3$, $NiCl_2/Al_2O_3$, $CuCl_2/Al_2O_3$ and $ZnCl_2/Al_2O_3$ catalysts. They reported that the homogeneous indium chloride, gave lower conversions than to the supported catalyst, and in the presence of an acid catalyst, tert-butanol undergoes dehydration to iso-butylene even at room temperature.

Blagov et al. 2006, studied the kinetics of side reactions of the formation of *n* butyl acetate in the heterogeneous catalyst. They were reported that the reaction rate is practically equal for their catalysts and the side reactions occur primarily on the active sites inside the pores of catalysts.

Izci and Bodur 2007, observed that initial reaction rate increases with increasing of reaction temperature and catalyst loading and Dowex 50 Wx2 ion exchange resin has very high activity in the synthesis of isobutyl acetate.

Ali et al., 2007, studied the kinetics of the esterification reaction of propionic acid with 1-propanol over the ion-exchange resin Dowex 50Wx8-400. They were found that both external and internal diffusion limitations did not affect the overall reaction rate, the conversion of propionic acid increased with increasing temperature and catalyst loading and decreased with increasing initial mole fraction of acid.

Korkmaz et al., 2009, used PDMS (Polydimethylsioxane) membrane with two different catalysts for isobutyl acetate production. It was observed that increasing the catalyst concentration and using the thinner membranes increase the conversion, and that while the reaction occurs slowly in Dowex 50W-X8 catalyzed PVMR, the conversion obtained is higher for longer reaction times than the one using H_2SO_4.

Bhorodwaj and Dutta, 2011, studied the esterification of acetic acid with primary (n-), secondary (sec-) and tertiary (ter-) butanol catalyzed by supported heteropoly acids (HPAs), they were reported that the conversions of different alcohols into the corresponding esters decrease in the following order: n-butanol>sec-butanol>ter-butanol. The selectivities for the corresponding esters are nearly 100%.

Tsai et al., .2011, studied the heterogeneous esterification of glutaric acid with methanol over acidic cation exchange resin beads, Amberlyst 35, were investigated through a packed-bed reactor. They were found that the equilibrium conversion of glutaric acid increases slightly as the molar ratio of feed increases from 15 to 20. The same observation was found with **Tsai et al.,** for the esterification of acetic acid with methanol.

Akbay and Altiokka, 2011, found that Amberlyst-36 has slightly higher activities for esterification of acetic acid with amyl alcohol.

Ju et al., 2011, studied the experimental parameters were reaction temperatures (100–110 ◦C), molar ratios of reactants (butyric acid/n-butanol = 0.25–4) and catalyst loading (10–40 g/L), they found that the conversion increased with temperature and catalyst loading whereas it decreased as the molar ratio of reactants increased.

The present work was undertaken to find the reaction kinetic representing the esterification of acetic acid with tert-butanol in the presence of Dowex 50Wx8. The effect of the significance of both external and internal diffusion limitations on the esterification system, reaction temperature, catalyst amendment with HCl, catalyst loading, and initial reactants mole ratio on the reaction kinetics were investigated. To take into consideration, the nonideality of the liquid mixture, activities of the species in liquid phase, estimated by the group contribution method UNIFAC, were used instead of molar fractions.

2. EXPERIMENTAL WORK

2.1 Apparatus

Fig. 1 shows the schematic diagram of the experimental which was used to carry out the esterification reaction. The reaction was carried out in a round-bottomed QVF flask with two necks with capacity of 1000 ml. A reflux condenser was placed on the top of the reactor in order to prevent the escape of volatile compounds. A thermocouple immersed in the flask and was used to control the temperature within ±0.1K by Digital temperature controller. The mixture was mixed using a magnetic stirrer, with speed 1000 rpm.1 cm^3 of liquid sample was withdrawn from the reactor at regular intervals for analysis and immediately transferred to a crucible in refrigerator at 5 ^oC to ensure that no further reaction took place.

2.2 Materials

Tert-butanol of 99% purity was manufactured by Riedel-de Haën Ag Seelze-Hannover (Germany); acetic acid of 99% purity was manufactured by Rioel-de Haën chemicals (Germany) were used as the reactants. Among various cation exchange resins, Dowex 50Wx8 with a particle size range of 0.04–0.07 mm was obtained from Fluka which is a strong acid ion-exchange resin.

2.3 Procedure

In the experiments, the catalyst was prepared by treatment with (1N) HCl to increase acidity. Each 100 gm of catalyst was stirred for 2 hrs with 500 ml HCl (1N).The chloride ions were washed three times with distilled water to remove it. After that the catalyst was dried at 60 ^oC for 12 hours to remove the moisture. The dried catalyst was stored in a desiccator before further use. Dowex 50Wx8 and tert-butanol were placed in the reactor. A known weight of the catalyst was added at the same time the reactor contents well mixed. After a steady value of the desired temperature was attained, the acetic acid at the same temperature was added and this was taken as zero time for a run. 1 cm^3 of liquid sample was withdrawn from the reactor at regular intervals for analysis. The operating conditions of the present study are given in **Table 1**.

Before any experiment the reactants were prepared in the vessel maintaining the required molar ratio with overall volume of 800 ml.

3. GC ANALYSIS

At a certain time, 0.1ml of liquid product sample was extracted through a syringe filter and analyzed with a gas chromatograph (GC type Shimadzu, Model 2014) equipped with a flame ionization detector (FID) at temperature 180 ^oC, column (30 m length, 0.35 mm inner diameter and 1.15 cm^3/min column flow), N_2 as carrier gas at 50 kpa, split ratio 50 at temperature 150 ^oC, 61.8 cm^3/min total flow,6 min total time, 24.5 cm/sec linear velocity and temperature program 110 ^oC hold for 1 min, heat at 10 K/min to 130 C hold for 1 min.

4. KINETIC MODEL

4.1 Reaction kinetics

The kinetic model for the esterification reaction was developed using the obtained concentration over a temperature range of 50-80 ^oC a catalyst loading between 25-50 gm of catalyst for feed (tert-butanol + acetic acid) and a tert-butanol/acetic acid mole ratio of 1:1, 1:3, and 3:1. The reaction kinetic model has the following form **, Altiokka and Çıtak, 2003.**

$$CH_3COOH + C_4H_9OH \leftrightarrow CH_3COOC_4H_9 + H_2O$$

$$r_j = m_H \frac{dx_j}{dt} = \delta_j M_{cat} K_f \left(a_{HAc} a_{TBuOH} - \frac{1}{K_a} a_{TBuAc} a_{H2O} \right) \quad \ldots (1)$$

The initial reaction rates in the carried experiments are calculated by the following expression:

$$-r_i = \frac{\Delta C_i}{\Delta t} = C_T \frac{\Delta x_i}{\Delta t} \quad \ldots . (2)$$

Experimental reaction rate data was fitted using a nonlinear regression method. Seven data points were used to calculate the parameters.

The following steps are used to calculate parameters of reaction kinetics:

1) Determining the rate constant of the reaction by using Eq. (1).
2) Depending on assumed forward and reversible reaction rate constant, simulation of the kinetic reactions is performed by using MATLAB R 2010b program.
3) The simulation results are compared with experimental results at each point. All deviations between experimental and calculated values are squared and summed up to form an objective function F**:**
4)

$$F = \sum (exp.conc. - cal.conc.)^2 \quad \ldots (3)$$

5) For each experimental data, the concentration-time data and seven new values for F is calculated. The rate constants corresponding to the minimum F are stored and considered improved rate constants for final or next iteration.
6) The iteration proceeds until the absolute difference between two successive objective functions is less than a predefined tolerance ε. The final obtained values of K_f and K_a will be the optimal rate and equilibrium constants respectively.

The study of the effect of temperature is very important since it is useful to calculate activation energy of the reaction. The observed reaction rate constants (k) data at different temperatures were fitted to the Arrhenius-type equation Eq. (4) and the model parameters, k^o (frequency factor) and (EA) (activation energy), were determined using linear regression technique **, Altiokka and Çıtak, 2003.**

$$K = K^0 exp\left[-\frac{E_A}{R.T}\right] \quad \ldots . . (4)$$

4.2 Estimation of Activity Coefficient

The determination of the activity coefficient can be done without the need for actual data, by assembling the pure component from individual groups and assessing the contributions of their interactions. One of these methods is the UNIFAC (universal functional activity coefficient) model. UNIFAC was used to account for system non-ideality.

The expression for the activity coefficient is written as the sum of combinatorial and residual terms:

$$\ln \gamma_i = \ln \gamma_i^C + ln\gamma_i^R \quad \ldots..(5)$$

Table 2 contains all UNIFAC model parameters that used in this study to calculate liquid phase activity coefficient.

5. DIFFUSION

It is necessary to eliminate both external and internal diffusion limitations.

The effect of external diffusion limitation on the esterification reaction rate was studied by earlier workers **, Ali, et al., 2007 and Ju, et al., 2011.**

If the production of the ester is independent of stirrer speed, this indicates that external diffusion is not the rate controlling step. Thus, to ensure that the reaction rate is not influenced by external diffusion; the experiments should be run at a high enough stirrer speed [1].

In general, external diffusion controls the overall rate in catalytic processes if the viscosity of the reactant mixture is very high or the stirrer speed is very low **, Othmer, 1994.**

To consider the effect of external mass transfer resistance on the rate of reaction, the Mears criterion for external diffusion was examined and the dimensionless Mears parameter (C_M) was calculated as follows:

$$C_M = \frac{r_{A.obs}\rho_c R_c n}{k_C C_{Ab}} < 0.15 \quad \ldots.(6)$$

To estimate the mass transfer coefficient (k_C), the following equation was employed **,Geankoplis, 1993.**

$$k_C = \frac{2D_{AB}}{d_p} + 0.31 N_{Sc}^{-2/3} \left(\frac{\Delta\rho\mu_c g}{\rho_c^2}\right)^{1/3} \quad \ldots..(7)$$

Note that k_C is dependent on the limiting reactant; as the limiting reactant is tert-butanol in all the cases.

The diffusivity (D_{AB}) was obtained from the multi-component diffusivity correlation, Perkin and Geankoplis method, as shown below **,Perry and Green, 1997.**

$$D_{AB}\mu_B^{0.8} = \sum_{\substack{j=1 \\ j\neq A}}^{n} x_j D_{Aj}\mu_j^{0.8} \quad \ldots..(8),$$

The D_{Aj} can be obtained from the Wilke–Chang correlation [19]:

$$D_{Aj} = 7.4 \times 10^{-8} \left[\frac{(\emptyset Mwt_2)^{1/2}}{\mu_2} \times \frac{T}{V_1^{0.6}}\right] \quad \ldots..(9)$$

If the value of left-hand side in **Eq. 6** is lower than 0.15, the external mass diffusion can be negligible in the kinetic study ,**Fogler, 1999**.

Table 3 shows that the calculated Mears parameters (C_M) are less than 0.15.

The effect of internal diffusion on the catalytic reaction can be studied by screening catalyst into different particle sizes or by calculating certain dimensionless parameters such as the well-known Weisz–Prater criterion.

The occurrence of any internal pore diffusion limitation is determined on the basis of the Weisz–Prater criterion, where the dimensionless Weisz–Prater parameter (C_{WP}) is calculated as follows:

$$C_{WP} = \frac{-r_{A.obs}\rho_c R_c^2}{D_{eff} C_A} \quad \ldots\ldots(10)$$

The effective diffusivity (D_{eff}) can be expressed as:

$$D_{eff} = \xi_v^2 D_{lm} \quad \ldots\ldots(11)$$

If $C_{WP} \ll\ll 1$ there are no internal diffusion limitations and no concentration gradient exists within the pellet, but if $C_{WP} \gg 1$ internal diffusion limits the reaction **, Fogler, 1999**. D_{eff} was calculated by applying finite difference approximation.

As listed in **Table 3**, the calculated Weisz–Prater parameters were less than 1, implying that the resistance to internal pore diffusion is sufficiently small and the internal diffusion can be negligible in the kinetic study.

6. RESULTS AND DISCUSSION

6.1 Effect of External and Internal Diffusions:

To study the kinetics of the esterification reaction, the effect of external and internal diffusion limitations should be eliminated.

It was found that values of the external diffusion and internal diffusion parameters are significantly less than 0.15 for external ($C_M \ll 0.15$) and one for internal ($C_{WP} \gg 1$). These results indicate that external and internal diffusion does not limit the reaction of acetic acid with tert-butanol over Dowex 50Wx8-400 for the reaction conditions implemented in this study. This is in agreement with the results obtained by **Ju, et al., 2011**.

The external diffusion limitation is negligible at stirrer speed of ≥ 200 rpm [1]. Therefore, a stirrer speed of 1000 rpm was maintained during all experiments to ensure that the measured reaction rate was free from external diffusion effects.

6.2 Effect of Temperature

In esterification reaction, the investigation on the effect of temperature is very important because this information is useful in calculating the activation energy. It was realized at different temperatures of 333, 348 and 358K under the constant reaction conditions: 1:1 mole ratio and the catalyst weight at 50 g. Results are given in **Fig. 2**. The reaction rate strongly depends on temperature. It can be seen that the reaction rate increases substantially with the increasing temperature. Moreover, the equilibrium conversion was nearly equal in the temperature range studied in this work. It shows that the higher temperature yields the greater conversion of t-butanol at a fixed contact time. This is in agreement with the results obtained by **Akbay and Altiokka 2011 and Ju, et al., 2011**.

6.3 Effect of catalyst amendment with HCl

In **Fig. 3** tert-butanol conversion was plotted by using Dowex-50 catalysts prepared with HCl while the other was Dowex-50 without amendment. From the **Fig.**, it can be concluded that this amendment with HCl catalyst has little effect on increasing the reaction

rate and the reason for this is due to the activity of the resin catalyst used and a strong amendment with HCl has no significant effect on the increasing acidity of the catalyst. This is in agreement with the results obtained by **Bhorodwaj and Dutta, 2011**.

6.4 Effect of Catalyst Loading

The effect of catalyst loading on the conversion of tert-butanol and the initial reaction rates is represented in **Fig. 4**. Catalyst loading was varied from 25 g to 50 g at a temperature of 65 C, feed mole ratio of 1:1, and stirrer speed of 1000 rpm. It can be seen from **Fig. 4** that as the catalyst concentration increases, the reaction rate, conversion of acetic acid increases and thus the reaction time decreases. But the catalyst loading does not have any effect on the equilibrium conversion. This is in agreement with the results obtained by **Bhorodwaj and Dutta 2007**.

6.5 Effect of Initial Reactants Mole Ratio

The effect of acid to alcohol molar ratio was investigated by varying the acid to alcohol molar ratio (ranging from 1:3 to 3:1). As shown in **Fig. 5**, changing the molar ratio from 1:3 to 1:1 increases the conversion of the tert-butanol, and shows that the increasing of the molar ratio from 1:1 to 3:1 increases the conversion of the tert-butanol. **Fig. 5** shows that acid to alcohol molar ratio of 3:1 gives a higher conversion of the alcohol than 1:3. Moreover, a more significant increase in conversion was obtained at a ratio of 3:1 rather than 1:3. This is in agreement with the results obtained by **Ju, et al., 2011**.

7. REACTION KINETICS

Experimental reaction rate are fitted using a nonlinear regression method. Different values of the forward reaction rate constants K_f and equilibrium constant K_a are constructed and by applying Genetic Algorithm optimization method to predict the better constants that represent the minimum least square error between the experimental and predicted results.

$$K_f = K_f^0 exp\left(-E_f/RT\right) \quad \ldots\ldots (12)$$

$$K_f = 20.7654 exp(3.68 \times 10^4/RT)$$

$$K_a = K_a^0 exp(-E_a/RT) \quad \ldots\ldots (13)$$

$$K_a = 1.5815 exp(-1.09 \times 10^3/RT)$$

The activation energy of the esterification reaction is found to be (1.09 kJ/mol).

Figs. 6, 7, and 8 show that the model predictions for different operating conditions are compared with experimental data at temperatures 50 C, 65 C, and 80 C respectively. Depending on different initial condition and with the aid of 4^{th} order (Rung-Kutta) integration method, the mathematical model was used to predict tert-butanol conversion respect with time can be predicted from **Eq. 1**. From these **Figs.**, it was concluded that the predicted kinetic model Correspond to a large degree with the experimental kinetics.

The lower line which is start from zero represents the experimental and model result for H_2O and tert-butel acetate concentration while the upper line is start from (0.5) mole fraction represent concentration of acetic acid and tert-butanol.

8. CONCLUSIONS

The reaction kinetic data have been determined experimentally for the esterification of acetic acid with tert-butanol over acidic ion exchange catalyst beads, Dowex 50Wx8, at temperatures from 50 C to 80 C, catalyst loading (25-50 gm), and the molar ratios of acetic acid to tert-butanol in the feed stream from 1 to3.The reaction rate was found to increase with increasing temperature, catalyst loading, and the conversion of the tert-butanol as the molar ratio of acid to alcohol increases from 1/3 – 3/1. Absence of resistance to external and internal diffusion was verified with theoretical criteria, the Mears ($C_M \ll 0.15$) and Weisz–Prater ($C_{WP} \ll 1$). The activation energy for the esterification reaction was estimated to be 1.09 kJ/mol. UNIFAC was used successfully to account for the non-ideal thermodynamic behavior of the reactants and the products.

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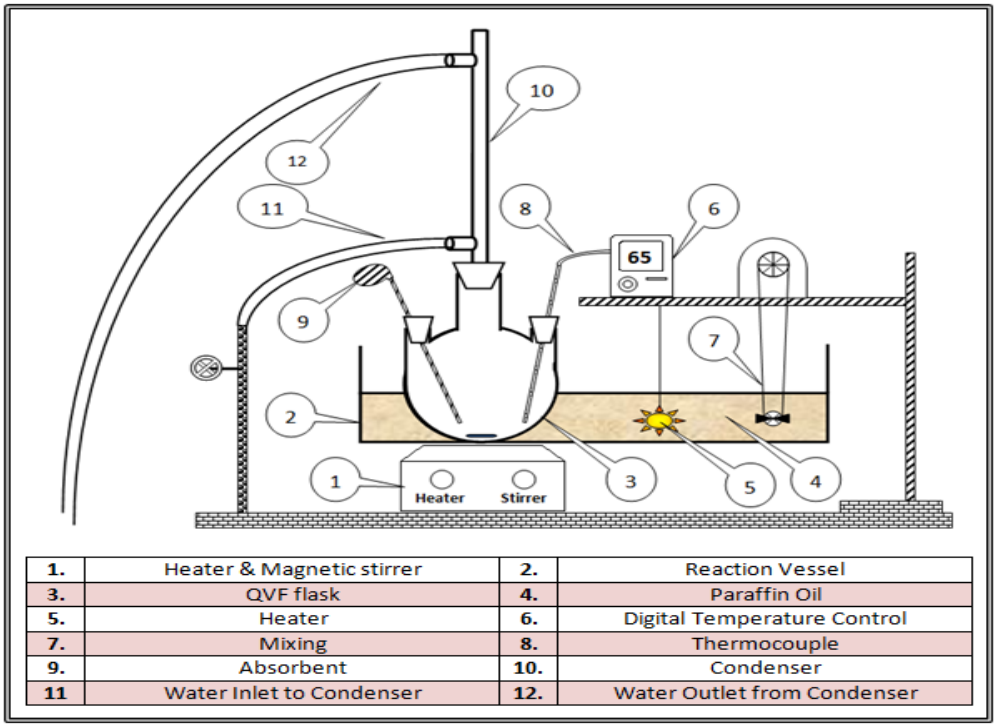
NOMENCLATURE

a_i	activity of component i
C_A	reactant concentration (mol/cm^3)
C_{ab}	bulk concentration (mol/cm^3)
C_i	concentration of component i (mol/cm^3)
C_{li}	bulk concentration of the limiting reactant (mol/cm^3)
C_M	mears parameter
C_{WP}	weisz–Prater parameter
D_{AB}	diffusivity of solute A (cm^2/s)
D_{Aj}	dilute binary diffusion coefficient of solute A in j (cm^2/s)

D_{Am} dilute diffusion coefficient of solute A through the mixture (cm^2/s)
D_{eff} effective diffusivity (cm^2/s)
D_{lm} diffusivity of limiting reactant in the mixture (cm^2/s)
d_p diameter of the catalyst particle (cm)
E_A activation energy (J/mol)
g gravitational acceleration (cm/s^2)
HAc acetic acid
i identifies species
j dummy index running over all species
k identifies subgroups
K_a equilibrium constant (-)
K_a^0 preexponential factor for K_a(-)
k_C mass transfer coefficient (cm/s)
K_f forward reaction rate constant (mol/gm cat. hr)
K_f^0 preexponential factor for K_f(mol/gm cat.hr)
M dummy index running over all subgroups
M.wt. molecular Wight (g/mal)
m_H molar holdup (mol) in equation (1)
M_{cat} mass of the catalyst, gm.
n reaction order
N_{Sc} schmidt number
r rate of reaction (mol/hr.gm catalyst)
$-r_{A,obs}$ observed reaction rate (mol/gcat s)
R_c catalyst particle radius (cm)
r_i relative molecular volume
R_k relative volume
t reaction time (s)
T temperature (C)
TBuAc tert-Butyl acetate
TBuOH tert-Butanol
V molar volume
W water



1.	Heater & Magnetic stirrer	2.	Reaction Vessel
3.	QVF flask	4.	Paraffin Oil
5.	Heater	6.	Digital Temperature Control
7.	Mixing	8.	Thermocouple
9.	Absorbent	10.	Condenser
11	Water Inlet to Condenser	12.	Water Outlet from Condenser

Figure. 1 Schematic diagram of the experimental apparatus.

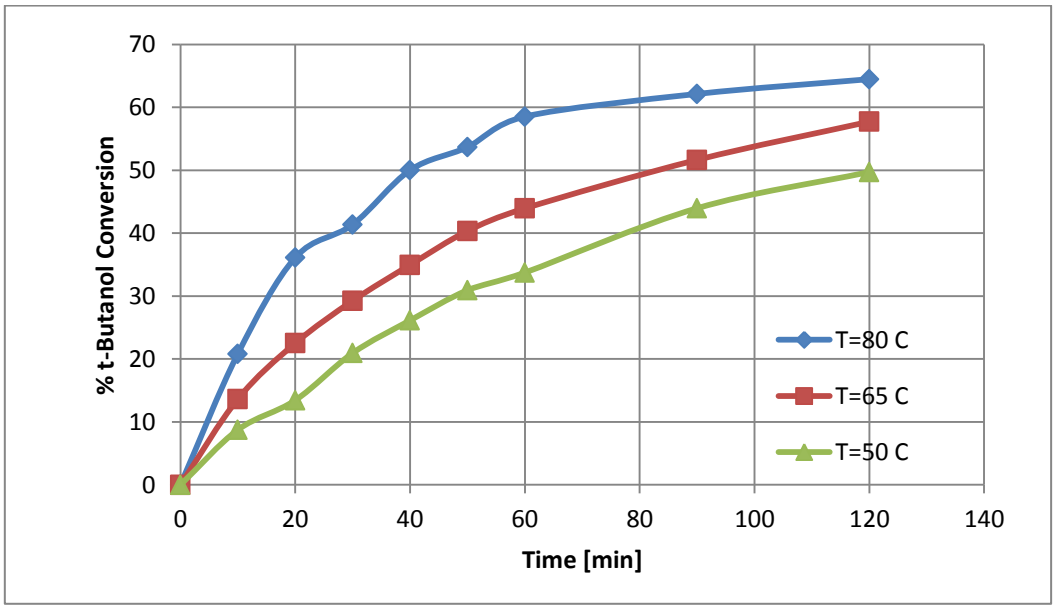


Figure. 2 Effect of temperature on t-butanol conversion (catalyst Dowex 50 modified with HCL, wt:50gm ,ACH:TBuOH=1:1).

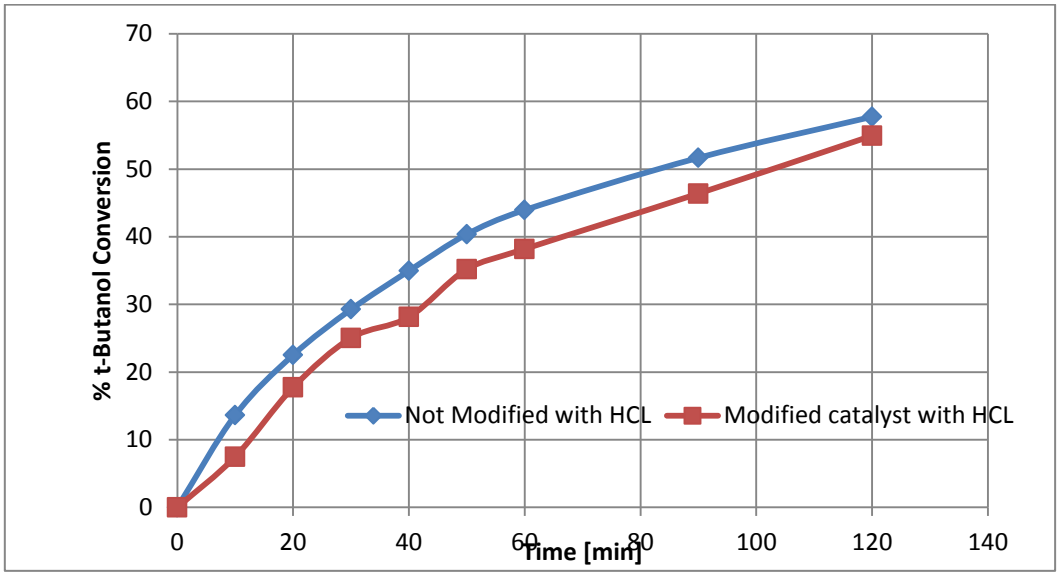


Figure. 3 Effect of catalyst modification on t-butanol conversion (catalyst dowex50 , wt:50gm,T=65 C ,HAc:TBuOH=1:1).

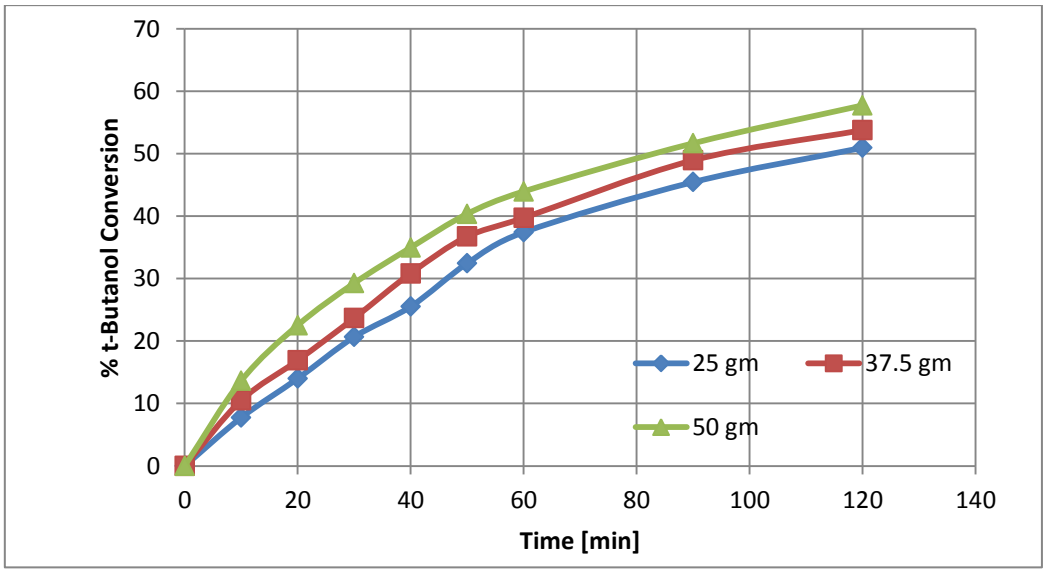


Figure. 4 Effect of catalyst weight on t-butanol conversion (catalyst Dowex 50 modified with HCL, T=65 C, HAc:TBuOH=1:1).

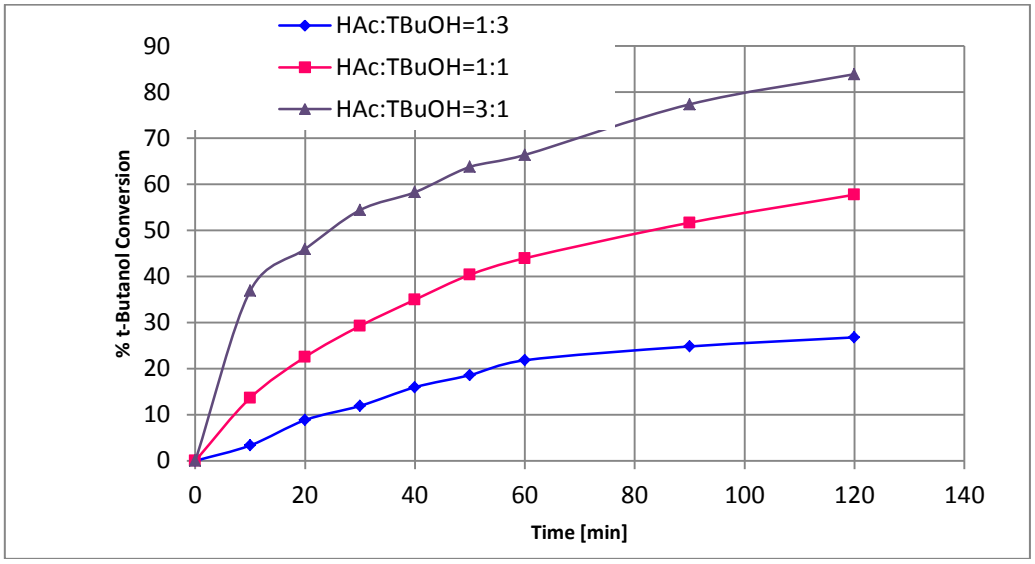


Figure. 5 Effect of feed mole ratio on t-butanol conversion (catalyst Dowex 50 modified with HCL, wt:50gm).

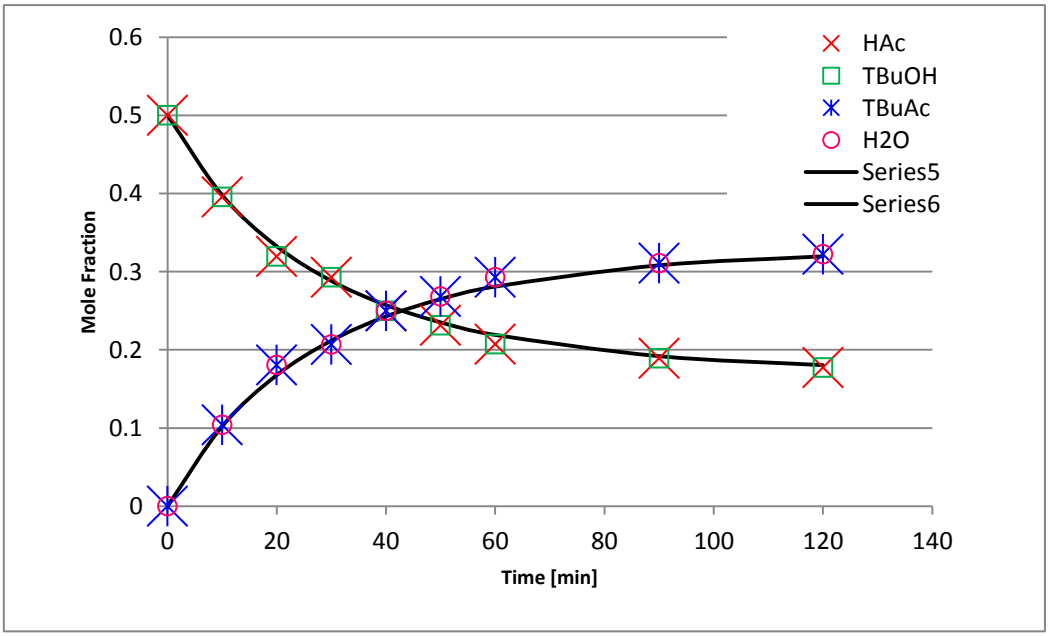


Figure. 6 Comparison between experimental data and rate equation results (catalyst Dowex 50 prepared with HCl, wt:50 gm, HAc:TBuOH=1:1, T=80 C), solid line represents rate equation results.

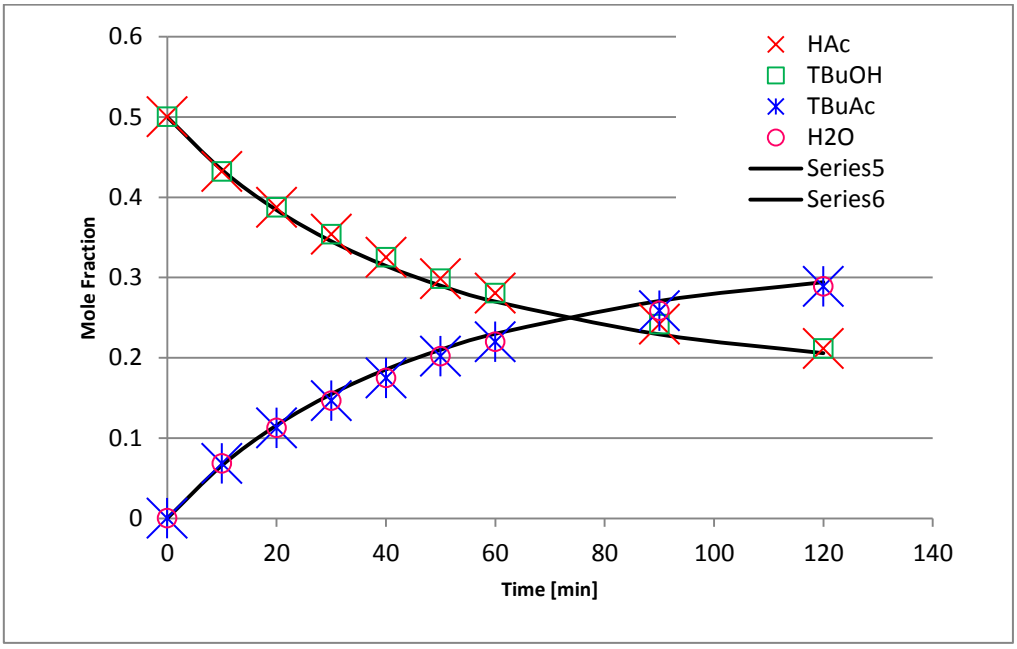


Figure. 7 Comparison between experimental data and rate equation results (catalyst Dowex 50 prepared with HCl, wt:50 gm, HAc:TBuOH=1:1, T=65 C), solid line represents rate equation results.

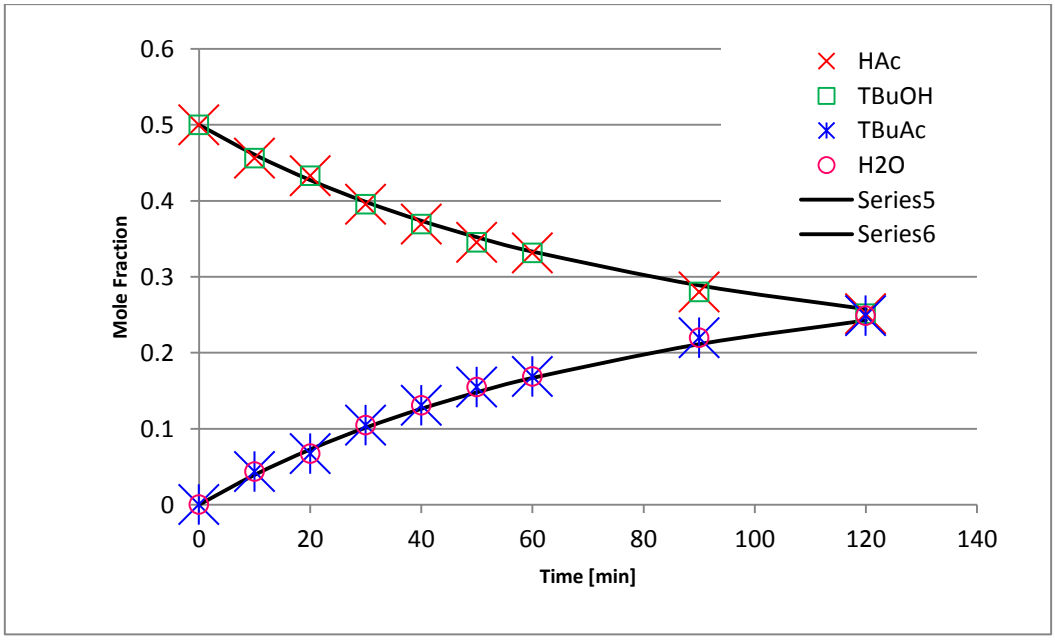


Figure. 8 Comparison between experimental data and rate equation results (catalyst Dowex 50 prepared with HCl, wt:50 gm, HAc:TBuOH=1:1, T=50 C), solid line represents rate equation results.

Table1. Reaction conditions**.**

Run	Temperature (C)	Ratio of HAc:TBuOH	Catalyst loading (g/L)	amendment with HCl
1	80	1:1	50	Yes
2	65	1:1	50	Yes
3	50	1:1	50	Yes
4	65	1:1	50	No
5	65	1:1	25	Yes
6	65	1:1	37.5	Yes
7	65	1:3	50	Yes
8	65	3:1	50	Yes

Table 2. The values of the various parameters for the UNIFAC model equations.

Component	r	q
Acetic acid	3.9243	3.668
tert-Butanol	2.6724	2.688
tert-Butyl acetate	5.3700	4.848
Water	0.92	1.
$a_{1,1}=0$	$a_{1,2}=0$	$a_{1,15}=255.7$
$a_{1,17}=255.7$	$a_{1,19}=597$	$a_{1,20}=597$
$a_{2,1}=0$	$a_{2,2}=0$	$a_{2,15}=255.7$
$a_{2,17}=255.7$	$a_{2,19}=597$	$a_{2,20}=597$
$a_{15,1}=65.33$	$a_{15,2}=65.33$	$a_{15,15}=0$
$a_{15,17}=0$	$a_{15,19}=481.7$	$a_{15,20}=481.7$
$a_{17,1}=65.33$	$a_{17,2}=65.33$	$a_{17,15}=0$
$a_{17,17}=0$	$a_{17,19}=481.7$	$a_{17,20}=481.7$
$a_{19,1}=24.82$	$a_{19,2}=24.82$	$a_{19,15}=0$
$a_{19,17}=0$	$a_{19,19}=0$	$a_{19,20}=0$
$a_{20,1}=24.82$	$a_{20,2}=24.82$	$a_{20,15}=0$
$a_{20,17}=0$	$a_{20,19}=0$	$a_{20,20}=0$

Table 3 The criteria for external and internal diffusion.

Run	C_{li} at 30 min (mol/cm^3)	$r_{A.obs}$ at 30 min ($mol/g_{cat}.sec$)	Mears parameter		Weisz-prater parameter	
			K_c (cm/sec)	C_M	D_{eff} (cm^2/sec)	C_{WP}
1	0.00386	$6.85x10^{-8}$	$3.50x10^{-2}$	$3.90x10^{-6}$	$3.87x10^{-6}$	$1.93x10^{-4}$
2	0.00466	$3.39x10^{-6}$	$2.65x10^{-2}$	$2.90x10^{-4}$	$2.83x10^{-6}$	$1.10x10^{-2}$
3	0.00521	$3.03x10^{-6}$	$2.00x10^{-2}$	$2.22x10^{-4}$	$2.05x10^{-6}$	$1.20x10^{-2}$
4	0.00494	$4.53x10^{-6}$	$2.65x10^{-2}$	$2.65x10^{-4}$	$2.83x10^{-6}$	$1.40x10^{-2}$
5	0.00523	$5.66x10^{-6}$	$2.65x10^{-2}$	$3.12x10^{-4}$	$2.83x10^{-6}$	$1.60x10^{-2}$
6	0.00503	$4.89x10^{-6}$	$2.65x10^{-2}$	$2.80x10^{-4}$	$2.83x10^{-6}$	$1.45x10^{-2}$
7	0.00846	$6.39x10^{-6}$	$2.50x10^{-2}$	$2.31x10^{-4}$	$2.56x10^{-6}$	$1.24x10^{-2}$
8	0.00171	$1.69x10^{-6}$	$2.43x10^{-2}$	$3.11x10^{-4}$	$3.26x10^{-6}$	$1.27x10^{-2}$

Adsorption of Levofloxacine Antibacterial from Contaminated Water by Non – Conventional Low Cost Natural Waste Materials

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ABSTRACT

An experimental study was conducted with low cost natural waste adsorbent materials, barley husks and eggshells, for the removal of Levofloxacine (LEVX) antibacterial from synthetic waste water. Batch sorption tests were conducted to study their isothermal adsorption capacity and compared with conventional activated carbon which were, activated carbon > barley husks > eggshells with removal efficiencies 74, 71 and 42 % with adsorbents doses of 5, 5 and 50 g/L of activated carbon, barley husks, and eggshells respectively. The equilibrium sorption isotherms had been analyzed by Langmuir, Freundlich, and Sips models, and their parameters were evaluated. The experimental data were correlated well with the Langmuir model which gives the best fit for LEVX adsorption / biosorption on to activated carbon, barley husks, and eggshells respectively.

The adsorption capacity was almost dependent on temperature. The thermodynamic parameters associated with the adsorption process, ΔG^o, ΔH^o and ΔS^o were reported and it is suggested to be physisorption, and of exothermic nature.

Keywords: adsorption, biosorption, levofloxacine, activated carbon barley husks, eggshells

إمتصاص المضادالحيوي ليفوفلوكساسين (LEVX) من الماء الملوث باستخدام مواد غير تقليدية من مخلفات طبيعية رخيصة

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الخلاصة

تم دراسة الإمدصاص / الامدصاص البيولوجي للمضادالحيوي الليفوفلوكساسين (LEVX) لأزالته من الماء الملوث على مجموعة مختارة من الممتزات غير التقليدية من مخلفات طبيعية رخيصة هي:قشور الشعير وقشور البيض ومقارنتها مع الكربون المنشط بطريقة الوجبة .هذه الدراسة تناولت تأثير عدة عوامل على عملية الإمدصاص مثل : درجة الحموضة ,الرقم الهيدروجيني ,وقت الاتصال بين الدواء والمادة الممتزة ,تركيز الدواء ,كمية المادة الممتزة ودرجة الحرارة. تم تحديد الإمدصاص عن طريق قياس تركيز الدواء قبل وبعد الاتزان باستخدام مطياف من خلال قياس الأشعة فوق البنفسجية والمرئية (Spectrophotometer Spectrophotometer –Visible) عند طول الموجة المناسبة للدواء,واستخدمت النتائج لتحديد الامدصاص (Adsorbance) ومنحنى الإمدصاص . حيث تبين ان الكربون المنشط > قشور الشعير> قشور البيض. حيث وجد ان كفائة الازالة 74،71،42% عندما يكون تركيز المادة الممدصة 5،5،50 g/L لكل من الكربون المنشط ، قشور الشعير و قشور البيض على التوالي. تم تطبيق علاقات الإمدصاص على النتائج (Adsorption isotherms) وكذلك عدة موديلات رياضية للأمدصاص / الإمدصاص البيولوجي حيث وجد انها ذات ارتباط قوي مع موديل لانكماير لجميع الممتزات اعلاه. كما تم حساب المتغيرات الثرموديناميكية ΔG^o, ΔH^o, ΔS^o , وتبين ان الإمدصاص / الإمدصاص البيولوجي ذو طبيعة فيزياوية وباعث للحرارة.

1. INTRODUCTION

The occurrence of pharmaceutical products in the aquatic environment has become crucial topic in the last few years. The investigation efforts focused in an initial phase mainly on the environmental risk assessment and extensive data have been gathered to document the contamination of the aquatic environment by these pollutants**, Nikolaou, et al., 2007; Farré, et al., 2008** and **Kümmerer, 2009a**. The studies point out the continuous introduction to sewage waters of these compounds along with their metabolites and the inefficiency of many conventional wastewater treatment plants (WWTPs) in their removal**, Jones, et al., 2005; Batt, et al., 2006** and **Kümmerer, 2009a**. Antibiotics are among the most commonly detected pharmaceutical compounds in the aquatic environmental. Several classes of antibiotics have been detected in different environmental waters such as groundwater, surface, and in a few cases even in drinking water**, Batt, et al., 2006** and **Farré, et al., 2008**. Some of the major concerns about the presence of these drugs in the environment include possible ecotoxicological effects to non-target organisms human pharmaceuticals pollute aquatic environments and there is considerable scientific uncertainty about the effects that this may have on aquatic organisms. Human drug target proteins can be highly conserved in non-target species**, Farré, et al., 2008; Kümmerer, 2009a** and **Santos, et al., 2010**. Ecotoxicological assessment of pharmaceuticals has been based on acute toxicity experiments performed by standard tests according to existing guidelines (i.e. OECD) using laboratory organisms belonging to different trophic levels such as algae, zooplankton, other invertebrates and fish. There is very little information about the chronic toxicity, or the bioaccumulation potential of pharmaceuticals in biota and food chains. An exception represents diclofenac, which is accumulated in prey of vultures**, Oaks, et al., 2004**, and the development of antibiotic-resistant bacteria**, Baquero, et al., 2008,** and **Kümmerer, 2009b**.

Due to the high public and health concern about the presence of these compounds in the environment and there cognizance of the WWTPs as the major source of pharmaceutical contamination, a number of conventional and innovative treatment methods, such as activated carbon, oxidation via chlorination, zonation, Fenton and photo-Fenton, biological process (activated sludge treatment), and membrane bioreactor and filtration, have been evaluated**, Homem,** and **Santos, 2011**. Each option of treatment has its own limitation and benefit in removing trace contaminants.

Adsorption is a well-established technique to remove pollutants, and it has been considered superior to other techniques in terms of initial cost, flexibility and simplicity of design, ease of operation, and insensitivity to toxic pollutants**, Crini, 2006**. One of the main advantages of the adsorption processes is that no byproducts are generated**, Homem,** and **Santos, 2011**.

Although activated carbon is probably one of the most effective methods for the removal of organic pollutants from water, its comparably high cost typically prohibits the treatment of large amounts of wastewaters; hence, alternative sorbent materials have been proposed that rely on low cost and readily available natural material, **Crini, 2006, Ngah,** and **Hanafiah, 2008, Gupta,** and **Suhas, 2009** and **Gupta, et al., 2009**. Several waste materials from industry or agriculture have been studied as non-conventional sorbents for inorganic**, Gupta, and Rastogi, 2008a; Freitas, et al., 2008** and **Gupta, et al., 2010.** As well as organic substances**, Crini, 2006;** and **Gupta, and Ali, 2008.** Most frequently, these materials are chemically modified to increase their sorption capacities or to remove nonstructural constituents such as tannins, terpenes, or phenolic compounds**, Crini, 2006**.

LEVAQUIN® is a synthetic broad-spectrum antibacterial agent for oral and intravenous administration. Chemically, levofloxacin, a chiral fluorinated carboxyquinolone, is the pure (-) (S)-enantiomer of the racemic drug substance ofloxacin. The chemical name is (-)-(S)-9-fluoro2,3-dihydro-3-methyl-10-(4-methyl-1-piperazinyl)-7-oxo-7H-pyrido[1,2,3-de]-nzoxazine-6-carboxylic acid hemihydrate. The chemical formula is $C_{18}H_{20}FN_3O_4 \bullet ½\ H_2O$ and the molecular weight is 370.38 as in **Fig. 1, RxList, 2013.**

Levofloxacin is a light yellowish-white to yellow-white crystal or crystalline powder. The molecule exists as a zwitterion at the pH conditions in the small intestine. The data demonstrate that from pH 0.6 to 5.8, the solubility of levofloxacin is essentially constant (approximately100 mg/mL). Levofloxacin is considered soluble to freely soluble in this pH range, as defined by USP nomenclature. Above pH 5.8, the solubility increases rapidly to its maximum at pH 6.7 (272 mg/mL) and is considered freely soluble in this range. Above pH 6.7, the solubility decreases and reaches a minimum value (about 50 mg/mL) at a pH of approximately 6.9. Levofloxacin has the potential to form stable coordination compounds with many metal ions. This in vitro chelation potential has the following formation order: $Al^{+3}>Cu^{+2}>Zn^{+2}>Mg^{+2}>Ca^{+2}$**, RxList, 2013**. Binding and chelation of the Levofloxacin and metal ions will result in decreased adsorption of bioavalability of Levofloxacin and potential increase the risk for treatment failure of the infection. Although they can be beneficial in cases of heavy metal poisoning, chelating agents can also be dangerous. Use of disodium Ethylenediaminetetraacetic acid (EDTA) instead of calcium EDTA has resulted in fatalities due to hypocalcemia**, RxList, 2013**.

The aim of this study is to compare and analyze the adsorptive behavior and the potential application of some adsorbents such as: activated carbon, and raw natural waste materials like barley husks and eggshells for the uptake of Levofloxacin Hemihydrate from aqueous solutions. The effect of the following parameters on adsorption process will be evaluated: Concentration of the drug used, amount of adsorbent used, contact time between adsorbent and drug (equilibrium time), particle size of adsorbent, pH value of the drug's solution, and temperature.

2. THEORY

2.1 Adsorption Mechanism, Isotherms, and Kinetics

Adsorption isotherms or known as equilibrium data are the fundamental concept in adsorption science that is the correct explanation of experimental adsorption in mathematical equations or functions.

Isotherm's parameters (q_e, C_e, K_f, n_f, q_m, b, K_s, a_s, and β_s) express the surface properties and affinity of the adsorbent at known temperature and pH. The most frequently isotherms used in describing the non-linear equilibrium are: Langmuir isotherm model assumes that the adsorption is limited to a monolayer, Freundlich isotherm model assumes that the adsorption is a multilayer, originally empirical in nature, but later was interpreted as the sorption to heterogeneous surfaces or surfaces supporting sites with various affinities, and Sips isotherm model represent combination of Langmuir and Freundlich isotherm models.

Adsorbents must have high abrasion resistance, high thermal stability and small pore diameters, those results in higher exposed surface area and hence high surface capacity for adsorption. The

adsorbents must also have a distinct pore structure, which enables fast transport of the pollutants, **Gupta, and Rastogi, 2008a**.

The study of sorption kinetics of pharmaceutical products removal from wastewater is significant as it provides valuable insights into the reaction pathways and into the mechanism of sorption reactions. It describes the solute uptake rate which in turn controls the residence time of sorbate uptake at the solid–solution interface**, Gupta, et al., 2009**.

2. 1.1 External mass transfer coefficient (k_f)

The external mass transfer coefficient k_f in meters per second, in a batch adsorber was determined from the concentration decay curves at optimum speed and the initial rate data, using Eq. (1)**, Ziagova, et al., 2007**.

$$k_f = -\frac{R_P \rho_P V_L}{3 w_a t} \ln\left(\frac{C_t}{C_0}\right) \qquad 0 < {}^{C_t}/_{C_0} < 1 \tag{1}$$

2.1. 2 Pseudo-first-order kinetic model

The Lagergren rate equation was the first rate equation for the sorption of liquid/solid system based on solid capacity and this model represents physical adsorption for pollutants onto sorbent/biosorbent surface Eq. (2)**, Sulaymon, et al., 2013** and **Gupta,** and **Rastogi, 2008b:**

$$q_t = q_e(1 - \exp(-k_1 t)) \tag{2}$$

2. 3 Pseudo-second-order kinetic model

If the sorption rate of system is a Pseudo-second-order mechanism, the rate-limiting step may be chemisorption involving valence forces through sharing or the exchange of electrons between sorbent and sorbate as covalent forces Eq. (3)**, Gupta, and Rastogi, 2008b;** and **Holan, and Volesky, 1995:**

$$\frac{t}{q_t} = \left(\frac{1}{k_2 q_e^2} + \frac{t}{q_e}\right) \tag{3}$$

The initial sorption rate is $h = k_2 q_e^2$, and K_2 Pseudo second-order coefficient.

2.2 Sorption Thermodynamics

Based on fundamental thermodynamic concepts, it is assumed that in an isolated system, energy cannot be gained or lost and the entropy change is the only driving force. The apparent equilibrium constant for the process has been shown to be as shown in Eq. (4)**, Gupta, and Rastogi, 2008b**:

$$\Delta G^0 = -RT \ln \pi(K_c) \tag{4}$$

Also, enthalpy changes (ΔH) and entropy changes (ΔS) can be estimated by Eq. (5):

$$\Delta G^0 = \Delta H^0 - \Delta S^0 T \tag{5}$$

The negative values of ΔH° reveal the adsorption is exothermic and physical in nature. Generally, the change in adsorption enthalpy for physisorption is in the range of −20 to 40 kJ mol^{-1}, but chemisorptions are between −400 and −80 kJ mol^{-1}**, Tuzun, et al., 2005**.

3. EXPERIMENTAL PROCEDURE AND METHOD

3.1 Levofloxacin Hemihydrate (LEVX) Adsorbate

Levofloxacin Hemihydrate (LEVX) 500 mg tablets were obtained from the commercial Iraqi market. For this study LEVAQUIN®500mg tablets are available as film-coated tablets and contain the following inactive ingredients: 500 mg (as expressed in the anhydrous form) crospovidone, hypromellose, magnesium stearate, microcrystalline cellulose, polyethylene glycol, polysorbate 80, synthetic red and yellow iron oxides and titanium dioxide**, RxList, 2013**.

Fresh stock solutions of 500 mg/L LEVX were prepared daily by dissolving one tablet of LEVX in 1000 mL distilled water, 0.1M HCl was added to the solution to control the pH to 7,and then vigorously shacked on a mechanical gyratory shaker (HV-2 ORBTAL, Germany), 200 rpm for 1h. Absorbance was measured at 280 nm by (T80 Spectrophotometer /VIS spectrometer PG Instrument Ltd.) against blank at 30 ±3^{o}C. The stock solution was protected from light exposure by aluminum foil and kept at room temperature**, Sarkozy, 2001**. Stock solutions showed stability at room temperature with time.

Activated carbon, barley husks, and eggshells were used as adsorbents. Their characteristics were examined at the (Ministry of Oil, Petroleum Development and Research Center, Baghdad, Iraq) as shown in Table1 and according to **APHA, 1995.**

3.2 Determination of the Optimum Contact Time and pH

The optimum contact time was found by measuring the time to reach equilibrium conditions when the uptake q_e was constant with time for the three adsorbents. 0.5 g of activated carbon, and barley husk, while 5 g of eggshells were mixed with 100 mL of LEVX solution concentration of 150 mg/L, 200 rpm, normal pH, and 30 °C. The optimum time was used for the next experiments.

The effect of pH on sorption LEVX onto activated carbon, barley husk and eggshells were studied; 0.5 g of activated carbon, and barley husk, while 5 g of eggshells were mixed with 100 mL of LEVX solution concentration of 150 mg/L. These were maintained at different pH values ranging from 4 to 9 by using 0.1 M HCl or NaOH solution, the flasks were placed on the shaker at an agitation speed of 200 rpm for a period of 3 h (as found experimentally in **Fig.2** and at temperature of 30°C. Samples of 10 mL were taken from each volumetric flask and measured by the Spectrophotometer.

3.3 Isotherms

Different sorbate concentrations (25, 50, 75,100,125, and 150 mg/L) of 100 ml LEVX solution were used. 0.5 g of activated carbon, and barley husk, while 5 g of eggshells using (electronic balance Sartorius BL 210S) were placed separately in 250 mL volumetric flasks because of its low uptake of LEVX, respectively. pH of the solutions were adjusted to the desired value pH=7 using 0.1 M NaOH or 0.1 M HCl. The flasks were then placed on the shaker, and agitated continuously for 3 h at 200 rpm and 30°C. The samples were filtered by no. 42 Whatman filter paper. The final equilibrium concentrations of LEVX were measured by the Spectrophotometer, the adsorbed amount is then calculated by Eq. (6)**, Gupta, et al., 2010**.

$$q_e = \frac{V_L(C_0 - C_e)}{W_a} \quad (6)$$

3.4. Kinetics and Thermodynamics

Reaction pathways were found using 2 L pyrex beaker fitted with a variable speed mixer. The beaker was filled with 1 L of 150 mg/L concentration of LEVX and the agitation was started before adding the Activated carbon, barley husk, or eggshells as adsorbents separately. At time zero, the accurate weight of sorbent was added and the samples were taken at specified time intervals. The necessary dosage of sorbents, to reach equilibrium related concentration of C_e/C_o equals to 0.05, were calculated from better isotherm model and mass balance Eq. (6). For accurate estimation of k_f, samples were taken after 3, 6, 9, and 12 min and analyzed.

The principle parameter required for solving the batch model is the external mass transfer coefficient (k_f) which was obtained using the concentration decay curve obtained from experimental data at optimum agitation speed and Eq.(1).

The effect of temperature on LEVX sorption onto each of activated carbon, barley husk and eggshells were determined using 0.5 g of activated carbon, barley husks, and 5 g of eggshells respectively, mixed with 100mL of 150 mg/L of LEVX solution. These were maintained at different temperatures ranging from 20 to 50 °C for a period of 3 h, and agitation speed was 200 rpm. Samples of 10 mL were taken from each volumetric flask and the absorbency was measured by the Spectrophotometer.

4. RESULTS AND DISCUSSION

4.1 Effect of Contact Time and pH

Barley husks show a constant uptake rate (50 min),while activated carbon uptake (about 110 min) for the same adsorbent dose, but eggshells show lower uptake (40 min) in spite of increasing the biomass dose (about 10 times more than activated carbon and barley husks), considering same operating experimental conditions as shown in **Fig. 2**. These are due to that the eggshells that have been measured by the Spectrophotometer; there was a high percentage of LEVX concentration in the raw material due to the use of the antibiotic in vaccines for the chickens.

The pH of the LEVX solution usually plays an important role in the sorption of LEVX, RxList, 2013. **Fig. 3**, shows that the sorption capacities were enhanced significantly from 3.8 to 5.2 mg/g for activated carbon, from 2.1 to 3.7 mg/g for barley husk, and from 1.1 to 1.5 mg/g for eggshells, respectively, when pH value was raised from 4 to 7. The s effect of pH influences on adsorption of LEVX onto biomass adsorption capacities were increased with attractive interaction at pH 7 and decreased with repulsive interaction at pH 9. It could be indicated that combination of electrostatic interaction and hydrophobic force might effect on adsorption capacity of the biomass and activated carbon, same results were obtained by**, Hattab, 2010,** at pH of 7 the sorption capacity of LEVX onto charcoal was 5.5 mg/g.

4.2 Adsorption/Biosorption Isotherms

At equilibrium point adsorption/biosorption isotherms reflected the molecular distribution between the liquid and solid phases. At that point, adsorption quantity q_e of LEVX onto activated carbon, barely husks, and eggshells, at initial concentrations, 25 to 150 mg/ L for LEVX, are shown in Table (2). The amounts of adsorbed/ biosorbed LEVEX increased with the increasing of the concentration of LEVX in the equilibrium solution**, Hattab, 2010**.

The analysis of experimental results of equilibrium adsorption isotherms is important in developing accurate data that could be used for adsorption design purpose. The adsorption isotherm curves for adsorption of LEVX onto activated carbon, barley husks, and eggshells, were obtained by plotting the equilibrium concentration C_e of the LEVX solute with the experimental uptake (q_e) as shown in **Fig. 4**.

The adsorption/biosorption capacity (q_e) and LEVX removal rate were related to the amount of sorbent/ biosorbent added **Fig. 5**; the greater adsorption/ biosorption capacity was obtained at lower sorbent/ biosorbent dose, these results agreed with**, Gupta, and Ali, 2008** and **Ziagova, et al., 2007**. The higher removal rate was achieved at higher sorbent / biosorbent dose. The Langmuir model gives the best fit for the experimental data for LEVX adsorption / biosorption on to activated carbon, barley husks, and eggshells respectively, compared with Freundlich, and Sips models recognized by the highest values of (R^2). These models have been used successfully to describe equilibrium sorption/biosorption, with results agreed with**, Hattab, 2010**. Results were compared for the three adsorbants in term of adsorption/biosorption capacities: Activated carbon > Barley husks > Eggshells. This is due to increase the saturation of adsorbent surface with increase in initial LEVX concentrations. The activated carbon has greater surface area for adsorption.

4.3 Adsorption / Biosorption Kinetics

The amount of activated carbon, barley husks, and eggshells, used for the adsorption of LEVX were calculated for final equilibrium related concentration of $C/C_0 = 0.05$, the Langmuir model constants were used with the mass balance in 1 L of solution. The initial concentration was 150 mg/L with doses 20.745, 30.722, and 720 g of activated carbon, barley husks, and eggshells respectively as shown in **Figs. 6-8**. The average calculated values of k_f for each adsorbent were found to be 4.7×10^{-6}, 1.3×10^{-5} and 1.33×10^{-7} m/s for activated carbon, barely husks, and eggshells respectively. These indicate that the rate of surface mass transfer of barely husks is higher than the other adsorbents. In other words, LEVX is absorbed by barely husks at higher rate than others. Pseudo-first-order and Pseudo-second-order. Table 3 show the Pseudo second-order model for LVEX, the correlation coefficient values for the linear plots being higher than 0.98 as shown in **Figs. 9-10**.

4.4 Adsorption / Biosorption Thermodynamic

Table 4 shows the thermodynamic constants of adsorption / biosorption for LEVEX onto activated carbon, barley husks, and eggshells respectively. The value of enthalpy ΔH° was 7.478, 26.3 and 20.91 kJ/mole for activated carbon, barley husks, and eggshells respectively, suggested the physisorption and exothermic nature of adsorption **Fig. 11**. This is also supported by the decrease in the values of uptake capacity of adsorbent / biosorbents with the rise in temperature**, Sulaymon, et al., 2013**. The values of entropy ΔS° were –0.0327, -0.095 and -0.0735 J/mole K, reflect the affinity of LEVX to be adsorbed onto activated carbon, barley husks, and eggshells respectively.

The increase in the value of the free energy ΔG° with the increase in temperature indicates that the adsorption / biosorption process is exothermic and it is thereby favored with decrease in temperature, thus, the process is better carried out at low temperature**, Sulaymon, and Ahmed, 2008**.

5. CONCLUSIONS

The equilibrium isotherm for single component is of a favorable type and Langmuir isotherm gives the best fit model for the experimental data , and adsorption capacity parameters for LEVX onto activated carbon > barley husks > eggshells. Optimum pH was 7. Van der Wall's electrophoresis force play the major role in adsorption / biosorption of LEVX. There was a good matching between experimental and predicted data in batch experiments using second order kinetic model for all sorbent / biosorbents, sorption / biosorption of LEVX were exothermic and physical in nature.

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NOMENCLATURE

a_s	sips constant, dimensionless
b	langmuir adsorption constant related to the affinity to binding sites, l/mg
C_{ad}	adsorbed on adsorbents surface concentration, mg/l
C_e	equilibrium concentration of LEVX, mg/l
C_o	initial LEVX concentration, mg/l
C_s	saturation concentration of the adsorbed component, mg/l
C_t	concentration of LEVX at time t, mg/l
K_1	pseudo-first order coefficient, s^{-1}
K_2	second order kinetics, l mol^{-1} s^{-1}
K_c	C_{ad}/C_e constant used in Eq. (4), dimensionless
k_f	fluid to particle mass transfer coefficient, m/s
K_F	freundlich adsorption constant, related to adsorption intensity, $(mg/g)(mg/l)^{1/nf}$
K_s	sips constant, dimensionless
n_F	freundlich adsorption constant, related to the affinity to binding sites, dimensionless
q_e	amount of adsorbate adsorbed per mass of adsorbent of component, mg/g
q_{eq}	adsorbed LEVX quantity per gram of activated carbon, barley husk and eggshells at

	equilibrium, mg/g
q_m	langmuir adsorption constant of the pollutants shows the maximum amount of pollutants bound to the activated carbon, barley husk and eggshells, mg/g
qt	uptake amount at time t, mg/g
R	universal gas constant (=8.314), kj/mol.k
Rp	radius of adsorbent/ biosorbent particles, m
T	absolute temperature, k
t	time, s
V_L	volume of solution, l
W_a	weight of adsorbent/ biosorbent (activated carbon, barley husk, and eggshells), g
$\Delta G°$	standard Gibbs free energy change, kj mol^{-1}
$\Delta H°$	change in enthalpy (heat of adsorption/sorption), kj mol^{-1}
$\Delta S°$	change in entropy, kj mol^{-1}
β_s	Sips constant, dimensionless
ρ_p	bulk density of adsorbent/ biosorbent, kg/m^3

Table 1. Physical characteristics of the adsorbents (Ministry of oil, petroleum development and research center, Baghdad, Iraq).

Physical Property	**Barley Husk**	**Egg Shells**	**Activated Carbon**
Particle size range, (mm)	0.6 – 1	0.6 - 1	0.6 - 1
Equivalent diameter, (mm)	0.775	0.775	0.775
Apparent density,(kg/m^3)	332	640	480-490
Bulk density,(kg/m^3)	1011	1600	450
Solid density base dry, (kg/m^3)	1480	2350	770
BET Surface area, (m^2/g)	0.302	0.163	1100
Porosity	0.5	0.32	0.55
Ash %	19.6	84	5

Table 2. Parameters of single solute isotherm for Levofloxacin onto activated carbon barley husks, and eggshells at initial concentrations 25 to 150 mg/L of LEVX.

Model		Parameters	AC	BH	ES	Reference
Freundlich	$q_e = K_F C_e^{1/nF}$	K_F	2.059	o.468	0.0093	Gupta and Rastogi 2008
		n_F	1.625	0.958	0.775	
		R^2	0.970	0.982	0.986	
Langmuir	$q_e = \frac{q_m b C_e}{(1 + bC_e)}$	q_m	34.211	125.735	5.6423	Sulaymon et al. 2013
		b	0.0335	0.00498	0.00435	
		R_L	0.421	0.834	0.816	
		R^2	**0.995**	**0.988**	**0.995**	
Sips	$q_e = \frac{K_s C_e^{\beta_s}}{1 + a_s C_e^{\beta_s}}$	k_s	1.334	0.120	0.052	Sulaymon et al. 2013
		ß$_s$	0.9116	1.604	0.622	
		a_s	0.033	0.0029	-0.050	
		R^2	0.973	0.986	0.970	

Table 3. Kinetic parameters for activated carbon, barely husks, and eggshells.

Kinetic Model	Parameter	Activated Carbon	Barley Husk	Eggshells
Pseudo-first-order (Equation 2.24)	q_e(mg/g)	30.66	23.81	17.12
	K_1(min^{-1})	4.6×10^{-4}	1.4×10^{-4}	1.15×10^{-4}
	Correlation coefficient	0.7224	0.7022	0.8099
Pseudo-second-order (Equation 2.28)	qe cal. (mg/g)	4.71	6.87	0.21
	K_2(mg/g.min)	0.0355	0.0108	0.1438
	h_0	28.174	92.388	6.955
	Correlation coefficient	0.9988	0.9966	0.9846

Table 4. Thermodynamic parameters for activated carbon, barley husk and eggshells.

Adsorbents	Temperature, K	ΔG◦ (kJ.mol^{-1})	ΔH° (kJ.mo1^{-1})	ΔS° (J.$mol^{-1}K^{-1}$)	R^2
Activated Carbon	293	-0.91	7.478	-0.0327	0.9778
	303	-2.418			
	313	-3.424			
	232	-4.503			
Barley Husks	293	-1.769	26.3	-0.095	0.989
	303	-2.524			
	313	-3.448			
	323	-4.653			
Eggshells	293	-0.719	20.98	-0.0735	0.966
	303	-1.049			
	313	-1.986			
	323	-2.856			

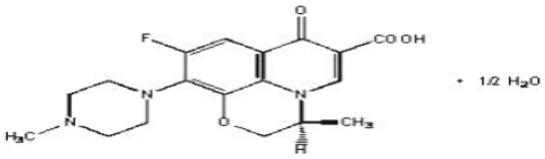

Figure 1. The chemical structure of Levofloxacin.

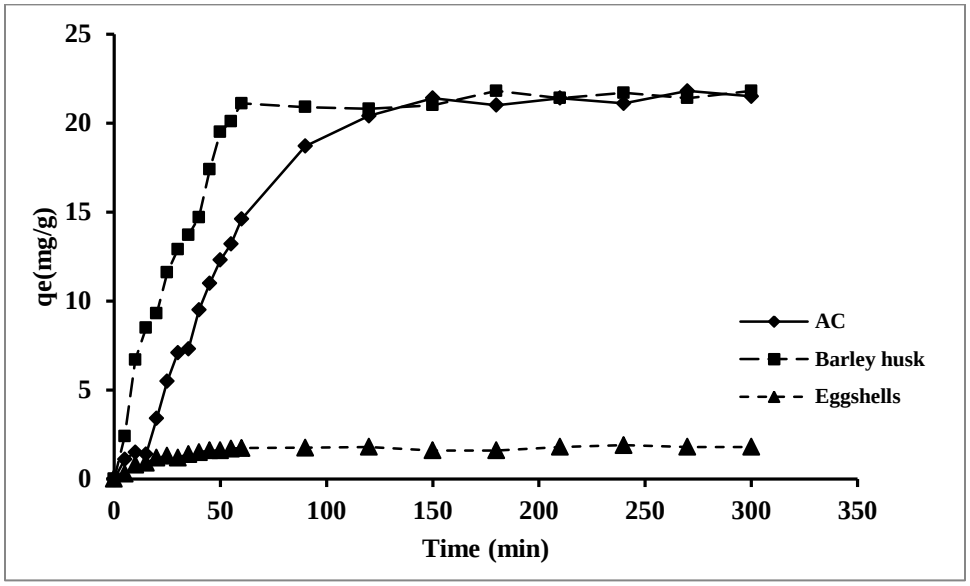

Figure 2. Effect of contact time on the uptake of Levofloxacin onto activated carbon, barley husk and eggshells, $C_{biomass}$= 0.5 g/L, $C_{0Levofloxacin}$= 150 mg/L, pH= 7 and agitation speed= 200 rpm.

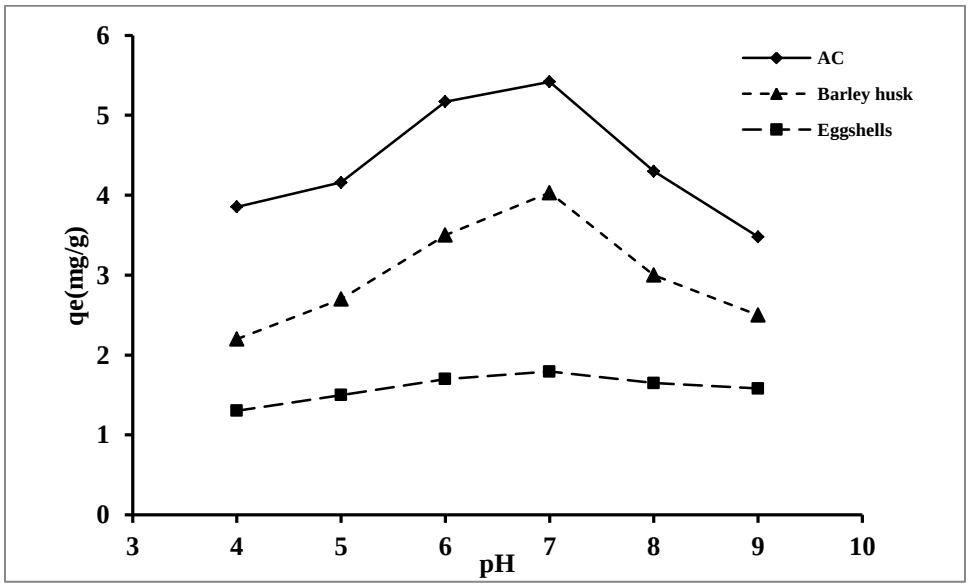

Figure 3. Effect of pH on the uptake of Levofloxacin onto activated carbon, barley husk, $C_{biomass}$= 5 g/L, and eggshells $C_{biomass}$= 50 g/L, $C_{0Levofloxacin}$= 150 mg/L, contact time = 3 h, and agitation speed= 200 rpm, temperature= 30°C.

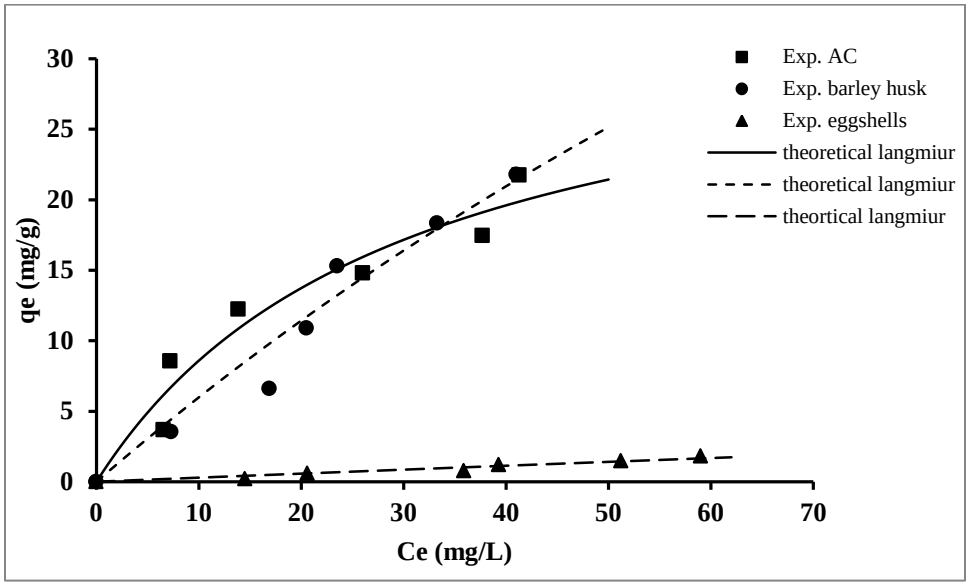

Figure 4. Adsorption isotherms of Levofloxacin as single solutes onto activated carbon, barley husk, $C_{biomass}$= 5 g/L and eggshells, $C_{biomass}$= 50 g/L, pH= 7 and agitation speed= 200 rpm.

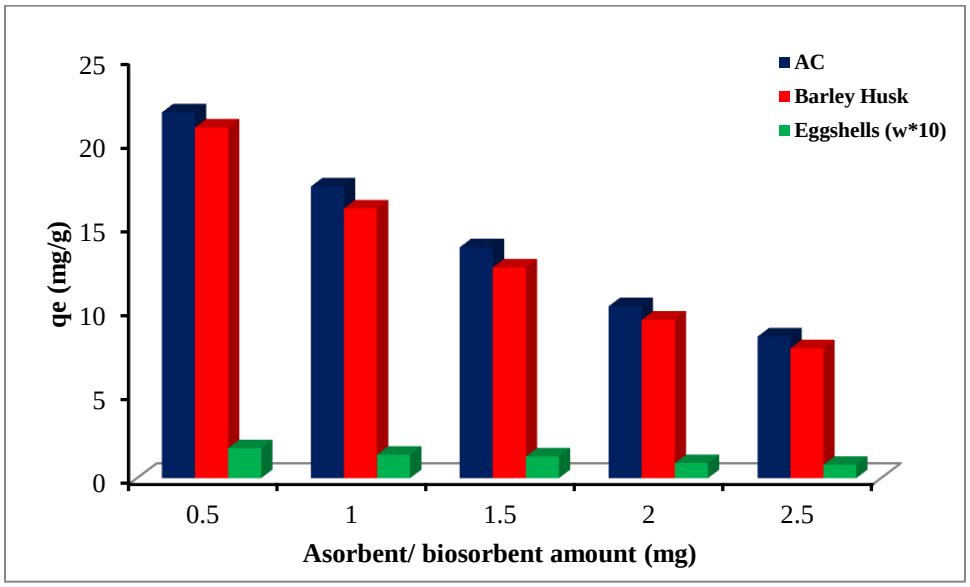

Figure 5. Effect of adsorbent/biosorbent amount on to the uptake capacity of Levofloxacin as single solutes, pH= 7, C_0=150 mg/L, and agitation speed= 200 rpm.

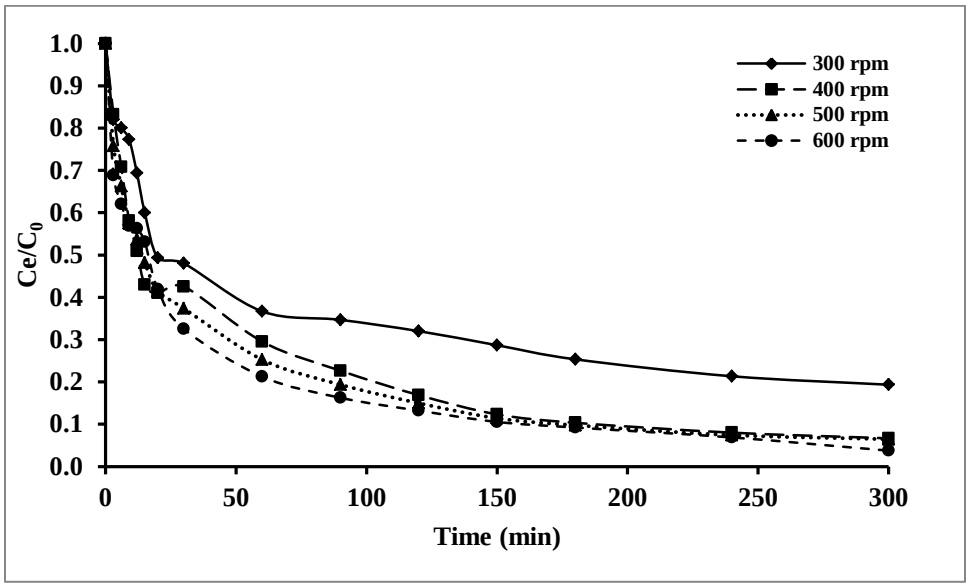

Figure 6. Concentration-time decay data for Levofloxacin onto activated carbon, $C_{absorbent}$= 20.744 g/L, $C_{0Levofloxacin}$ = 150 mg/L, pH= 7 at different agitation speeds.

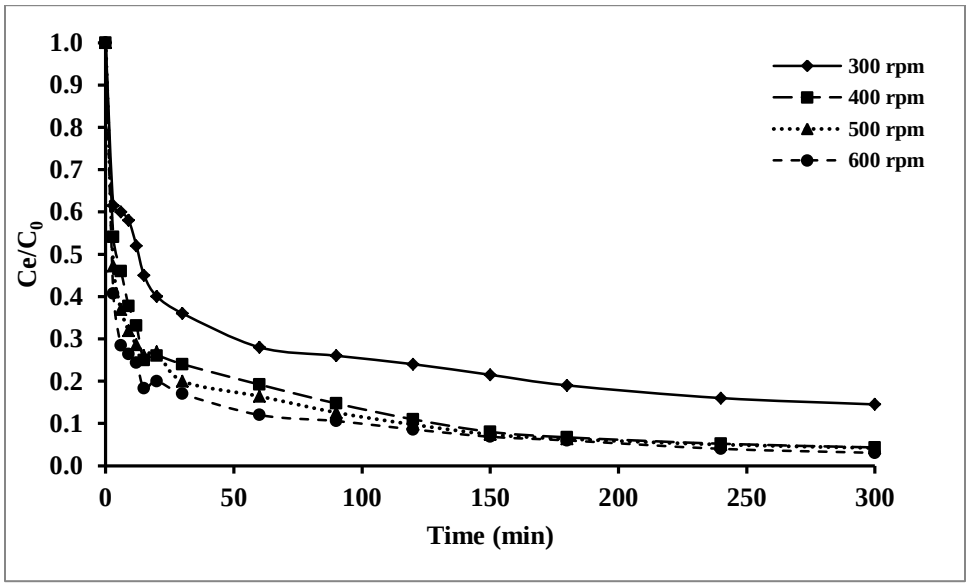

Figure 7. Concentration-time decay data for Levofloxacin onto barley husk, $C_{absorbent}$= 30.722 g/L, $C_{0Levofloxacin}$ = 150 mg/L, pH= 7 at different agitation speeds.

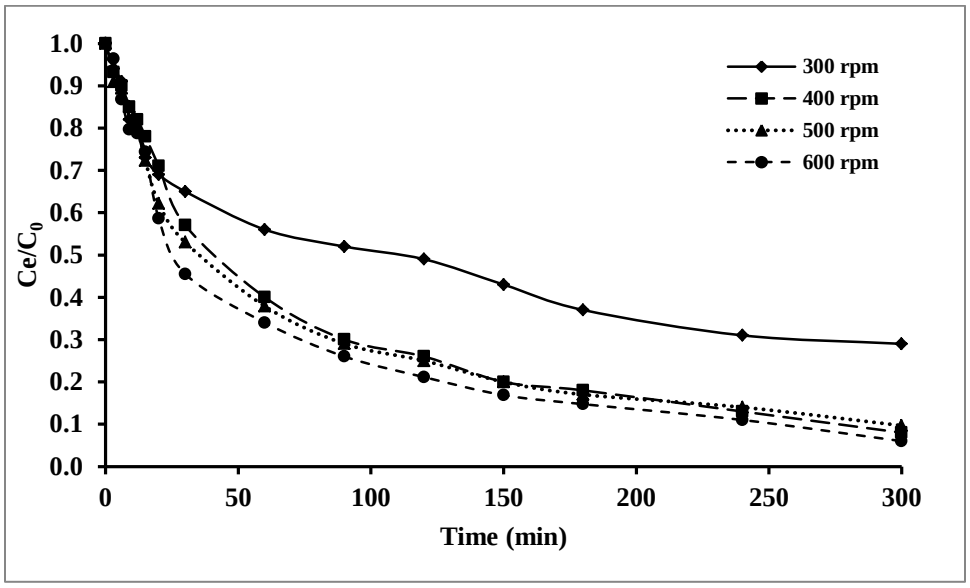

Figure 8. Concentration-time decay data for Levofloxacin onto Eggshells, $C_{absorbent}$= 720.3 g/L, $C_{0Levofloxacin}$ = 150 mg/L, pH= 7at different agitation speeds.

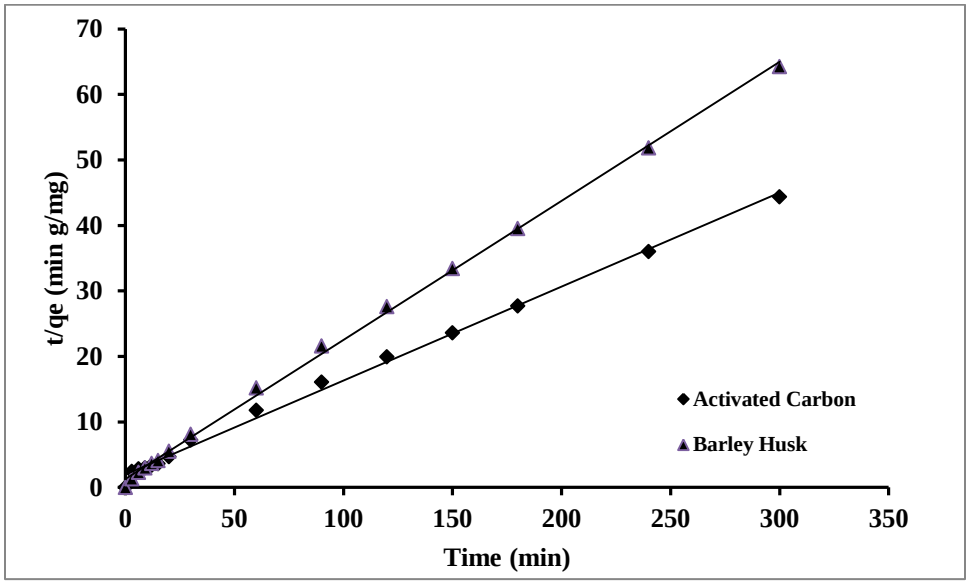

Figure 9. Pseudo-second-order model for Levofloxacin onto activated carbon and barley husk; $C_{0Levofloxacin}$ = 150 mg/L, pH= 7.

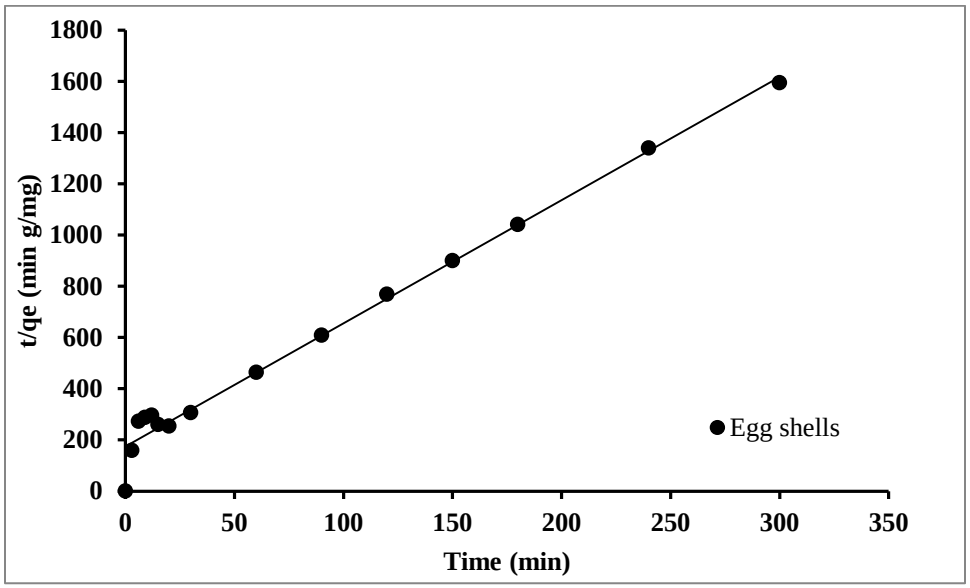

Figure 10. Pseudo-second-order model for Levofloxacin onto egg shells; $C_{0Levofloxacin}$ = 150 mg/L, pH= 7.

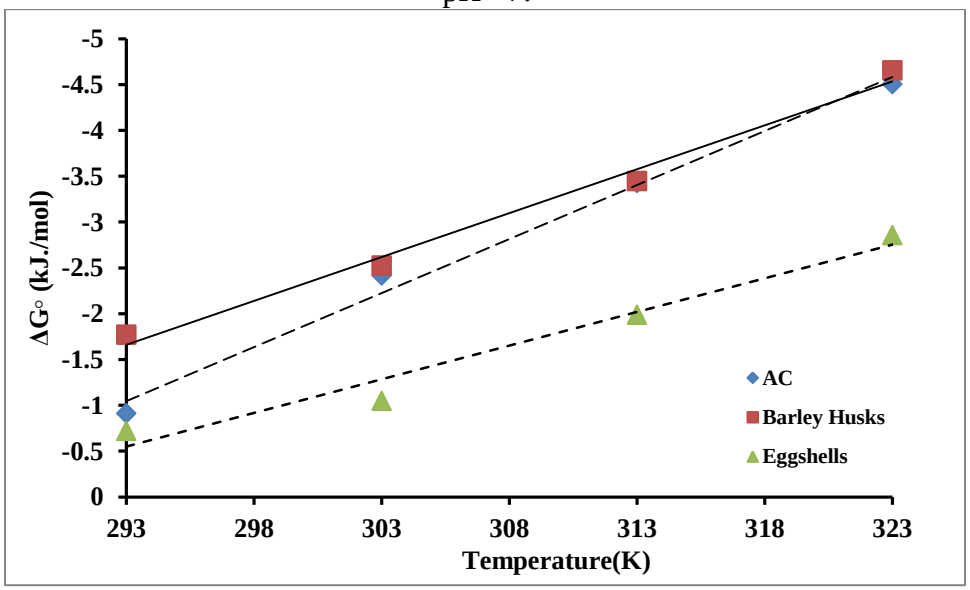

Figure 11. Change in free energy with temperature for the adsorption/biosorption of Levofloxacin onto activated carbon, barley husks and eggshells, at initial concentration of 150 mg/l, pH 7.

1-DOF Model for Fluid-Structure-Interaction Vibration Analysis

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ABSTRACT

In this paper an attempt to provide a single degree of freedom lumped model for fluid structure interaction (FSI) dynamical analysis will be presented. The model can be used to clarify some important concept in the FSI dynamics such as the added mass, added stiffness, added damping, wave coupling ,influence mass coefficient and critical fluid depth . The numerical results of the model show that the natural frequency decrease with the increasing of many parameters related to the structure and the fluid .It is found that the interaction phenomena can become weak or strong depending on the depth of the containing fluid .The damped and un damped free response are plotted in time domain and phase plane for different model parameters It is found that the vibration free response is still sinusoidal for weak FSI coupling ,however for strong coupling it behaves as modulated periodic response .To justify some of the theoretical aspects such as; the effects of the fluid density and the interact shape on the natural frequency an experiment was conducted .The results of the experiment shows a good agreement with the theory where the error is not exceeded 7%.

Key words: FSI, mass influence coefficient , interact shape ,added mass ,added damping

نموذج ذو درجة حرية واحدة لتحليل الاهتزاز للهيكل المتفاعل مع المائع

محمود رشيد اسماعيل
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الخلاصة

في هذا البحث محاولة لتوفير موديل ذو درجه حريه واحدة للتحليل الديناميكي للهياكل المتفاعله مع الموائع .يمكن استخدام هذا النموذج لتوضيح مفاهيم اساسيه في الديناميك التفاعلي مثل الكتله المضافة والجساءة المضافة والتخميد المضاف والتداخل الموجي ومعامل الكتلة المؤثر وعمق المائع الحرج .بينت النتائج العددية ان التردد الطبيعي يتناقص بتاثير زيادة بعض المعاملات التي تخص الهيكل والمائع .كما بينت النتائج بان ظاهرة التفاعل يمكن ان تكون ضعيفه او قوية وذلك اعتمادا على عمق المائع الحاوي .تم رسم الاستجابة الحره المخمدة والغير مخمدة باستخدام احداثيات الزمن وطريقة مستوي الطور لعدة متغيرات فبينت المخططات ان استجابة الاهتزاز تبقى موجيه في حالة التفاعل الضعيف بينما تكون من النوع الدوري المتضمن في حالة التفاعل القوي .للتحقق من بعض النتائج النظريه مثل تاثير كثافة السائل والشكل المتفاعل فقد تم اجراء تجارب عملية .بينت النتائج العمليه تطابق جيد مع النظري حيث لم تتعدى نسبة الخطأ 7%.

الكلمات الرئيسية :الهياكل المتفاعلة,معامل تأثير الكتلة ,الشكل المتفاعل ,الكتله المضافه ,التخميد المضاف.

1. INTRODUCTION

The dynamics of fluid structure interaction (FSI) has wide applications in many branches of engineering such as aerospace ,aerodynamics, ship motion, medical applications and other flow induced vibration problems.

In the FSI systems the couplings between, fluid and structure include many kinds. It is well known now as frictional coupling, Poisson coupling, junction coupling, Bourdon coupling, wave-.flow coupling and wave–wave coupling, etc ,**Amabili,2000.**

In general the dynamical behavior of structures interacts with fluid is very complicated and they are normally evaluated by numerical technique like finite element or finite difference methods .Many models are treated by using simulation methods based on experiments under wind tunnel .An exact analytical models are seldom available in the literature, however there existed many approximate models for analyzing some special problems under some assumptions . For example an idealized case of elastic structure in free lateral vibration and interacting with an enclosure fluid cavity where the fluid medium has been infinite was investigated by **Aitkinson, et al.,2007** ,in their analysis, the wall reflecting of the fluid pressure waves was neglected. **Daniel et al., 2007** constructed a model for analyzing vibration of cantilever beam interact with finite volume air cavity for using in vibration of health monitoring .The analysis of the coupled free vibration of distributed structure such as beams, plates and shells in interaction with a fluid-filled was performed by **Gorman et al., 2001**, which produced natural frequencies of the coupled system .The results were agreed well with the finite element analysis and experiment . **Sarkar and Paidoussis, 2004,** treated the dynamical behavior of pipes conveying fluid as another type of FSI syatems .It was found that, the fluid adds additional forces on the structure such as axial and coriolis forces . An extended literature survey about the FSI can be found in a book published by **Paidoussis, 1998.**

In the present work an attempt to provide a lumped one degree of freedom model for treating the FSI dynamic will be presented. The present model treats the various fluid effects such as the added mass, added stiffness, added damping and the fluid pressure wave for compressible and incompressible fluids. Such a model may has the benefit of its simplicity for the approximate analysis of FSI as a first insight in this vital field.

2. THEORITICAL CONSIDERATIONS

Consider a coupled fluid-structure 1-DOF mass-damping–stiffness (*m*-*c*-*k*) model shown in **Fig.1,** is interacting with a enclosed fluid space of depth *H*. The coordinate of the mass is y and that of the fluid container is *Y* as shown in the figure .The containing fluid is considered inviscid (non viscous) which may be compressible or incompressible. For small vibration the effect of vortex is neglected.

The equation of motion of 1-DOF mass spring damper, taking into account the effect of the induced pressure force is;

$$(m_s + m_d)\frac{d^2y}{dt^2} + (C_s + C_d)\frac{dy}{\partial t} + (k_s + k_d)y = AP\big|_{y=H} \quad (1)$$

Where *s* and *d* refer to the structure and the added parameters due the fluid effect, respectively. Eq.(1) can be written in the following form ;

$$m\frac{d^2y}{dt^2} + C\frac{dy}{\partial t} + ky = AP\big|_{y=H} \quad (2)$$

Where,
$m = m_s + m_d$
$C = C_s + C_d$
$k = k_s + k_d$, (3)

are the total mass ,damping and stiffness, respectively .*P* is the pressure and *A* is the interacted area of the mass block .

Now dividing Eq.(2) by *m* giving;

$$\frac{d^2y}{dt^2} + \frac{C}{m}\frac{dy}{\partial t} + \frac{k}{m}y = \frac{A}{m}P\Big|_{y=H} \tag{4}$$

As shown in **Fig. 1**, the fluid boundary lies only under the mass block . The fluid domain is bounded above by the block mass and by perfectly absorbent walls on all other sides. The fluid is assumed to be inviscid and may be compressible or incompressible and can well described by Laplace's equation over the domain. The boundary condition of the fluid-structure interface is described as a Neumann boundary condition by coupling the velocities across the interface **Blevins, 2010**. The sides and bottom containing the fluid represent a Dirichlet boundary at which the fluid potential is zero. The fluid system can be characterized by the following Laplace's equations **Paidoussis,1998**.

$$\nabla^2\phi = (\frac{1}{S})^2 \frac{\partial^2\phi}{\partial t^2} \tag{5a}$$

Where ϕ is potential flow function and *S* is the speed of sound .For one dimensional motion (in *Y* direction only) the potential function takes the following form;

$$\frac{\partial^2\phi}{\partial Y^2} = (\frac{1}{S})^2 \frac{\partial^2\phi}{\partial t^2} \tag{5b}$$

Eq.(5b) can be solved by trying the following harmonic solution;

$$\phi(Y,t) = \eta(Y)e^{i\omega t} \tag{6}$$

Separating the variable leads to the following general solution;

$$\phi(Y,t) = [C_1 \sin\frac{\omega}{S}Y + C_2 \cos\frac{\omega}{S}Y]e^{i\omega t} \tag{7}$$

Where C_1 and C_2 are arbitrary constant depending on the boundary conditions and ω is the natural frequency.
The velocity at the bottom is zero; hence the first boundary condition is;

$$V_y = \frac{\partial\phi}{\partial Y}\Big|_{Y=0} = 0 \tag{8}$$

Substituting Eq.(8) into Eq.(7) ,Gives;C_1=0
Hence Eq.(7) is reduced to;

$$\phi = C_2 \cos(\frac{\omega}{S}Y)e^{i\omega t} \tag{9}$$

Now the fluid pressure, P excreted at the bottom surface of the mass block can be evaluated as follows, **Atikinson and Marique, 2007**,

$$P\big|_{Y=H} = -\rho S \frac{\partial \phi}{\partial t}\ \big|_{Y=H} \tag{10}$$

Combining of Eqs. (4,9) and (10) giving;

$$\frac{d^2y}{dt^2} + \frac{C}{m}\frac{dy}{\partial t} + \frac{k}{m}y = -C_2 \frac{i\omega A\rho S}{m}\cos\frac{\omega H}{S}e^{i\omega t} \tag{11}$$

The solution of Eq.(11) can be written as;

$$y = \frac{-iC_2\omega A\rho S\cos(\omega H/S)}{k - m\omega^2 + i(Ck\omega/m)}e^{i\omega t} \tag{12}$$

Eq.(12) can be used to plot the free vibration response due to a given initial conditions in the time domain.
At Y= H, the fluid velocity V_y and the lateral velocity of the mass are equal, hence the second boundary condition is ;

$$\left.\frac{\partial \phi}{\partial Y}\right|_{Y=H} = \frac{\partial y}{\partial t} \tag{13}$$

Substituting Eq.(13) into Eq.(12), gives the frequency equation of free vibration of the FSI as follows;

$$\frac{\omega A\rho S^2}{k - m\omega^2 + i(Ck\omega/m)} + \tan\frac{\omega H}{S} = 0 \tag{14}$$

As stated above Eq.(3) the parameters m, C and k combine the structure parameters and the added ones due to the fluid interaction .The added parameters may be evaluated as the following

A-The added mass;

The added mass represents the fluid mass displayed by the block as it vibrates (Archimedes principle).It can be calculated from the following equation **Paidoussis, 1998** ;

$$m_d = \rho A C_I \tag{15}$$

Where C_I denoted the *added mass influence coefficient* which depends on the geometry of the body interacts with the fluid and can be found from tables presented by **Blevins, 2010** .
For example CI=1 and 1. 86 for circular and square cross sections , respectively.

B-The Added Damping

The damping mechanism is complex phenomenon which depends on many factor associated to the fluid and structure parameters such as viscosity, types of fluid ,the lift and drag forces , boundary conditions ,structure mass and stiffness ,fluid hammering, etc. However for still and non-viscous fluid with rigid bounded structure as it is the presented case, it is assumed that the predominate damping effect is due to the fluid hammering .This phenomena can be resulted from the influence of the shock resulting from the pressure wave as it strike the block due to vibration motion .The additional pressure induced by the surface area of the block can be evaluated according to Joukowsky equation as;

$$P_h = \rho S \frac{dy}{dt} \tag{16}$$

Due to this pressure the force excreted on the block is ;

$$F = P_h A \tag{17}$$

This force will create an additional damping force given by;

$$F = C_d \frac{dy}{dt} \tag{18}$$

Combining, Eqs. (16) ,(17)and (18) ,the added damping , C_d can be evaluated as;

$$C_d = \rho SA \tag{19}$$

C-The Added Stiffness

The added stiffness depend on the compressibility of the fluid and the geometry of its container In other words on the bulk modulus of the enclosed fluid .However for the present model since the fluid is not perfectly enclosed and can be easily escaped ,the effect of the added stiffness is so small and can be neglected .

Finally , considering the above effects the free time response Eq.(12) and the frequency equation Eq.(14) will take the following forms ;

$$y = C_2 \frac{-i\omega A\rho S \cos(\omega H / S)}{k + [k(C + \rho SA)/(m_s + C_I \rho A)]\omega - (m_s + C_I \rho A)\omega^2} e^{i\omega t} \tag{20}$$

$$\frac{S^2 \omega A\rho}{k + [k(C + \rho SA)/(m_s + C_I \rho A)]\omega - (m_s + C_I \rho A)\omega^2} + \tan\frac{\omega H}{S} = 0 \tag{21}$$

Eq. (21) has two terms; the first is characterized by the structure stiffness ,damping and mass and the second term is characterized by the fluid container .The FSI natural frequency is a

contributing of the two effects. An inspection of the second term it can be seen that this term can take two extreme values , which are; zero and infinity .When this term becomes zero this means that the FSI coupling effect due to the fluid is weak ,however, when it becomes infinity the FSI effect becomes strong . Hence one gets;

For weak FSI ; $\tan\frac{\omega H}{S}=0$, which gives , $\omega=S\pi/H$

For strong FSI; $\tan\frac{\omega H}{S}=\infty$, which gives ,$\omega=S\pi/2H$ (22)

Keeping in mind that only one root of the tangent function is taken since the model is 1-DOF.
For a certain fluid, the speed of sound *S* is constant, so that Eq. (22) indicates that the depth *H* is the only parameter which define the weakness or strengthens effects of the fluid on the natural frequency .In other words there are certain critical values of *H* at which the FSI coupling becomes maximum or minimum. This conditions are also observed by other FSI models for example the model given by **Daniel *et al*., 2007** .

3. EXPERIMENTAL INVESTIGATION

To justify some of the theoretical concepts an experiment was carried out .The main aim of the experiment is to investigate the effects of fluid and the interact shape on the natural frequency To maintain a same mass weight with different interact shapes. three plastic shapes was prepared and attached by using the arrangement shown in **Fig.2**. The dimensions and the corresponding mass influence coefficient of these samples are given in **Table.1**.
The test rig consists of the apparatus and the measuring instruments as shown in **Fig.4**.The apparatus consists of mass-spring system (k=2500N/m ,m=0.28 kg), as well as the fluid container (D=0.1 m, *H*=0.23 m) .These parameters are chosen to insure that the system is at the strong coupling regions. The measuring instruments are the accelerometer, charge amplifier and oscilloscope .In this test, water and kerosene (ρ =780 kg/m^3) are used as working fluids .For each fluid the three samples were used .The vibration signal was picked up by the accelerometer and amplified by the charge amplifier and fed to the scope .The natural frequency was recorded from the scope as shown in **Fig.4** .

4. RESULTS AND DISCUSSIONS

Exanimating of Eqs .(19) and (20) indicate that, the dynamical behavior of the present FSI model is affected by two main groups of parameters .The first are associated to the structure which are m_s , *k A,* C_I and *C*. The seconds are associated to the containing fluid which are ρ*, S,* and *H* .The effects of m_s , *k* and *C* can be clearly understood from considering the elementary analysis of a damped single degree of freedom oscillator The goal of the present investigation is to focus on the additional FSI parameters .

Figs.5,6, and 7, display the effects of the interacted area of the block mass ,fluid density and the influence mass coefficient on the natural frequency . In plotting these figures the following model parameters are chosen; m_s=0.25 kg (round cross section) ,C=20 Ns/m , k=500 N/m and *H*=0.25 m. With these data the vacuum natural frequency (i.e. without fluid) can simply be calculated as ω= 44.72 r/s .

In **Fig.5,** the area of the block mass is varied from $0.05\text{x}10^{-5}$ to $2.05\text{x}10^{-5}$ m^2 .As it is clear from this figure that ; increasing the area tends to reduce the natural frequencies .This behavior is logical since increasing the area produces resistance against the mass motion .

Fig.6 shows the effect of the influence coefficient which depends on the geometry of the block mass area .The minimum value of this coefficient is associated to the circular shape .The coefficient value increases as the shape become more complicated **Blevins.2010**.Examining of **Fig.6** indicates that increasing of the influence coefficient reduce the natural frequency, also This can be attributed to the increasing of the total mass which decreases the natural frequency .
In **Fig.7**, the effect of the fluid density is investigated for rang values from 1 to 1000 kg/m^3 Again the natural frequencies decrease with the increasing of the fluid density.
The un damped (C=0) natural response of the same model with the additional parameter data ρ=1000,H=0.25 , A=0.4x10^{-4} with rectangular shape , is plotted in **Figs. 8, a and b** in time domain and phase plane ,respectively .As it can be seen from these figures that the response is clean sinusoidal . To identify the response of the model near and at the strong zone of FSI coupling , the depth is assigned a new value which are (H=0.7 and 0.8 m) .The results are plotted in **Figs.9 and 10** for (2x10^{-7}m,0) initial displacement and velocity .In general these figures tell that the response is still sinusoidal but with variable amplitude this means that the response is a result of the modulation of two wave frequencies .These two frequencies are the acoustic wave frequency and the system natural frequency. The effect of this modulation becomes more clearly visible when the depth reach critical value (0.8 m) as it is shown in **Fig. 10,a and b** in both time and phase plane response .
The effect of damping is investigated in **Figs.11** .The damping ratio of the model is assigned ζ=0.1 value (ζ=C/2mω) .The under damping response at the strong zone is plotted in time domain and phase plane. The spiral trajectory of the phase plane indicates that the system is stable and the oscillation will be diminished after about ten periods.

The experimental and the corresponding theoretical results of the tested samples are collected in **Table 2**.In general the results show the decreasing in the natural frequencies due to the effects of the fluid and the interacting shape as it compared with the vacuum (without fluid) natural frequency .This confirm the theoretical conclusion that ;as the interact area becomes more sharply edge (from circular to squarer shape) the natural frequency decrease .Such a behavior can be attributed to the effect of drag force which increases as the profile sharpness increases .Moreover ,that; the natural frequency takes lower values as the fluid density increases (ρ_{water}=1000 kg/m^3, $\rho_{kerosene}$=780kg/m^3) . From comparing the experimental and theoretical the results show good agreements where the maximum error is not exceed the 7% .Also that the experimental results in general is lower than the corresponding theoretical .This may be due to the effect of the several sources of damping (friction ,drag ,internal , etc.) which are very difficult to be taking into account .

5. CONCLUTIONS

A lumped single degree of freedom analysis for FSI dynamics is treated in this work .It is found that; despite of its simplicity , it can serve a good model for investigating several main aspects of the FSI .The natural frequency was investigated .It is found that increasing the interacting area and the fluid density will reduce the natural frequency .Also, that the natural frequency can be increased as the shape of the interact area become irregular or complex .The free damped and un damped response are plotted in time domain and phase plain , It is concluded that the response in general is sinusoidal but it highly affected by the depth of the containing fluid .At certain critical fluid depths the FSI coupling become weak so that the response takes a pure sinusoidal form .However at other depth values the FSI coupling become strong leading to a modulated sinusoidal form .

Some aspects of the FSI was investigated experimentally such as the effects of fluid density and the shape of the interacting area .Comparing the results show good agreements where the maximum error is not more than 7% .
The model can be regarded as a useful tool for engineers for the crude estimating of the fundamental natural frequency and response of FSI systems .

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7. NOMENCLATURE

Ω= natural frequency, rad/s
ζ = damping ratio
A= interact area , m^2
C:=total damping , Ns/m
C_s=structure damping , Ns/m
C_d= added damping ,Ns/m
C_I =mass influence coefficient
K=total stiffness ,N/m
k_s= structure stiffness,N/m
k_d= added stiffness , N/m
m = total mass ,kg

m_d= added mass ,kg
m_s= structure mass ,kg
H= fluid depth ,m
S =speed of sound ,m/s

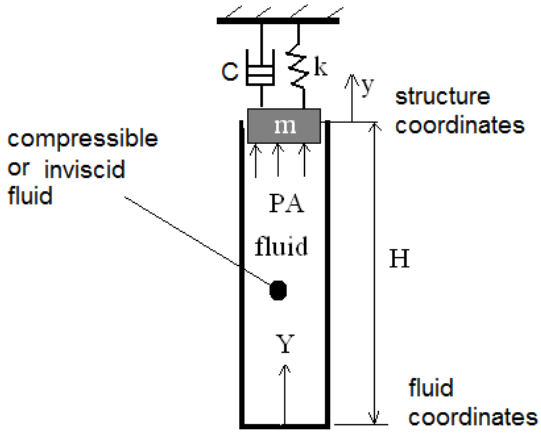


Figure 1. Schematic diagram of the idealized coupled FSI system.

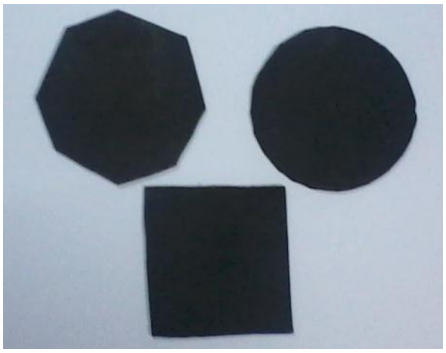


Figure 2. The tested samples.

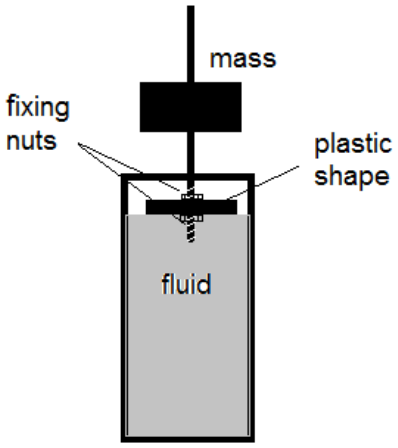


Figure 3. The mass-interacting shape arrangement.

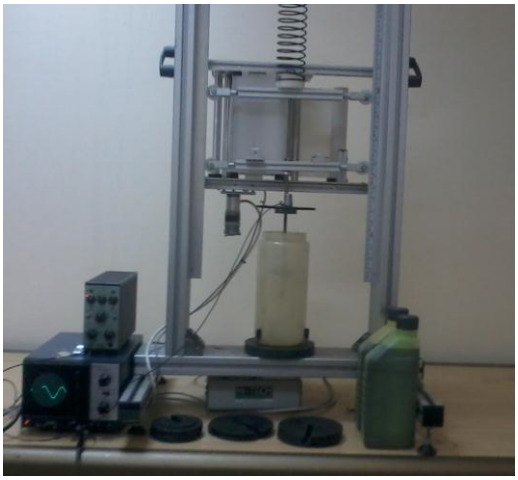


Figure 4. The test rig.

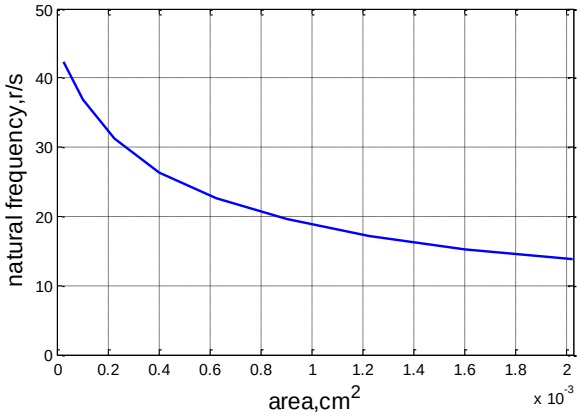


Figure 5. Effect of interacting area on the natural frequency.

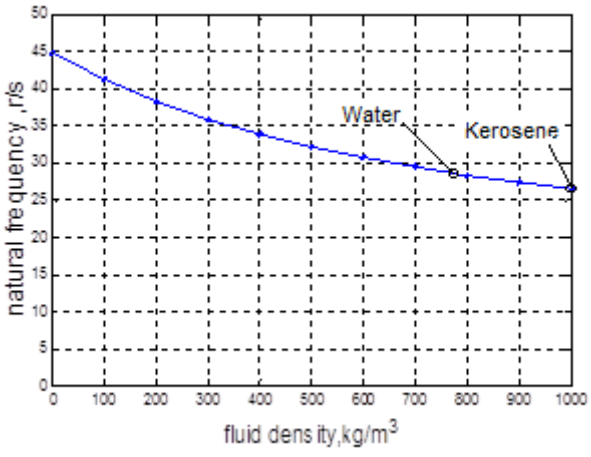


Figure 6. Effect of fluid density on the natural frequency.

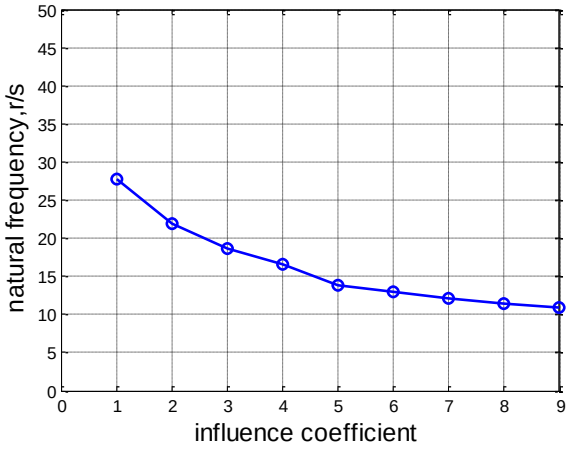
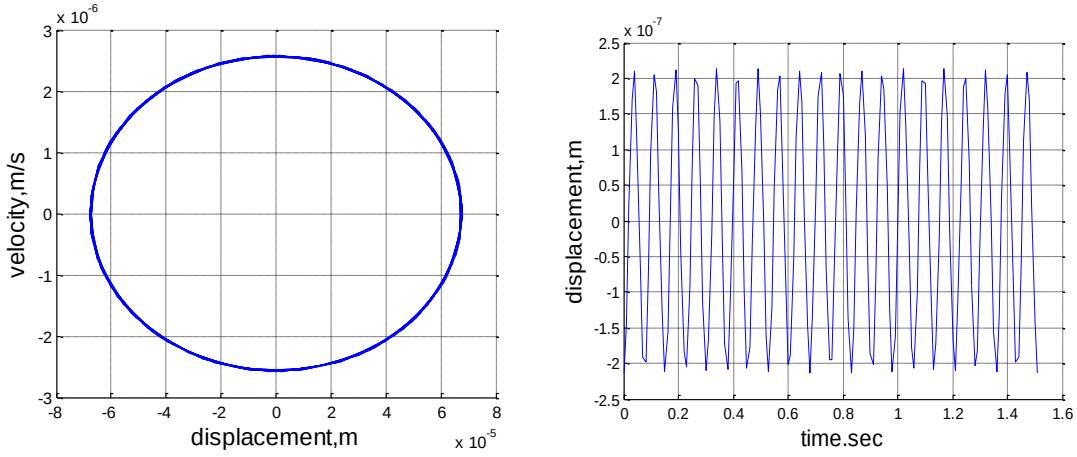
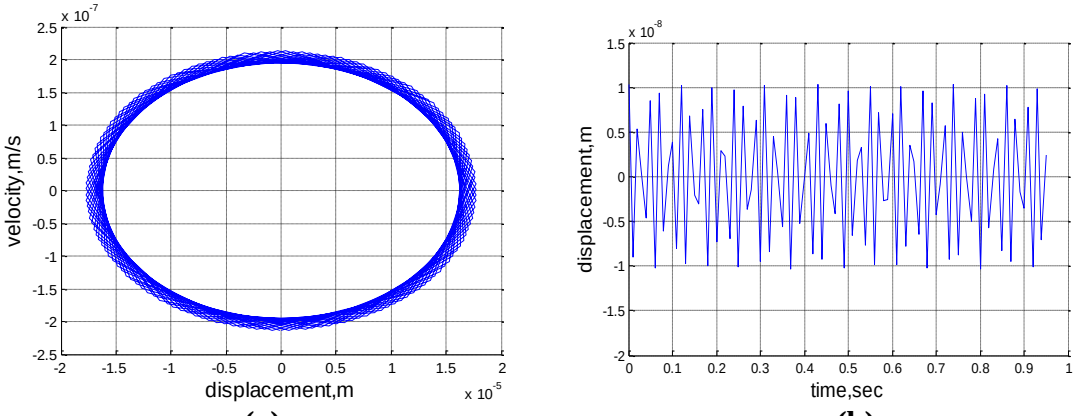


Figure7. Effect of mass influence coefficient on the natural frequency.



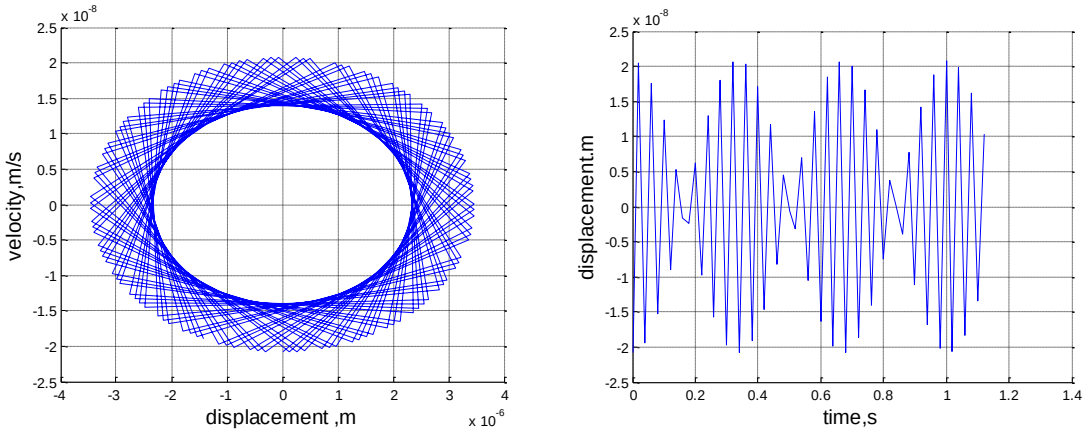
(a) **(b)**

Figure 8. Natural response at weak interaction zone,
(a) in phase plane (b) in time domain .



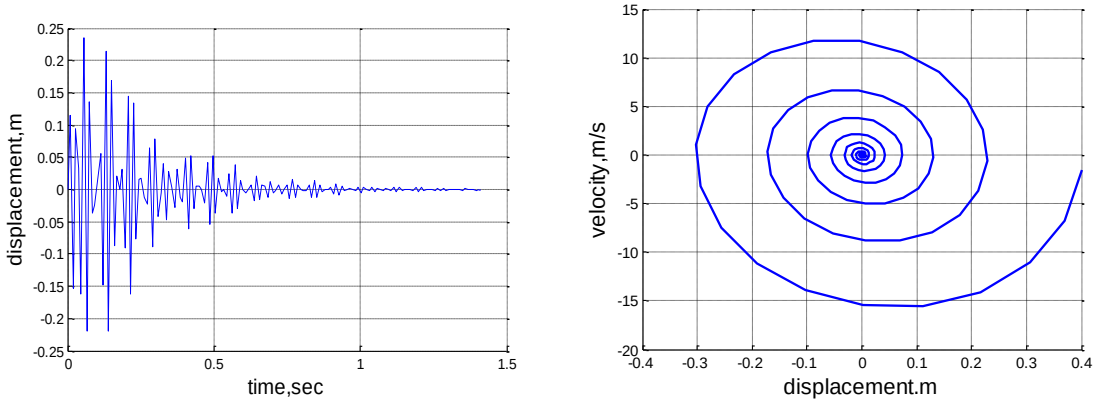
(a) **(b)**

Figure 9. Natural response close to strong interaction zone,
(a) in phase plane (b) in time domain .



(a) **(b)**

Figure 10. Natural response at strong interaction zone,
(a) in phase plane (b) in time domain.



(a) **(b)**

Figure 11. Damping response at ζ=0.1,
(a) in phase plane (b) in time domain.

Table 1. The tested samples dimensions and influence coefficients.

Sample no.	Shape	Radius or side length(m)	Area	C_I
1	Circle	0.082	πa2	1
2	Polygon	0.032	2(1+√2)a2	1.23
3	Squarer	0.073	a2	1.86

Table 2. Experimental and theoretical natural frequencies (Hz**).**

Interacting Shape	Vacuum (without fluid)		Kerosene		Water	
	Theo.	Exp.	Theo.	Exp.	Theo.	Exp.
Circle	11.2540	10.5	7.0337	6.5	6.4975	6
Polygon			6.5523	6	6.0155	5.5
Square			5.6975	5.2	5.1801	4.8

Using Alternative Cogeneration Plants in Iraqi Petroleum Industry

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ABSTRACT

The present paper describes and analyses three proposed cogeneration plants include back pressure steam-turbine system, gas turbine system, diesel-engine system, and the present Dura refinery plant. Selected actual operating data are employed for analysis. The same amount of electrical and thermal product outputs is considered for all systems to facilitate comparisons. The theoretical analysis was done according to 1st and 2nd law of thermodynamic. The results demonstrate that exergy analysis is a useful tool in performance analysis of cogeneration systems and permits meaningful comparisons of different cogeneration systems based on their merits, also the result showed that the back pressure steam-turbine is more efficient than other proposals. Moreover, the results of the present work indicate that these alternative plants can produce more electric power than that required in the refinery. At present time, the industrial cogeneration plants are recommended in Iraq, especially in petroleum industry sectors, in order to contribute with ministry of electricity to solve the present crisis of electric power generation. Such excess in the power can sold to the main electric network. The economic analysis are proved the feasibility of the proposed cogeneration plants with payback period of four year and six months ,three year and eight months, and ten years for steam cogeneration plant, gas turbine cogeneration plant and diesel engine cogeneration plant respectively.

Key words: cogeneration, power plants, energy, refinery, economic

استخدام محطات التوليد متعددة الاغراض في الصناعة النفطية في العراق

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الخلاصة

يتضمن البحث الحالي وصف وتحليل لثلاث مقترحات من محطات التوليد متعددة الاغراض ومقارنتها بالواقع الحالي المستخدم في مصفى الدورة. المحطات المقترحة تشمل الوحدات الغازية ووحدات الديزل ووحدات بخارية بتوربين ذو ضغط خلفي. تم التحليل والمقارنة استناداً الى قانوني الثرموديناميك الاول و الثاني وباختيار معطيات عمل حقيقية. اظهرت النتائج فائدة استخدام مفهوم الاكسيرجي في تحليل ومقارنة البدائل المقترحة مع الاخذ بنظر الاعتبار الاستفادة من مميزات التوربين ذو الضغط الخلفي و ادخاله في محطات التوليد متعددة الاغراض بانه افضل من بقية البدائل من حيث الاداء اضافة الى امكانية توليد طاقة كهربائية تفوق احتياج المصفى وهذه الطاقة تدعم وتساهم في حل ازمة الكهرباء وعلى هذا الاساس نوصي باستخدام هذه البدائل في الصناعة النفطية .اثبت التحليل الاقتصادي ان فترة استرداد راس المال المستثمر في منظومة التوربين البخاري ذو الضغط الخلفي تساوي اربع سنوات ونصف تقريبا بينما للوحدة الغازية ووحدة الديزل تساوي حوالي ثلاث سنوات وثمانية اشهر وعشرة سنوات على التوالي .

1. INTRODUCTION

Cogeneration is the production of electricity and heat energy for process simultaneously from the same energy source. Cogeneration plants capture wasted thermal energy. The main advantage of these systems is their ability to improve the thermal efficiency of the fuel used in the production more than one useful form of energy. Also cogeneration lead to significant environment advantages, that is the increase in efficiency and corresponding decrease in fuel used by a cogeneration system compared to other conventional processes for thermal and electrical energy production, normally yield large reductions in greenhouse gas emissions. Cogeneration systems utilizing internal combustion engines and gas-turbines in open cycle are the most utilized technologies worldwide. Heavy fuel-fired diesel power plants run on relatively inexpensive diesel fuel, a low-grade product of oil refineries such power plants can be set up quickly, normally in less than twelve months to generate hundreds of megawatts of energy. Large diesel engine-cogeneration systems are particularly well suited to applications requiring a relatively high proportion of electrical power compared to thermal products **Benelmir, and Feidet, 1998**. Many energy and exergy analyses of cogeneration systems have been reported and pointed out their advantages. **Ertesva, 2007** presented an exergetic comparison of efficiency indicators for cogeneration and he concluded that exergetic improvements were only captured to a limited degree by the various energy-based efficiency indicators. **Ust, et al., 2007** optimized a gas-turbine regeneration system by an exergetic performance criterion and indicated the advantageous of this method. **Khaliq, and Khan, 2007,** analyzed a gas-turbine heat and power system using the first and second law of thermodynamics. . **Kathem, 2007,** proposed using a back-pressure turbine instead of the present plant used in the Dura refinery in Baghdad. The result showed a substantial increase in efficiency (6-13%) as well as the achievement of (24%) saving in fuel. Moreover, the results of his work indicate that these alternative plants can produce more electric power than that required in the refinery. Such excess in the power can sold to the main electric network. **Isam Aljundi, 2009,** analyzed the system components of Al-Hussein power plant in Jordan using exergy and energy concept he concluded that there is no drastic change was noticed in the performance of major components and the main conclusion remained the same; the boiler is the major source of irreversibility in the power plant, chemical reaction is the most significant source of exergy destruction in a boiler system which can be reduced by preheating the combustion air and reducing the air–fuel ratio. **Godoy, et al., 2010,** presented optimization designs of a combined gas turbine (CCGT) power plant by second law efficiency, technical relationships are used to systematize optimal values of design and operative variables of a CCGT power plant into optimal solution sets named as optimal solution families. **Godoy, et al., 2011,** optimized combined cycle gas turbine power plants characterized by minimum specific annual cost values are determined for wide ranges of market conditions as given by the relative weights of capital investment and operative costs, by means of a non-linear mathematical programming model. A strategy for simplifying the resolution of the rigorous economic optimization problem of power plants is proposed based on the economic optima distinctive characteristics which describe the behavior of the decision variables of the power plant on its optima. **Abdolsaeid, et al., 2012,zaaaaa** presented comprehensive thermodynamic modeling of a dual pressure combined cycle power plant using exergy concept , results are compared with an actual data taken from one of the Iranian power plant to ensure the developed code, then they made optimization for number of decision variables to have a better understanding and optimal design of the system, The results show that gas turbine temperature, compressor pressure ratio and pinch point temperatures are significant design parameters. In this paper thermal analysis and economic analysis of various refinery cogeneration

plants is conducted through energy and exergy efficiencies, four plants are considered one of them is currently serves the Dura refinery, Baghdad and the others are proposed.

2. MATHEMATICAL MODEL

2.1. First and second laws analysis and thermodynamics relations

i. The general energy and exergy efficiencies, these are given as: **Hameed, 1990**.

$$\eta_{cog} = \frac{E + H}{Qin} \quad (1)$$

$$\eta_{th} = \frac{H}{Qin} \quad (2)$$

$$\eta_{ele.} = \frac{E}{Qin} \quad (3)$$

This relation is referred to as the utilization efficiency to differentiate it from the thermal efficiency, which is commonly used for a power plant with single output power.

It is normally inappropriate to compare commodities that are different. Although work and heat have the same units, they are fundamentally different, with work being more valuable. The efficiency in Eq. (1) treats the electrical and thermal products equally. We can overcome this deficiency by defining the efficiency of a cogeneration plant based on the second law of thermodynamics using the concept of exergy (i.e., exergy efficiency or second-law efficiency), as the ratio of total exergy output to exergy input:

$$\eta_{cog,ex} = \frac{E + Ex_p}{Ex_f} \quad (4)$$

$$Ex_f = \dot{m}_f \, ex_f \quad (5)$$

Where ex_f is the specific exergy of the fuel. The exergy of a fuel may be obtained by writing the complete combustion reaction of the fuel and calculating the reversible work obtainable assuming all products are at the state of surroundings. The exergy of the fuel is equal to the reversible work. For fuels which yield water as a combustion product, the exergy of the fuel differs depending on the phase of water (vapor or liquid). **Szargut, et al., 1988,** list the exergies of various fuels based on vapor phase of water in combustion gases.

ii. Power to heat ratio (PHR)

It is the ratio of the electric energy produced to the heat process, it is given by:

$$PHR = \frac{E}{H} \quad (6)$$

iii. Net heat rate (NHR)
It is the ratio of fuel convertible-to-power to net electricity generated. The fuel convertible-to-power is the fuel energy input rate less the amount that would be necessary to produce the useful thermal energy only by conventional means.it is determined by:

$$NHR = \frac{(Q_f - H/\eta_b)}{E} \quad (7)$$

iv. Consumed fuel rate
The relationship between the overall efficiency, generated power, consumed fuel rate and low heating calorific value is given by:

$$\eta_{overall} = \frac{E}{m_f \ C.V} \quad (8)$$

We can estimate the consumed fuel rate per MW of power for different type of fuel, the result are tabulated in Table 4 and used to estimate the rate of consumed fuel.

v. Fuel saving rate (FSR)
It is given by:

$$FSR = \frac{m_f)_{present} - m_f)_{proposed}}{m_f)_{present}} \quad (9)$$

Where m_f is fuel consumed for the same output (heat + electric) from both plants. Considering the lack of electric power (generated in the present plant) are supplied from another condensing plant with η= 0.35 (estimated from Table 4)

2.2 Economic analysis
The economic evaluation of the cogeneration plants depends on the payback period, the short period is desired. The payback period calculated from: **Mehervan, 2002**.

$$N = \frac{Ct}{R_{ef}} \quad (10)$$

The total cost (*Ct*) is the sum of the annual fixed cost and running cost, the annual fixed cost is the sum of annual payment and maintenance cost, the annual payment is the investment times capital recovery factor (*CR*) , the capital recovery factor is given by:

$$CR = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (11)$$

The total annual income (R_{ef}) is the sum of the incomes from electricity and heat energy sealing. The maintenance cost and the other cost are taken as a percent of the investment, the running cost mainly annual fuel cost, all the required data for economic analysis are taken from **Meherwan, 2002**.

3. DESCRIPTION OF THE PRESENT AND PROPOSED COGENERATION PLANTS

i. Present plant

Dura refinery was established in the middle of the last century and Iraq nowadays is interested in reconstruct his old refineries and inspired to build a new refineries. Therefore several researchers found that it is necessary to analyze the heat cycle of the present Dura refinery and propose a new design for cogeneration plants **Kathem, 2007** and **Hameed, 1990**.

The present plant shown in Fig.1 supplies the whole refinery with 21.6 ton/h process steam at 18 bars, 260 ^{o}C as well as about 4.5MW electric power **Hassan, 1988**. An additional 11 MW of electricity is purchased from the main electric network. **Fig. 1** shows the unit, while **Table 1** shows the quantitative details for the unit.

ii. Back pressure steam turbine cogeneration plant

The back-pressure non-condensing turbine of type R-50-127-13 were suggested, where the first number refers to power (MW), the middle one refers to inlet turbine pressure (bar) and the last number refers to turbine exit pressure (bar) **Kathem, 2007**. The back-pressure turbine can generate maximum electricity at approximately the same time as the system heat at its peak demands. Furthermore, it is simple in design and has high reliability and it also has a very low heat rate which permits the achievements of high fuel savings. Also, its equipment cost and space requirements for back-pressure (non-condensing) units are very much less than for condensing units. In this cogeneration system boiler was selected according to operation condition of **Kathem, 2007.** To supply the heat demand of unit turbine must be operated continuously at a partial load with exit pressure 18bar. The temperature of steam from turbine exhaust is around 316^{o}C, so most of superheat being removed by water injection. **Fig. 2** represents a simple layout for this unit and the quantitative details are listed in **Table 2** and **Table 3**. This plant can cover the process heat as well as, produce 34.5MW surplus electric powers which can be sold at a profit to the grid.

iii. Gas turbine based cogeneration plant

The refinery gas turbine cogeneration plant produces electricity and 21.6 ton/h of steam at 18bar and 260^{o}C from the waste heat recovery boiler. A cogeneration gas-turbine power plant considered in this study of a net power output of 20 MW and maximum and minimum pressures of 1200 and 100 kPa in the system, respectively. The fuel is natural gas, the turbine inlet temperature is 700^{o}C and the isentropic efficiencies of both the turbine and compressor are 85%. Under these operating conditions, exhaust gases leave the turbine at 303^{o}C. All steam and the required electrical energy are used in the refinery, while the surplus electric power can be sold at a profit to the grid. The gas turbine is operated continuously at full or part load by natural gas with lower heating value of 50050 kJ/kg. The general plant flow diagram is shown in **Fig. 3, Hameed, 1990** and **Hassan, 1988.**

iv. Diesel-engine based cogeneration plant

A diesel-engine powered cogeneration plant is considered where the outputs are electrical power and heat, which is transferred from the hot exhaust gases to water in an unfired waste heat recovery boiler, The general plant flow diagram is shown in **Fig. 4**. Some of the values to be used in this grid are from an actual diesel-engine power plant **Kanoglu, 2005**. The same rate of heat transfer as in the

steam and gas-turbine cogeneration is assumed. The net power output from the plant is 20 MW when the rate of fuel consumption is 1.25 kg/s and the air–fuel ratio is 40.4. This corresponds to an exhaust flow rate of 51.75 kg/s. The exhaust gases enter the waste heat recovery boiler at 400^{o}C, extra fuel needed to produce the required steam with 85% assumed boiler efficiency and flue gas inlet temperature of 150^{o}C. The plant uses heavy diesel fuel with a lower heating value of 39300 kJ/kg. Note that the exergy of heavy diesel fuel with an unknown composition is taken as 1.065 times the lower heating value of the fuel following the approach by **Brzustowski and Brena, 1986.**

4. RESULTS AND DISCUSSION

The aim of the present study includes a brief description of the present Dura refinery plant and the suggested alternative cogeneration plants in which back-pressure non-condensing turbine, gas turbine and diesel engine are examined, the analysis in this work gives a good agreement for currently Dura refinery plant and back pressure turbine plant alternative with, **Kathem, 2007.** In order to describe the performance of a cogeneration plants various thermodynamic parameters were determined, a summary of results are given in **Table 5** ,to facilitate comparisons of the plants the same heat requirement for the refinery is considered (145 MW) with different electric power output and depending on **Table 4** which help to estimate the rate of fuel consumed. The results show that the presently plant have the smallest efficiency compared with other alternative plants this because of its dependence on the bottoming cycle which leads to waste energy without power producing. The present plant consumes 6.1 kg/s of fuel **Hameed, 1990**. for both electric power and refinery heat requirement the fuel consumed rate and net heat rate decreased in all alternatives so there are a saving in the fuel consumed rate about 28.59% for back pressure turbine, 20.787% for gas turbine cogeneration plant and 12.787% for diesel engine cogeneration plant. This advantage is due to the thermal recovery from the flue gas by the heat recovery steam boiler and because of increase plant heat rate .This means new advantage that the alternatives can produced surplus electric power which can supports and solve the present crisis national electric power generation i.e. back pressure turbine plant can added 34.5MW to the national electric network. The back pressure turbine cogeneration plant is the best alternatives (high efficiency, low NHR, high fuel saving and surplus power produced). The payback period given in Table 6 indicate that the gas turbine unit payback period is shorter than other alternatives this due to the price of natural gas is cheaper than gas oil fuel used in both back pressure turbine cogeneration plant and diesel engine plant.

5. CONCLUSIONS

1- According to 1st and 2nd thermodynamics law, the proposed plants can improve thermal efficiency.

2- The back pressure turbine cogeneration plant is the most suitable for cogeneration. Although the application this type leads to increase initial cost, but at the same time leads to increase PHR by 222% and FSR by 28.6%.

3- The price of electric and heat power from cogeneration plants is depending on the method of estimation specific fuel consumption. Therefore this estimation method should be chosen so that it can be promote to build new cogeneration plants in Iraq.

4- The payback period of gas turbine unit is shorter than other alternatives.

5- Due to its high efficiency, the cogeneration plants are recommended in Iraq, especially in petroleum industry sectors, in order to contribute with ministry of electricity to solve the present crisis of electric power generation.

Table 1. Specifications data of steam circuit for Dura's refinery **, Kathem, 2007.**

State	P (bar)	t (^{o}C)	m (kg/s)	Pt.	P (bar)	T (^{o}C)	m (kg/s)
0	18.93	260	75.6	19	1.36	108.4	6.433
1	18.24	260	3.143	20	18.39	209.6	9.639
2	18.24	260	4.187	21	1.36	108.4	7.796
3	18.24	260	57.182	22	1.36	108.4	1.843
4	18.24	260	11.088	23	22.37	86.7	85.239
5	0.1	45.8	11.088	24	18.24	248.9	0.547
6	0.1	46.1	11.088	25	1.7	115.2	0.512
7	17.55	248.9	1.462	26	3.01	34	66.125
8	17.48	96.5	1.462	27	1.01	33.9	66.125
9	18.24	260	2.725				
10	1.7	115.2	2.725				
11	0.1	46.1	11.088				
12	1.01	71.1	11.494				
13	1.01	26.1	54.631				
14	1.01	93.3	76.627				
15	2.01	39.9	78.675				
16	18.24	260	0.887				
17	1.36	108.4	0.756				
18	1.8	86	85.239				

Table 2. Specifications data of steam circuit for Dura's refinery with the turbine type R 50-127-13**, Kathem, 2007.**

State	P (bar)	t (^{o}C)	m (kg/s)	Pt.	P (bar)	t (^{o}C)	m (kg/s)
0	130	565	83.337	17	1.01	93	51.115
1	34	389.7	3.571	18	1.01	27	48.232
2	23.61	343.3	2.232	19	1.01	38.94	58.695
3	18.24	316.18	77.534	20	6	38.96	58.695
4	18.24	316.18	7.232	21	18.24	260	1.216
5	18.24	316.18	70.302	22	6	158.8	83.337
6	18.24	316.18	11.607	23	130	160.3	83.337
7	18.24	316.18	58.695	24	130	204.5	83.337
8	1.01	27	2.871	25	130	218.2	83.337
9	18.24	260	61.566	26	130	238.1	83.337
10	17.55	258.9	1.216	27	34	240.9	3.571
11	18.24	260	60.35	28	23.61	221	3.571
12	1.01	27	0.012	29	23.61	221	5.803
13	17.55	248	1.228	30	18.24	207.8	5.803
14	1.01	93	60.35	31	18.24	207.8	13.035
15	1.01	93	9.235	32	6	158.9	13.035
16	17.48	96	1.228				

Table 3. Operation design conditions for turbine type R50-127-13 **, Kathem, 2007.**

P MW	p_{in} (bar)	t_{in} (^{o}C)	$m_{\max.}$ (kg/s)	m_{o} (kg/s)	$m_{1st_{.b}}$ (kg/s)	$m_{2nd.b}$ (kg/s)	$m_{3rd.b}$ (kg/s)	$p_{c.s.}$ (bar)	$p_{1st_{.b}}$ (bar)	$p_{2nd.b}$ (bar)	$p_{s.4}$ (bar)	p_{exit} (bar)
50	127	565	136	102	5.5	6	9.58	95	37	22	65	13

Table 4. Consumed fuel rate (kg/s)/MW_p for different efficiency and different fuel low heating value.

Heating value / Overall efficiency	30	32	34	36	38	40	42	44	46	48	50	52
0.14	0.238	0.223	0.210	0.198	0.188	0.179	0.170	0.162	0.155	0.149	0.143	0.137
0.16	0.208	0.195	0.184	0.174	0.164	0.156	0.149	0.142	0.136	0.130	0.125	0.120
0.18	0.185	0.174	0.163	0.154	0.146	0.139	0.132	0.126	0.121	0.116	0.111	0.107
0.2	0.167	0.156	0.147	0.139	0.132	0.125	0.119	0.114	0.109	0.104	0.100	0.096
0.22	0.152	0.142	0.134	0.126	0.120	0.114	0.108	0.103	0.099	0.095	0.091	0.087
0.24	0.139	0.130	0.123	0.116	0.110	0.104	0.099	0.095	0.091	0.087	0.083	0.080
0.26	0.128	0.244	0.113	0.107	0.101	0.096	0.092	0.087	0.084	0.080	0.077	0.074
0.28	0.119	0.112	0.105	0.099	0.094	0.089	0.085	0.081	0.078	0.074	0.071	0.069
0.3	0.111	0.104	0.098	0.093	0.088	0.083	0.079	0.076	0.072	0.069	0.067	0.064
0.32	0.104	0.098	0.092	0.087	0.082	0.078	0.074	0.071	0.068	0.065	0.063	0.060
0.34	0.098	0.092	0.087	0.082	0.077	0.074	0.070	0.067	0.064	0.061	0.059	0.057
0.36	0.093	0.087	0.082	0.077	0.073	0.069	0.066	0.063	0.060	0.058	0.056	0.053
0.38	0.088	0.082	0.077	0.073	0.069	0.066	0.063	0.060	0.057	0.055	0.053	0.051
0.4	0.083	0.078	0.074	0.069	0.066	0.063	0.060	0.057	0.054	0.052	0.050	0.048

Table 5. Energy and exergy analysis results for different cogeneration systems.

Parameter	Present plant	Back pressure turbine cogeneration	Gas-turbine cogeneration	Diesel engine cogeneration
Energy eff. %	58.3	76.89	68.22	70.3
Exergy eff. %	21.8	31.67	32.52	43.7
Ele. Power (E)(MW)	4.5	50	20	20
Surplus power(MW)	-11	+34.5	+4.5	+4.5
Heat requirement(H)(MW)	145	145	145	145
PHR	0.107	0.345	0.138	0.138
NHR	22.7	2.32	9.43	11.3
FSR %	-	28.59	20.787	12.787

Table 6. The economic analysis summary.

Item	Back pressure turbine cogeneration	Gas-turbine cogeneration	Diesel engine cogeneration
Investment (million $)	50	25	22
Interested (*i*)	15	15	15
Operation period (years)	25	20	15
Capital recovery factor (CR)	0.155	0.16	0.171
Annual payment(million $)	7.75	4	3.762
Operation & maintenance cost($/MWh)	0.6	0.4	0.6
Annual fixed cost(million $)	8.77	4.58	4.5
Annual variable cost(million $)	49.45	20.4	60.4
Total annual cost (*Ct*) (million $)	58.22	24.98	64.9
Annual income from electricity (million $)	10.512	4.205	4.205
Annual income from heat energy (million $)	2.27	2.27	2.27
Total incomes (R_{ef}) (million $)	12.782	6.475	6.475
The payback period(years)	4.55	3.858	10.02

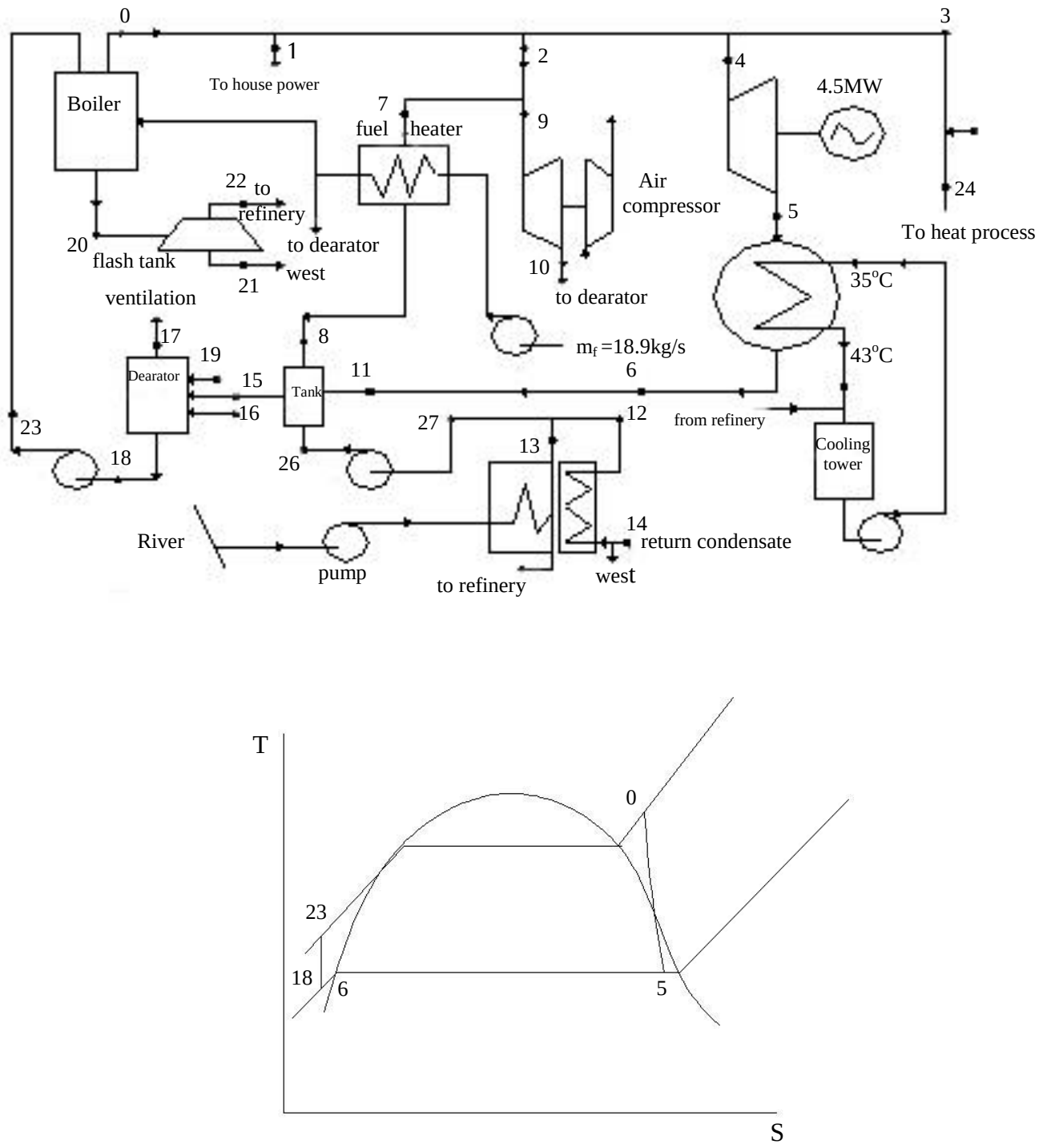

Figure 1. Present Dura refinery plant and T-S diagram.

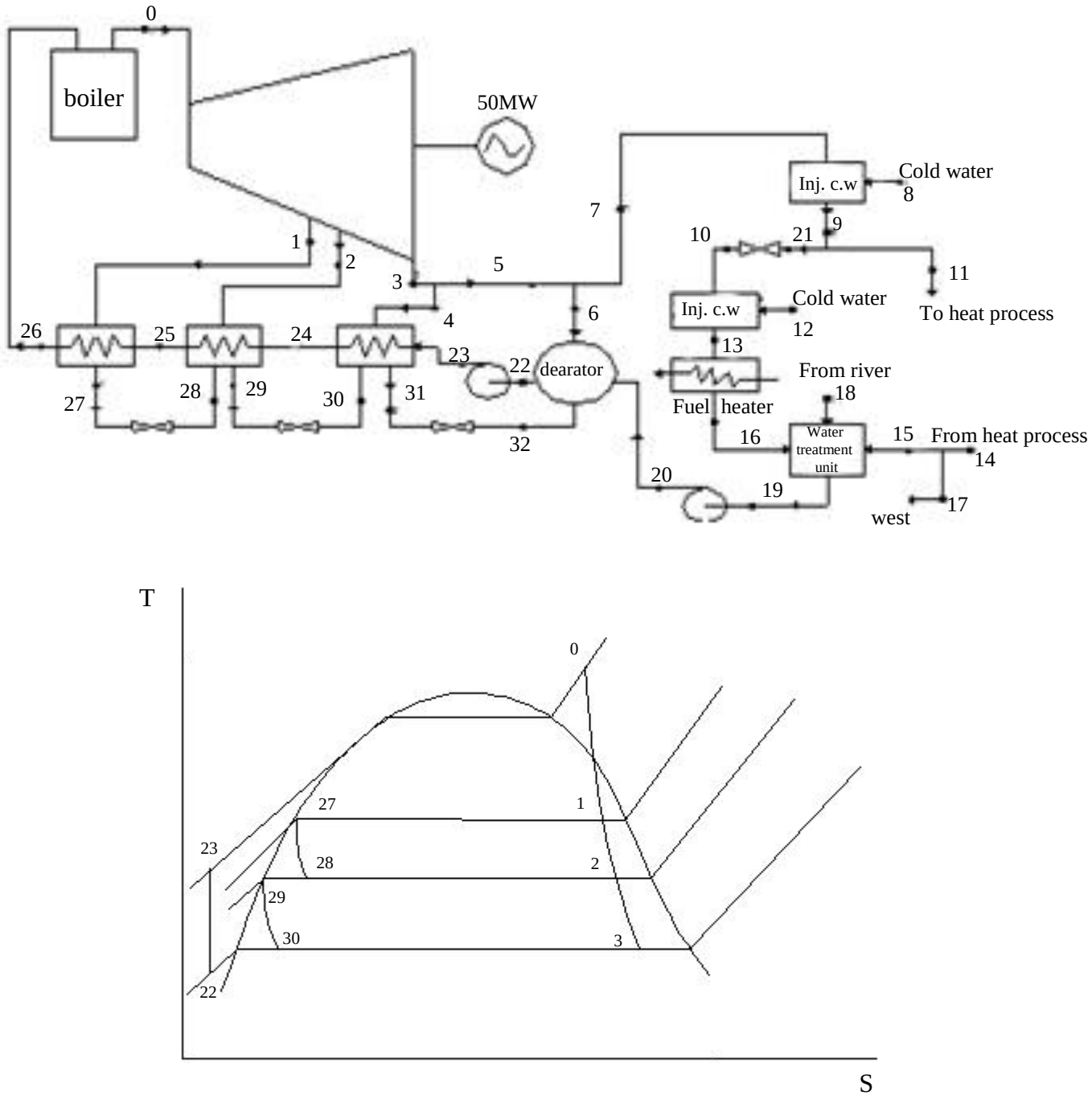

Figure 2. The back pressure cogeneration plant and T-S diagram.

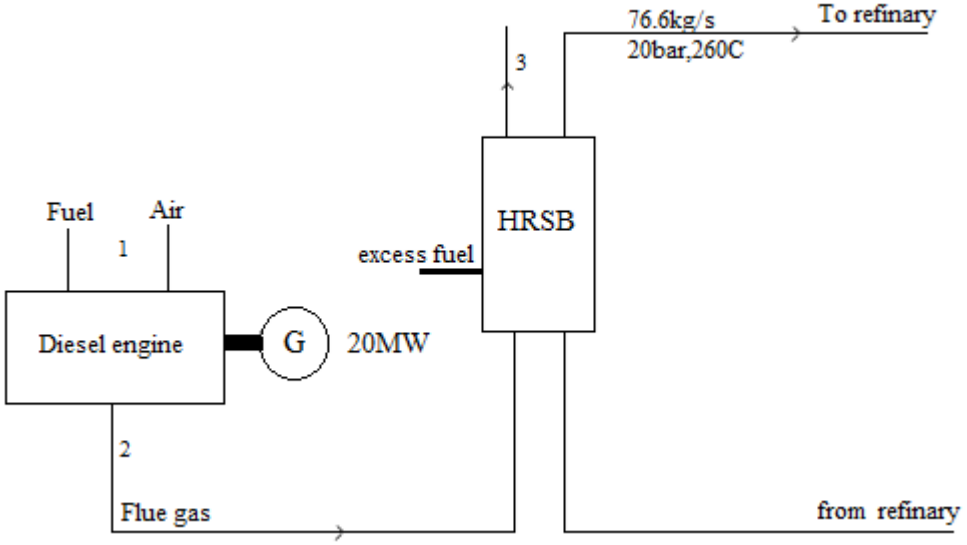

Figure 3. A cogeneration diesel engine plant plant.

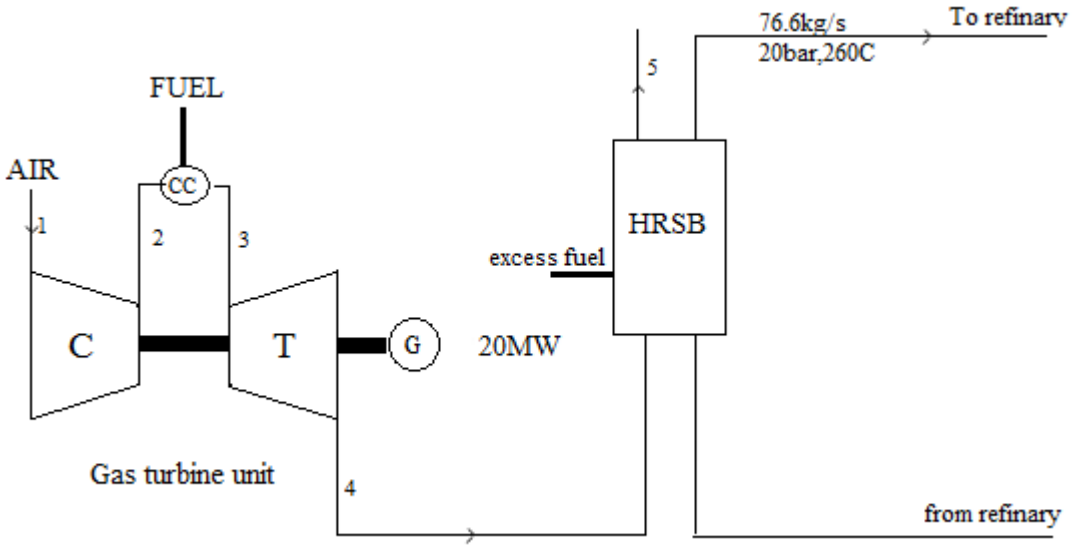

Figure 4. The gas turbine cogeneration power plant.

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Nomenclature

Latin

Ct = total annual cost ($)
CR = investment recovery factor
$H.V$ = fuel heating value (kJ/kg)
E = electric energy produced (MW)
H = heat requirement (MW)
m = mass flow rate (kg/s)
N = payback period (year)
Q = total heat (kJ)
R_{ef} = total annual income ($)

Greek letters

η : Efficiency

Subscript

add : added
b : boiler
ele.: electric
f : fuel
g : generated
h : heat
i : interest
in : inlet
n : number of years

Abbreviations

FSR**:** Fuel Saving Rate
HRSB: Heat Recovery Steam Boiler
NHR: Net Heat Rate
PHR: Power to Heat Ratio

Global NAVIGATION Satellite System Contribution for Observing the Tectonic Plate Movements: Status and Perspectives

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ABSTRACT

The long-term monitoring of land movements represents the most successful application of the Global Navigation Satellite System (GNSS), particularly the Global Positioning System. However, the application of long term monitoring of land movements depends on the availability of homogenous and consistent daily position time series of stations over a period of time. Such time series can be produced very efficiently by using Precise Point Positioning and Double Difference techniques based on particular sophisticated GNSS processing softwares. Nonetheless, these rely on the availability of GNSS products which are precise satellite orbit and clock, and Earth orientation parameters. Unfortunately, several changes and modifications have been made periodically on the policy of producing these products which led to degradation in the consistency of these products over time. For the long term monitoring of land movements, it is essential that any such developments and changes can also be used to produce improved products that go back in time, to enable the homogeneous reprocessing of archived observation data. This paper deals with two main themes. Firstly, it demonstrates the significant and imperative role of the GNSS in geological applications by addressing major global and regional studies of the Earth's deformation which represent one of the main and essential applications in satellite geodesy. The role of the continues GPS measurements in this application is highlighted and discussed for modeling global and regional plate motions and modeling Glacial Isostatic Adjustment. Secondly, this paper locates the most important obstacles which stand behind the inability to use the GNSS in applications of long-term monitoring of land movements.

Key words: land movements, GNSS, deformation, glacial isostatic adjustment

اسهامات الانظمه الملاحيه العالميه لمراقبة حركة الصفائح التكتونيه: الحاله والمنظورات

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الخلاصة

المراقبه طويلة الامد لحركة القشره الارضيه تمثل من اهم وابرز تطبيقات الانظمه الملاحيه العالميه (GNSS) وخصوصاً نظام تعين المواقع العالميه (GPS). حيث شهدنا مؤخرا العديد من البحوث والدراسات في هذا المجال. بيد ان عملية مراقبة حركة القشره الارضيه بأستخدام الانظمه الملاحيه العالميه تعتمد بكل اساسي على توفّر سلسله زمنيه لمواقع ارضيه دقيقه ومتجانسه ومستقره لفترات طويله الامد لمحطات ارضيه منتشره حول العالم. السلسله الزمنيه للمواقع الارضيه يمكن ان تُنتج بشكل فعال عن طريق تقنيات تعيين المواقع الدقيقه والمواقع التفاضليه باستخدام برامج المعالجه الدقيقه لارصادات التوابع الملاحيه. بيد ان هذه العمليه تعتمد كلياً على توفّر معلومات دقيقه لمواقع الاقمار الصناعيه و تصحيح ساعات القياس ومعاملات نمذجة حركة محور دوران الارض. ولكن بسبب التغيرات والتحديثات العديده والمستمره على اساليب حساب هذه المعلومات

أدى ذلك الى انحطاط كبير وملحوظ في مستوى التجانس والاستقراريه في دقة هذه المعلومات والذي اثر بشكل سلبي على اعتماد هذه المعلومات في حساب المواقع الدقيقه للمحطات الارضيه واستخدامها في رصد حركة القشره الارضيه.
هذا البحث يسلط الضوء على موضوعين رئيسيين في موضوع المراقبه طويلة الامد لحركة القشره الارضيه باستخدام ال GNSS. الموضوع الاول يعرض الدور الكبير والفعال لل GNSS في التطبيقات الجيولوجيه عن طريق الاشاره الى اهم الدراسات المنجزه (بمقياس عالمي ومحلي) في موضوع التشوهات الارضيه والتي تعتبر من المواضيع الاساسيه في علم جيوديسيا التوابع الملاحيه. وهذا الموضوع يشمل عرض ومناقشة اهم الدراسات والبحوث المنشوره في استخدامات ارصادات ال GPS المستمره لنمذجة حركة الصفائح التكتونيه و Glacial Isostatic Adjustment . اما الموضوع الثاني فانه يبحث في اهم المعوقات الاساسيه التي تقف وراء عدم امكانيه استخدام قياسات ال GNSS بشكل دقيق في مراقبة حركة القشره الارضيه.

الكلمات الرئيسية: القشره الارضية, التشوه الارضي, النظام الملاحي العالمي.

1. INTRODUCTION

The expression “long-term monitoring of land movements” covers an extensive range of geophysical phenomena studies using GNSS. In general, this is based on the interpretation of time series of the changes in continuous high precision horizontal and vertical positions over a period of time. Because the long-term monitoring of land movements based on GPS data is one of the main objectives of this paper, a considerable amount of literature that has been published on this subject is presented and highlighted in this study.

Owing to the fact that the Earth’s deformation leads to continuous changes in the geometric configuration of geodetic networks, the determination of the Earth’s deformation parameters has become one of the main and essential applications in geodesy. In the past, classical geodetic surveys were used to establish horizontal and vertical positions. Many drawbacks are associated with these techniques, e.g. their high-cost and time-consuming nature due to the effort required. In addition, the monitoring of the Earth’s deformation over vast areas requires precise and simultaneous measurements over long baselines, and classical geodesy does not provide this capability. Furthermore, because the horizontal and vertical positions are calculated from different types of measurements, which are collected at different times and places, this adds a complexity in the analysis of these time series. Consequently, research on the Earth’s deformation, since three decades ago, have tended towards using space geodetic techniques to estimate velocities over certain observation periods, based on: (1) Satellite Laser Ranging (SLR) **Smith et al., 1990**, and **Sengoku, 1998**; (2) Very Long Baseline Interferometry (VLBI) **Robaudo** and **Harrison, 1993**, and **Sato, 1993**; (3) GPS **Dixon et al., 1991, Dixon, 1993, Argus** and **Heflin, 1995, Larson et al., 1997, Segall** and **Davis, 1997, Prawirodirdjo** and **Bock, 2004, Mazzotti et al., 2007, Bouin** and **Wöppelmann, 2010,** and **Hammond et al., 2011**; (4) Doppler Orbitography and Radiopostioning Integrated by Satellite (DORIS) **Cazenave et al., 1992, Soudarin** and **Cazenave, 1993,** and **Soudarin** and **Cazenave, 1995**.

Recently, the use of continuous GPS (CGPS) data has received considerable interest as the essential means of geodetic investigation in comparison with the other space geodetic techniques for many reasons: first of all, GPS hardware and software are readily available and relatively inexpensive in comparison with the other techniques, which necessitate higher budgets; secondly, because some geodetic monitoring work, like earthquakes and volcanoes, require continuous, sub daily, and instantaneous observations, the GPS technique provides this capability due to continuous satellite coverage **Elósegui et al., 1995**; finally, the mobility of field GPS equipment which only requires small surveying teams **Segall** and **Davis, 1997**. In summary, studies of the Earth’s deformation have been widely carried out based on GPS data, especially

after the dramatic increase in the number of CGPS instruments installed regionally and globally around the world.

In 1993, CGPS data was firstly used by **Bock et al., 1993** and **Blewitt et al., 1993** for the Southern California Permanent GPS Geodetic Array (PGGA) to estimate the co-seismic displacements resulting from the Ms 7.5 Landers, California earthquake on 28th June 1992. **Bock et al., 1993** used ten weeks of PGGA data to demonstrate the possibility of using GPS data to detect the seismic deformation before, during and after the earthquake. They showed that there was no pre-seismic displacement, remarkably consistent co-seismic displacements at all PGGA stations, and post-seismic displacement at one PGGA station. **Blewitt et al., 1993,** then confirmed the results of **Bock et al., 1993,** through the detection of pre-seismic, co-seismic, and post-seismic displacements with millimeter precision by analyzing IGS data over three months. Consequently, many individuals, institutions, and geodetic agencies have established CGPS stations around the world which are coordinated by the International GNSS service (IGS). The IGS network is being used to routinely monitor the Earth's deformation and many significant achievements have increased the growth in the research into long-term monitoring of land movements with GPS. Since then, with the advent of the production of GPS satellite and receiver clock products as individual products, the methodology of Precise Point Positioning (PPP) has also been enabled in many software packages to provide three-dimensional absolute positions with a high-level of accuracy based on the introduced satellite orbit and clock, and the Earth Rotation Parameters (EOP) products.

In general, both of the methodologies of double-difference relative positioning and PPP can be employed for the long-term monitoring of land movements, but they depend entirely on the availability of consistent and homogeneous precise satellite orbit and clock, and EOP products over certain periods of time. In addition to the space geodetic techniques of SLR, VLBI, GPS, and DORIS, remote sensing technologies like Interferometric Synthetic Aperture Radar (InSAR) and Light Detection and Ranging (LiDAR) techniques (terrestrial, airborne, and satellite) have also taken on a significant role that cannot be ignored in the investigations of Earth's deformations . See **Chang et al., 2007, Sousa et al., 2010,** and **Wei et al., 2010** for InSAR technique, and **Kayen at al., 2006, Muller** and **Harding, 2007,** and **Jian-Qing** and **Ting-Chen, 2010,** for LiDAR technique.

This study addresses major global and regional studies of the earth's deformation which represent one of the main and essential applications in geodesy. The role of the CGPS measurements in this application will be highlighted and discussed for modeling global and regional plate motions; and modeling Glacial Isostatic Adjustment.

2. DEFORMATION of the EARTH: A BRIEF INTRODUCTION

The plate tectonic theory divides the Earth's lithosphere into a number of rigid plates (eight major and many minor plates) based on data from paleomagnetics, which is the study of the observations of the Earth's magnetic field, and seismological studies **DeMets et al., 2010**. Furthermore, both the continental drift and sea-floor spreading hypotheses contributed to the development of the theory of plate tectonic. These tectonic plates continually move relative to one another at one of three kinds of plate boundaries: convergent; collisional; or transform.

In general, geologists and geodesists classify the Earth's crustal deformations under two terms, global and regional deformations. The global deformations stand for all of the kinds of deformations that occur on very large areas like tectonic motions, whereas, the regional deformations involve smaller areas like plate boundaries. Under this concept, both the

deformations of continents and sea-floor movement, which correspondingly result from the continental drift and sea-floor spreading hypotheses, can be presented as global deformations. In general, the tectonic motions which cause global deformations lead to regional deformations which occur along plate boundaries, such as: earthquakes; faults; volcanoes; and oceanic trench formation **Prawirodirdjo** and **Bock, 2004**.

In the past, many global plate models were developed to describe plate motions, see **Larson et al., 1997**. In general, these models were based on data of spreading rates, transform fault azimuths, and earthquake slip vectors, which represent an average over a long-period of time **DeMets et al., 1990**. For more than two decades, many global plate motion models have then been developed to describe the current plate motions (see the UNAVCO website (http://www.unavco.org/unavco.html) which provides the latest models with their associated reference frames).

3. GLOBAL PLATE MOTION MODELS

Global plate motion models have shown great success in the interpretation of large scale plate motions. The global plate motion models are classified into two types, absolute plate motion models and relative plate motion models. These global plate motion models, in general, are realized using different methods, such as No-Net-Rotation (NNR) frame, hotspot data, and space geodetic measurements like VLBI, SLR, DORIS and GPS. However, such space geodetic techniques have also been used in the recent decade to observe the velocities of globally distributed CGPS stations for the estimation of the rotation vectors of rigid plates. The combination between the global plate motion model and any of these methods leads to a geophysical kinematic model that can describe the rigid plates' motion over a period of time (based on the used method) **Larson et al., 1997**.

Absolute plate motion models define the plate motions with respect to the Earth's deep interior (mesosphere). In contrast, relative plate motion models describe the plate motions with respect to an arbitrary fixed tectonic plate. Generally, these models can be formed based on various kinds of data, for instance, geological seismic data and conventional or space geodetic measurements; where space geodetic measurements can be effectively employed to obtain relative velocity estimates to sufficiently high precision over long-base lines.

One of the main initial global plate motion models that represented the basis for developing more recent models was NUVEL-1. This model, which has been widely used, was developed by **DeMets et al., 1990.** It depends on earthquake slip vectors and the average transform fault azimuths and spreading rates for the last 3Myr to predict tectonic plate velocities and provide the absolute angular velocity vectors for thirteen tectonic plates. **DeMets et al., 1994** recalibrated the NUVEL-1 model based on the latest amendments to the geomagnetic reversal time scale at that time. They found that by multiplying the NUVEL-1 angular velocities by a calibration factor (0.9562), results comparable with other rates of motion, especially those estimated based on the space geodetic measurements, were obtained. They pointed out that the motion rates for NUVEL-1A are faster on average by only 2% when compared to space geodetic measurements, whereas they were faster by about 6% with NUVEL-1 model.

The models NUVEL-1 and NUVEL-1A reference the plate motion to a No-Net-Rotation (NNR) frame to create a geophysical kinematic model (NNR NUVEL-1 and NNR NUVEL-1A) that can be used to describe the plate motions at any epoch over millions of years. In the NNR frame, the angular velocities for each plate are calculated with respect to the average of angular velocities for all plates. NNR NUVEL-1A model was widely used in the 1990s, but it has some

weaknesses. **Drewes** and **Angermann , 2001** stated that the NNR NUVEL-1A model does not meet the condition of NNR for two reasons. Firstly, it can be used effectively to describe the plate motions over the last 3 Myr but is not valid for the present time, which can yield biased velocity estimates for some plate pairs due to the continuous change in their speed and direction, for example the Nazca-South America plates **Angermann et al., 1999**. Secondly, the NNR NUVEL-1A model cannot be considered as a full global model due to lack of coverage for some zones, like the Mediterranean, the Pacific belt, and Japan. For these two reasons, **Drewes** and **Angermann, 2001** computed two different kinematic models based on space geodetic observations to estimate the angular velocities for globally distributed stations. The first model, was called the ITRF2000 kinematic model, and was based on using 405 ITRF2000 station velocities to estimate the motion of eleven major plates. While for the second kinematic model, which was called Actual Plate Kinematic Model (APKIM), they combined the space geodetic observations from SLR, VLBI, and GPS to compute 279 station velocities and estimate the velocity vectors (Euler vectors) for twelve tectonic plates. Both of these models were constrained to no-net-rotation.

In addition to the NNR NUVEL-1A deficiencies referred to by **Drewes** and **Angermann, 2001**, **Sella et al., 2002** mentioned that the NNR NUVEL-1A may also be biased due to insufficient kinematic data, for example the relative motion of America with respect to the Pacific plate**,** **DeMets** and **Dixon, 1999** and the relative motion of the Caribbean plate with respect to the North and South American plates **Pérez et al., 2001**. Furthermore, **Sella et al., 2002** pointed to the existence of systematic errors in the NNR NUVEL-1A model as a result of depending on sea-floor spreading rates which are calculated from sea-floor magnetic data that do not reflect the full plate rate as a result of tectonic complexities. They developed a new global plate motion model for REcent plate VELocities (REVEL) based on CGPS data over the period January 1993 to December 2000 to estimate the relative velocities for 19 plates and continental blocks with respect to ITRF97 **Sella et al. , 2002.** For this effort, GIPSY OASIS II V.5.0 was used for PPP with non fiducial GPS satellite orbit and clock products from JPL **Zumberge et al., 1997**. Moreover, they assessed the plate rigidity though the use of strict and autonomous estimates for CGPS velocity errors which are propagated to the relative angular velocity estimates.

Prawirodirdjo and **Bock** used a methodology similar to **Sella et al., 2002** to develop a global plate motion model. They analyzed CGPS observations from 106 globally distributed stations over the period from January 1991 to July 2003 to estimate velocities for seventeen major and minor plates. They aligned their solution with IGS00, the IGS realization of ITRF2000 **Altamimi et al., 2002.** Based on a seven-parameter similarity transformation and they applied a no-net-rotation condition. This is due to the fact that the latter (ITRF2000) maintained a no-net-rotation condition through aligning its orientation time estimates to NNR NUVEL-1A **Altamimi et al., 2003**. In addition, the semi-annual and annual effects, as referred to by **Nikolaidis, 2002** which were not considered by **Sella et al., 2002** modeled to improve the precision of the CGPS velocity estimates.

Most recently, **DeMets et al., 2010** presented a new global geological model, called MORVEL, to describe the angular velocities for twenty five tectonic plates. The MORVEL model combines two kinds of data: it depends on sea-floor spreading rates and fault azimuths data to provide the angular velocity estimates for 19 plates surrounded by mid-ocean ridges, including all major plates; and CGPS station velocities and azimuthal data for six smaller plates. In general, the MORVEL model is more useful than NUVEL-1A as it includes many small plates which are not included in NUVEL-1A, especially in Asia and the western Pacific. Thus, the MORVEL model is recommended to be used for studying the Earth's crustal deformation in these areas. Furthermore, **DeMets et al., 2010** stated that significant differences can be observed between

NUVEL-1A angular velocities and MORVEL angular velocities. Generally, they pointed that the historical description of the current plate motion that can be estimated by the MORVEL model is more accurate than when using the NUVEL-1 and NUVEL-1A models. This conclusion was realised based on carrying out least-squares differences between angular velocities estimated from GPS observations and those for the MORVEL, NUVEL-1, and NUVEL-1A models, with the MORVEL angular velocities being nearer to those estimated from CGPS.
Another recent model is GEODVEL 2010 which has been released by **Argus et al., 2010.** This model was determined based on space geodetic observations from SLR, VLBI, GPS, and DORIS data. The relative angular velocities of eleven major tectonic plates were estimated simultaneously assuming that the earth's center is fixed in ITRF.

4. PLATE MOTION STUDIES BASED on GPS DATA

Time series of regionally or globally distributed geodetic network based on observations obtained with GPS have been employed for investigating different-scales of geophysical phenomena. For example, **Dixon et al. 1991** estimated the Pacific-North American plates relative motions based on GPS observations from campaigns carried out in 1985 and 1989 in the Gulf of California. In addition, this relative motion was estimated based on VLBI by **Argus** and **Gordon 1991a.** and in the global plate motion models NUVEL-1 and NUVEL-1A **DeMets et al., 1990, DeMets et al., 1994**. **Argus** and **Gordon 1991b** showed that the Pacific-North American relative plate motion based on VLBI is faster than the relative motion predicted by NUVEL-1. Afterward, **Dixon, 1993** estimated the Cocos-Caribbean plates relative motion using GIPSY software based on the GPS observations from central and south America campaigns carried out in 1988 and 1991 for the Cocos-San Andres baseline and Cocos-Liberia baseline (Cocos Island on the Cocos plate and San Andres Island and Liberia on the Caribbean plate).
Since July 1992, when the nominal 24-GPS satellite constellation was completely realised, many geodynamics investigations have been carried out based on GPS observations. Some of the applications of such data were demonstrated initially by **Blewitt, 1993** who studied the development stages of the GPS user hardware from the early 1970s to the early 1990s. Furthermore, **Blewitt 1993** highlighted methods of assessment of GPS precision and accuracy which focused on repeatability of the coordinate estimates, comparison with other coordinate estimates from different space geodetic techniques, like VLBI and SLR, and the use of statistical analysis. Additionally, **Blewitt, 1993** detailed the precision, technique and network scale and density required for each geophysical application, (see **Table 1**) **Blewitt, 1993**.
Argus and **Heflin 1995** used the CGPS data for 43 globally distributed stations over four years to estimate fifteen relative angular velocities between six major plates, and the relative motion between the plate boundaries at ten sites in plate boundary zones. They showed that the relative angular velocities between six major plates based on GPS data differ slightly from the corresponding relative angular velocities predicted from NUVEL-1A, which is based on average plate motion over the last 3 Myr. Furthermore, they concluded that the Pacific-Eurasian and Pacific-North American relative motions are faster than the corresponding relative motions predicted by NUVEL-1A. Thus, they supported the **Argus** and **Gordon, 1991b** inference that based on VLBI that the Pacific-North American relative motion has sped up over the past 3Myr.
The first effort to estimate the Antarctica plate motion based on space geodetic data was carried out by **Larson** and **Freymueller, 1995**. Three years of CGPS observations were used in this effort to estimate the angular velocities for seven IGS sites on the Australian, Pacific and Antarctica plates. They showed an agreement between their solution and the angular velocity predicted from the NNR NUVEL-1A kinematic model. **Larson et al., 1997** carried out a similar

effort to that of **Argus** and **Heflin, 1995** but with more sites, more tectonic plates, and a longer time series. They estimated velocities for 38 globally distributed sites, based on analyzing one day per week of the CGPS observations collected over the period of time, from January 1991 to March 1996. They used the estimated station velocities to compute eight absolute angular velocities for eight tectonic plates and twenty eight relative angular velocities, and found an agreement within 95% confidence between the absolute angular velocities based on GPS with those predicted from NNR NUVEL-1A, except for the Pacific plate. In addition, an agreement was found between the relative angular velocity based on GPS for each plate pair with the corresponding one predicted from NUVEL-1A, except for some of those associated with the Pacific plate. To prevent aliasing systematic errors in the estimated station velocities which increases the complexity of the tectonic interpretations, **Larson et al., 1997** emphasized the necessity of analysing time series which are built on consistent, homogenous and precise data over the entire period of time. Consequently, they used the same models and strategies for this effort, see **table 2**, **Larson et al., 1997.**

Segall and **Davis 1997** surveyed the capability of employing the GPS technique for geophysical investigations to observe a wide range of different geophysical phenomena e.g. seismology, hydrology, volcanology, tectonic plate motion and Earth's crustal deformation at plate boundaries, and deformation related to Glacial Isostatic Adjustment (GIA), Earth rotation, and Earth mass distribution.

Regarding the combination between GPS and other geodetic techniques, in the early 1990s, the geophysical applications of radar interferometry gained massive attention. **Massonnet** and **Feigl, 1998** reviewed the geophysical applications that were published before 1998 and stated that the majority of the publications dealt with the geophysical monitoring of natural risks caused by earthquake, volcanoes, and glaciers. In addition, they presented some case studies of monitoring natural risk and environmental alterations related to landslides, subsidence, and agriculture

In recent years, space geodetic techniques have been employed in conjunction with the Interferometric Synthetic Aperture Radar (InSAR) technique (terrestrial, airborne, and satellite InSAR), to become a reliable means for monitoring the Earth's deformations. Airborne and satellite InSAR imagery can be used effectively to generate maps of deformation or digital elevation models based on two or more SAR images which cover the area of interest. Typically, this technique can be used to observe rapid centimetre-level changes in deformation for thousands of points in a relatively small area, while the GPS technique gives long-term stability and better temporal coverage , **Wei et al., 2010**. **Zerbini et al., 2007** stated that the main point from the combination between space geodesy techniques and InSAR technique is to complement the weaknesses of each technique through the strengths of the other technique.

5. GLACIAL ISOSTATIC ADJUSTMENT STUDIES

Over hundreds of thousands of years, a cycle of alternating glacial and interglacial conditions has happened as a result of the Earth's climate change with a periodicity of the order of 105 years. In the duration of a glacial period, the ice sheets grow at higher altitudes, due to low temperatures that lead to removal of water from the ocean basins and relative sea-level (RSL) falls. On the contrary, during the period of interglacial conditions, several of these ice sheets are melted, which leads to a return of water to the ocean basins and additional changes in the RSL because of the Earth's crustal deformation under the load of ice and water and the change in the gravitational potential of the Earth–ocean-ice system **Lambeck, 2004**. This periodic movement of water over the Earth's surface acts like a load upon the Earth's lithosphere. Consequently, the Earth's crust is deformed in response to the action of these forces. Earth's deformations caused

by the change in ice-mass loading, are known as Glacial Isotactic Adjustment (GIA) or post-glacial rebound. GIA is defined, conventionally, as the global response of the solid Earth to the ice-mass redistribution that occurred during cycles of glaciation and deglaciation **Whitehouse, 2009**. The speed of this response is variable based on the viscosity of the mantle.

Many geophysical studies have been carried out on GIA to realize how this process can be modelled and understand the horizontal and vertical crustal deformations, and the changes in sea-level and the volume of the ice sheets, during the last glacial cycle **Peltier, 1998**. Furthermore, GIA involves changes in pole motion and Earth rotation **Mitrovica et al., 2001**.

For more than three decades, many studies have been achieved successfully for numerical modelling of GIA, especially in North America, Europe, and Australia. These numerical models have shown great success in representing GIA, especially after the introduction of additional constraints which have been made on GIA models, such as: absolute gravity (AG) measurements **Larson** and van **Dam, 2000,** and **Lambert et al., 2001**; geological sea-level records **Lambeck, 2004**; tide gauge records **Teferle, 2003**; and space geodetic measurements **Blewitt, 1993**. The latter playing a major role in providing a precise description to the structural features of the Earth's interior.

One of the initial projects established in support of this purpose was the BIFROST project (Baseline Inferences for Fenno-Scandinavia Rebound Observations, Sea-level, and Tectonics). This project was initiated in 1993 to detect the Earth's crustal deformations in Fenno-Scandinavia due to GIA. This project combines networks of CGPS receivers in Sweden and Finland. **Johansson et al. 2002** compared horizontal and vertical crustal deformations based on the BIFROST CGPS results over the period from 1993 to 2000, to predictions calculated from a high-resolution Fenno-Scandinavia deglaciation model proposed by **Lambeck et al., 1998**. They obtained an agreement in the order of 1 mm/yr between the maximum observed uplift rate and maximum predicted uplift rate, which is approximately 10 mm/yr.

Since 2002, such accurate GIA models (global and local scales) have become increasingly required by the Gravity Recovery and Climate Experiment (GRACE) satellites mission. GRACE data have been used to investigate exchange between the ice sheets and ocean basins' water, but this application requires accurate GIA models to detect signals of the horizontal mass distribution. Unfortunately, GIA models are uncertain, owing to a lack of sufficient constrains for the past glacial changes, and a lack of available measurements of surface velocities in the Polar regions. For these reasons, space geodetic measurements can be used to improve constraints on global and local GIA models, especially local GIA models which are formed based on specific ice distribution and lithosphere depths that can be estimated effectively using accurate CGPS measurements. **Johansson et al., 2002** pointed to the urgent need for a dense and robust CGPS network for obtaining accurate horizontal and vertical velocity estimates in order to observe the Earth's deformations.

Some studies have also been carried out on the greenland ice sheet. **Wahr et al., 2001, Dietrich et al., 2005** and **Wahr et al., 2001** studied vertical crustal motion of the Greenland ice sheet, using vertical velocities based on CGPS measurements taken at stations Kellyville and Kulusuk. For this effort, GIPSY OASIS II V.5.0 was used for PPP **Zumberge et al., 1997,** with GPS satellite orbit and clock products generated by the JPL AC based on analysing more than 40 globally distributed stations. These studies compared the vertical velocity estimates based on CGPS measurements with the corresponding estimates from absolute gravity observations and showed that these vertical velocity estimates are associated with the ongoing viscolelastic response of the Earth to changes in Greenland's ice mass. Later, **Khan et al.,** 2008 expanded the study carried out by **Wahr et al. 2001,** by taking account of seven more years of CGPS measurements at Kellyville and Kulusuk and including three additional CGPS stations

(Qaqortoq, Scoresbysund, Thule). The daily coordinates for these sites were again calculated based on GIPSY OASIS II's PPP strategy **Zumberge et al., 1997**. They found the vertical velocity estimates for Kellyville and Kulusuk differed from the estimates of **Wahr et al., 2001** and gave the reasons of using a different reference frame realisation and different models. In the meantime, **Dietrich et al., 2005** studied vertical crustal deformation in the west of Greenland by analyzing GPS measurements which were taken over a period from 1995 to 2002 at 10 locally distributed GPS stations in the area of interest; BSW5.0 software with double-difference strategy was used for this effort. They strongly emphasized the necessity of using consistent and homogeneous time series of GPS satellite orbit and EOP products to generate equivalently homogeneous station coordinate time series; a homogeneity that can only be reached when applying unique standards (models and reference frame) over the whole of the period of interest. Consequently, **Dietrich et al., 2005** stated that using the IGS products during the period under consideration would result in inhomogeneous results due to using different standards, so, they used the GPS satellite orbit products and EOPs from a first reprocessing of the global GPS network **Rothacher et al., 2004**.

In addition, many studies have been carried out to investigate the isostatic rebound to resolve the vagueness concerned with Antarctic deglaciation and enhance the uncertainties associated with velocity changes and lithosphere thickness. **Velicogna and Wahr 2002** showed that when adding CGPS measurements, vertical velocity estimates taken near or around the ice accumulation centers have noticeable effect on the improvement of the ice mass balance estimations and the postglacial rebound generated based on a combination of space-based observations of the gravity and altimetric height.

Raymond et al., 2004 analyzed the CGPS measurements taken over the period between November 1996 and January 2001 at two CGPS stations located in the Northern Transantarctic Mountains to study the three-dimensional velocity estimates in this area. For this study, they used GIPSY OASIS II V.5.0 and the PPP strategy. **Zumberge et al., 1997** stated that the uplift that they estimated was caused by GIA, and that the uplift estimated based on the CGPS measurements differed from predictions based on the global models of late Pleistocene deglaciation ICE-3G .**Tushingham and Peltier, 1991**, ICE-4G ,**Peltier, 1994**, and **Dietrich et al., 2004** analysed CGPS measurements from more than 20 stations distributed in Antarctica between 1995 and 1998 using BSW4.2 software to provide a regional densification solution for the ITRF2000. As they focused on the deformation of the Antarctic Peninsula, the estimated GPS stations velocities showed that the relative motion between the east and west of Antarctic does not exceed 2 mm/yr in the horizontal, with maximum uplift rates of about 10 mm/yr in the Northern Antarctic Peninsula. They also stated that even if the deformation signals are relatively small in the horizontal components, the GPS observations still provide constraints for GIA models.

Ohzono et al., 2006 analyzed CGPS measurements taken from 9 IGS stations distributed around Antarctica between 1998 and 2003. They used precise satellite orbit and clock, and EOP products provided by JPL to carry out a PPP processing strategy in GIPSY/OASIS II **Zumberge et al., 1997**. Their PPP horizontal components, which were referred to ITRF2000 and presented as coordinate time series, showed that the Antarctic plate motion can be explained as a rigid plate motion. While their vertical velocity estimates from most of processed sites appeared to be an effect of GIA. Furthermore, they concluded that none of the current GIA models could effectively reproduce their results for vertical crustal movement.

More recently, the level of uncertainty in the surface displacement (3-dimention) for the current local GIA models for Greenland and Antarctica ice sheets have been demonstrated by **King et**

al., 2010 who stated that improving GIA modeling necessitates massive effort due to the very short time period of the CGPS measurements.
In summary, with the advent of modern space geodetic techniques (SLR, VLBI, GPS, and DORIS), GIA has become observable along with other geodynamic signals which come from the changes in the Earth's global gravity field, variation in the Earth's rotation rates, and the geocentre motion **Chao et al., 2000**.

6. SUITABILITY OF GNSS FOR MONITORING OF THE EARTH'S DEFORMATION

One of the most significant current discussions in the crustal deformations studies is the application of GNSS to long-term monitoring of land movements. In general, this application is based completely on producing daily time series of the changes in positions of stations over a period of time. In recent years, the methodologies of double-difference relative (DD) or precise point positioning (PPP) have been used to investigate horizontal and vertical land movements at the millimeter level, and this has been referred to in the review of literature mentioned in this paper. However, these methodologies depend entirely on the availability of satellite orbit and clock, and Earth orientation parameter (EOP) products that are precise, homogeneous and consistent over such a period of time. Consequently, any lack in the accuracy, homogeneity, and consistency of these products will be an obstacle to employ GNSS for monitoring the land movements.
The International GNSS Service (IGS) represents the main source of post-mission, precise satellite orbit and clock, and EOP products. Since its beginning in June 1992, the IGS has provided high quality observation data and an uninterrupted series of its products as the standard for GNSS in support of Earth science research, multidisciplinary applications, and education. **Table 1** summarizes the GPS satellite products currently available through the IGS (http://igscb.jpl.nasa.gov/components/prods.html).

The IGS is continually trying to improve their products and gain a higher-level of accuracy by implementation of the latest and most sophisticated approaches for modeling the atmospheric delay. For example. in November 2006, significant improvements were made through the adoption of absolute antenna phase center models for both satellite and receiver antennas and the use of mapping functions based on numerical weather models, such as the Global Mapping Function (GMF) for the modeling of tropospheric delay. Furthermore, there have been periodic changes of International Terrestrial Reference Frame (ITRF), and the subsequent realization of the IGS reference frame. **Figure 1** shows the changes in the used reference frame for the generation of the IGS final products; on 2nd December 2001 it was changed from IGS97 to IGS00, on 11th January 2004 it was changed from IGS00 to IGb00, and finally, on 5th November 2006, it was changed from IGb00 to IGS05 **Teferle et al., 2007**.

However, such changes in the realization of the ITRF together with the significant enhancement of different models and processing strategies considered individually by the IGS Analysis Centers (ACs) have contributed to inhomogeneous and inconsistent products over time. Nevertheless, such improvements only really benefit short term applications, such as GNSS meteorology and future monitoring schemes. Furthermore, the continuous development and improvement of the processing software employed by the IGS ACs and the changes in the realization of the reference frame have also played a significant role in the refinement and improvement of IGS products. Moreover, due to the growing quantity and quality of GNSS observations and the improvement in the processing strategies which have been witnessed during

the last decade, further effects had to be considered which were unthought-of in the past. Accordingly, several studies have pointed out that the accuracy of coordinate estimates can be adversely affected due to the insufficient modeling of the tropospheric delay, not taking into account higher-order ionosphere corrections, and applying different loading processes for both the GNSS product generation and coordinate estimation.

As a consequence, the IGS products are constantly evolving over time. For long-term monitoring, the ideal would be for such developments to be used to produce improved products not only for the future but that go back in time. This then enables the re-analysis of older observation data that has been continuously recorded and archived to obtain improved estimates of, for example, land movements. **Zumberge at al., 1997** mentioned the disadvantage of constraining different reference frames in the analysis of data from a global network to generate satellite products. Moreover, they pointed out the future necessity of reprocessing the global data to overcome the discontinuity problems. Therefore, a strong emphasis has been placed on the importance of re-analysing the GNSS archived observation data to generate accurate, consistent, and homogenous precise satellite orbit and clock, and EOP products over a long period of time.

The IGS made its first effort (repro1) to reprocess all the GPS observation data which were recorded and archived during the period between 1994.00 and 2007.99 as one of its core objectives to produce a fully accurate, consistent, and homogenous set of precise satellite orbit and clock, and EOP products **Ray, 2011**. IGS repro1 campaign was finalized in April 2010 **Gendt** and **Ferland, 2010**. **Alhamdani 2012** carried out an evaluation of the individual IGS repro1 ACs' products as well as the IGS repro1 combined products. Two techniques were considered in this evaluation to investigate the consistency and the homogeneity of the re-processed GPS satellite orbit, clock and EOP products. In the first technique, the IGS repro1 orbit and available clock products were assessed individually over ten years (1998.0 to 2007), whereas in the second technique, PPP was considered to assess IGS ACs' products over the same period. One of the more significant findings to emerge from **Alhamadani, 2012** study is that an obvious improvement in the orbit products over ten years. Moreover, there is high level of consistency between some IGS ACs. However, **Alhamdani, 2102** pointed out that there is a clear problem and significant deviations in some IGS ACs due to wrong constraints in their solutions affecting the frame in which the orbit products were estimated. Additionally, the most interesting finding of **Alhamadni, 2012,** study was that the repro1 products are suitable only for double difference relative positioning technique and not for precise point positioning (PPP) technique due to some weaknesses in the satellite clock products.

7. CONCLUSIONS

The long-term monitoring of different parameters of the Earth system, such as the land movement which is of particular interest in this study, can be carried out through the geophysical interpretations of coordinate time series derived from Global Navigation Satellite Systems. However, in the past, such geophysical interpretations could not be trusted owing to the fact that such time series were inconsistent and inhomogeneous, due to periodic changes in processing strategies, modeling of the atmospheric delays, parameterization, and the definition of the geodetic datum. As a result, many of the studies previously carried out have emphasized the necessity to reprocess all the continuous GPS observation data and produce a fully consistent set of products using the latest processing strategies, modeling techniques of the atmospheric delays, and parameterization.

This paper drew an attention to some of the recent regional and global monitoring studies based on CGPS measurements. Here, it was interesting to note that in most of the regional investigations of the Earth's deformation studies were carried out based on the double-difference processing strategy to obtain a high level of precision for three-dimensional relative velocity estimates between stations, whereas the absolute horizontal and vertical velocity estimates for global networks have been produced very efficiently using PPP processing strategy.

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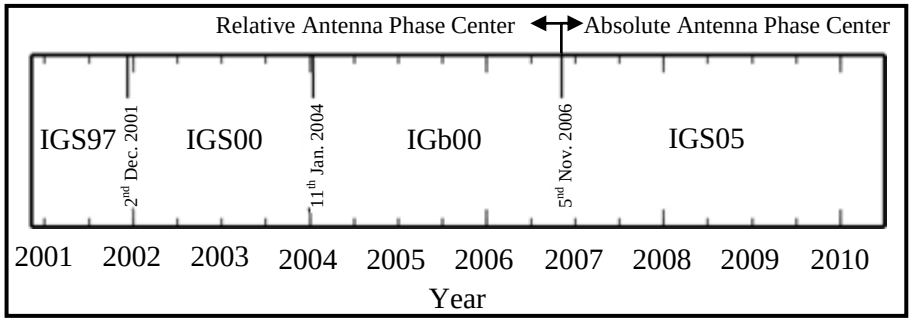

Figure 1. Changes in the used reference frame for the IGS final products generation.

Table1. Accuracy and latency of IGS GPS satellite products.

IGS product types			Sample Interval	Accuracy	Latency	Update
Final combination		Orbits	15 min	~2.5 cm	12-18 days	Weekly/ Every Thursday
		Clocks	30 sec	~ 75 ps*		
Rapid combination		Orbits	15 min	~2.5 cm	17-41 hours	Daily/at 17 UTC daily
		Clocks	5 min	~75 ps*		
Ultra-rapid combination	Observed half	Orbits	15 min	~3 cm	3-9 hours	4 times per day at 03, 09, 15, 21 UTC
		Clocks	15 min	~150 ps*		
	Predicted half	Orbits	15 min	~5 cm	Real time	
		Clocks	15 min	~3 ns*		
* Root Mean Square (RMS).						

Effect of Polymers on Permanent Deformation of Flexible Pavement

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ABSTRACT

The permanent deformation of flexible pavement represent serious problem in hot climate region. Numerous efforts are devoted to mitigate this distress such as modifying asphalt binder by polymers. The present study demonstrate the effect of utilizing four types of polymers to reduce the permanent deformation, these polymers are **P**oly**e**thylene **W**ax (**PEW**), **S**tyrene **B**utadiene **R**ubber (**SBR**), **E**thylene **P**ropylene **D**ien **M**onomer (**EPDM**) and **E**thylene **V**inyl **A**cetate (**EVA**). The prepared mixtures composed of 4.9 % of 40/50 asphalt binder, 12.5 mm nominal aggregate maximum size and limestone dust as filler. The permanent and resilient strains have been recorded when the cylindrical specimens, 101.6 mm in diameter and 203.2 mm in height, tested by repeated loading system. The main conclusions exhibit that SBR and EPDM with the same concentration (15 % by weight of asphalt binder) reduced the permanent deformation by 30.20 % and 30.46 % respectively. Although, the PEW and EVA reduced permanent deformation by lower values, 13.24 % and 17.35 % respectively, but the incremental percentage of their action are higher. The influences of testing temperature and stress level on permanent deformation were investigated. Linear regression model was established to correlate the values of permanent deformation and the resilient modulus of asphalt mixtures.

Key words: asphalt pavement, permanent deformation, polymers, resilient modulus

تأثير البوليمرات على التشوه الدائمي للتبليط المرن

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الخلاصة

يمثل التشوه الدائمي للتبليط المرن مشكلة جدية في مناطق المناخ الحار، جهود عديدة وجهت لتقليل هذا الضرر مثل تعديل الرابط الاسفلتي بالبوليمرات. تعرض الدراسة الحالية تاثيراستخدام اربع انواع من البوليمرات لتقليل التشوه الدائمي، هذه البوليمرات هي شمع البولي اثيلين **(PEW)**، مطاط الستايرين بوتادين **(SBR)**، إيثيلين بروبيلين دبين مونومر **(EPDM)** و خلات فينيل الاثيلين**(EVA)**. الخلطات المعدة تتكون من 4.9% رابط اسفلتي 50/40، 12.5 مم مقاس اقصى اسمي للركام وغبار حجر الكلس كمادة مالئة. الانفعالات الدائمية والمرنة تم تسجيلها عندما فحصت النماذج الاسطوانية بقطر 101.6مم وارتفاع 203.2مم بنظام الاحمال المتكررة.اظهرت النتائج الرئيسة بان SBR و

EPDM ولنفس نسبة التركيز (15% من وزن الرابط الاسفلتي) قللتا التشوه بمقدار 30.20% و 30.46% بالتعاقب. رغم ان PEW و EVA قللتا التشوه بقيم اقل، 13.24% و 17.35% بالتعاقب ، لكن النسبة التزايدية لفعلهما كان اكبر. تم بحث تاثير حرارة الفحص ومستوى الاجهاد. تم تكوين انموذج انحدار خطي لربط قيم التشوه الدائمي ومعامل المرونة للخلطات الاسفلتية.

1. INTRODUCTION

Generally, polymer modified asphalt binder are become more widespread in road construction to meet today's high traffic loading. Furthermore, many efforts are devoted toward modifying asphalt mixtures by various types of polymers to enhance the resistance of asphalt paving to high and low temperatures consequences, allowing reduction in common failure mechanisms as rutting and cracking.

Permanent deformation termed as rutting is one of the most considerable load-associated distress types affecting the performance of asphalt concrete pavement, **Alavi, et al., 2011**.

Based on comprehensive survey carried out by Federal Highway Administration in 1998, rutting was considered to be the first ranking distress mechanisms in flexible pavement, followed by fatigue cracking and then by thermal cracking **, FHWA, 1998**.

The research conducted by **Pardhan, 1995,** depicted that rutting usually appears as longitudinal depression in the wheel path accompanied by small upheavals to the side. **Kaloush, 2001,** revealed that repetitive action of heavy traffic loads caused an accumulation of permanent deformations in asphalt pavement.

An extensive work in this field has been carried out by **Sousa, et al., 1991**, they reported that permanent deformation expressed by rutting occupied a major concern for at least two reasons; ruts trap water and hydroplaning which represent threat particularly for passenger cars, and ruts that develop in depth make steering increasingly become difficult, leading to major safety concerns.

Mirzahosseini, et al., 2011, as well as many other researchers deduced that rutting decreases the useful service life of the pavement and by affecting vehicle handling characteristics; it creates serious hazards for highway users, consequently, it can decrease drainage capacity of pavement structure resulting in accumulation of water. Another negative effect of permanent deformation as declared by **Bahuguna, 2003,** is the reduction of pavement thickness, which boosts the occurrence of pavement failures through fatigue cracking.

1.1 Objective of the Study

This study tends to characterize the role of utilizing different types of polymers in order to improve the resistance of asphalt mixtures against permanent deformation. For this purpose, four types of polymers have been added by different concentrations to the asphalt binder to compose mixture that will be tested under repeated loading system to record the permanent deformation. These synthetic polymers are **P**oly**e**thylene **W**ax (**PEW**), **S**tyrene **B**utadiene **R**ubber (**SBR**), **E**thylene **P**ropylene **D**ien **M**onomer (**EPDM**) and **E**thylene **V**inyl **A**cetate (**EVA**).

2. REVIEW OF LITERATURES

Basically, polymer is a long string (or net) of small molecules connected together through chemical bonds. The chain connectivity of the polymer can give the chain great strength and at the same time, they can be very flexible, **Hakseo, et al., 2012**.

Vonk and **Valkering, 1996,** conducted laboratory track test to determine the effect of Styrene Butadiene Rubber (SBR) addition on rutting resistance at 40 °C and 50 °C; their work results deducted that unmodified asphalt mixture has higher rutting rate comparing to SBR modified asphalt mixtures. **Arnold** and **Pidwerbesky, 1996,** performed testing to evaluate the SBR modified asphalt

rutting, the SBR was mixed with an optimum asphalt content of 6 % by total mix weight, the mix was applied at four different sections by different residual rate of asphalt and the results remarked that flushing is less in the section where less asphalt cement has been used.

According to **Boza** and **Gallegos, 2009**, the addition of 1.0 and 2.0 percent of high density Polyethylene (HDPE) to asphalt binder is not able to modify the mechanical behavior of asphalt mixture effectively. **Ahmadinia, et al., 2012,** used polyethylene terephthalate; the appropriate amount of polyethylene terephthalate was determined to be 4.0 to 6.0 percent by weight of asphalt binder content, however, the result of the study indicated that modified mixture had lower trend to rut when compared to the non- modified asphalt mixtures.

The research published by **US Army Corps of Engineers, 2011,** pointed out that for optimal economy; it is desirable to choose an asphalt modifier that resists multiple distresses such as rutting, it was found that the choice of polymer might have significant impact on rutting properties and that mixtures boasting the highest rutting life contained reactive Styrene-Butadiene cross linked polymers. Research carried out by **Kumar** and **Veerara, 2011,** conformed the improvement in rutting resistance due to modify the asphalt concrete by Styrene Butadiene Rubber.

Ganesh, et al., 2011, monitoring the behavior of asphalt mixture at varying temperatures from 30°C to 50°C in steps of 5°C, they depicted that the performance of modified binders in the asphalt concrete mixtures is superior than plain binders, hence, the use of modified binders in the asphalt concrete mixtures increases the life of the pavement during adverse climatic conditions.

The work conducted by **Pareek, et al., 2012,** demonstrated the results of elastic recovery and rutting resistance of mixtures modified by Styrene Butadiene Rubber, they founded that modified mixtures have a 79 percent increase of elastic recovery and 54 percent increase of rutting resistance.

Xu, et al., 2010, investigated the effect of EPDM on rutting properties of asphalt mixtures; the results showed that asphalt binder with 3.5 percent of EPDM had the lowest rutting depth after 2500 cycles of load repetitions, which is reduced by 32.56 percent in comparison with unmodified mixtures.

EVA polymer has been widely used in the road construction industry for more than 40 years, where it improves both the workability of the asphalt during compaction and its deformation resistance in service. EVA polymers significantly improve the bitumen properties but to a different extent depending on the bitumen source and the polymer characteristics **, Haddadi, et al., 2008.**

The results of experimental work conducted by **Ahmed, 2012,** revealed that polyethylene with its optimum content of 5 percent by weight of binder is a useful modifier for increasing the stiffness of asphalt concrete and confer additional pavement stability at elevated temperatures to minimize rutting.

3. MATERIALS AND METHODS OF TESTING

3.1 Asphalt Mixtures

Essentially, all of asphalt mixtures materials were assiduously brought from locally well known sources. Concerning the asphalt cement binder, it was originally brought from Al-Daurah refinery and has 40/50 penetration grade, which is recommended to be used in hot region. The common test results are summarized in **Table 1**.

Regarding aggregates portion, the conventional source for the coarse aggregate was Al-Nibaee quarry while Karbala province was the exporter for both of river sand and limestone dust that was servant as mineral filler. For appropriate production of dense asphalt mixtures, the mid limit gradation selection is consent with the recommended values offered by **SCRB R/9, 2003**. It was

established to use the 12.5 mm nominal aggregate maximum size, which is suitable for wearing course pavement.
The demonstration of available characterizations of aggregates and mineral filler are listed in **Tables 2** and **3** respectively whilst the gradation path selection and sieve analysis are summarized in **Table 4** and portrayed in **Fig.1**.

3.2 Polymers

The SBR and EPDM polymers have been brought from Babylon Tires Factory in Al-Najaf province, while the source of the PEW and EVA polymers was the State Company for the Petrochemical Industries in Basra. **Fig.2** display samples of these polymers.
Based on previous studies mentioned in literature review, the quantity of polymers blended with asphalt cement hold constant by three categories with different concentrations, thus, the PEW and EVA have been added by 2, 4 and 6 percent of asphalt cement weight and for SBR and EPDM the percent became 5,10 and 15.
The specified percent of polymer was mixed with toluene in a flask (500 ml vol.) by the ratio of 1gm/1 ml and placed in air for approximately 24 hours. This procedure increased the polymers digestion and swelling as well as decreased the time of mixing. The homogenous slurry was added to the heated asphalt and mixed using an electrical stirrer at 1200 r.p.m for one hour at approximately 180 ^{o}C.
The first phase of asphalt mixture preparation involved: washing, drying, separating and recombined the aggregates particles with limestone dust to obtain the required gradation. Subsequently, both of aggregates and asphalt modified cement were heated to suitable mixing temperature, in this case, the mixing temperature was relatively high (160 ^{o}C, due to the presence of polymers substances) .
The binder content was held constant by 4.9 percent of total mixture weight throughout the forming of asphalt mixtures specimens. Each cylindrical testing specimen has dimensions of 101.6 mm in diameter and 203.2 mm in height, which required approximately 3800 g of asphalt mixture raw materials.
The specimens were compacted by double plunger method with a load of 16600 kg. The load was applied to each end of the specimen for one minute. Finally, the specimen was carefully transferred to a smooth and flat surface, allowed to cool by standing it overnight at room temperature and then removed from the mold using a hydraulic extractor. The specimens were then numbered and placing in testing chamber for two hours at the desired temperature as shown in **Fig.3**.
The axial repeated load test was conducted using the Pneumatic Repeated Load System **, Albayati, A.H, 2006**. In this test, repetitive compressive loading was applied to the specimen and the axial deformation was measured under the different loading repetitions. Compressive loading was applied in the form of rectangular wave with a constant loading frequency of 60 cycles per minute including 0.1 sec loading time and 0.9 sec rest period.
The experiment is commenced by application of repeated axial stress and recording the vertical deformation. Upon completion of test after 3000 load repetitions or any number for load repetition when the specimen failed earlier (as demonstrated in **Fig.4)**, the recording is terminated and the specimen is removed from the test chamber.

The permanent deformation is expressed as vertical microstrain and calculated by using Eq.(1);

$$\varepsilon_p = \frac{\Delta H}{H} \quad (1)$$

where;
ε_p = vertical microstrain, mm/mm
ΔH = vertical deformation at the specified load repetition, mm
H = original height of the specimen, 203.2 mm

The resilient modulus of asphalt mixture , **ASTM D-4123**, can be applied as indicator of flexible pavement ability to resist the harmful effects of high axle loading and elevated temperature conditions. According to **Huang, 2003**, the resilient modulus is the elastic modulus based on recoverable strain in repeated load test and can be expressed by Eq.(2);

$$M_R = \frac{\sigma_d}{\varepsilon_r} \quad (2)$$

where;
M_R = resilient modulus of asphalt mixture, psi
σ_d = deviator stress, which is the axial stress for unconfined compression test, 20 psi
ε_r = recoverable vertical strain corresponding to the 200 th repetition of load application.

4. RESULTS AND DISCUSSIONS

4.1 Effect of Temperature on Permanent Deformation and Resilient Modulus

The temperature has a significant influence on both of permanent deformation and resilient modulus of asphalt mixture. As demonstrated in **Fig.5** and **Fig.6,** increasing the test temperature from 40 ^{o}C to 50 ^{o}C produce an increase in permanent deformation by 25.8 % and a reduction in resilient modulus by 40.1 %. These two percentages became 69.2 % and 64.3 % respectively when the temperature raised to 60 ^{o}C. This behavior is quite understood and logically accepted because the stiffness of asphalt binder is adversely affected by the temperature increasing.

4.2 Effect of Stress Level on Permanent Deformation

One of the most important factor that affect the permanent deformation is the stress level, to put light on this point, the repeated load test conducted at three stress levels; 10, 20 and 30 psi. The outcome of the test is portrayed in **Fig.7**, which clearly shows that increasing stress level from 10 psi to 20 psi yields mixtures with higher deformation value by 13.8 %, in the same way, the percent of deformation increase reached 31.8 % as the stress level increased to 30 psi.

4.3 Effect of Polymers on Resilient Modulus

The resilient modulus test of asphalt mixtures have been performed as outlined by **Huang, 2003** at 40 ^{o}C and by applying stress magnitude equal to 20 psi, the elastic strain recorded at 200 th No of repetitions. **Fig.8** depicts the effect of incorporating a specified amount of PEW on the resilient

modulus, inspecting this figure deliver the message that the maximum resilient modulus occurred at 4.0 % polymer content , furthermore, the total percent of modulus increase reached 3.74 with an incremental value equal to 0.62 % for each percent of PEW addition.

This behavior is quite similar in the case of SBR usage, herein, adding SBR with a value up to 15 %, elevate the resilient modulus by 7.39 % and by an incremental value equal to 0.49 % for each 1.0 % of added polymer, as clearly shown in **Fig.9**. This improvement in resilient modulus is just similar to the situation when the EPDM is act as additive, in the same way, and within the range of polymer dosage, the enhancing percent in resilient modulus recorded 0.46 % for each 1.0 % of EPDM addition with total percent of increase equal to 6.92 as demonstrated in **Fig.10**. The justification of this similarity deduced his credibility from the fact that both of these polymers lie in the same polymer category of elastomer.The influence of blending asphalt binder with EVA polymer is portrayed in **Fig.11,** which declare that, this polymer also increase the resilient modulus by total amount of 4.64 % and with incremental magnitude of 0.77 %.

4.4 Effect of Polymers on Permanent Deformation

The particular concern of this study is to investigate the role of modifying asphalt binder with certain polymers in improving asphalt mixture resistance against permanent deformation. The participations of experimental work devoting to reach this goal are visualized in Figures 12, 13, 14 and 15.

The general remark triggered to mind by observing these figures, is that all of these polymers succeed in the purpose of permanent deformation reduction, which follow the same path of other researchers results. Good demonstration of PEW amount influence on microstrain magnitude can be understood by monitoring **Fig.12**, as the PEW dosage increased up to 6.0 %, the total microstrain reduced by 13.24 % with an incremental value of 2.20 % for each one percent of PEW dosage. Content of **Fig.13** display clearly the relationship between SBR and microstrain, as shown; increasing this polymer concentration from 0.0 % to 15 % caused a decreasing in microstrain by 30.20 %.The value of incremental reduction equal to 2.01%. **Fig.14** focus on the role of EPDM content on microstrain, again, increasing EPDM value up to 15 % reduced the microstrain by total amount of 30.46 % and by 2.03 % of incremental value. This similarity in results is not surprisingly as mentioned previously.**Fig.15** explicit the effect of EVA concentration increase on the microstrain, herein, expanding the amount of polymer in mixture spectrum up to 6.0 %, lower the total microstrain value by 17.35 % with 2.89 % of incremental decrease for each one percent increase of EVA.

The relationship between the resilient modulus of asphalt mixtures and the permanent deformation expressed by microstrain can be found as portrayed in **Fig.16**. By monitoring this figure, it is obvious that resilient modulus improvement play an important role in enhancing the resistance of asphalt mixture toward permanent deformation. To support this opinion, a linear regression analysis conducted to the data displayed in the mentioned figure. As a result, the following empirical equation has been established:

$$\boldsymbol{\varepsilon_p} = 14329 - 3.0\ M_R \quad , \quad R^2 = 0.80 \qquad (3)$$

where;

ε_p = vertical microstrain, mm/mm
M_R = resilient modulus of asphalt mixture, psi

5. CONCLUSIONS

- It is invariably found that, all four types of polymers used in this study succeed in improving the ability of asphalt mixture to resist the permanent deformation, however, the degree of success vary from one type to other. whereas, the SBR and EPDM polymers are sharing approximately the same value of permanent deformation reduction by 30.20 % and 30.46 % respectively and at the same polymer content of 15 % by weight of asphalt binder. On other hand, the PEW and EVA polymers reduce the permanent deformation microstrain by 13.24 % and 17.35 % respectively at the 6 % polymer content.

- The resilient modulus of asphalt mixture clearly effected by the participation of polymers as additives. In other words, incorporating PEW substance into the mixture increased the resilient modulus by 3.74 % at 6.0 % content of PEW. The SBR and EPDM polymers seems to be more effective in this activity, their percentages of extended the resilient modulus raised to 7.39 and 6.92 respectively and at exact 15 % of polymer content. The EVA polymer exhibit an improvement value equal to 4.64 % at 6.0 % of material content.

- Elevating the test temperature from 40 ^{o}C to 50 ^{o}C produce an increase in permanent deformation by 25.8 % and a reduction in resilient modulus by 40.1 %. These two percentages became 69.2 % and 64.3 % respectively when the temperature raised to 60 ^{o}C.

- Increasing stress level from 10 psi to 20 psi yields mixtures with higher deformation value by 13.8 %, in the same way, the deformation percent of increase reached 31.8 % as the stress level increased to 30 psi.

- Simple linear regression model has been established to correlate the influence of resilient modulus on permanent deformation resistance.

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NOMENCLATURE

ASTM = american Society for Testing and Materials

EPDM = ethylene Propylene Dien Monomer

EVA = ethylene Vinyl Acetate

ε_p = vertical microstrain, mm/mm

ε_r = recoverable vertical strain corresponding to the 200 th repetition of load application.

FHWA=Federal Highway Administration

H = original height of the specimen, 203.2 mm

M_R = resilient modulus of asphalt mixture, psi

σ_d = deviator stress, which is the axial stress in an unconfined compression test, 20 psi

PEW = polyethylene Wax

SBR = styrene Butadiene Rubber

SCRB = state Corporation of Roads and Bridges

ΔH = vertical deformation at the specified load repetition, mm

Table 1. The physical properties of asphalt cement.

Test	Unit	Result	Specification Requirement
Penetration (25 ^{o}C, 100 g, 5 sec). ASTM D 5	1/10 mm	42	40-50
Softening Point (Ring & Ball). ASTM D 36	^{o}C	49	…….
Ductility (25 ^{o}C, 5 cm/min). ASTM D 113	cm	102	≥ 100
Flash Point (Cleveland open Cup) ASTM D-92	^{o}C	283	≥ 230
Specific Gravity (25 ^{o}C). ASTM D-70	…..	1.03	…..

Table 2. The physical properties of aggregates.

Property	Coarse Aggregate	Fine Aggregate
Bulk Specific Gravity, ASTM C-127 and C-128	2.51	2.64

Apparent Specific Gravity, ASTM C-127 and C-128	2.54	2.68
Percent Water Absorption, ASTM C-127 and C-128	0.382	0.514

Table 3. The physical properties of limestone dust.

Property	Unit	Result
Specific gravity	-----	2.69
Passing No.200	%	96

Table 4. The Gradation selection of combined aggregates

Sieve Size	Sieve Opening (mm)	Specifications limit (SCRB R/9,2003)	Selected Gradation
3/4″	19	100	100
1/2″	12.5	90-100	95
3/8″	9.5	76-90	83
No.4	4.75	44-74	59
No.8	2.36	28-58	43
No.50	1.18	5-21	13
No.200	0.075	4-10	7

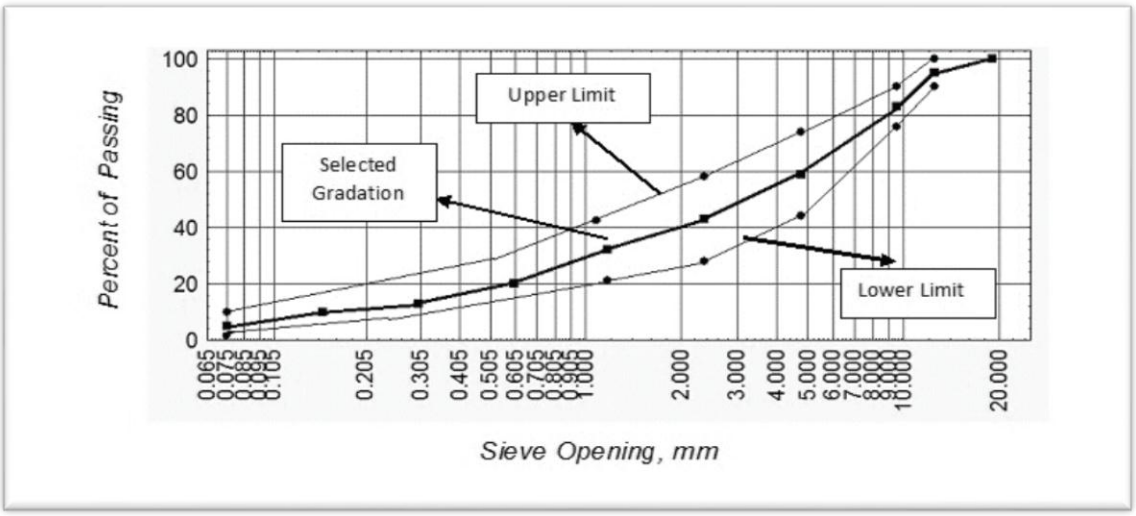

Figure.1 Sieve size analysis of combined aggregates.

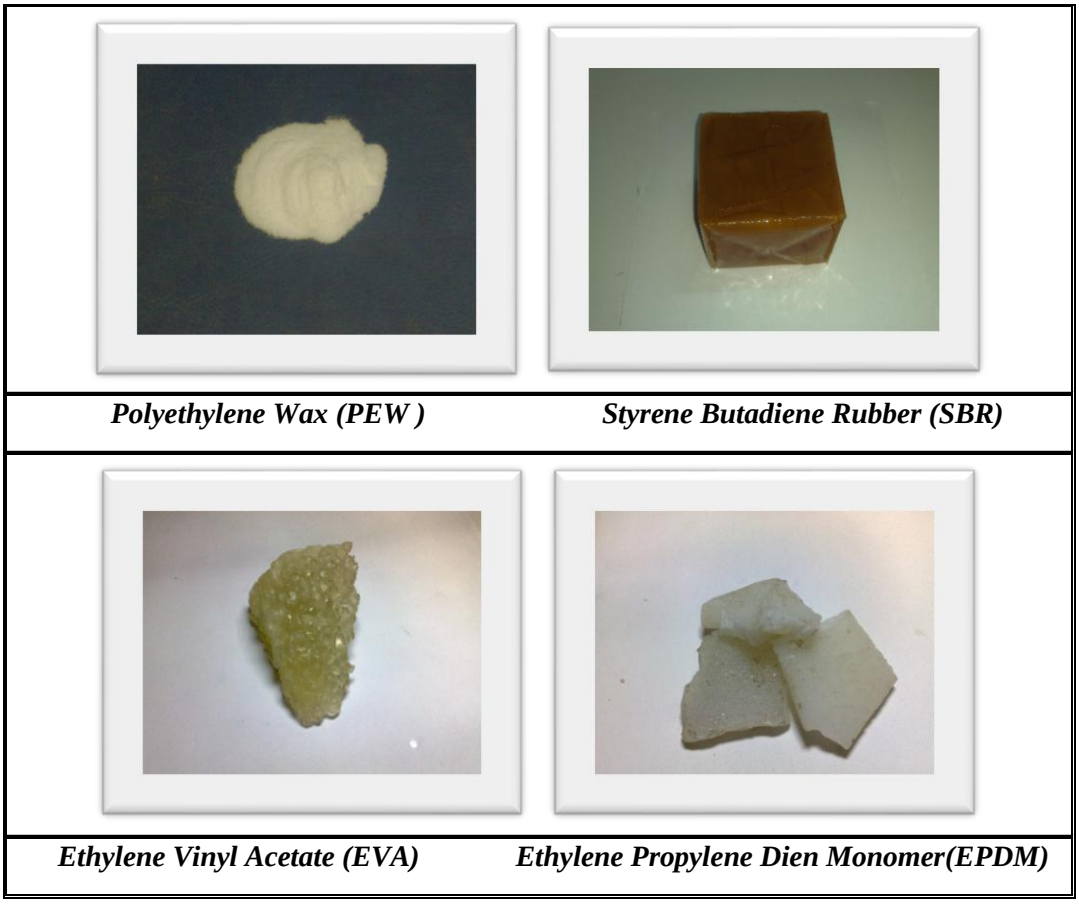

Figure.2 Samples of the polymers.

Figure.3 Specimen in the testing chamber.

Figure.4 Specimen at the end of test.

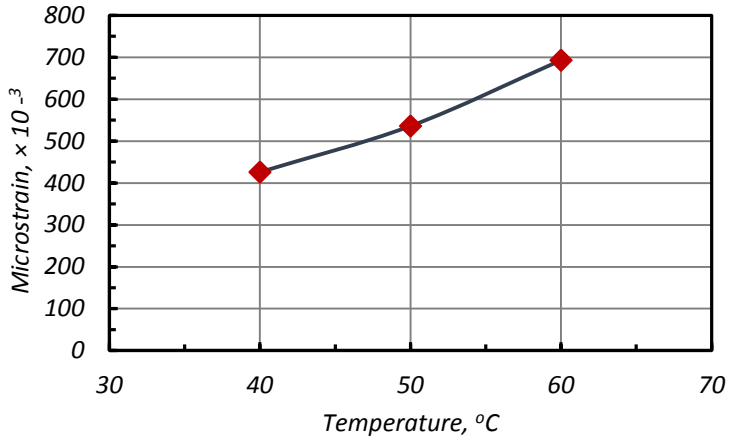

Figure 5. Effect of test temperature on permanent deformation (@ stress level=10 psi, 1000 load repetitions) .

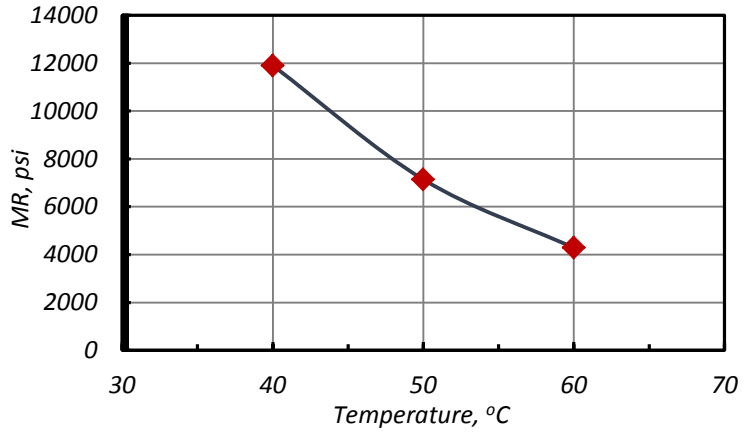

Figure 6. Effect of test temperature on resilient modulus (@ stress level=20 psi, 200 load repetitions, T=40 ^{o}C).

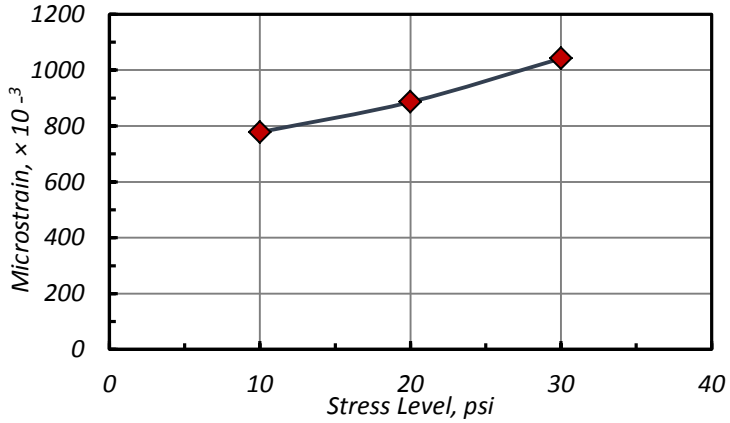

Figure 7. Effect of stress level on permanent deformation (@3000 load repetitions, T= 40 ^{o}C) .

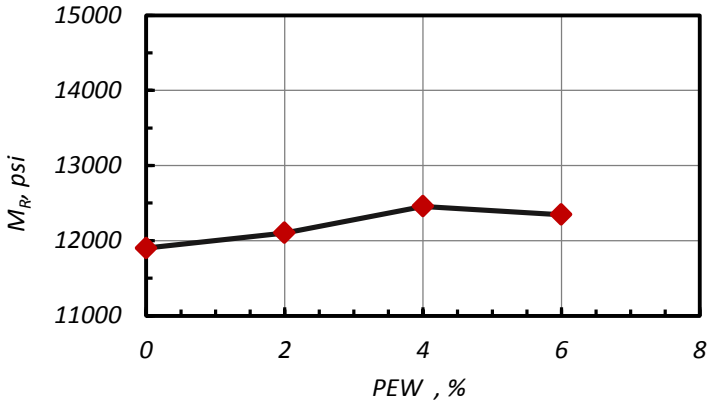

Figure 8. Effect of PEW on resilient modulus
(@ stress level= 20 psi, 200 load repetitions, T= 40 ^{o}C) .

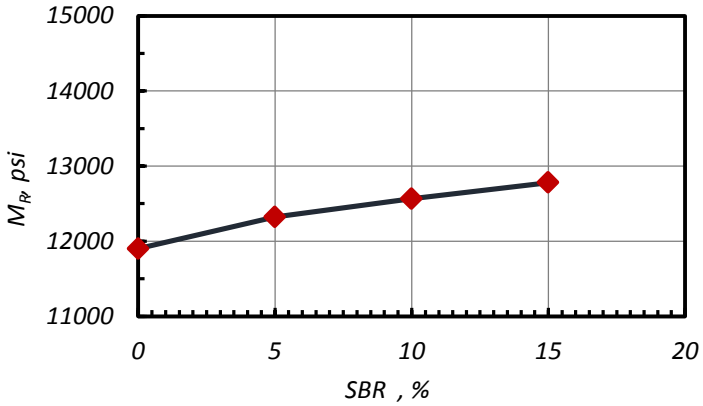

Figure 9. Effect of SBR on resilient modulus
(@ stress level= 20 psi, 200 load repetitions, T= 40 ^{o}C).

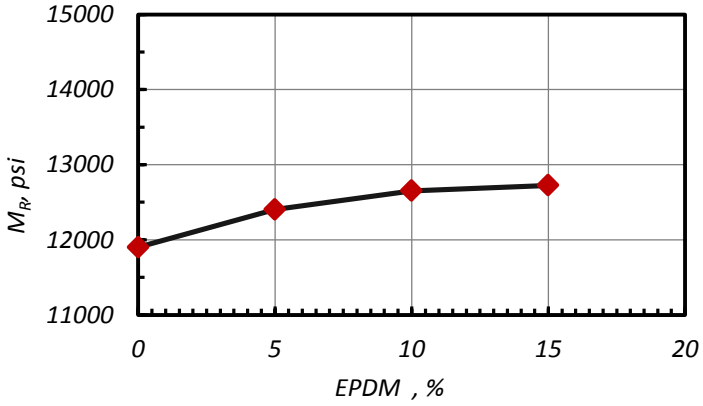

Figure 10. Effect of EPDM on resilient modulus
(@ stress level= 20 psi, 200 load repetitions, T= 40 ^{o}C).

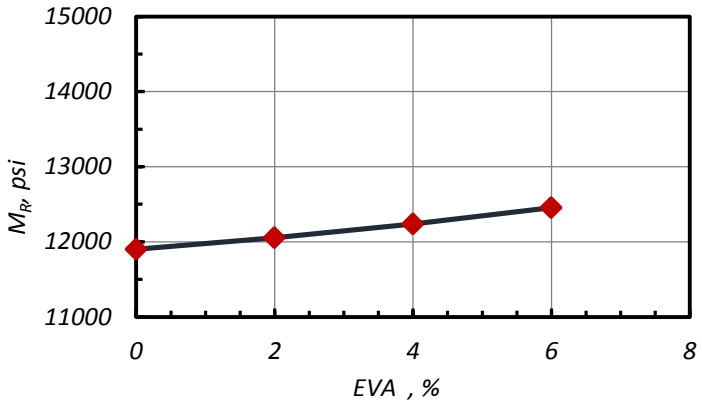

Figure 11. Effect of EVA on resilient modulus (@ stress level= 20 psi, 200 load repetitions, T= 40 ^{o}C) .

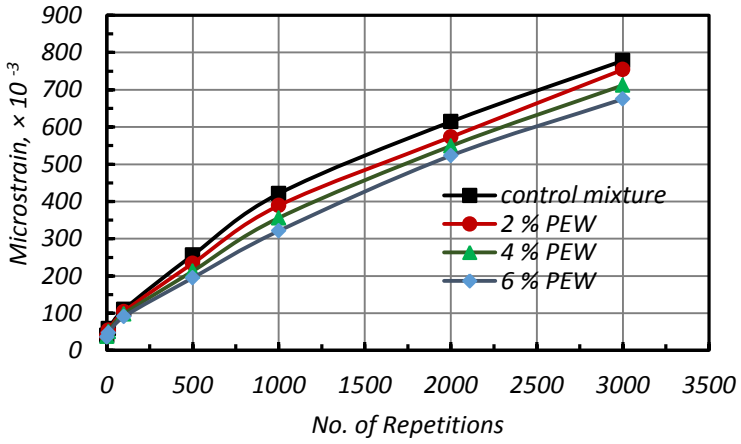

Figure 12. Effect of PEW on permanent deformation (@ stress level= 10 psi, T= 40 ^{o}C) .

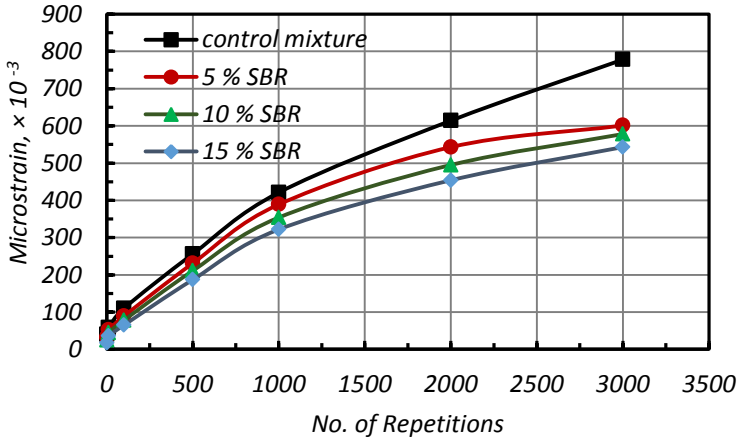

Figure 13. Effect of SBR on permanent deformation (@ stress level= 10 psi, T= 40 ^{o}C) .

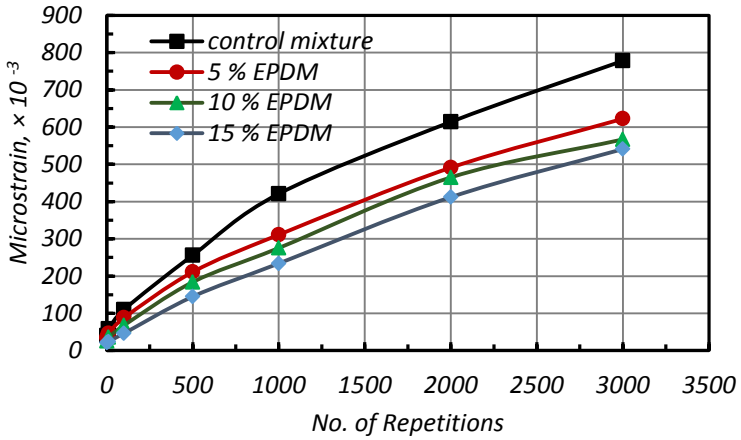

Figure 14. Effect of EPDM on permanent deformation (@ stress level= 10 psi, T= 40 ^{o}C) .

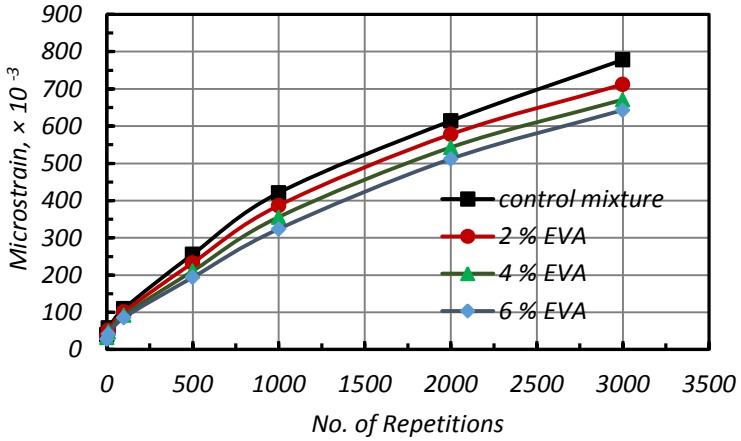

Figure 15. Effect of EVA on permanent deformation (@ stress level= 10 psi, T= 40 ^{o}C) .

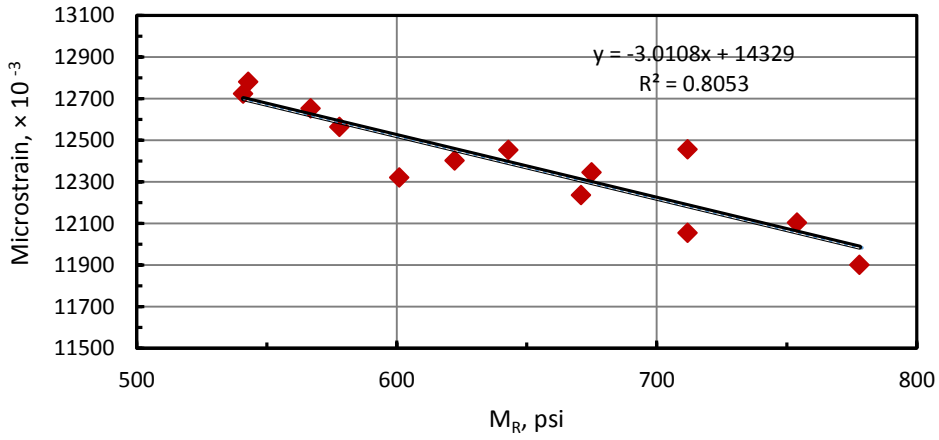

Figure 16. Relationship between permanent deformation and resilient modulus .

تتابع البنى الحضرية لمدينة بغداد

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الخلاصة

يتقصى البحث نشوء وتطور مدينة بغداد عبر مسارها التاريخي الطويل، بدءً من استجلاء طبيعة الموقع وخصائصه البيئية قبل الشروع ببناء بغداد المدورة، مروراً بمرحلة وضع خططها واكتمال بناءها في فترة ولاية ابو جعفر المنصور. ثم يسترسل البحث في وصف المراحل التعاقبية للنمو والتوسع العمراني على جانبي نهر دجلة وصولاً الى ما ألت الية بغداد في وضعها المعاصر.

ان التدقيق في ملامح البنية التخطيطية لمدينة بغداد المعاصرة، يوحي باختفاء العديد من الدلالات التخطيطية التاريخية التي زالت او ازيلت ولم يعد لها حضوراً فعلياً او رمزياً في المخططات الحديثة المتتابعة لمدينة بغداد.

من هنا تبلورت مشكلة البحث متمثلة بتلاشي الملامح الاساسية التي منها ومن ترابطاتها تشكلت هوية مدينة بغداد التاريخية.

فرضية البحث: الشحة المعرفية عن اهم الملامح العمرانية والتخطيطية التي اسهمن في رسم ملامح هوية بغداد عبر مراحلها التاريخية المتعاقبة من اهم مسببات قطع سلسلة التواصل في بنية مدينة بغداد.

من هنا تبلور هدف البحث في تأشير ووصف اهم المقومات والدلالات العمرانية والتخطيطية البارزة والتي بالإمكان اعادة احيائها فعلياً او رمزياً لاستعادة هوية بغداد وسماتها التاريخية في المخططات الاساسية المعاصرة.

Succession of Urban Structures of the City of Baghdad

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ABSTRACT

The research shed light on the historic evolution of Baghdad through its long, expansive history. The starting point focuses on the geographic characteristics, and the nature of its habitation, prior to laying the circular plan of Baghdad. Then the research proceeds to cover the stage of building the round city of Baghdad. The research continue to cover the expansion and sequential growth across the banks of Tigris river.

A concentrated attention is devoted to analyses the morphological, geographical and above all the makeup of present day city of Baghdad, pinpointing the apathetic plans, decisions, and actions which completely disfigured the image, and tradition of the old city of Baghdad, behind the delusive slogans of "comprehensive development". From the above ejective acts, the research problem is formulated as: The gradual dilapidation of major components that recall the historic image of Baghdad.

The research assumption thus formulated the causes that lead to the disfigurement of Baghdad historic identity in the consequent plans and policies which gave little or no attention to the historic developmental formation of the city. From the above assumption, the research goal can be stated as "Pin pointing the historic path of development to enclose the salient historic features that makes impact on the present day image of Baghdad.

المقدمة

تتميز المدن التاريخية وخصوصاً مناطقها القديمة ومراكزها الحضرية بكونها تحمل قيماً معنوية متميزة متمثلة بسمات بارزة أعطت لكل مدينة خصوصيتها وانتمائها التاريخي والجغرافي وتمثل إرثا" حضاريا", وتعد مدينة بغداد من المدن التاريخية والتي تتميز بكثر مراكزها التاريخية التي تميزت على مراحل مختلفة من التاريخ، وفي عام 2013م مر على البدء ببناء المدينة المدورة في موقع بغداد 1251 عام حيث بدأ البناء عام 762م وانتهى عام 766م*، ولكن تاريخ بغداد اقدم من ذلك بكثير حيث اتى ذكر اسم بغداد في العديد من المصادر البابلية والكلدانية والآرامية القديمة وكذلك تم ذكر اسم بغداد في الفتوحات الاسلامية و في اخبار الدولة الاموية.

لكن هذه العاصمة التاريخية والمدينة الاسطورية يشوب تاريخها وعمارتها وبنيتها الحضرية الكثير من الغموض، وقلة في المعرفة حول المواقع الحضرية ومخططاتها المتعاقبة زمانياً، وقد مرت بمتغيرات كثيرة سياسية واقتصادية واجتماعية وغيرها، حتى يكاد المخطط الدائري لمدينة بغداد (والذي يعد من اول المخططات الحضرية شاملة لمدينة في التاريخ) يعد غير معرف زمانياً ولا مكانياً, فقلة من المعماريين فقط يعرفون موقع المدينة المدورة من المحيط الحضري للمدينة قديما ومعاصرا، كما ان هنالك نقص وغياب في المعرفة عن الحقبة الزمنية التي عاشتها المدينة المدورة، وكذلك غياب المعرفة عن اهم البنى الحضرية للمدينة وكذلك البنى المعمارية لها ويختلط لدى الكثيرين امرها مع بغداد في جانب الرصافة، كما يختلط امر الرصافة التاريخية مع الرصافة المعاصرة سواء مركز الرصافة التاريخي، او الرصافة بمعنى الجانب الايمن من نهر دجلة.

لقد حظيت مدينة بغداد بكم كبير من الدراسات التاريخية ودراسات الاثارية بدءاً من نهاية القرن التاسع عشر ومطلع القرن العشرين، كما وضعت للمدينة مخططات تم مسحها عملياً تتابعياً.

كما وضعت مخططات اساس للمدينة التي بدأت بالنمو المتسارع بعد اعلان الدولة العراقية المعاصرة عام 1921م، وكان من تداعيات هذا النمو الكبير واحلال التخطيط الحديث في اجزاء كبيرة من النسيج التراثي غياب كثير من ملامح المدينة ومعالمها التخطيطية.

1: البنية الحضرية:

لقد قامت دراسات حضرية متعددة بطرح مفهوم البنية الحضرية التي تعني الوسط او المجال المكاني المحيط بالإنسان، وتضم جانبي الزمان والمكان، ينتج عنها كلُ متكامل يعكس القيم الثقافية والاجتماعية ويمثل نظاما معقدا يتصف بالاستمرارية الحضارية (Rapoport, 1981, pp161-184).

عرف (Amos Rapoport) البيئة بأنها سلسلة من العلاقات بين العناصر الفيزيائية والإنسان، وهذه العلاقة تكون على مستويين، بين العناصر والعناصر الأخرى، او بين العناصر والإنسان، او بين الإنسان والإنسان من جهة أخرى، ويرى أن مجموعة العلاقات التي تكونها البيئة تتصف بالانتظام والتناسق، وتمتلك شكلا وهيكلا، فالبيئة ليست تنظيما عشوائيا، إنما تخضع لنمط من العلاقات الفضائية، ولا تقتصر على العناصر والإنسان، لكنها مترابطة وبدرجات متباينة لتحقيق الفصل الفضائي بين شاغليها (Rapoport, 1977, pp 8-12).

وهذه البيئة يمكن تفسيرها كبنية حضرية، فكل من العمارة والإنسان هي بنى، والبنية تتكون من عناصر وعلاقات بين العناصر. ونستنتج مما سبق ان المهم هي الخصائص العلائقية بين العناصر، وليس العناصر ذاتها، فهي تركز على الوحدة والتماسك، والبنية الحضرية تنشأ من علاقة الجزء بالجزء والجزء بالكل وتعاني (تحولات تتحكم بها قوانين وقواعد دون أن تتعدى حدودها وتذوب بعناصر خارجة عنها).

ويشير المفهوم إلى علاقة الأجزاء ضمن الكل وان معنى الأشياء متجسد في العلاقات الداخلية للعلاقات الكامنة في الشيء نفسه وان العلاقة بين الأجزاء أهم من الأجزاء ذاتها التي تكون قابلة للتبادل مع بقاء العلاقات بينها ثابتة. ولكون الكتل والفضاءات التي بمجملها تكون المدينة هي وسيلة من وسائل الاتصال، أي إن هناك معنى خلف الوقائع المادية والأشكال الماثلة في الوجود، فقد اعتبر بعض الباحثين إن المدينة هي مجموعة تعابير تحاول إيصال معنى معين إلى متلقٍ من خلال شخصيتها المادية في الحدود، الطرائق، والفضاءات، والعلاقات وأساليب حركتها. وهذه يمكن اعتبارها علامات توضيحية ومفردات محددة للمعنى ضمن نص متكامل يحاول إبراز المعنى الكامن خلفه، هذه المعاني التي ترشحت من حضارة وثقافة معينة واكتشفت مدلولاتها من خلال علاقات الأشياء مع بعضها البعض (عزيز، 1998، ص9).

وصف (Aldo Rossi) بنية النسيج الحضري من خلال مفهوم الفضاء، فالمدينة بحسب تعريف (Rossi) مجموعة من السطوح, ما يميز خصائصها الثابتة هو تنظيمها الفضائي (Rossi 1982/p 62) , وعرف (David Gosling) البنية الحضرية من خلال مجموعة من العناصر والقواعد التي تربط تلك العناصر وتشبهها باللغة من حيث وجود حروف أبجدية وقواعد تربطها للحصول على بنية لغوية، وفي الموسيقى لابد من وجود نوتة موسيقية ترتبط بطريقة مميزة في التنظيم للوصول الى الألحان المميزة، وأشر وجود تقارب كبير بين البنية الشكلية

والبنية الوظيفية للنسيج الحضري، في كلا البنيتين يظهر التغير في الهيئة من خلال التغيير في العناصر والعلاقات، وان طبيعة هذه العلاقات بين العناصر تتغير بتغير التوجهات الفكرية والحضارية (Gosling 1984/p152).

كما بين (Rapoport) أن البنية الحضرية تنتج عن علاقة الكتلة بالفضاء والعلاقات المختلفة قد تنتج أشكالا وهيئات حضرية مختلفة باختلاف العلاقة بين الكتلة والفضاء، وأشر إن المدن الإسلامية ذوات بنية داخلية، أي المدن التي تنفتح فضاءاتها الى الداخل من خلال طبيعة العلاقة بين الكتلة والفضاء في حين إن المدن الحديثة هي مدن الانفتاح نحو الخارج (Rapoport 1977/p10).

من هذا يتبين إن بنية النسيج الحضري تتشكل من مجموعة من البنى التي (عناصر أساسية) هي (الكتلة – الفضاء – والخصائص العلاقاتية بين نظم الفضاءات والكتل)، وان العلاقات التي بين هذه العناصر الاساسية واختلافها هي ما تحدد النسق الحضري، وان طبيعة هذه العلاقات بين الكتل والفضاءات يعكس طبيعة الفكر الذي تمثله.

لقد تناولت دراسة (Curran) ودراسة McCluskey) الخصائص الموضعية للبنية الحضرية من خلال مفهوم النسق الفضائي المقترح في هيكلة النسيج الحضري، ثم دراسة عناصر بنية النسيج الحضري. فقد عرف (Curran) البنية الحضرية على وفق أنماط نظم الحركة المعتمدة في هيكلة الفضاء المفتوح من خلال تحليل المخططات لمدد زمنية مختلفة, وقد صنف (Curran) الفضاءات المفتوحة الى فضاءات خطية وفضاءات متجمعة، وأكد أهمية العلاقة بين الفضاءات الخطية والفضاءات المتجمعة بوصفها العناصر الأساسية في بنية النسيج الحضري، وأشر العلاقة بين العنصرين الأساسيين من خلال طبيعة ارتباط الفضاء التجميعي بالفضاء الخطي، وقسم الفضاءات التجميعية الى فضاءات استراتيجية وفضاءات مركبة وفضاءات معزولة، إذ تنتج البنى الحضرية من اختلاف العلاقات الفضائية بين الفضاءات الاتجاهية والفضاءات التجميعية (Curran, 1983,p 79).

أما (McCluskey) فقد أكد الخصائص الموضعية للفضاء الحضري (المكان) و (المسار) من خلال تأكيده على استمرارية واجهات المباني والارتفاعات في تحقيق الاحتواء الفضائي شكل، وحدد عدداً من الخصائص الموضعية للكتلة التي تعزز الاحتواء الفضائي (McCluskey,1972,p 108-110):-

- اتجاه الشارع (استمرارية الواجهات واستمرارية الفضاء الحضري).
- عرض الشارع (ارتفاع المباني بما يتناسب مع عرض المسار لتحقيق الاحتواء).
- التقاطعات (تأكيد وتعريف واجهات المباني التي تعرف تقاطعات مسارات الحركة).
- الشواخص.

وقد أكد (Colin Rowe) في بحثه المستمر عن علاقة المبنى بالفضاء الحضري أهمية الواجهات الأمامية والخلفية والركنية للعمارة في تعريف الفضاء، وكذلك ارتباط المبنى بالأرض لاحتواء الفضاء وتعريف حدوده، مما يعكس الملمس في المخططات من خلال قراءة العلاقة بين الكتلة والفضاء في تشكيل النسيج الحضري, وبطرح كتابه الموسوم (Collage City) والمنشور عام (1976) ثم مجموعة مقالاته المنشورة تحت عنوان (Grid/Frame/Lattice/web) والمنشورة في (Cornel Journal) عبر فيهما عن أفكار في هيكلة المدينة من خلال العلاقة بين الكتلة والفضاء، عن طريق تحويل المخططات الى رسوم بالأبيض والأسود، التي تعكس طبيعة العلاقة بين الكتلة والفضاء والمعتمدة على نظرية الكشتالت (Gestalt)، وطور مفهوم (الكتلة – الفضاء) ويعد كل منهما العنصر الأساسي في بنية النسيج الحضري، وعلاقة الكتلة بما يحيطها من خلال خصائص (الملمس والنمط والحافة والمحور) بوصفه رد فعل ضد الصورية في التصميم الحضري، والارتباطات الاجتماعية، إذ حلل المدينة بوصفها نصاً معزولاً عما حوله من المتغيرات الاقتصادية والاجتماعية (Rowe 1998/p95) .

وأكد على ثلاثة مبادئ أساسية في تحليل البنية الحضرية:-

مبادئ الـ(Gestalt) في دراسة علاقة (الحقل – الملمس – الحافة) وعلاقة الشكل بالخلفية.

السياقية.

اما (Alexander) فقد اكد في كتاب (A New Theory Of Urban Design-1987) على أن المدن الحديثة قد دمرها النمو الحديث، والهدف هو البحث عن الفضاء الموجب وتأكيد مركزية النمو الحضري من خلال خمسة مكونات أساسية في بنية النسيج الحضري وهي (المباني، ومحاور حركة المشاة، والفضاءات المفتوحة "الحدائق العامة"، وشوارع الحركة، ومواقف السيارات) من خلال التعامل مع العناصر الأساسية في بنية النسيج الحضري للمدينة بوصفها مراحل ديناميكية متداخلة، وبهذا نحصل على فكرة المدينة المتكاملة شموليا مرة أخرى. أكد (Alexander) تعريف بنية النسيج الحضري من خلال تعريف محاور المشاة إذ إن ارتباطات محاور المشاة تعرف النسيج الحضري، في حين أن اعتماد المدن الحديثة مبدأ التدرج الوظيفي في التنطيق وفي العلاقات بين أجزاء المدينة وعزل الفعاليات المختلفة أدى الى تجزئة نسيج المدينة.

كما أكد فكرة المركز الحضري الذي تتداخل فيه الفعاليات مقابل التدرج الفضائي إذ يظهر التكامل الشمولي في مراكز المدن التقليدية، بينما تبنى المدن الحديثة وفق أجزاء موضعية فيكون الكل مجموع من أجزاء موضعية ولا يمتلك كياناً خاصاً مميزاً (Alexander 1987/p93).

اما (Gosling) فقد قدم في طروحاته وصفا للبنية الحضرية من خلال أجزائها الموضعية ومن خلال تأكيد المسار والعقد وتحقيق الارتباط بين مسارات الحركة لتنتج أجزاء مميزة موضعيا ومن خلال ارتباط الأجزاء الموضعية ينتج الهيكل الشمولي للبنية الحضرية. وأكد حركة المشاة والساحات وتحديد فكرة المكان والاتجاه من خلال تأكيد التسلسل الفضائي بين البيئة القديمة في المدينة والأجزاء الحديثة، وفي تعريف المكان أكد الخصائص الموضعية للسطوح المحيطة بالفضاء من حيث ارتفاعاتها ودرجة احتوائه، إلا أن الدراسة في مجالها العام والأوسع كانت تؤكد مسارات الحركة والقطاع، وأهمية العقد في بنية النسيج الحضري (Gosling 1984/p 154).

ومن خلال تحليل عدد من النظم الحضرية التقليدية على وفق عنصري محاور الحركة و العقد، أكد (Gosling) أهمية الارتباطات الموضعية لمحاور الحركة في تحديد الخصائص الشمولية للبنية الحضرية.

يتأكد هنا ان البنية تتشكل من علاقات أساسية ترتبط بقواعد نسقية تعطي للبنية خصائص اسماها بعض الباحثين بالشمولية، وهي مغايرة لخصائص العناصر، والبنية تحمل مجموعة من التحولات وهي ليست شكلاً ساكناً، ويمكن تعريف بنية النسيج الحضري بأنها تتشكل بشكل اساسي من مكونين أساسيين (مغلق) وتمثل أصغر وحدة كتلة مفتوحة، وتمثل نواة لفضاء مفتوح. ترتبط المكونات المغلقة مع بعضها والتي بتشكيلاتها تعرف الكتل الحضرية، أما المكونات (المفتوحة) فأنها بتجميعها تشكل المحيط الكلي ويعرف الفضاءات الحضرية الذي يربط الكتل الحضرية، ويميز العلاقة بين الكتلة والفضاء المفتوح عن النسق الحضري.

كذلك أوضحت الدراسات أن البنية تتكون بالأساس من بنية أساسية تسمى (بنية عميقة) تشكل وتؤثر في التشكيل واخرى التي تسمى (البنى السطحية) وتظهر البنى السطحية نتاجاً للتحولات المتعددة التي تحصل من خلال ثبات البنى العميقة التي تولدها.

ووفق ما ذكر فان بنية المدينة هي انعكاس لحالة العلاقات في صورة المدينة حيث تدخل اجزاؤها في علاقة مع الكل وفق قوانين خاصة بها تحكمها سلسلة من التحولات تعمل على خلق وبلوغ حالة التوازن الشامل بفضل قدرتها على الضبط الذاتي، وتعد المدينة حية بمقدار استمراريتها وفق خصائص البنية – حيث تمر بتحولات في بناها السطحية مع ثبات بناها العميقة. (الجمالي، 2004، ص44).

1-1- مفردات البنية الحضرية:

يتضح انطباق خصائص البنى وعلاقاتها على البنية الحضرية ومنها بنية المدينة – ويمكننا ان نرى ان المكونات الاساسية لهذه البنية تتمثل من خلال نواتي الفضاء والكتلة والخصائص المرتبطة بانساق الفضاءات والكتل، وهذا ما يعطي للبنية الحضرية خاصية مهمة جداً هي ارتباطها بالمكان.

هذا على المستوى الفيزياوي، اما من ناحية القيم المرتبطة بالهوية والمكونات الاجتماعية والثقافية والديموغرافية تكون للبنية الحضرية بنى عميقة وبنى سطحية مرتبطة بالمكونات والخصائص الثقافية، والبعض يدخل في علاقات (ركزيه او مباشره) مع البنى الفيزياوية من خلال مكون (الشكل) وارتباطه بالذاكرة والاخر يدخل في علاقات سطحية مع المكونات الفيزياوية للفضاء والكتلة.

وقد جرت عدة دراسات لتصنيف مكونات البنية المكانية ، استندت معظمها على دراسة (Lynch) الرائدة (The Image of the City,1960) التي سبق ذكرها والتي اثبت فيها ان المدينة او اية بيئة مبنية تكون قادرة على توليد صور ذهنية قوية ومتماسكة عند أي متلقي، اذا كان من الممكن فهمها بصيغة انماط شكلية (Formal Patterns) ذات استمرارية وحضور عاليين مع وجود مجموعة من الاجزاء المتميزة عن بعضها والمتفصلة بشكل واضح ومقروء.

1-1-1-صورة المدينة:

قدم لنج منذ الستينيات طرحة المشهور حول صورة المدينة Image of the city بكونها بنية لها سلسلة من العناصر النمطية وهي مهمة لهيمنتها البصرية كتلميحات للتوجيه وكعلامات لخصائص اجتماعية او تاريخية او وظيفية للمدينة. وقد حدد عناصر البناء الفيزيائي الخمس لهيكل المدينة التي يستخدمها الناس عادة في بناء مخططاتهم الذهنية (Mental Schemata) عن المكان وهي : المسارات (Paths) والحافات (Edges) والقطاعات (Districts) والعقد (Nodes) والمعالم (Landmarks)، ولأجل استخلاص مفردات البنية الحضرية بربط المكونات الفيزيائية مع المكونات الثقافية والادراكية سيتقصى البحث ثلاثة طروحات اساسية بدءاً ب(صورة المدينة).

ورغم كثرة تداولها الا ان طرحها هنا باختصار جاء لأهميتها ولاستخلاص مفردات البنية الحضرية.

- **المسارات Paths**
- **الحافات Edges**
- **القطاعات Districts**
- **العقد Nodes**
- **المعالم Landmarks**

1-1-2-1- الكتل الحضرية :

تتمثل الكتل الحضرية بحجم ونسق وارتفاع الاجزاء الكتلية واسلوب ترابطها كأبنية وشواخص، وتظهر المقومات المختلفة كأنماط وانساق تحدد الجانب المورفولوجي للمدينة او البنية الحضرية، (الاشعب، 1983، ص10)، وتشكل الكتل مجموعة متلاحمة تنتشر في مجالات تحددها الطرق ويقسمها جزئياً التقطيع، وهو يشكل الاستعمالات الحضرية المملوءة ، ويمكن تمييز ثلاثة أنماط اساسية لأنواع الكتل الحضرية:

- نمط الكتل المستقلة (تكوين منفصل).
- نمط تشكيل بين الكتل (توازي – تقاطع – تمركز – خطية).
- نمط الفضاءات الداخلية : وتظهر الكتل البنائية في هذا الاتجاه ملتحمة او شبه ملتحمة مع بعضها وتلتف حول الفضاءات الداخلية (Henry, 1990, p31).

1-1-2-2- الفضاءات الحضرية :

تمثل الفضاءات التي تتوفر من خلال انماط الكتل وانساقها واسلوب ترابطها ويسهل الاحساس بالفضاءات عندما تحدد بكتل الابنية، وكلما التئمت الكتل مع بعضها يزداد انغلاق الفضاء وتحديده، وتعتمد درجة الانغلاقية على النسبة بين ارتفاع المباني المحيطة والمسافة الافقية بينها، وهذا ما امتازت به المدن التقليدية.

لقد أكد كولن (Cullen) (Cullen, 1961, p11) على ان ظاهرة ترابط الابنية قد تعطي متعة بصرية اعلى من رؤيتها بصورة منفصلة، وهذه النقطة قد تم تأويلها بمصطلح (التعقيد البصري) الذي يوفره الترابط المذكور اعلاه كمصطلح مضاد للـ (انفرادية) . ويؤثر تخطيط النسيج العمراني لأية مدينة على مخططها البصري وكذلك على اماكن وضع العناصر البنيوية فيها.

لقد تمت دراسة انماط الفضاءات الحضرية وطبيعة تعريفها بالكتل الحضرية في دراسات المدن، وقد ظهرت التكوينات الحضرية عبر التاريخ، فضلاً عن التكوينات الشبكية في الحداثة وصيغ متعددة من الربط بينها.

1-1-2-3- استعمالات الارض :

ان استعمالات الارض في المدينة ما هي الا نتاج السلوك الفردي الجماعي للسكان كافة بدافع من قيمهم ومثلهم، والسلوك الانساني هو التصرفات الفردية والجماعية التي تؤثر وتتأثر باستعمالات الارض، وعبر الزمن ارتبطت فعاليات الانسان بحالة من (تنطيق) مكاني لهذه الفعاليات فنشأت مناطق سكنية ومناطق تجارية ومناطق حكومية او عامة او دينية – فضلاً عن ظهور تداخل تكاملي بين هذه الاستعمالات التي مثلت وظائف المدن، وهذه الفعاليات والاستعمالات انعكست فيزياوياً بالأنماط السابق ذكرها على مستوى الكتل الحضرية والفضاءات الحضرية، فالأنماط الفضائية تعد انعكاساً وليس اقحاماً على طريقة حياه الناس وانعكاساً للثقافة والقيم والسلوكيات التي تمثل الهوية المميزة للمجموعات الثقافية والاجتماعية.

فضلاً عن ذلك فان هناك عوامل اخرى تؤثر في استعمالات الارض داخل المدن يمكن ايجازها: (حيدر،1999، ص151).

العوامل الطبيعية Natural Factors، العوامل الاقتصادية Economic Factors وتقسم الى (قيمة الارض Value Land، عامل المنافسة Competition، عامل النقل Transportation)، العوامل التقنية Technological Factors، تغير نمط الاستثمار العائد على قطعة الارض Change in the Pattern of Land Investment، التغير في نمط الاستثمار المجاور Change in the Pattern of Investment Next to the Activity.

تسهم هذه العوامل ، مجتمعة او منفردة في توزيع استعمالات الارض داخل نطاق المدن، وتنعكس استعمالات الارض الحضرية والتي تمثل علاقات اجتماعية واقتصادية ضمن البيئة الحضرية كفعاليات ونشاطات مختلفة معرضة للتغير نتيجة هذه العلاقات.

الطرح الثالث الذي يتم تقصيه في استخلاص مفردات البنية الحضرية هو مفهوم الشبكة الحضرية urban web حيث تطور مفهوم العقدة ليعني عقد العناصر الطبيعية وعقد الفعاليات الانسانية والعقد المعمارية كما تطرح الترابطات بينها وكذلك التدرجات الهرمية لهم.

1-2- الشبكة الحضرية Urban Web :

يطرح Nikos Salingaros مصطلح الشبكة الحضرية Urban Web ويعرفها على انها:

البنية التنظيمية المعقدة الموجودة اساساً في الفضاء بين البنايات، فكل بناية تحوي او تأوي واحدة او اكثر من عقد الفعاليات الانسانية وتتشكل الشبكة الحضرية من العناصر الخارجية والعناصر الرابطة بين تلك العقد كالمماشي والمناطق الخضراء، الجدران الحرة والطرق وغيرها. (Salingaros, ,2002,p2).

تتولد الشبكة الحضرية من مجموعة من العمليات التي تحدث ضمن مجموعة من العناصر التي تشكل المبادئ البنيوية الحضرية وهي العقد والترابطات والتنظيم الهرمي.

1-2-1- المبادئ البنيوية للشبكة الحضرية – Structural Principles of Urban Web :

- العقد Nodes:

تتمركز الشبكة الحضرية حول عقد الفعاليات الانسانية والتي من تفاعلاتها مع بعضها تتشكل الشبكة، هنالك انواع مختلفة من هذه العقد كالبيت، العمل، المتنزه، المخزن، المطعم، الكنيسة...الخ، وتعمل العناصر الطبيعية والمعمارية على تعزيز عقد الفعاليات الانسانية ومساراتها الرابطة.

- الترابطات Connections:

هي شكل من العلاقات والروابط ثنائية الاتجاه، تصل بين عقد الفعاليات الانسانية، ان اقصر الترابطات من عقدة الى اخرى هي الخط المستقيم ولكن بعض تلك العقد تحتاج الى طرق منحنية الشكل احياناً واخرى متعرجة، وتعرف المسارات الناجحة كحافة Edge بين مناطق تخطيطية متغايرة وتتشكل على طول الحدود الفاصلة بينها.

- التنظيم الهرمي Hierarchy:

تنظم الشبكة الحضرية نفسها بان تخلق تنظيما هرميا من الترابطات على مستويات مختلفة من المقياس فتصبح متعددة الترابطات ولكنها ليست فوضوية فالعملية التنظيمية تتبع ترتيباً محكماً، بدءاً من المقياس الصغير (المماشي) وصولاً الى الاعلى مقياساً (الطرق متعددة السعة)، ان هذا النوع من التسلسل الهرمي لايمكن ان يتشكل بصورة مفاجئة ومرة واحدة ولكن تدريجياً عبر الزمن.

1-2-2- طبيعة الترابطات في الشبكة الحضرية:

يتطرق البحث الى الترابطات Connections لما لها من اهمية في تشكيل الشبكة الحضرية وصورة المدينة، ان الترابطات في التصميم الحضري تربط ثلاث انماط من العناصر مع بعضها البعض. (Salingaros,2002,p4).

- العناصر الطبيعية Natural Elements:

كحافة النهر او مجموعة الاشجار او كعقد من المزارع الخضراء.

- عقد الفعاليات الانسانية Human Activity Nodes:

فالفعاليات الانسانية هي التي تعرف العقد، كالمناطق الطبيعية والمناطق السكنية والتجارية.. الخ ويعزز من عقد فعالياته الحيوية.

- العناصر المعمارية Architectural elements:

وتتضمن كل ما يبنيه الانسان لربط العناصر الطبيعية ويعزز من عقد فعالياته الحيوية.

ان جزءاً من الترابطات التي يقترحها Salingaros تكون بصرية ومرئية وتشكل صورة الترتيب الحضري للعناصر في المشهد الكلي، والاخرى قد تكون انساق ضمنية وترابطات غير ظاهرة. (Salingaros,2002,p3).

1-3- استخلاص مفردات البنية الحضرية:

ان الاساس الذي تم بناءه من قبل لنج حول ما يمكن ان يعتبر (مكونات اي كيان حضري), و هي خمسة مكونات : المسارات paths , الحافات edges , القطاعات districts , العقد nodes والشواخص أو العلامات الدالة landmarks، يبقى صالحاً للتحليل ولكن تتم مقارنته بالأطروحات الاخرى وصولاً الى المفردات النهائية التي ستستخلص بالبحث.

1- **المسارات – تبقى المسارات من اهم المفردات على المستوى الحضري، وهي اساسية على المستويات الفيزيائية واساسية على مستوى الادراك والوضوح في البنية الحضرية.**
2- **عقد الفعاليات الانسانية – حيث تلعب الفعالية الانسانية الاساس الذي تنشأ منها استعمالات الارض، فمنها تلك التي تستمر ومنها تلك التي تتوقف او تتغير عبر الزمن، وحيث ان المدينة كيان حي وليس مجموعة كيانات فيزيائية فقط فيتم اضافة عقد الفعاليات البشرية كتصنيف للعقد في المكون الحضري، ان هذه العقد تغطي مكون القطاعات وبنفس الوقت تربط التكوين الفيزياوي بالنمط الوظيفي والاستخدامي.**
3- **الحافات – وتمثل كل من الحافات الطبيعية كالانهار والحدود الطوبوغرافية وتلك المقامة من قبل الانسان كالاسوار.**
4- **ونستخلص ايضاً العلاقة الثانية المتمثلة بالترابطات بين العلاقات وتدرجاتها وتوضع كالاتي:**
   - **الترابطات او التدرج الهرمي للعلاقات.**
5- **ان الشواخص التي اعتمدها لنج هي المستوى الدلالي الوحيد قد تم تضمينها في الاطروحات الدلالية الايحائية حيث تطرح كل المكونات بدلالاتها ومعانيها، وعليه فيكمن اضافة تصنيف ومؤشر اخر يمثل المستويات الدلالية والامكانية لكل العلاقات اعلاه.**

حيث ان الإمكان : هو عندما تختفي الملامح الفيزيائية وتبقى معانيها وحوادثها في ذاكرة المدينة والناس وارتباطها برمزية الأماكن وفيها، وبالتالي الإمكان يمثل وجود غير ظاهر لقوى كامنة في الامكنة للمكونات المدينة.

وعليه فان اهم المفردات التي ستوظف لتحليل البنية الحضرية والمعمارية والتي سيتم طرحها بشكل العلاقات الاساسية هي كالاتي :

1- العلاقات الاساسية على مستوى المحاور (المسارات).
2- العلاقات الاساسية على مستوى عقد الفعاليات الانسانية .
3- العلاقات الاساسية للحافات (الطبيعية والحضرية).
4- الترابطات او التدرج الهرمي للعلاقات
5- المستويات الدلالية ومستويات الإمكان للعلاقات اعلاه.

4-1- تتابع البنى الحضرية:

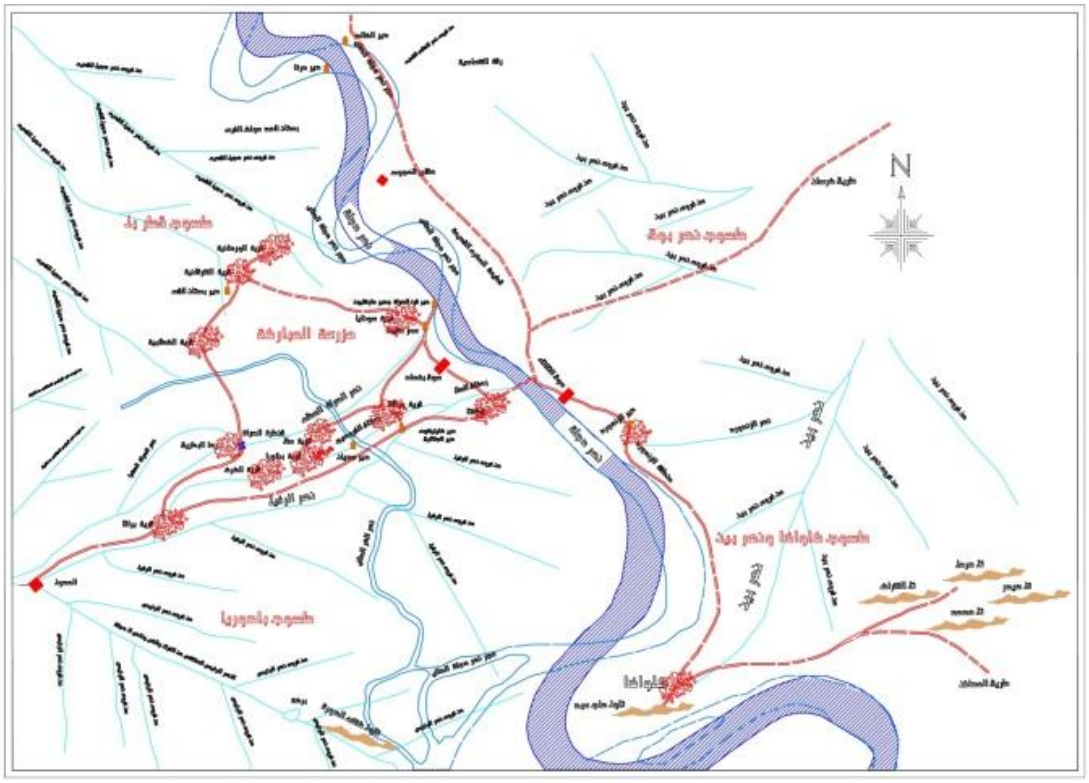
بعد استخلاص المؤشرات التي يمكن تطبيقها لأية بنية حضرية، نوضح هنا المقصود بالتتابع في البنى الحضرية، مصطلح التتابع Succession يعني التسلسل الزمني لأحداث معينة او ظواهر معينة – وبهذا فان المقصود بتتابع البنى الحضرية يعني دراسة اكثر من بنية حضرية لمكان معين يمر بمراحل عدة يمكن تحليلها كبنى حضرية تسلسلت في حضورها الزمني في نفس المكان.

لكن التتابع كما رأينا يرتبط بمفهوم التعاقب – الذي بحث كمبدأ بنيوي من التزامن، ومن هذا المنطق فان معنى التتابع في هذا البحث يحمل ايضاً تحليلات للقيم التتابعية وهي كما مر بنا خلال الفصل، تمثل الاحداث والتاريخ والمحيط ومن خلال تحليل هذا التتابع للبنى الحضرية يمكن تحديد الثابت والمتغير فيها، وتحديد البنى العميقة على المستويين الفيزياوي والدلالي في كل العلاقات الانسانية المطروحة (المسارات، وعقد الفعاليات البشرية والعقد المعمارية، والحافات) ثم الترابطات بين العلاقات وتدرجها والمستويات الدلالية ومستويات الامكان لها ومعرفة التحويلات في البنى السطحية عبر الزمن.

وهدف هذا البحث ايضاح التتابع للبنى الحضرية لمدينة بغداد ذات العمق التاريخي والتي مرت بعدد من المراحل التاريخية المتداخلة ثقافياً والمتعددة الجوانب سياسياً واقتصادياً واجتماعياً، فضلاً عن الجوانب الفيزياوية والادراكية، وايضاح العلاقات البنيوية الاساسية التي استمرت منها وابرازها امام المخططين والمصممين المعاصرين كمعرفة اصيلة في بناء مشاريع التطوير واعادة التأهيل الحضري والمعماري.

2- تحليل البنى الحضرية لمنطقة بغداد قبل بناء المدينة المدورة:

لقد تم اختيار هذه الحقبة من تاريخ مدينة بغداد لإيضاح اهمية الموقع الذي انشأت عليه مدينة بغداد المعروفة حاليا، ولإيضاح اهم ما احتواه هذا الموقع من موارد، زادت من اهميته وساعدت في نفس الوقت على نشوء كيان حضري متميز على مختلف الاصعدة والازمنة، وتبدأ هذه الحقبة كما تم الاشارة اليه سابقاً من الفتح الاسلامي للمنطقة سنة 634م وحتى نشوء مدينة بغداد المدورة سنة 766م. (الشكل 1).



الشكل (1) مخطط يوضح موقع بغداد قبل بناء المدينة المدورة
اعداد الباحث بالاعتماد على مخطط د.غادة السلق 2008

2-1- العلاقات الاساسية على مستوى المحاور (المسارات) للحقبة الاولى:

من خلال الاعتماد على المخططات التي اوردها المؤرخون والباحثون، وبالاعتماد كذلك على تحليل هذه المخططات وايضاح أهم العقد التي تواجدت في الموقع، يمكن ان نرى بعض من المسارات الرئيسية التي تواجدت في الموقع، ومن ابرز المسارات هو الطريق الواصل بين: **كلواذا – الزندورد – سوق الثلاثاء** (في الجزء الشرقي من نهر دجلة) **– الجسر – قطفتا – سوق بغداد – سونايا – قرية سال – قرية ورثالا – قرية بناورا – قرية الكرخ – قرية براثا – المحول** (في الجزء الغربي من نهر دجلة)، (الشكل الرقم 2)، ويكون هذا الطريق بشكل مستعرض على اتجاه نهر دجلة. وتقع على هذا الطريق القرى والمستوطنات الزراعية والمواقع التجارية، ويمثل هذا الطريق طريق المواصلات الرئيسي في الموقع والموازي للطريق النهري (الصراة العظمى والرفيل)، ويتجه هذا الطريق بعد كلواذا الى المدائن شرقاً

وبعد المحول الى الانبار غرباً، وبهذا يمثل الطريق المحور الحركي والوظيفي الرئيسي للموقع. وعند مقارنة هذا المسار بمدينة بغداد المعاصرة نجده مقارباً للمسار الذي يبدأ من الكرادة الحالية فشارع السعدون ثم شارع الرشيد حتى ساحة حافظ القاضي، ويعبر جسر الاحرار مرورا بالعلاوي ومحاذيا او قاطعا بعض اجزاء متنزه الزوراء ومارا بمنطقتي المنصور واليرموك حتى قرابة موقع ام الطبول. (السلق، 2008، ص18).

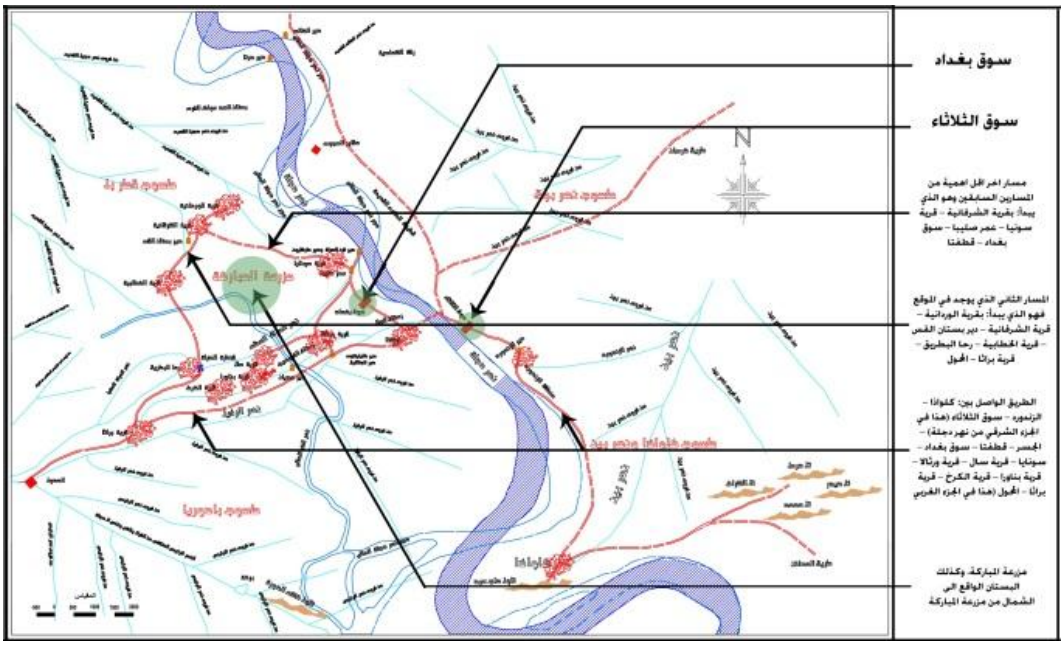
اما المسار الثاني الذي يوجد في الموقع فهو الذي يبدأ: **بقرية الوردانية – قرية الشرفانية – دير بستان القس – قرية الخطابية – رحا البطريق – قرية براثا – المحول**، (الشكل 2)، ويكون هذا الطريق بشكل عمودي على الطريق الرئيسي الذي تم ذكره، واستخدم هذا الطريق ايضا كطريق للمواصلات وللتجارة وصولا الى الطريق الرئيسي، وعند مقارنته مع بغداد المعاصرة نجدة مقارباً للمسار الذي يبدأ من العطيفية ثم الاسكان ثم المنصور (14 رمضان) ثم اليرموك حتى قرابة موقع ام الطبول.

ويوجد مسار اخر اقل اهمية من المسارين السابقين وهو الذي يبدأ: **بقرية الشرفانية – قرية سونيا – عمر صليبا – سوق بغداد – قطفتا**، (الشكل 2)، ويسير هذا الطريق بشكل موازي لنهر دجلة وعمودي على الطريق الرئيسي، والذي يقارب عند مقارنته ببغداد مسار شارع حيفا.

2-2- العلاقات الاساسية على مستوى عقد الفعاليات الانسانية للحقبة الاولى:

بالنسبة الى هذا المستوى من العلاقات وخصوصاً في تلك الحقبة، بالتأكيد فان الزراعة كانت تمثل العقد الاساسية في الموقع، فكما تبين اعلاه ان القرى نمت بشكل رئيسي على ضفاف الانهار والقنوات مما يدل على استخدام هذه الانهار لأغراض الري والزراعة بشكل رئيسي، إضافة الى الاستخدامات الاخرى.
كما تواجد في الموقع عدد من المزارع والبساتين الكبيرة التي كان لها دور اساسي في ابراز هذه العقدة الانسانية، مثل مزرعة المباركة، وكذلك البستان الواقع الى الشمال من مزرعة المباركة والذي كان لاحد ملوك الفرس. (الشكل 2).

اما بالنسبة الى العقدة الاخرى والتي تعتبر من العقد الانسانية المهمة في الموقع فهي متمثلة في وجود السوقين المهمين وهما: سوق الثلاثاء الواقع الى الشرق من نهر دجلة، وكذلك سوق بغداد الواقع الى الغرب من نهر دجلة يجتمع فيه التجار للبيع والشراء من كافة أنحاء البلاد بما يعكس أهميته آنذاك، فضلا عن الأهمية الكبيرة لموقع السوق في بغداد من حيث انه يتوسط العراق ، ولكونه يقع على طريق التجارة البرية والنهرية ويرتبط مع مستوطنات الشمال والجنوب بالمواصلات النهرية، مما يدل على ان الموقع كان ذو طابع تجاري مهم في المنطقة ولم يكن مكتفيا بالزراعة فقط، حيث ان موقع بغداد كان مركزاً تجارياً ووظيفياً مهما بسبب كونه واقعاً في المنطقة ما بين نهر دجلة والفرات ووجود قناتين هما الصراة والرفيل مما زاد من اهمية الموقع التجارية. (الشكل 2).
اما من اهم الاستعمالات التي تواجدت في المنطقة فهي السكن، حيث ان الموقع قد شكل بالأساس موقع سكني، لذلك نلاحظ انتشار القرى السكنية في مناطق متفرقة من الموقع،، ومن اهم القرى التي تواجدت في المنطقة هي قرية براثا وقرية سونيا والشرفانية والخطابية وزندورد وغيرها من القرى التي تواجدت في الموقع والتي استمرت الى ازمان لاحقة.



الشكل (2) مخطط يوضح المسارات والفعاليات الانسانية لمنطقة بغداد قبل انشاء المدينة المدورة سنة 634م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

2-3- العلاقات الاساسية للحافات (الطبيعية والحضرية) للحقبة الاولى:

في هذه الحقبة لم تكن الحافات واضحة وبارزة وخصوصاً الحافات الحضرية. اما بالنسبة الى الحافات الطبيعية فقد تتمثل بالأنهار الرئيسية وضفافها، بسبب كون هذا الموقع هو موقع رسوبي سهلي ذو تربة خصبة تجري فيه عدد من الانهار الصغيرة بالإضافة على القنوات المائية، حيث ان من الطبيعي ان تتواجد عدد من القرى والمستوطنات على ضفاف هذه الانهار او بالقرب منها، وفي مقدمة هذه الانهار هو نهر دجلة الذي يعتبر النهر الرئيسي في المنطقة والذي تواجدت على ضفافه عدد من القرى والمستوطنات، منها قرية سونيا (المنطقة الواقعة على جهة الغربي من جسر الصرافية الحالي)، وكذلك قرية قطفتا (منطقة المشاهدة الحالية)، وكذلك منطقة الشماسية (الصليخ حالياً)، وكذلك توجد قرية المباركة، هذا في الجزء الغربي من نهر دجلة، اما في الجزء الشرقي من النهر فتوجدت عدد من القرى مثل قرية كلواذا (تقع بين منطقة السعدون والكرادة حاليا)، وكذلك منطقة الزندورد التي تقع الى الشمال من قرية كلواذا. (عماد عبد السلام رؤوف,2004, ص75)، (الشكل 3).

فضلا عن ان نهر دجلة الذي يعتبر العقدة الرئيسية في الموقع يوجد كذلك عقدة اخرى ذات اهمية كبيرة للموقع والمتمثلة في القناتين هما (الصراة العظمى) و(الرفيل او كما يسمى بنهر عيسى)، واللذان ينطلقان او ينبعان من المحول غربا ويسيران بشكل شبه متوازي حتى يصبان في دجلة، وتوجد على ضفافهما عدد من القرى والمستوطنات مثل قرية سال، وقرية ورثالا، وقرية بناورا، وقرية الكرخ، وقرية براثا.
ونجد كذلك من خلال مؤشرات الموقع ان هاتين القناتين قد استخدمتا للمواصلات وكذلك لأغراض الري، مما يجعلهما من العلاقات الاساسية في الموقع. (الشكل 3).

فضلاً عن هذه العقد المتمثلة بنهر دجلة وكذلك بقناتي الصراة والرفيل، توجد في الموقع قنوات وانهار صغيره لم تكن ذات دور اساسي ضمن محيط الموقع، ولكن تواجدت عليها بعض القرى الصغيرة، مثل نهر بين الذي يقع الى الشرق من نهر دجلة، وكذلك فروع نهر الدجيل القديم الواقعة الى الغرب من نهر دجلة واللذان تواجدت عليهما عدد من القرى الصغيرة مثل قرية الوردانية، والقرية الشرفانية، والقرية الخطابية.(الشكل 3).
اما بالنسبة الى الحافات الحضرية فلم تكن واضحة، كون المنطقة لم تحتوي على كيانات حضرية واضحة بل احتوت على عدد من القرى الصغيرة المنشرة بأماكن متفرقة ضمن المنطقة، اي انها لم تكن محددة بحدود واضحة، وكذلك لم تكن تحتوي هذه المنطقة على مركز حضري اداري مما جعلها تفتقر الى ابسط مكونات المدينة الحضرية.

2-4- الترابطات او التدرج الهرمي للعلاقات للحقبة الاولى:

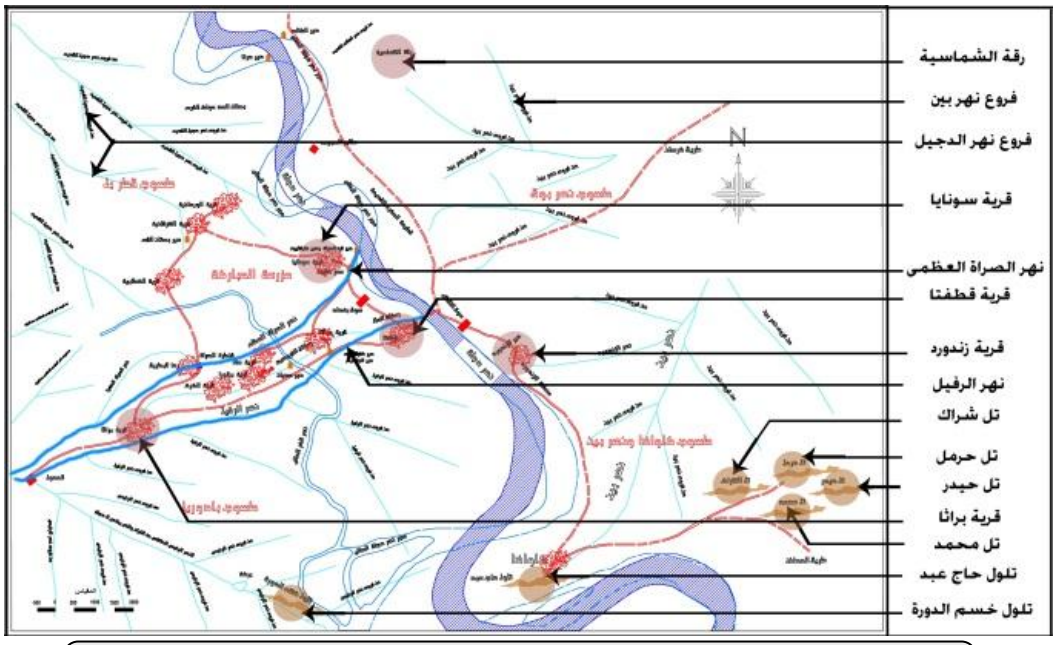
بالنسبة الى هذا المستوى من العلاقات وبالاعتماد على ما تم تحليله في عقدة العمارة يتبين ان القرى والمستوطنات لم تحتوي على نواة مركزية او نواتين ضمن القرية نفسها، ولكنها تقترب من صيغة التكوين العضوي وتتوزع فيها المسارات والمساكن الصغيرة بشكل غير هندسي و يمكن ان تحتوي على بعض من المساكن الكبيرة لكبار المزارعين او كبار التجار.

بما يخص بناية الدير الذي يعتبر المركز الديني ضمن القرى او المستوطنات، فكان موقعه في اطراف القرى وليس في وسطها، هذا بالنسبة الى التدرج ضمن القرية او المستوطنة نفسها، اما على مستوى الموقع ككل المتضمن عدد من القرى والمستوطنات، فتظهر هنالك علاقة اساسية متمثلة بالمحور الرئيسي الذي يربط بين السوقين الموجودين في الموقع (سوق الثلاثاء في شرق دجلة وسوق بغداد في غرب دجلة)، بالإضافة الى المحاور المائية الثلاثة (نهر دجلة ونهر الصراة والرفيل)، حيث يمكن اعتبار هذه المحاور النواة المركزية لتجمع القرى والمستوطنات ضمن الموقع ككل اما لأسباب الزراعة او اسباب التجارة والتنقل، بالإضافة الى وجود بعض المحاور الثانوية سواء كانت محاور حركية (مسارات) او محاور مائية التي كانت اقل اهمية من المحاور الرئيسية في تجمع القرى والمستوطنات حولها.

2-5- المستويات الدلالية ومستويات الإمكان للعلاقات اعلاه للحقبة الاولى:

بالنسبة الى المستويات الدلالية لموقع مدينة بغداد ضمن تلك الحقبة، فلم تكن ذات اهمية كبيرة لأننا لا نجد ضمن الموقع تأثيرات رمزية او دلالية للأقوام الذين تواجدوا ضمن الموقع، ولا للحقب الزمنية السابقة، على الرغم من وقوع هذا الموقع تحت الحكم والسيطرة الساسانية ولحقبات طويلة سبقت الفتح العربي، مما يدلنا على ضعف السيطرة الحاكمة عليه، ولكن نرى في نفس الوقت انتشار واضح للدين المسيحي.

وبالرغم من ذلك فقد احتوى موقع بغداد على بعض التلال مثل تل حرمل وتل حيدر وتل محمد وتل الشراك (في الجزء الشرقي من نهر دجلة) وتل خشم الدورة (في الجزء الغربي من نهر دجلة)، والتي يمكن ان نستدل منها على وجود مواقع اثرية لاتزال قائمة لكنها غير مكتشفة او غير مدروسة من قبل المختصين والباحثين، (الشكل 3).

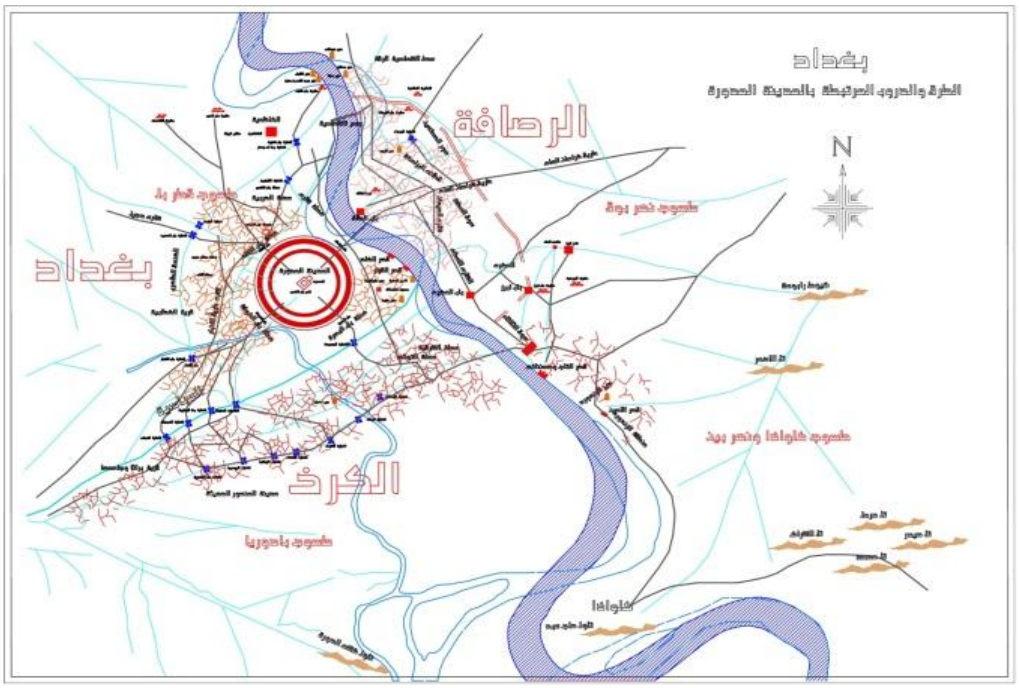


الشكل (3) مخطط يوضح الحافات الطبيعية والحضرية ومستويات الامكان لمنطقة بغداد قبل انشاء المدينة المدورة سنة 634م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لأحمد سوسة

مما سبق يتبين ان موقع مدينة بغداد قد احتوى على بعض العلاقات التي اصبحت مهمة ورئيسة في تاريخ مدينة بغداد والتي كان لها دوراً واضحاً في تحديد ملامح وشكل المدينة الحضري والعمراني، يمكن ان نستدل بان في هذه الحقبة لا يمكن اعتبار هذا الموقع (مدينة متكاملة) وذلك لأسباب مهمة واساسية في تكوين المدينة ومن اهمها: افتقاد الموقع نواه مركزية ادارية وسياسية واضحة فضلاً عن عدم وجود حافات تحدد ملامح المدينة حيث ان الموقع كان عبارة عن عدد من القرى السكنية الصغيرة المنتشرة على الانهار والقنوات النهرية والتي كان لها دور اساسي في نشأت هذه القرى، وعليه يمكن ان نضع جدولاً يبين اهم العلاقات الاساسية التي تواجدت في الموقع قبل بناء المدينة المدورة.

3- تحليل البنى الحضرية والمعمارية لمنطقة بغداد بعد بناء المدينة المدورة:

ان انشاء المدينة المدورة من قبل ابي جعفر المنصور في سنة 762 – 766م وجعلها عاصمة للدولة العباسية، كان لها دوراً كبيراً في تغير ملامح الموقع فضلاً عن انها تمثل اول دليل لنشوء كيان حضري، حيث اصبح للموقع مركز مدني وسياسي وعسكري في ان واحد، فاصبح في الامكان تسميتها بمدينة، وهي البداية الاولى لنشوء مدينة بغداد الحالية. (الشكل 4).



الشكل (4) مخطط يوضح موقع بغداد من سنة 762 – 766م الى سنة 1094م
اعداد الباحث بالاعتماد على مخطط د. غادة السلق 2008

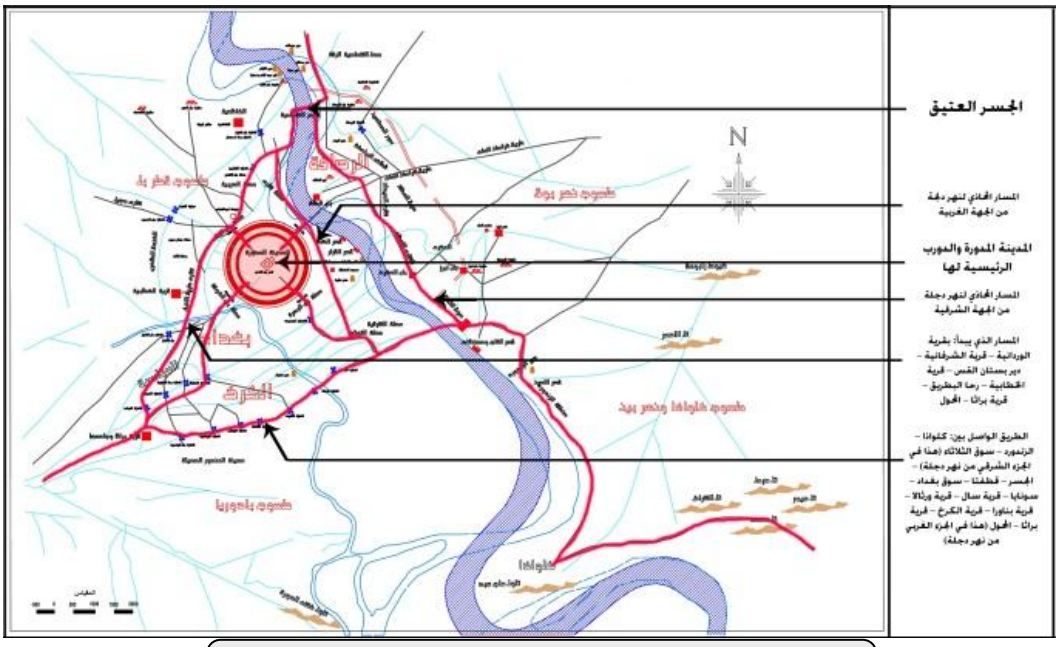
3-1- العلاقات الاساسية على مستوى المحاور (المسارات) للحقبة الثانية:

بالنسبة الى هذا المستوى من العلاقات نجد انه قد ظهرت علاقات جديدة مع احتفاظ العلاقات السابقة بأهميتها ضمن الموقع، حيث ان نشوء المدينة المدورة على يد الخليفة ابو جعفر المنصور وموقعها المركزي وكذلك بأبوابها الاربعة ساعد على ان تكون هنالك طرقا مؤدية اليها، وهذه الطرق تعود بدورها لترتبط بالمحاور الاخرى الموجودة ضمن الموقع،(الشكل 5).

وبقي المحور الرئيسي للموقع هو الطريق الواصل بين: **كلواذا – الزندورد – سوق الثلاثاء** (هذا في الجزء الشرقي من نهر دجلة) **– الجسر – قطفتا – سوق بغداد – سونايا – قرية سال – قرية ورثالا – قرية بناورا – قرية الكرخ – قرية براثا – المحول** (هذا في الجزء الغربي من نهر دجلة)، محتفظاً بأهميته، وقد زادت هذه الاهمية وازدادت قوته خصوصاً بعد نشوء العمارة وبشكل كبير في الجانب الشرقي من نهر دجلة وفي المناطق القريبة من سوق الثلاثاء مما ساعد على تعزيز العلاقة الاساسية للموقع، (الشكل 5)، وقد عاد وازدادت من اهمية هذا المحور بعد ظهور دار الخلافة في الجانب الشرقي من نهر دجلة مع استمرارية الجانب الغربي (الكرخ) من نهر دجلة.

اما المحور الرئيسي الاخر ضمن الموقع يتمثل بنفس المحور الذي كان موجوداً في منطقة بغداد قبل نشوء المدينة المدورة واستمر بعد انشائها، والذي يبدأ: **بقرية الوردانية – قرية الشرقانية – دير بستان القس – قرية الخطابية – رحا البطريق – قرية براثا – المحول**، ولكن في هذه الحقبة استمر هذا الطريق باتجاه الشرق ليعبر نهر دجلة في منطقة قرب الكاظمية الحالية ويستمر في الجانب الشرقي الى حد التقائه بالطريق المستعرض المحاذي لنهر دجلة في الجانب الشرقي. (الشكل 5).

اما بالنسبة الى المحاور الاخرى المتواجدة في الموقع، فقد ازدادت اهمية المحاور المحاذية لنهر دجلة على الجانبين الشرقي والغربي، وظهر بعد ذلك محور استمر لاحقا في الزمن يربط الرصافة بالجزء الغربي من دجلة بجسر في الموقع الذي كانت فيه قرية سونايا والتي استمرت بعد ذلك باسم العتيقة في العصر العباسي. (الشكل 5).



الشكل (5) مخطط يوضح المسارات لمنطقة بغداد بعد انشاء المدينة المدورة سنة 766م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

3-2- العلاقات الاساسية على مستوى عقد الفعاليات الانسانية للحقبة الثانية:

بالنسبة الى هذا المستوى من العلاقات فأننا نجد ان العقدة التجارية المتمثلة بالأسواق، كسوق بغداد في جانب الكرخ وسوق الثلاثاء في الجانب الشرقي من نهر دجلة، والتي كانت ذات اهمية كبيرة في الحقبة التي سبقت بناء المدينة المدورة، قد أزادت قوتها في الحقبة التي تلت بناء المدينة المدورة، وقد اختيرت هذه المنطقة (غرب دجلة – جنوب المدينة المدورة) من اجل انشاء الاسواق فيها خارج حدود المدينة المدورة والتي نمت بعد ذلك وازدادت اتساعاً شرقاً وغرباً واصبحت مركز محلة كبيرة وهي الكرخ والتي بقيت المركز التجاري لمدينة بغداد لفترة طويلة من الزمن، **وعليه نجد ان محلة الكرخ التي تأسست من خلال هذه الاسواق بقيت قائمة طيلة حياة مدينة بغداد وحتى اليوم، وهي بذلك اقدم منطقة لا تزال قائمة ومسكونة في نفس الوقت منذ عصر ما قبل المدينة المدورة وحتى اليوم ضمن مدينة بغداد.** (الشكل 6).

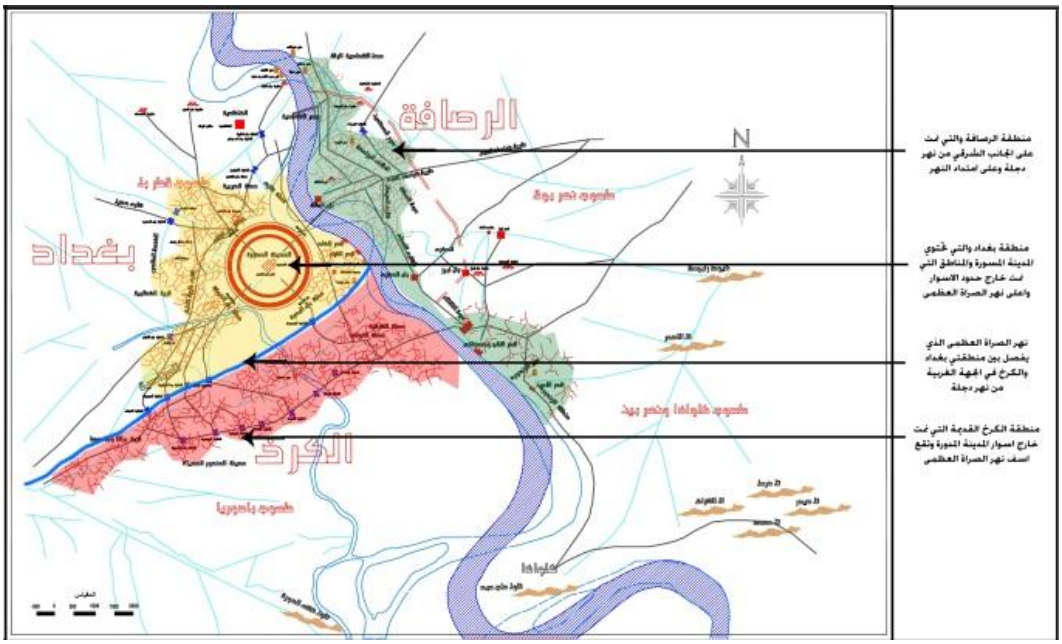
لقد ساعد نمو المدينة للفترة من (768م – 1094م) على تزايد نشاط الأسواق داخل وخارج المدينة المدورة، بحيث جذبت أعدادا جديدة من التجار والباعة والمشترين ، وأنعكس ذلك على زيادة عدد الدكاكين وتنوع ما يعرض فيها. (جواد وسوسة ،1958، ص44).

اما بالنسبة الى العقدة الثانية والمتمثلة بالزراعة فقد استمرت ونجد انها كانت ذات اهمية اقل ضمن هذه الحقبة، بسبب النمو المدني وظهور الفعاليات الحضرية، ولكنها ازدادت اتساعاً خارج المواقع التي ازدادت فيها الكثافة السكانية، حيث تمركزت بشكل كبيرة حول المدينة المدورة وكذلك في الجانب الشرقي من نهر دجلة المسمى بالرصافة.

وفضلاً عن هذا كله ظلت فعالية السكن هي الفعالية الاساسية في الموقع، حيث انتشرت القرى والمستوطنات السكنية على ضفاف الانهار والقنوات المائية، فضلاً عن قربها من المدينة المدورة التي اصبحت المركز الاساسي للمدينة، والتي كانت تمثل المركز السياسي والاداري والديني للمنطقة ككل، حتى بناء المسجد في الكرخ وظهوره كمركز ديني لتلك المحلة. (الشكل 6).

اما الرصافة فنستطيع ان نراها محلة لها كيانها بوجود جامع يمثل المركز الديني وقصر لابن الخليفة يمثل مركزاً مدنياً فضلاً عن كون موقعها الجغرافي يتمتع ببنية فيزياوية منفصلة عن المدينة المدورة وما جاورها من خلال نهر دجلة.

ظهرت في الحقبة التي تلت انشاء المدينة المدورة عقد فعالية انسانية اخرى مهمة وهي الفعالية السياسية، فبتأسيس المدينة المدورة التي اصبحت عاصمة للخلافة العباسية ظهرت الفعالية السياسية، مع ما يرتبط بها من فعاليات ادارية وخدمية ودفاعية، وقد استمرت هذه الفعالية السياسية عبر الزمن ولحقبات طويلة، وفي اغلب العصور ضم هذه الموقع مدينة كبرى كانت عاصمة للدولة الكبيرة.



الشكل (6) مخطط يوضح عقد الفعاليات الانسانية واسماء منطقة بغداد بعد انشاء المدينة المدورة سنة 776م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لأحمد سوسة

3-3- العلاقات الاساسية للحافات (الطبيعية والحضرية) للحقبة الثانية:

فيما يخص العلاقات الاساسية على مستوى الحافات وخصوصاً الحافات الحضرية فقد حصل تغير عن الحقبة السابقة وهي بناء المدينة المدورة من قبل ابو جعفر المنصور واحاطتها بثلاث اسوار دائرية فضلاً عن خندق مائي يحيط بالمدينة، وبالتالي فان هذه الاسوار تعد اول حافات حضرية احاطت بمركز الحكم والمركز الاداري والسياسي، والذي اصبح بعد ذلك مركز لمدينة بغداد ككل.

اما على مستوى الحافات الطبيعة ضمن هذه الحقبة وكما تم توضيحها في المخططات التي تم وضعها من قبل المؤرخين والباحثين لم تتغير، اي ان طبيعة الموقع الجغرافية والطبوغرافية لم تتغير كثيراً، فالعلاقات الطبيعة الاساسية بقيت على حالها، ولكن اصبح هنالك تعزيزاً مهماً للعلاقات الاساسية لهذه الحافات.

بالنسبة لنهر دجلة الذي يعتبر الحافة الاساسية ضمن الموقع ككل وعلى الرغم من ان المدينة المدورة التي انشاءها الخليفة ابو جعفر المنصور لم يتم توقيعها على نهر دجلة، الا ان اغلب واهم القصور التي بنيت في تلك الحقبة تم انشأها على ضفاف نهر دجلة وخاصة في المنطقة عند مصب نهر الصراة في دجلة، حيث اقيم قصر الخلد وقصر عيسى وقصر القرار وكذلك قصر الحسني على الضفة الشرقية للنهر وفي الجنوب من سوق الثلاثاء، فضلاً عن هذا فلم تتغير اهمية هذه الحافة الاساسية (نهر دجلة) من حيث استخدامه لأغراض الزراعة والري وكذلك لأغراض التنقل النهري. (الشكل 7).

اما بالنسبة الى الانهار والقنوات المائية الاخرى والتي شكلت الحافة اساسية ايضا ولكن بأهمية اقل من نهر دجلة مثل نهر الصراة ونهر الرفيل الذي اصبح يعرف باسم نهر عيسى، فقد بقيت اهمية هذه القنوات المائية من حيث اهميتها في الري والزراعة وكذلك التنقل النهري، وقد ازدادت من اهميتها حيث اقيم عليها عدد من الاسواق ضمن القرى والمستوطنات المبنية على ضفاف هذه القنوات.

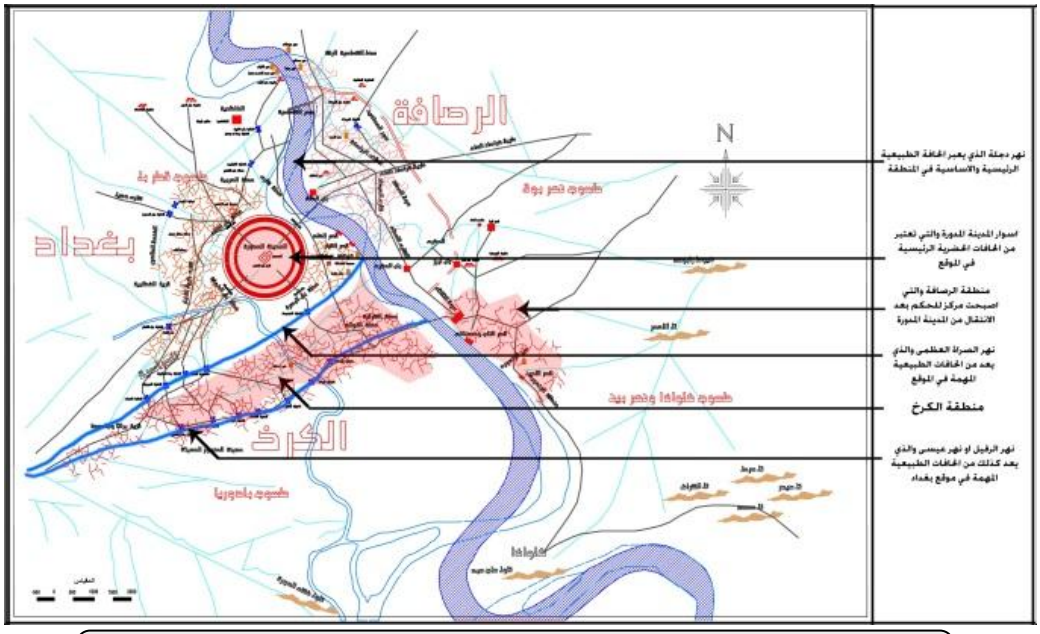
هذه الحافات الطبيعة الاساسية منها والثانوية زادت من اهمية الموقع الذي جرى اختياره من قبل الخليفة ابو جعفر المنصور لبناء مدينته المدورة، حيث وفرت امكانيات كبيرة بما يتعلق بأغراض الري والزراعة وكذلك كوسيلة نقل مائية، فضلاً عن ذلك فان هذه الحافات الطبيعية قد وفرت حماية دفاعية اضافية للمدينة المدورة والتي قد تم تعزيز هذه العلاقة الجديدة بحفر الخندق المحيط بالمدينة المدورة وخندق اضافي اخر من الجهة الغربية للمدينة. (الشكل 7).

3-4- الترابطات او التدرج الهرمي للعلاقات:

اهم علاقة في هذا المستوى من العلاقات التي تواجدت ضمن الموقع هي من خلال مركزية موقع المدينة المدورة والذي يعتبر اول مركز مدني واضح في تاريخ بغداد، حيث اصبحت هذه المدينة جزءاً اساسياً ومركزياً للموقع. و ساعد هذا على نشوء بقية اجزاء المدينة من اسواق وسكن وغيرها من الفعاليات وتجمعها بشكل رئيسي حول هذه النواة المركزية.

وان هذه المركزية القوية التي تمثلت بالمدينة المدورة التي بناها الخليفة ابو جعفر المنصور، قد بدأت تفقد قوتها بعض الشي نتيجة لأمر الخليفة بأنشاء الاسواق خارج حدود المدينة واسوارها مما ساعد هذا الشي على نمو الجانب الغربي من نهر دجلة (الكرخ) بشكل كبير، هذا فضلاً عن ان هذه المركزية فقدت قوتها وبشكل اكبر بعد نشوء الجانب الشرقي من نهر دجلة (الرصافة) والذي كان مخصصاً لنزول الجيش في بداية الامر، الا انه بدأ بعد ذلك يأخذ اهميته ضمن الموقع وكجزء اساسي ورئيسي في موقع بغداد، وعليه فان التدرج الهرمي لموقع بغداد في هذه الحقبة كان يبدأ طبعا بالمدينة المدورة وما احاطها والذي غلب اسم بغداد عليهما معا، ثم يليها الجانب الغربي من نهر دجلة القريب من المدينة المدورة (الكرخ)، ثم بعد ذلك يأتي من حيث الاهمية الجانب الشرقي من النهر (الرصافة). (الشكل 7).

ان هذا التدرج كان هو الاساسي في الموقع ضمن هذه الحقبة والذي استمر على حاله تقريباً حتى نهاية حكم الخليفة المأمون، حيث انتقل بعد ذلك مركز الخلافة من المدينة المدورة الى الجانب الشرقي من نهر دجلة القريب من موقع سوق الثلاثاء، حيث اصبح التدرج بعد هذا الانتقال في السلطة يبدأ بمركز الخلافة في الجانب الشرقي من نهر دجلة ثم يليه بعد ذلك الجانب الغربي من نهر دجلة (الكرخ) الذي بقي محتفظ بأهميته التجارية بسبب كثرة الاسواق فيه، ثم بعد ذلك يأتي دور (الرصافة) في الجانب الشرقي من نهر دجلة حيث انها بدأت بالنمو والتطور العمراني، ثم يأتي اخيراً دور المدينة المدورة التي انشأها ابو جعفر المنصور، حيث انها فقدت الكثير من قوتها وتداعت اهميتها والسبب في ذلك انتقال السلطة منها وتحولها الى سامراء وحتى بعد عودة السلطة الى بغداد فان الخليفة لم يعد الى المدينة المدورة بل اصبح دار الخلافة هو مركز السلطة، حيث ساعد هذا كله بانتهاء المدينة المدورة واصبحت جزءاً من الكرخ. (الشكل 7).



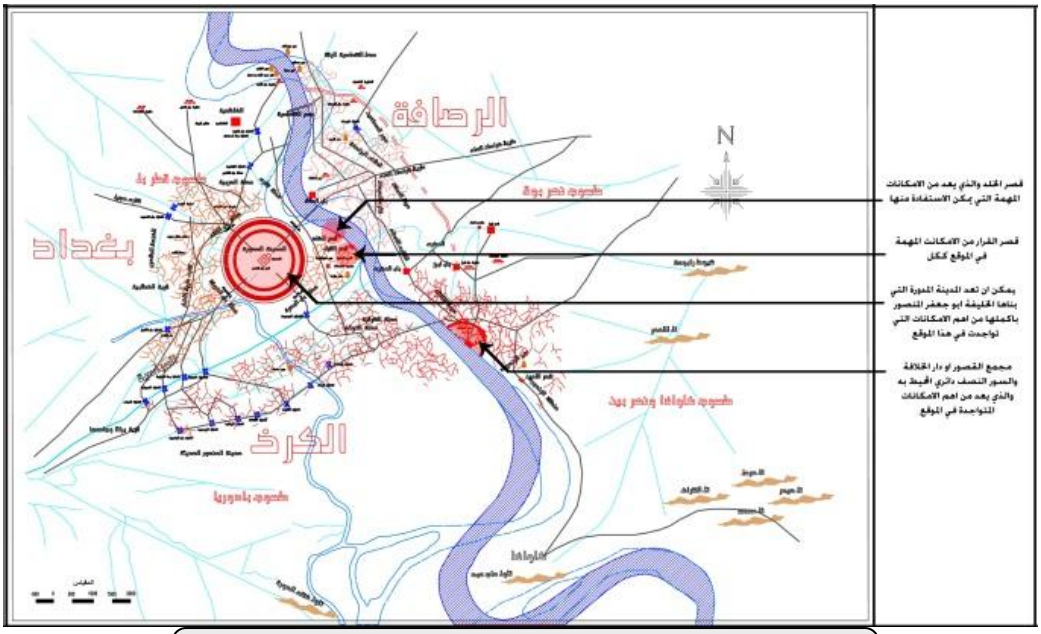
الشكل (7) مخطط يوضح الخانات الطبيعية والحضرية والتدرج الهرمي لمنطقة بغداد بعد انشاء المدينة المدورة سنة 813م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

3-5- المستويات الدلالية ومستويات الإمكان للعلاقات اعلاه للحقبة الثانية:

بالنسبة الى هذا المستوى من العلاقات فان للدلالة والرمزية اهمية كبيرة في هذه الحقبة، حيث نجد ان للمؤثرات ذات البعد الرمزي اهمية كبيرة، حيث تدخل هذه المؤثرات في قرار اختيار موضع المدينة المدورة وكذلك في اسماء هذه المدينة، حيث ان الخليفة ابو جعفر المنصور استعان بالمنجمين في اختيار تاريخ البناء مما يدل على الاهمية الرمزية في بناء المدينة المدورة، وكذلك تظهر المستويات الدلالية في اسماء المدينة المدورة مثل دار السلام او مدينة السلام تيمناً او محاكاه لاسم نهر دجلة الذي كان يدعى بهذا الاسم، ونجد هذا حتى في اسماء القصور التي بناها الخلفاء في تلك الحقبة مثل قصر الخلد حيث جاء الاسم تيمناً بجنات الخلد اي الامور ذات الدلالات الرمزية القوية.

ولا تخفى رمزية الشكل الدائري (المركزية) الذي اختاره الخليفة ابو جعفر المنصور وما يمثله المركز بالنسبة للخلافة، وقصر باب الذهب، احتل مركز المدينة ومتنافساً بذلك مع الجامع، مما يدل على تزايد القيم المدنية على القيم الدينية، فضلاً عن هذا فأننا نجد تجلي واضح لهذه الرمزية في فخامة القصور التي تم بنائها وفي غنى مفرداتها، وكذلك تظهر دلالات تأكيد سلطة الخلافة وهيبتها في العقد المعمارية التي تميزت بكبرها وفخامتها مثل ضخامة الاسوار وتأكيد تحصينها.

اما بالنسبة الى مستويات الامكان في هذه الحقبة من تاريخ مدينة بغداد فيمكن ان تعد المدينة المدورة التي بناها الخليفة ابو جعفر المنصور بأكملها من اهم الامكانات التي تواجدت في هذا الموقع وعلى مد العصور، ولذلك يأتي من اهميتها كأول مركز مدني، سياسي، اداري، ضمن الموقع، هذا فضلاً عن شكلها المميز والهندسي الذي زاد من اهميتها كمركز للخلافة. (الشكل 8).



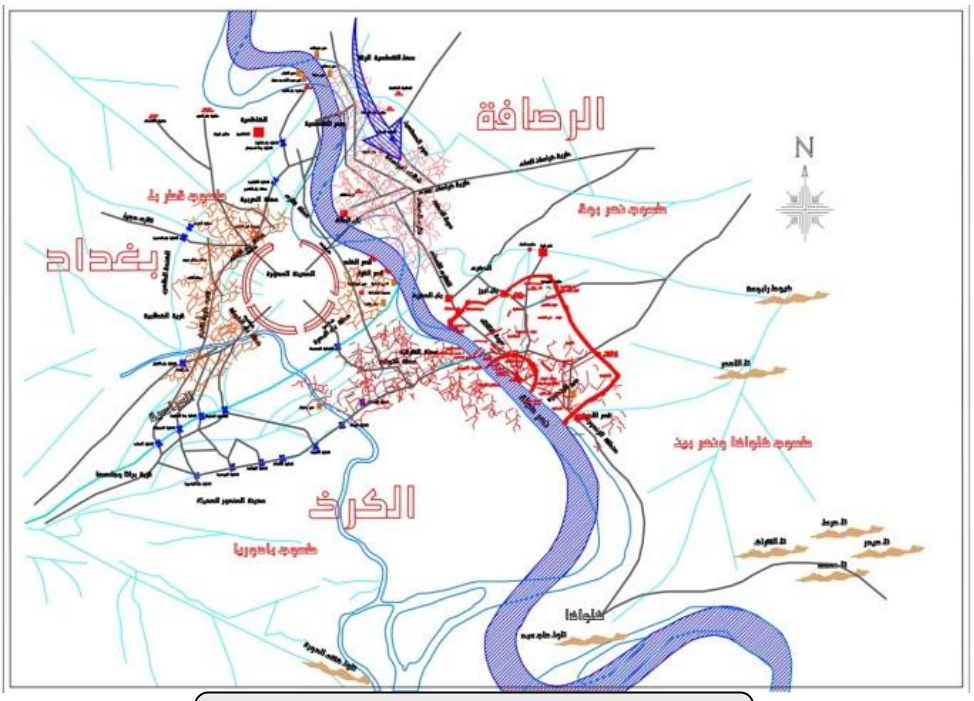
الشكل (8) مخطط يوضح مستويات الامكان لمنطقة بغداد بعد انشاء المدينة المدورة سنة 833م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

فضلاً عن المدينة المدورة، فقد تواجدت في الموقع وضمن هذه الحقبة بعض الابنية التي يمكن ان تعد من مستويات الامكان المتمثلة بالقصور التي انتشرت ضمن الموقع في تلك الحقبة. واهم هذا القصور (قصر باب الذهب، قصر الخلد، قصر عيسى، قصر القرار، وغيرها من القصور) التي كان لها دور اساسي وواضح في تحديد شكل المدينة الحضري. (الشكل 8).

مما سبق يتبين ان في هذه الحقبة من تاريخ مدينة بغداد قد احتوى الموقع على بعض العقد المهمة والاساسية والتي كان لها دور اساسي في تحديد ملامح وخصائص المدينة، ويمكن ان تعد هذه الحقبة هي الحقبة الاولى التي شهدت ظهور اول اشكال المدينة حيث احتوى الموقع على جزء مدني، سياسي، اداري، مركزي والذي تمثل بالمدينة المدورة التي بنها الخليفة ابو جعفر المنصور والتي كانت مركز للحكم والخلافة، فضلاً عن هذا المركز فقد احتوى الموقع على السكن والمتمثل بالقرى السكنية المنتشرة حول المدينة المدورة والقرب من العقد الاخرى مثل نهر دجلة وبقية قنوات وانهار المنطقة والتي كان لها دور اساسي في نشأت هذه القرى.
في هذه الحقبة من تاريخ المدينة يمكن تسمية محلاتها الثلاث (المدينة المدورة مع ما يحيطها – الكرخ – الرصافة) مثلت النشوء التاريخي للمدينة الكبرى Metropolis والتي امتدت عن حدود هذه المحلات فيزياوياً والتي كانت عاصمة لإمبراطورية كبرى سكن فيها وقصدها اناس من قوميات متعددة واديان ومذاهب عدة، وبدأت فيها الفعالية الثقافية والعلمية تأخذ مساراً رائداً فتأسست الهوية الحضرية والثقافية لها والتي استمرت عبر حقب عدة.

4- تحليل البنى الحضرية والمعمارية لمدينة بغداد الشرقية والغربية المسورة:

ان سبب اختيار هذه الحقبة من تاريخ مدينة بغداد بكونها تمثل اكتمال انشاء المدينة على الجانبين الشرقي والغربي من نهر دجلة واضح لها كيانها الفيزياوي الخاص، وكذلك ظهور منطقتي الكاظمية في الجزء الغربي والاعظمية في الجزء الشرقي من نهر دجلة، فضلاً عن ذلك فان طول الحقبة الزمنية التي استمرت عليها هذا المدينة التي يقارب ال 1000 سنة، والتي تبدأ من انشاء السور عام 1094م وتنتهي بهدم السور عام 1869م، مما جعلها فترة غنية بالأحداث بالبنى الحضرية والمعمارية المهمة والمتميزة في تاريخ مدينة بغداد. (الشكل 9).

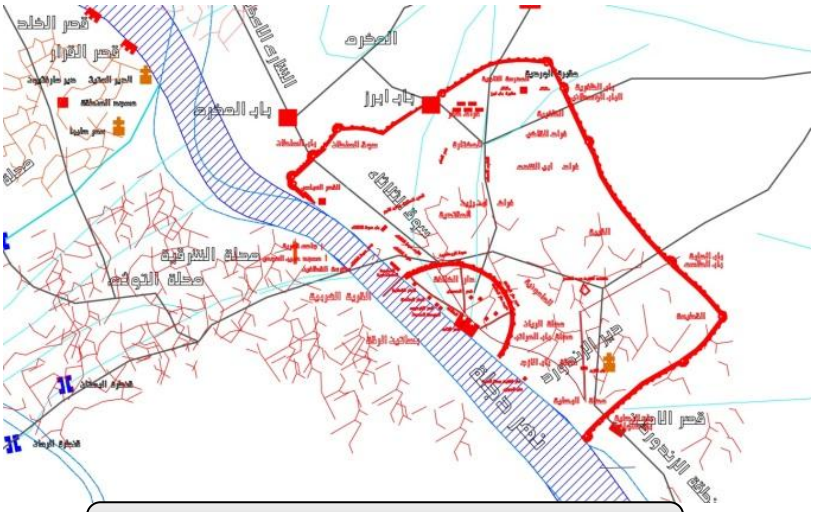


الشكل (9) مخطط يوضح موقع بغداد من سنة 1094م الى سنة 1869م
اعداد الباحث بالاعتماد على مخطط مصطفى جواد واحمد سوسة

4-1- العلاقات الاساسية على مستوى المحاور (المسارات) للحقبة الثالثة:

بالنسبة الى المسارات في هذه الحقبة من تاريخ بغداد يمكن ان تحدد بالمسارات التي تواجدت داخل الاسوار وكذلك داخل منطقتي الكاظمية والاعظمية، فضلاً عن المسارات التي كانت تربط بين هذه المناطق وبين جانبي نهر دجلة، وكذلك المسارات التي كانت تربط مدينة بغداد بالمدن المجاورة.

ففي جانب الرصافة تواجدت عدد من المحاور التاريخية داخل الاسوار وهذه المحاور **(الباب الوسطاني – القلعة، الباب الوسطاني – الاسواق، باب الطلسم – السنك، الكيلاني – الميدان، والميدان – شارع المستنصر)**. اما جانب الكرخ فقد كانت المحاور قليلة ومنتشرة بين الازقة السكنية ولكن يوجد مساراً واحداً واضحاً يمتد على طول منطقة الكرخ وبمحاذاة نهر دجلة والذي يوازي شارع حيفا في الوقت الحاضر وكذلك يمتد هذا المسار ليرتبط الجانب الرصافة عبر نهر دجلة. (الشكل 10).

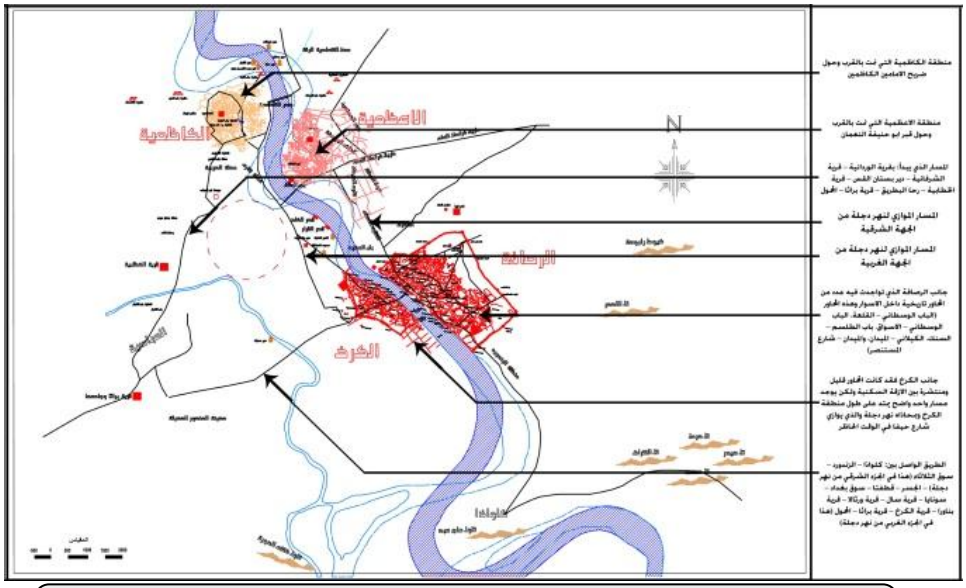


الشكل (10) المحاور التاريخية في جانبي الرصافة والكرخ
اعداد وايضاح الباحث بالاعتماد على مخطط بغداد لمصطفى جواد واحمد سوسة

اما الطريق الواصل بين: **كلواذا – الزندورد – سوق الثلاثاء** (هذا في الجزء الشرقي من نهر دجلة) **– الجسر – قطفتا – سوق بغداد – سونايا – قرية سال – قرية ورثالا – قرية بناورا – قرية الكرخ – قرية براثا – المحول** (هذا في الجزء الغربي من نهر دجلة)، والذي كان هو

المحور الرئيسي في الموقع، فقد بقي على حالة ولكن اهميته بدأت تقل بالنسبة الى الموقع كون المناطق السكنية بدأت بالانحسار باتجاه نهر دجلة، مما اضعف من اهمية هذا المسار وبقاء استعماله كأحد الطرق الرئيسية للربط بين مدينة بغداد والمدن المجاورة. (الشكل 11).

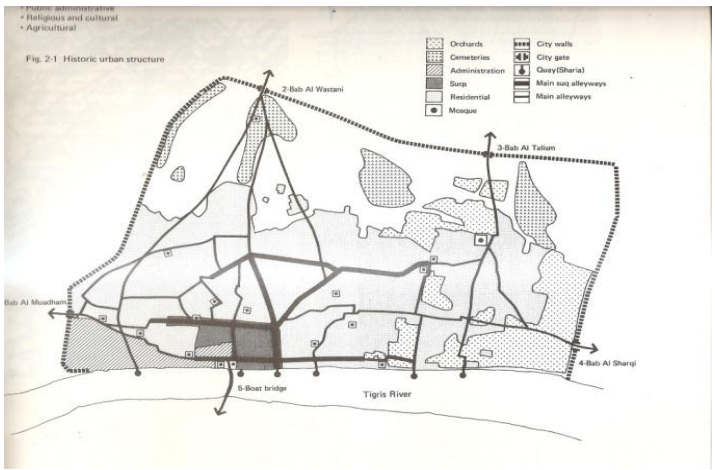
اما في منطقة الكاظمية على الجانب الغربي من نهر دجلة وكذلك منطقة الاعظمية على الجانب الشرقي من النهر فقد كانت المسارات داخلية منتشرة بين الازقة السكنية ومتمحورة بشكل رئيسي حول ضريحي الامام موسى الكاظم في الكاظمية ومرقد الامام ابي حنيفة في منطقة الاعظمية، فضلاً عن وجود مسارات اخرى تربط منطقتي الكاظمية والاعظمية عبر نهر دجلة، واخرى تربط منطقة الكاظمية بمنطقة الكرخ بمسار محاذي لنهر دجلة وكذلك مسارات تربط منطقة الاعظمية بمنطقة الرصافة بسمار محاذي للنهر ايضاً. (الشكل 11).



الشكل (11) مخطط يوضح المسارات وعقد الفعاليات الانسانية في منطقة بغداد بعد نشوء السور الشرقي سنة 1519م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

ان اهمية المسار الرابط بين ضفتي النهر قد ازدادت مع ازدياد تكاثف البناء على جانبي النهر حيث بقي النهر المحور الطبيعي ومورد الحياة وطرق المواصلات. وعليه فان المحور الرابط بين الضفتين قد ازداد اهمية، ويقوم اليوم بموقع جسر الاحرار. كما ان استمرارية المحور الى الجنوب من الكرخ وصولاً الى منطقة العلاوي والتي تؤشر المحور التاريخي، ان البوابة الرئيسية للسور الغربي كانت تقع في هذه المنطقة وكذلك موقع توقف قوافل المسافرين بين الحلة الى بغداد، اذ كانت الحلة هي الموقع الذي يتوقف فيه الراحلة في الفرات – وعليه تعرف اهمية هذا المحور الرابط بين طرفي المدينة وبنفس الوقت الرابط بالمواصلات مع خارج المدينة مع جنوب العراق وشرقه.

ويوضح المخطط الذي وضعته دراسة (J.C.C.P) في الثمانيات من القرن العشرين لمنطقة الرصافة المحاور التاريخية، وهذه المحاور داخل المدينة المسورة تظهر بوضوح المسارات الرابطة بين البوابات وضفتي النهر، فضلاً عن المسار الموازي للنهر وكما سبق القول، فان هذه المحاور تظهر المسارات في نهاية الحقبة العثمانية وعدم وجود تأشير لموقع دار الخلافة يوضح حقبتها التاريخية المحددة. (الشكل 12).



الشكل (12) المخطط الذي وضعته دراسة (J.C.C.P) في الثمانينات الذي يوضح المحاور التاريخية لمنطقة الرصافة
المصدر: دراسة (J.C.C.P)

4-2- العلاقات الاساسية على مستوى عقد الفعاليات الانسانية للحقبة الثالثة:

اما بالنسبة الى العقد التي كانت موجودة في الحقبات السابقة والمتمثلة بالأسواق التجارية، فقد استمرت وبشكل كبيرة ومتميز في هذه الحقبة، واستمر نمو الاسواق في مواقع كانت قائمة بها، وامتدت الى مناطق اخرى حول دار الخلافة وازداد تخصصها في مراحل لاحقة ضمن هذه الحقبة من تاريخ المدينة , واهمها سوق دعيت بسوق الريحانيين، دامت عبر الزمن لتبلور حولها منطقة الشورجة الحالية الواقعة قرب جامع الخلفاء , وهي احدى اهم المراكز التجارية لبغداد حتى اليوم، وكذلك سوق الصفارين وسوق الدهانة في الجانب الشرقي من بغداد، اما في الجانب الغربي من بغداد فهناك سوقين رئيسيين في المنطقة هما سوق الحدادين وسوق عيسى.

لقد بدأت عمارة الاسواق في هذه الحقبة بالوضوح في مسارات طولية ليست بالضرورة مستقيمة، تتقاطع معها مسارات معترضة مكملة، كان المسار الرئيسي مسقفاً بقباب مفتوحة الوسط من الاعلى وبشكل مستمر عبر محورية السوق، وهكذا كان وضع سوق الشورجة حتى مطلع القرن العشرين، ولا يزال واحد فقط من اسواق بغداد يحمل هذه الخواص العمرانية وهو سوق السراجين الموازي لسوق السراي والذي يفتح عليه باب جامع الوزير.

ولا تزال محاور هذه الاسواق قائمة الى اليوم كبنى واضحة في بغداد وان زال اسلوب تسقيفها الاول الا ان التسقيف استمر بأساليب اخرى خلال القرن العشرين، ومن اهمها اسواق باب الاغا واسواق الشورجة كما سبق ذكره واسواق منطقة الصدرية والسيد سلطان علي.

اما بالنسبة الى الفعالية الاهم في الموقع والتي هي فعالية السكن، فقد استمرت على ماهي عليه من الاهمية ولكن بشكل بدأ بالانحسار باتجاه نهر دجلة وداخل الاسوار بشكل رئيسي فضلاً عن تجمع السكن في منطقتي الاعظمية والكاظمية حول المراقد (جامع الامام ابو حنيفة النعمان في منطقة الاعظمية في الجزء الشرقي من نهر دجلة، ومرقد الامام الكاظم (عليه السلام) في منطقة الكاظمية في الجزء الغربي من نهر دجلة). (الشكل 11).

ان كل ما تبقى من النسيج التاريخي (التراثي) في مدينة بغداد يعود لهذه المنطقة داخل الاسوار في الرصافة والكرخ، وقد خرب جزء كبير من هذا النسيج، ولا تزال هناك قطاعات تخطيطها قائما على عضوية ذلك النسيج بأزقته وتضام بنيانه وان كانت قد تداخلت معها شوارع عريضة فتحت في القرن العشرين وهدمت اجزاء منه وبنيت محلها ابنية معاصرة – ولن نتطرق هنا الى خواص النسيج السكني التراثي بتكامل تكوينه الوظيفي السكني الاجتماعي، المناخي، والثقافي وعلى مدى مئات من السنين والتي تعود الى الحقبة العباسية المتوسطة.

وهذا النسيج هو من البنى العميقة الرئيسية على مستوى الفعالية السكنية وكذلك على المستوى الفيزياوي العمراني الاساسي لعلاقات الكتل والفضاءات في المدينة.

عقدة الزراعة التي كانت متميزة وواضحة في الحقب السابقة، اصبحت هذه العقدة ربما غير واضحة او غير معرفة بشكل كبير كما في السابق حيث لم يأت على ذكرها احد من المؤرخين او الباحثين او تحديد الاماكن التي استخدمت للزراعة ضمن المنطقة، بل اكتفوا بذكر ان المناطق التي تقع خارج اسوار المدينة الشرقية والغربية قد استخدمت للزراعة.

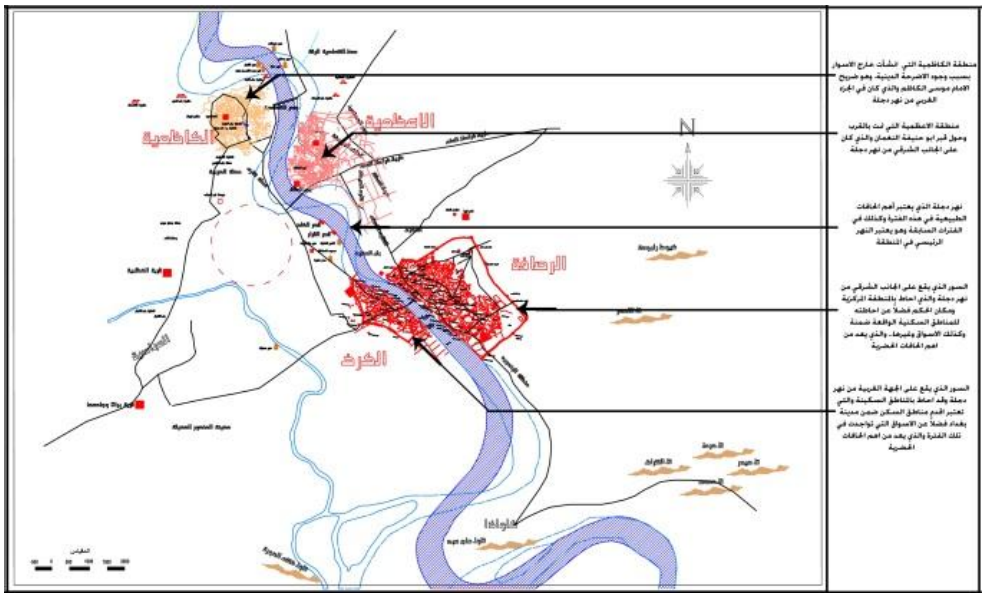
4-3- العلاقات الاساسية للحافات (الطبيعية والحضرية) للحقبة الثالثة:

طوال 1000 عام من تاريخ مدينة بغداد شهدت المنطقة تغيراً في جغرافيتها وطوبوغرافيتها، حيث انها لم تستمر على ما كانت عليه، وخصوصاً من ناحية الحافات الحضرية التي شهدت هذه الحقبة احاطة المدينة بأسوار ضخمة تحتوي على عدد من الابواب والتي كانت مكونة من جزئيين، جزء يقع على الجانب الشرقي من نهر دجلة والذي احاط بالمنطقة المركزية ومكان الحكم فضلاً عن احاطته للمناطق السكنية الواقعة ضمنة وكذلك الاسواق وغيرها، اما الجزء الثاني فهو يقع على الجهة الغربية من نهر دجلة وقد احاط بالمناطق السكنية والتي تعتبر اقدم مناطق السكن ضمن مدينة بغداد، فضلاً عن الاسواق التي تواجدت في تلك الحقبة. (الشكل 12).

وقد نمت مناطق اخرى خارج حدود الاسوار وهي على جانبي نهر دجلة، و نشأت هذه المناطق بسبب وجود الاضرحة الدينية، مثل ضريح الامام موسى الكاظم عليه السلام والذي كان في الجزء الغربي من نهر دجلة (منطقة الكاظمية حالياً)، اما الضريح الثاني والذي كان على الجانب الشرقي من نهر دجلة فهو ضريح ابى حنيفة النعمان (منطقة الاعظمية حالياً). (الشكل 12). وكما اتينا على ذكرها سابقاً.

بالنسبة الى الحافات الطبيعة التي كانت متواجدة في حقبات سابقة، فأهم الحافات الطبيعية في هذه الحقبة وكذلك في الحقبات السابقة هو نهر دجلة الذي يعتبر النهر الرئيسي في المنطقة والتي نمت على جانبيه الشرقي والغربي مدينة بغداد في مختلف ادوارها، فضلاً عن الجزء الشرقي والغربي المسور من مدينة بغداد والذي كانت على جانبي نهر دجلة.

اما بالنسبة الى بقية الانهار والقنوات التي تواجدت في المنطقة وفي حقبات سابقة فقد اختفت او لم تعد ذات اهمية للمنطقة، حيث ان المخططات التاريخية التي وردت من قبل المؤرخين والباحثين في وصف المنطقة في تلك الحقبة لم يأتوا على ذكر هذه الانهار مثل (نهر الصراة ونهر الرفيل)، اما بسبب اختفائها من المنطقة او لانها لم تعد نقطة تجذب الناس لأنشاء القرى والمستوطنات على جوانبها. (الشكل 12).



الشكل (12) مخطط يوضح الحافات الطبيعية والحضرية في منطقة بغداد بعد نشوء السور الشرقي سنة 1519م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

وعلية فان نهر دجلة هو الحافة الطبيعة الوحيدة التي استمرت طوال تاريخ مدينة بغداد، اي قبل نشوء المدينة المدورة الى يومنا هذا، كعقدة حيوية مهمة في حياة مدينة بغداد، واحد الاسباب الرئيسية في انشائها. (الشكل 13).

الشكل (13) نهر دجلة (الحافة الطبيعية الرئيسية لمدينة بغداد).
عن (الانترنت www.iraker.dk)

4-4- الترابطات او التدرج الهرمي للعلاقات للحقبة الثالثة:

بالنسبة الى التدرج الهرمي في تلك الحقبة من تاريخ بغداد فقد انحسر التجمع السكاني في اربع مناطق واضحة ورئيسية ضمن المنطقة ككل، حيث يظهر ذلك واضحاً في المخططات التي وردت من قبل المؤرخين والباحثين، وهي متمركزة في منطقتي الرصافة المسورة والاعظمية على الجانب الشرقي من نهر دجلة، وكذلك في منطقتي الكرخ والكاظمية على الجانب الغربي من نهر دجلة.

فضلاً عن وجود تدرج في الكثافة والارتفاعات كلما ازداد الاقتراب من مركز المنطقة، كما في منطقة الكاظمية ومنطقة الاعظمية حيث تزداد الكثافة السكانية والبنائية كلما ازداد الاقتراب من ضريح الامام موسى الكاظم ومرقد الامام ابي حنيفة، وكذلك الحال في منطقتي الرصافة والكرخ حيث تزداد هذه الكثافة باتجاه المساجد والكنائس والاديرة وكذلك الحال باتجاه الاسواق، وعليه فان هذا التدرج اعتمد بالأساس على وجود نواة مركزية (سواء كانت مركزية من حيث الوظيفة او من ناحية الحجم والارتفاع، او حتى من ناحية الاستخدام اليومي كالأسواق والجوامع)، وتنتشر حول هذه النواة المركزية بقية مكونات المدينة او المنطقة فضلا عن ارتباطها بالمناطق المجاورة لتوفير الاحتياجات التي تعذر وجودها في هذه المناطق.

وقد اصبح هناك تدرج وانتقال في مركز الحكم، حيث انتقل المركز من دار الخلافة الذي هو مجمع لقصور الخلفاء الى القلعة في القرن السادس عشر واعتبارها المركز العسكري الرئيسي، وقد استمر في نفس الحقبة استخدام القصر العباسي كمركز عسكري ومركز مدني ضمن ابنية القلعة، ثم دار الوالي، ثم ظهور القشلة والتي اصبحت مركزا للجيش ومركزا مدنياً.

وعليه فان اهمية دار الخلافة بكونها مركزاً حضرياً قد انتهت مع نهاية الحقبة (نهاية الاحتلال العثماني)، وبذلك نؤشر انتقالا لموقع المركز السياسي الحضري الى الشمال منها وعلى امتداد دجلة مع ابنية المدرسة الرشدية (ابنية المحاكم في منتصف القرن العشرين ومنتدى بغداد حالياً)، ثم مبنى القشلة الذي بني في منتصف القرن التاسع عشر مروراً بالسراي وهو المركز الحكومي الرئيسي الذي بدأ بناؤه مع بدء الحكم العثماني في القرن السادس عشر ثم دار الوالي، وصولاً الى المدرسة العلية ثم ابنية القلعة، وكانت تجاور هذا المجمع الحكومي ساحة الميدان والتي عدت العقدة الفضائية الرئيسية للمدينة في نهاية الحقبة العثمانية.

4-5- المستويات الدلالية ومستويات الإمكان للعلاقات اعلاه للحقبة الثالثة:

ان المستويات الدلالية والرمزية في هذه الحقبة من تاريخ مدينة بغداد، ربما لم تكن بالوضوح الذي كانت علية في الحقبة السابقة، حيث ان تكوين المدينة جاء نتيجة تتابعية لتحولات ظهرت على مدينة بغداد ككل، ومع ذلك فان هذه الحقبة لم تخلو من هذه الدلالات الرمزية، وربما في مقدمتها هو وجود الرمزية الروحية العالية والتي تواجدت في الاضرحة والمتمثلة بضريح الامام موسى الكاظم في الجانب الغربي من نهر دجلة وفي منطقة الكاظمية بالتحديد والتي كانت تعرف بمقابر قريش في اوقات سابقة، وكذلك بمرقد وقبر الامام ابي حنيفة النعمان في الجانب الشرقي من نهر دجلة وفي منطقة الاعظمية بالتحديد فضلاً عن ضريح ومدرسة عبد القادر الكيلاني في منطقة المركز وهي موضوع بحثنا، حيث لهذه الرمزية الروحية والدينية العالية لدى الناس جعل من هذه المراكز نقاط جذب، حيث ساعدت على نشوء الاسواق والمناطق السكنية حولها، فضلاً عن ان لهذه الاضرحة دلالية ادراكية متمثلة في ارتفاعها وحجمها وكونها ترى من كافة انحاء المدينة.

اما بالنسبة الى منطقتي الرصافة في الجانب الشرقي والكرخ في الجانب الغربي من نهر دجلة، ربما لم تكن هنالك تلك الرمزية الروحية المركزية كما في منطقتي الكاظمية والاعظمية، بل تواجدت دلالات رمزية روحية منتشرة في ارجاء المنطقة والتي كانت بدورها نقاط جذب للمناطق الصغيرة القريبة منها، فضلاً عن وجود دلالات رمزية عمرانية ومتمثلة بالقصور والمدارس والتي تواجدت في تلك الحقبة.

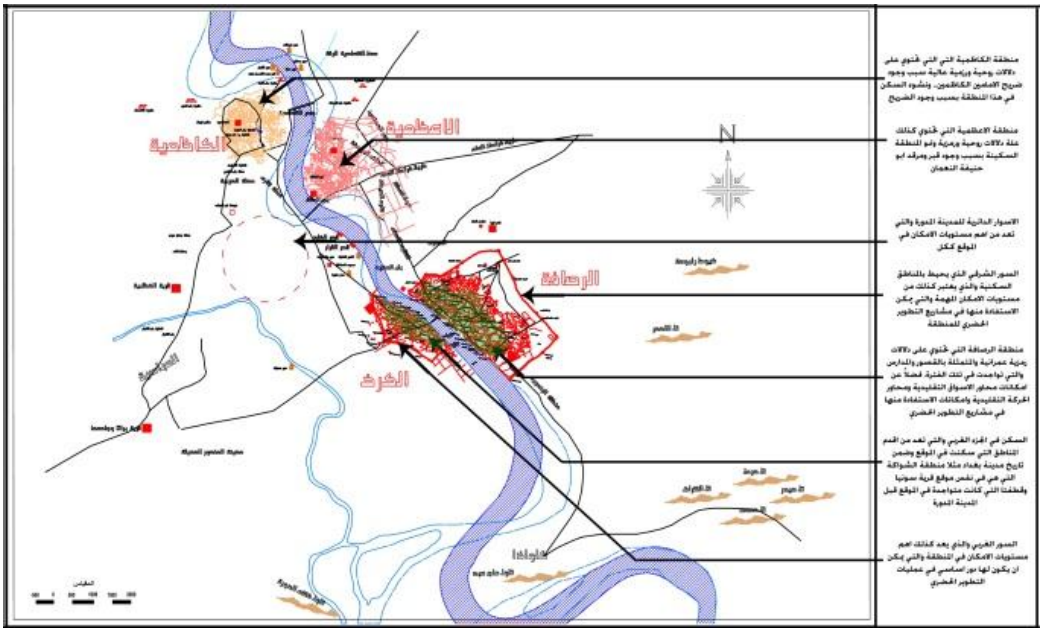
ولا يخفى في هذا كله دور الدين الاسلامي في كثير من الجوانب الحضرية والمعمارية، حيث كان للدين ودلالاته الروحية والرمزية دور في اظهار وبلورة روحية المدينة.

اما بالنسبة الى مستويات الامكان فان هذه الحقبة غنية بهذه المستويات، واهمها هو الامكانات الكبيرة التي تؤثر به اماكن الاسوار سواء كانت الاسوار الدائرية للمدينة المدورة او الاسوار اللاحقة التي بنيت حول الرصافة والكرخ وعلى جانبي نهر دجلة، حيث ان لهذه الاسوار رمزيتها الكبيرة ضمن المكان وتاريخ المدينة بشكل خاص.

وكذلك هناك مستويات الامكان خاصة لدار الخلافة وما يعني هذا الموقع والمركز للمدينة ككل حيث يمكن ان يستفاد من هذه المستويات في مشاريع التطوير الحضري لمدينة بغداد، لاسيما مشاريع التطوير الحضري الخاصة في الرصافة التاريخية ومشاريع تطوير شارع الرشيد.

هذا فضلاً عن مستويات الامكان الخاصة بالمناطق السكنية ولاسيما في الجزء الغربي من نهر دجلة التي تعد من اقدم المناطق التي سكنت في الموقع وضمن تاريخ مدينة بغداد مثلا منطقة الشواكة التي هي في نفس موقع قرية سونيا وقطفتا التي كانت متواجدة في الموقع قبل المدينة

المدورة. فضلاً عن امكانات محاور الاسواق التقليدية ومحاور الحركة التقليدية وامكانات الاستفادة منها في مشاريع التطوير الحضري.(الشكل الرقم 14).



الشكل (14) مخطط يوضح مستويات الامكان في منطقة بغداد بعد نشوء السور الشرقي سنة 1800م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

مما سبق يتبين ان في هذه الحقبة من تاريخ مدينة بغداد قد احتوى الموقع على بعض العقد المهمة والاساسية التي كان لها دوراً اساسياً في تحديد ملامح وخصائص المدينة، ويمكن ان تعد هذه الحقبة اهم الحقبات التي شهدت ظهور حافات حضرية واضحة وقوية ومتينة، ومتمثلة بالأسوار التي تم انشائها على جانبي نهر دجلة الشرقي والغربي، فضلاً عن مراكز الحكم التي كانت متميزة في هذه الحقبة. فضلاً عن المناطق السكنية التي تعد من اهم العقد التي تواجدت في الموقع واقدمها، الى جانب نهر دجلة الذي يعد اقدم واهم حافة طبيعية تواجدت في الموقع ككل.

5- تحليل البنى الحضرية والمعمارية لمدينة بغداد المعاصرة:

تبدأ هذه الحقبة في اواخر القرن التاسع عشر وتحديداً في عام 1869م عندما قام الوالي العثماني مدحت باشا بهدم اسوار مدينة بغداد لإكمال بناء المراكز الحكومية والعسكرية العثمانية، وتستمر هذه الحقبة الى عام 2013م ولا يشمل تحليلنا المناطق الجديدة المستحدثة من بغداد، ولكن يشمل تقصي ما حصل بالمواقع التي تم تحليلها في الحقب السابقة، ولقد كان لهذه الفعل (هدم الاسوار) دور كبير في التوسع العمراني والحضري للمدينة وانتشارها خارج حدود الاسوار، حيث اصبحت هنالك تطورات كبيرة في البنى الحضرية والمعمارية لمدينة بغداد وضمن حقبات زمنية قصيرة نسبياً على العكس من الحقبات السابقة من تاريخ المدينة حيث كانت هنالك تطورات حضرية ومعمارية قليلة وضمن حقبات طويلة نسبياً.

أن بغداد التي لم تختلف صورتها الحضرية العامة طوال قرون عن صورة المدينة عند بناء اسوارها، بتراص كتلها البنائية وطراز البناء التقليدي مع بعض ملامح الطرز الاسلامية التاريخية، وبدأت مع مطلع القرن العشرين تمر بالتغير الكبير، وقد قسم معظم الباحثين المراحل المتعاقبة التي مرت بها المدينة وفق العقود الزمنية المتعاقبة للقرن العشرين، لكن بغداد مرت بنقاط (لحظات) تغير اساسية في مسارها الحضري والثقافي، بعضها ارتبط بالتغيرات السياسية وبعضها الاخر بالتغيرات الاقتصادية، ومع هذين المتغيرين كانت المتغيرات الاجتماعية والسكانية تحصل بتواتر شديد، مما جعل المدينة تنتقل بتسارع من صورة الى اخرى ثقافيا واجتماعيا وحضريا.

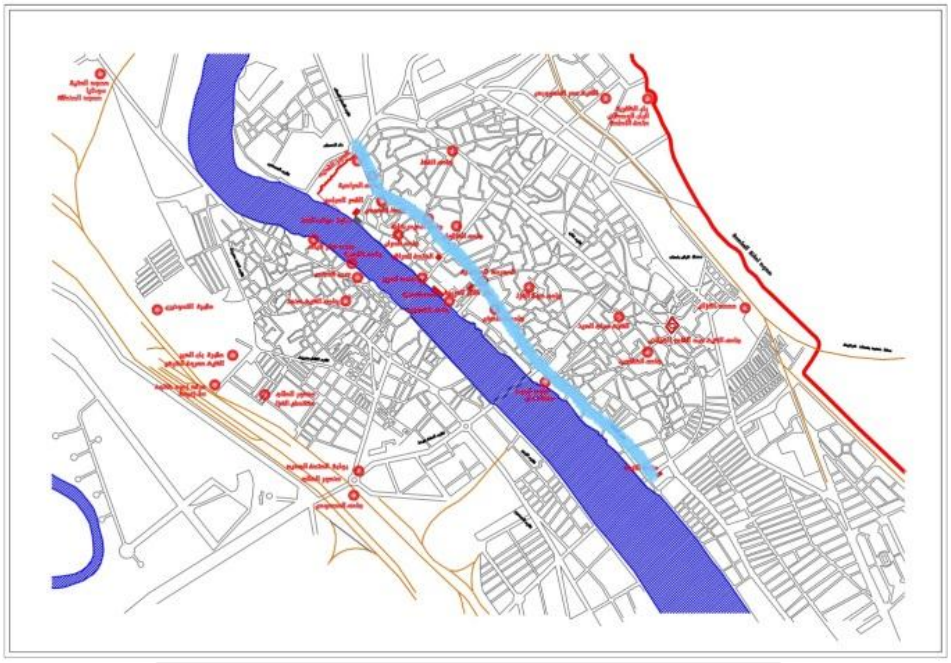
5-1- العلاقات الاساسية على مستوى المحاور (المسارات) للحقبة الرابعة:

في هذه الحقبة من تاريخ مدينة بغداد شهدت المسارات تطور وتوسع كبير، حيث اصبح هنالك مسارات رئيسة ضمن المدينة واخرى مسارات ثانوية، وان هذا التوسع والتطور الكبير الذي ظهر على المسارات والمحاور الحركية سببه التوسع الكبير للمدينة، حيث لم تبق مدينة بغداد متقيدة بنهر دجلة في نموها بل اصبح نالك نمو بالاتجاه العمودي على نهر دجلة اي باتجاه الشرق الغرب، حيث ان هذا الانتشار والتوسع لاسيما للمناطق السكنية وبعيداً عن مركز المدينة، تطلب انشاء عدد كبير من المسارات والمحاور الحركية من اجل ربط هذه المناطق مع

بعضها، فضلاً عن ربطها بمركز المدينة، وقبل ايضاح اهم المسارات في هذا الحقبة لابد من التأكيد على ان المسار التاريخي لموقع بغداد (الطريق الواصل بين: **كلواذا – الزندورد – سوق الثلاثاء** (هذا في الجزء الشرقي من نهر دجلة) **– الجسر – قطفتا – سوق بغداد – سونايا – قرية سال – قرية ورثالا – قرية بناورا – قرية الكرخ – قرية براثا – المحول** (هذا في الجزء الغربي من نهر دجلة)، قد استمر ولازال محافظاً على مساره ولو بتغيرات بسيطة .

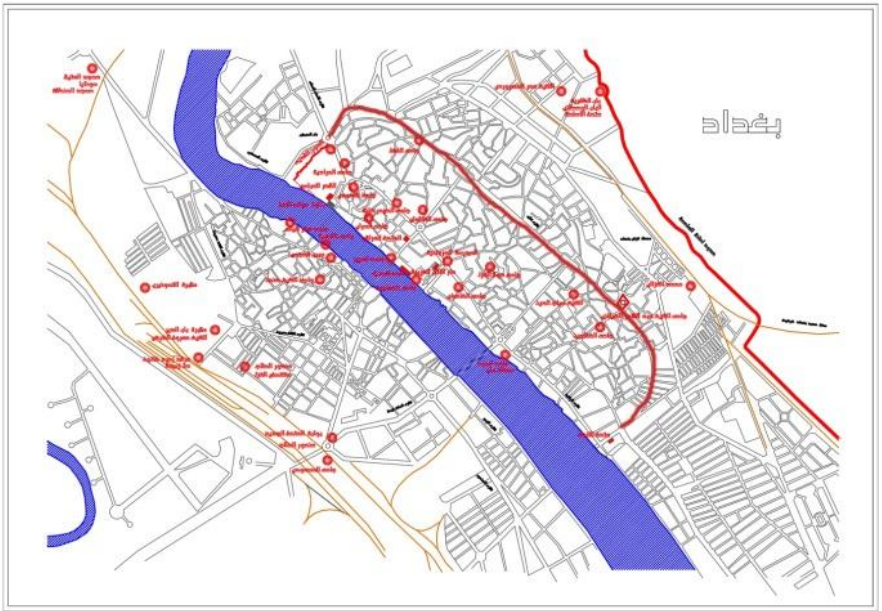
ولعل اهم هذه المسارات هذه الحقبة والذي يعد اول شارع حقيقي في بغداد المعاصرة هو :

شارع الرشيد: يعتبر شارع الرشيد بالمفهوم التخطيطي الحديث أول شارع رئيسي يشق في المدينة، حيث يمتد حوالي (3 كم) من الشمال الى الجنوب و يتفرد موقعه بتحديده ما بين بوابتين قديمتين ما بين الباب الشرقي و باب المعظم، وافتتح الشارع في ولاية خليل باشا في 23 تموز عام 1916 وقد سمي أول الأمر باسم (جادة خليل باشا) أو الجادة العامة أو الجادة اختصارا وثبت ذلك على قطعة من الكاشي المزجج كانت موضوعة فوق قاعدة منارة جامع سيد سلطان علي في الزاوية الجنوبية ، وبعدها اطلق الانكليز عند احتلالهم بغداد في 11 آذار 1917 على هذا الشارع اسم (الشارع الجديد) وبعده سمي (شارع الرشيد) .(النقشبندي، 2002،ص10). (الشكل 15).



الشكل (15) منطقة حوض شارع الرشيد الممتد بين باب المعظم وساحة التحرير
اعداد وايضاح الباحث بالاعتماد على مخطط بغداد من http://www.iraqnaa.com

شارع غازي (الكفاح): بعد فتح شارع الرشيد تم فتح شارع الكفاح وباسم شارع غازي سابقاً ويربط بين ساحة التحرير (ساحة الملكة عالية) وباب المعظم، وذلك في اربعينات القرن العشرين، وهذا الشارع ايضاً له رواق معمد لكن طراز بنائه المعماري امتاز بالحداثة مغايراً لرواق شارع الرشيد، وهذا الشارع قطع جزءاً كبيراً من النسيج التراثي، وهو بشكل متعامد مع اغلب المحاور التاريخية التي كانت قائمة في المنطقة. (النقشبندي، 2002،ص13) (الشكل 16).



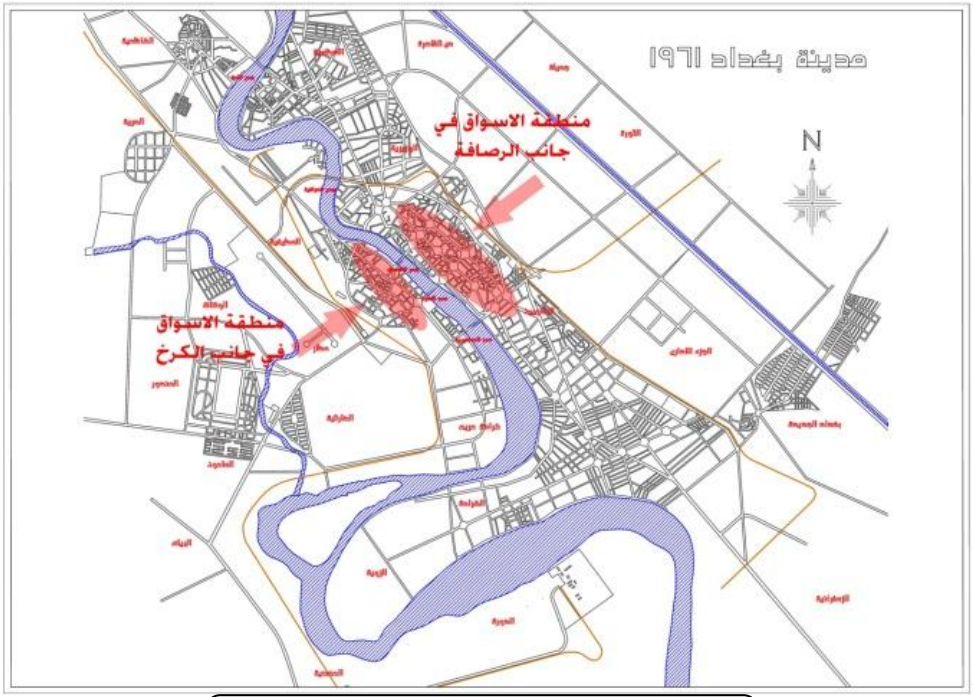
الشكل (16) منطقة حوض شارع الكفاح الممتد بين ساحة التحرير وباب المعظم
اعداد وايضاح الباحث بالاعتماد على مخطط بغداد من http://www.iraqnaa.com

5-2- العلاقات الاساسية على مستوى عقد الفعاليات الانسانية للحقبة الرابعة:

في هذه الحقبة من تاريخ بغداد شهدت العلاقات الاساسية على مستوى الفعاليات الانسانية تغيرات كبيرة، لاسيما ان الحياة في بغداد اخذت منحنى اخر وظهور فعاليات لم تكن متواجدة في الحقبات السابقة، اما بالنسبة الى السكن فمازالت هذه قائمة ولا زال السكن التاريخي في الجانب الغربي من نهر دجلة والذي يعد اقدم سكن في الموقع ككل مستمرا وبشكل كبير ومهم، فضلاً عن السكن في بقية المناطق التاريخية مثل الرصافة ومنطقتي الاعظمية والكاظمية على جانبي نهر دجلة.

تعرض السكن في هذه المنطقة للكثير من الاستعمالات غير السكنية كالفعاليات التجارية والادارية وحركة السيارات والسابلة وتدهور الخدمات السكنية الرئيسة، خاصة بعد ان تعرضت الازقة التقليدية الى التقاطعات مع الشوارع الكبيرة التجارية، بما جزء المحلات السكنية وترابطاتها النسيجية التي كان تكاملها يمثل البنية الاساسية للسكن فيها، وعليه فان هذه البنية قد تعرضت لتحولات كبيرة وان كانت لم تندثر كلياً ولكن من الصعب اعتبارها بنية عميقة مستمرة، فنوع السكن فيها والتحولات الاخرى الحاصلة تقتضي ان يعاد معالجتها في اعمال اعادة تأهيل لاستعادة العلاقات الاساسية للبنية.

نشأت بنى الفعاليات مستمرة في المنطقة اهمها الفعالية الحكومية والفعالية المالية مع استمرار الفعالية التجارية المتمثلة بالأسواق عدا محاور الاسواق التقليدية والتي بقت على تخصصاتها التاريخية، فقد نشأت فعالية تجارية معاصرة على جوانب الشوارع العريضة وتداخلت مع الاسواق التقليدية، ورغم ان بنية الاسواق التقليدية لاتزال قائمة مع اغلب علاقاتها الاساسية، لكن تداخلها ضمن الانماط التخطيطية التي تمثل بنية جديدة للمنطقة، فضلاً عن تدهور الخدمات واستمرار اسواق الجملة وتداخلها مع الفعاليات الصناعية يهدد هذه البنية مما يجعلها بحاجة الى اعادة تأهيل ضرورية شاملة للعلاقات القائمة والمستحدثة بما يضمن استمرارية البنية التي كانت ذات حيوية دائمة. (الشكل 17).



الشكل (17) منطقة الاسواق القديمة في جانب الرصافة والكرخ
اعداد وايضاح الباحث

اما بالنسبة الى الزراعة فلم تعد كما كانت حيث انحسرت هذه المهنة بشكل كبير، واتجهت نحو اطراف المدينة، اي ان المساحة التي كانت تستخدم في الزراعة في الحقبات السابقة من تاريخ بغداد لم تعد هي نفسها بل اختصرت بشكل كبير واصبحت خارج حدود المدينة.

5-3- العلاقات الاساسية للحافات (الطبيعية والحضرية) للحقبة الرابعة:

بالنسبة الى الحافات الطبيعية في هذه الحقبة من تاريخ مدينة بغداد، لم يشهد تغير كبير عن الحقبة السابقة وان نهر دجلة هو الحافة الطبيعية الرئيسية ضمن محيط المنطقة، حيث تمحورت وامتدت المدينة على الجانبين الشرقي والغربي من نهر دجلة الذي يعتبر السبب الرئيسي لنشوء مدينة بغداد، حيث ان بداية الامتداد الحضري للمدينة والذي حصل بعد هدم السور كان على جوانب نهر دجلة ثم اخذ بالانتشار بالاتجاه العمودي على النهر.

في الستينيات من القرن الماضي قامت امانة بغداد بأنشاء ممر مائي اطلق عليها اسم قناة الجيش والذي يبلغ طوله 23كم، يمتد من شمال بغداد الى الجنوب في الجانب الشرقي من نهر دجلة وبشكل موازي تقريباً لنهر دجلة، وكان الهدف من انشاء هذا الممر المائي ليس تجهيز المياه الى اراضي زراعيه فقط وانما انشاء حدائق وساحات جميلة لزيادة الرقعة الخضراء وانشاء واحدة من المعالم السياحية الواسعة الجميلة ممتدة من نهر دجلة الى نهر ديالى حيث مصب هذه القناة. (الشكل 18).

هذا بالنسبة الى الحافات الطبيعية المائية، ولكن قد برز وربما بشكل واضح في هذه الحقبة حافات او عقد طبيعة اخرى متمثلة بالمساحات الخضراء والمتنزهات والتي تم أنشاءها في حقبات مختلفة واماكن مختلفة من بغداد، وربما في مقدمتها هي متنزه الزوراء (كانت معسكراً سابقاً باسم معسكر الوشاش)، وجزيرة الاعراس (جزيرة ام الخنازير سابقاً)، فضلاً عم منطقة ترفيهية شمال بغداد تعرف باسم جزيرة بغداد فضلاً عن مواقع اخرى في شارع فلسطين.(الشكل 18).

اما بالنسبة الى الحافات الحضرية فقد ازداد اتساع المدينة وبشكل كبير وضمن حقبات زمنية قليلة وتم تقسيمها الى شبكة من الطرق والمناطق الحضرية وربطها مع بعضها مما جعلها وحدة واحدة، هذا بالنسبة الى الحافات الداخلية ضمن المدينة اما بالنسبة الى الحافات الخارجية وهي في تغير ونمو مستمرة وهنالك عدد من المخططات الاساس لمدينة بغداد التي وضعت من قبل شركات مختصة وفي حقبات مختلفة، وقد حددت هذه المخططات ملامح وشكل المدينة وحدودها الخارجية.

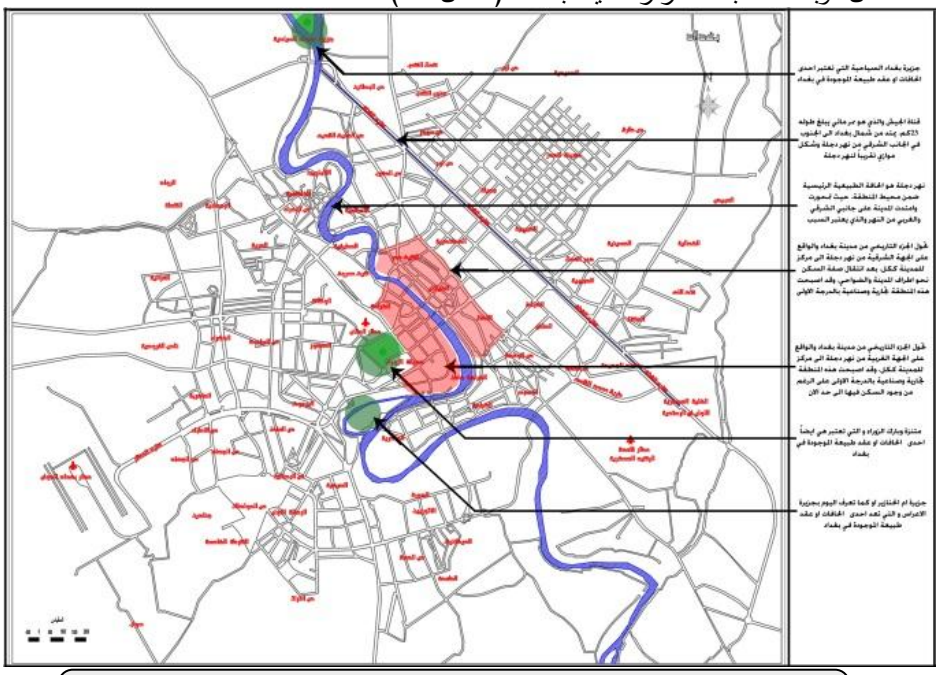
ان ما تم طرحة في تحليل البنية التخطيطية في المدينة من شبكة الشوارع وترابطاتها قد خلقت حافات معينة وخاصة الطرق السريعة التي لا يمكن للسابلة قطعها – وقد تم في التسعينات الغاء مسار (نهر الخير) في الكرخ وهو ما يؤشر اندثاراً اخر ملامح الانهار والقنوات المائية التي كانت قائمة جنوب المدينة المدورة، ان اندثار هذا النهر او القناة لا يمثل فقط الغاءاً لبنية قائمة (كانت قد مرت بمراحل تحول خلالها الى منطقة غير صحية) انه الغاء لكل البنية التي تعود الى مرحلة المدينة المدورة ومقابلها، ان الابقاء عليها او اعادة تأهيلها يمثل ديمومة واستمرارية لبنية فضاء مفتوح تاريخي وليس مشروعاً اعتيادياً فقط.

5-4- الترابطات او التدرج الهرمي للعلاقات للحقبة الرابعة:

ان العلاقات الاساسية على مستوى الترابطات والتدرج الهرمي في هذه الحقبة من تاريخ بغداد ما بقت كما كانت عليه في السابق، حيث ان المدينة ما بقت محصورة او متمركزة في المناطق القريبة من النهر او في المناطق القريبة من عقد الفعاليات الانسانية كما كانت علية، مثل تجمع المناطق السكنية حول الاضرحة الدينية وكذلك بالقرب من مناطق الاسواق وغيرها من العقد المكانية، حيث ان المدينة اخذت طابعا مختلف في الامتداد معتمداً بذلك التوسع نحو الاطراف والاستفادة من المساحات المتوفرة.

من ابرز ملامح التغير التي حدثت على النسيج الحضري فكان في ظهور الضواحي الجديدة خارج القلب التاريخي (الجزء المسور) , فظهرت مناطق الوزيرية شمالا والسعدون جنوبا والصالحية وكرادة مريم في الضفة الغربية لدجلة، وفي حين كان النسيج الحضري التقليدي قائما باختراق بسيط، فظهرت هذه الضواحي وفقا لأنماط تخطيطية معاصرة (كما ذكرنا) مثل المدن الحدائقية Garden city والتخطيط الشبكي Grid iron. (السلق، 2006، ص42).

وعليه يتبين ان مدينة بغداد اصبحت مترابطة بشكل مختلف عما كانت عليها ولسبب كبر المساحة التي شغلتها المدينة بسبب ازدياد اعداد السكان فيها، فضلاً عن التحول الذي حصل في المناطق التاريخية والقديمة التي اصبحت مناطق تجارية وصناعية بالدرجة الاولى، وانتقال صفة السكن نحو اطراف المدينة او الضواحي، مما اعطى لهذه المناطق (المناطق التاريخية والقديمة من بغداد) صفة المركز، حيث اصبحت مناطق جذب لمزاولة الاعمال، وبذلك اصبحت مركز لمدينة بغداد. (الشكل 18).



الشكل (18) مخطط يوضح الحافات الطبيعية والحضرية والتدرج الهرمي لمدينة بغداد المعاصرة سنة 2013م
اعداد وايضاح الباحث بالاعتماد على اطلس بغداد لاحمد سوسة

5-5- المستويات الدلالية ومستويات الإمكان للعلاقات اعلاه للحقبة الرابعة:

في هذه الحقبة لم يعد مستوى الدلالية واضحاً كما كان عليه في الحقبات السابقة، حيث ان نمو المدينة بشكل كبير وسريع، جعل من الصعب المحافظة على روحية المدينة، حيث ان هذه الرمزية والدلالية اقتصرت على عدد من العقد المعمارية وبعض من الفعاليات الانسانية.

وكما تبين في السابق عن دور الاسلام في صياغة روحية المدينة، فلا يخفى في هذه الحقبة عن هذا الدور الذي يمثله الدين الاسلامي حيث يمكن ملاحظة مظاهر الاسلام في المناطق التي نشأت بشكل كبير وسريع، اذ انها غالباً ما تحتوي على مركز ديني فضلاً عن عقد للفعاليات الانسانية مثل الاسواق والمتنزهات وغيرها، والتي تنتشر حولها القطاعات السكنية، فعليه يتبين ان هذه المناطق نشأت وفق روحية ورمزية محددة وهي روحية الدين الاسلامي.

وكذلك الحال بالنسبة الى مستويات الامكان فلم تعد مدينة بغداد بالقوة التي كانت عليها في حقبات سابقة من تاريخ مدينة بغداد كون ان اغلب عقد هذه الحقبة والتي يمكن ان تشكل امكانات كبيرة في التطوير الحضري لمدينة بغداد لازالت مستمرة ولكن بشكل سيء، اي ان اغلب العقد لاسيما العقد المعمارية لهذه الحقبة تعاني من الاهمال وقلة الاهتمام، مما حولها الى كيانات وابنية فارغة وغير مستغلة، والتي بدورها اذا ما استغلت بالشكل الصحيح يمكن ان تكون امكانات كبيرة واساسية في تطوير الحضري لأي منطقة من مناطق بغداد بشكل خاص ولتطوير لمدينة بغداد في الكامل بشكل عام.

فضلاً عن ذلك ظهرت في هذه الحقبة الطويلة والتي شملت مراحل في القرن العشرين (وربما كانت متواجدة في الحقبات السابقة ولكن بشكل غير واضح او لم تذكر بشكل كافي من قبل المؤرخين والباحثين)، عناصر دلالية نصبيه تحمل في طياتها رمزية او دلالة عالية لأحداث مهمة، او اشخاص مهمين قادوا الى احداث تغيرات مهمة في تاريخ مدينة بغداد المعاصر، ومن هذه النصب التي تواجدت في بغداد ضمن حقبات زمنية مختلفة نصب الجندي المجهول القديم الذي بني في مطلع الستينات في ساحة الفردوس، ومثل قيمة دلالية مهمة في المدينة، وقد تم هدمه في الثمانينات، الا ان قيمة الامكان لهذا النصب لاتزال قائمة ومؤثرة في مسار الاحداث في المدينة وخاصة السياسية والحضرية،(الشكل 19).

الشكل (19) نصب الجندي المجهول القديم في ساحة الفردوس
عن (الانترنت – مكتبة الصور النادرة)

ونصب الشهيد، وكذلك نصب التحرير في ساحة الحرية الذي مثل عملاً فنياً وحضرياً متميزاً قدم معلماً مهماً لبغداد ارتبطت به المدينة ولايزال قائماً ومؤثراً في الهوية الحضرية المعاصرة فضلاً عن الاثر النحتي الفني المميز له (الشكل 20)، وكذلك نصب لأشخاص مثل تمثال الرصافي، وتمثال كهرمانة ونصب الامومة، وتمثال ابي نؤاس وتمثال شهريار وشهرزاد وتمثال السعدون وتمثال عبد المحسن الكاظمي وتمثال ابي جعفر المنصور وتمثال عباس بن فرناس، وغيرها من التماثيل والنصب التي تعكس حدث او شخص مهم في تاريخ مدينة بغداد المعاصر.

الشكل (20) نصب التحرير في ساحة التحرير
عن (الانترنت – مكتبة الصور النادرة)

الاستنتاجات النهائية:

ومن تتابع البنى الحضرية لمدينة بغداد امكن استخلاص نقاط اساسية كانت مؤثرة في تتابع بناها تاريخياً.

- **ان موقع مدينة بغداد غني بالبنى الحضرية والمعمارية حتى قبل بناء المدينة المدورة، مما جعلها مركزاً مهماً ونقطة جذب ابي جعفر المنصور لأنشاء مدينته المدورة.**
- **بقى نهر دجلة المحور الاساسية لمدينة بغداد وعبر تاريخها الطويل، حيث يمكن اعتباره العقدة الطبيعية الوحيدة التي كانت وما زالت مصدر الحياة لمدينة بغداد.**
- **مثلت المدينة المدورة مع ما جاورها بنية حضرية واحدة (هي بغداد) كانت المدينة المدورة نواتها وتكاملت هذه البنية بنشوء محلتين اخريتين فيها هما الكرخ والرصافة.**
- **اعطى بناء المدينة المدورة في هذا الموقع اهمية ومركزية للموقع، ولكن مع بقاء البنى الحضرية والمعمارية (المحاور الاساسية وعقد الفعاليات الانسانية) التي كانت متواجدة في الموقع قبل بناء المدينة المدورة، بقيت نفسها واستمرت وتطورت فيه، مما يدل على ان الموقع قادر على استيعاب التغيرات والتبدلات والمحافظة على وجوده وقيمته.**
- **كان لابد لنشوء (المدينة المدورة) من ان تخلق مركزية في كيانها كمركز لدولة, وهكذا يمكن ان تعدد هذه الفترة هي الاولى التي تشهد نشوء مدينة ضمن الموقع بسبب نشوء مركز حضري ومدني للموقع ككل، فقد بقيت بنفس قيمتها المركزية هذه عندما حطم المأمون المدينة المدورة وقصر باب الذهب وسكن في قصر في الجانب الشرقي لبغداد .**
- **شهدت بغداد المعاصرة وخصوصاً بعد هدم السور على يد مدحت باشا، نمواً كبيراً وسريعاً، حيث اخذت مناطق سكنية جديدة بالظهور، وانتشرت في جميع الاتجاهات، وازداد عدد المسارات والمحاور الحركية عما كانت عليه من اجل تحقيق ترابط بين هذه المناطق الواسعة وربطها مع المركز.**
- **شهدت بغداد القرن العشرين تغيرات واضحة في مجال التخطيط، مما جعل القرن العشرين مليئاً بالبنى الحضرية.**

التوصيات النهائية:

- **عند القيام باي مشروع تطوير حضري او اي مشاريع تخطيطية لابد من دراسة بنية بغداد عبر تاريخها وعلاقاتها الاساسية مما سيسهل اتخاذ القرارات المهمة، حيث ان هذه الدراسة يمكن ان تكون السبب في عدم حصول انقطاع عن ماضي مدينة بغداد والتعامل مع هذه البنية بشكل سليم وعدم التعامل معها بشكل يقطع تلك البنية ويشتتها بدل ان يكاملها ويتواصل معها، حيث ان معرفة المسارات ومحاور الحركة الاساسية ضمن الموقع وكذلك اهم المناطق السكنية التاريخية ومناطق الفعاليات الانسانية يحول دون التداخل فيما بينها او ضياعها او الغائها نتيجة لعملية التطوير المعاصرة.**
- **ضرورة التعامل من اهم محور موجودة في الموقع مدينة بغداد وهو نهر دجلة بشكل اكثر تخصصاً ولاسيما من حيث استغلال مجرى النهر كمسار للنقل بشكل اكثر جدية، وكذلك استغلال الواجهة النهرية بشكل اكثر ملائمة وبما يناسب الانفتاح نحنو النهر بما يخص مشاريع التطوير الحضري للمناطق المطلة على النهر وكذلك بالنسبة الي المدينة بغداد ككل، وحتة بما يخص الابنية المعمارية المنفردة المطلة على نهر دجلة.**
- **ضرورة التعامل مع موقع المدينة المدورة وعدم تجاهله في عملية تطوير الحضري، وان لم يكن هذا التعامل تعاملاً فيزيائيا، ولكن بشكل يسمح بالاستفادة من الامكانات التي توفرها هذه العقدة المهمة في تاريخ بغداد ككل، فضلاً عن هذا يوصى الى الجهات المتخصصة القيام بأعمال التنقيب عن موقع المدينة المدورة واسوارها الثلاثة وقصرها المميز وقبته الخضراء، وكشف الكثير مما هو غامض الان من عمارتها.**
- **يوصى بضرورة الكشف والتنقيب عن مواقع الاسوار الشرقية والغربية لمدينة بغداد على جانبي نهر دجلة وكذلك ابوابها، والاستفادة من الامكانات المهمة والكبيرة التي يمكن ان تقدمها هذه العناصر في اي عملية تطوير حضري او تخطيط يحصل في المناطق القريبة منها او على مستوى مدينة بغداد ككل.**
- **ضرورة التعامل مع عقد الفعاليات الانسانية والمتمثلة بالأسواق ولاسيما الاسواق التاريخية ضمن مدينة بغداد، بأسلوب اكثر جدية، وضرورة دراسة تاريخ هذه الاسواق لتسهيل عملية تطويرها، وكذلك التأكيد على هذه الاسواق وعلى اهميتها في حياة**

المدينة السابقة والمعاصرة ضمن اي عملية تخطيط او تطوير حضري يحصل في المناطق المعنية او على مستوى مدينة بغداد بالكامل.

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تأثير العمر والمهنة على نوع وعدد الأصابات للعاملين في قطاع التشييد في العراق

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الخلاصة

أثبتت الأحصائيات العالمية أن أكثر حوادث العمل خطورة والتي وينجم عنها وفيات عديدة هي تلك التي تقع في الأعمال الأنشائية. أن تلك الحوادث تتعلق بالكثير من الأسباب التي تحصل أثناء عملية التشييد. ومن أهم الأسباب التي تؤدي الى حدوث الأصابات في العمل هي نقص الخبرة لدى العاملين وأهمال قواعد الأمن والسلامة المهنية وبالأخص العاملين من فئة الشباب. ونظراً للمخاطر التي يمكن في مواقع البناء، جاءت فكرة هذا البحث لتوضيح العلاقة بين عمر العامل وعدد الأصابات والحوادث وانواعها وتحديد الأسباب التي تؤدي لتلك الأصابات ومن ثم اقتراح الحلول المناسبة لأزالة أو التقليل من مخاطر أصابات العمل. كما تناول البحث التعرف على أهم المفاهيم والمصطلحات التي تتعلق بموضوع السلامة والصحة المهنية لتكوين صورة أوضح حول موضوع البحث. تم أعداد أستمارات أستبيان لجمع المعلومات ومن ثم تحليل نتائج الاستبيان أحصائياً والخروج بنتائج يمكن أن تسهم في التقليل من حدوث الأصابات بين العاملين في مواقع العمل وتوصيات والتي من ابرزها ان هنالك نقص شديد وعدم أهتمام بعلم السلامة المهنية ومتطلبات الوقاية الشخصية في مواقع المشاريع الأنشائية في العراق.

الكلمات الرئيسية: – السلامة المهنية، اصابات العاملين، انواع الاصابات، اعمار العاملين

The Effect of Age and occupation on the Type and the Number of workers injuries in construction sector in Iraq

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ABSTRACT

World statistics proved that the most of work dangerous accidents, which causes death, are occurred in the construction works. These accidents related to many causes such as loss of workers experience and ignoring rules of safety requirements, especially young workers. Due to the risk of accidents that may occur in the site of work, the idea of this study crystallized to show the relationship between the age of worker and number of injuries and accidents, to identify the causes of these injuries, and to put the appropriate solutions to avoid or reduce the risk of work injuries. Also, the research shows the main principles of safety requirements to forming a clear picture about the subject of the study. A questioner form was prepared to collect the information and then analyzing it statistically in order to reach to the results and recommendations which contribute to decrease the occurrence of work injuries in the sites of construction projects.

Key Words: Occupational Safety, Workers Injuries, Types of Injuries, Age of Workers

التعاريف والمصطلحات

أولا: السلامة المهنية

السلامة والصحة المهنية هي فرع من فروع العلوم ذي مجال واسع يشتمل على الكثير من مجالات التخصص. وتمثل مجموعة الأجراءات التي تؤدي لتوفير الحماية المهنية للعاملين والحد من خطر المعدات والآلات على العمال والمنشأة ومحاولة منع وقوع الحوادث أو التقليل من حدوثها، وتوفير الجو المهني السليم الذي يساعد العمال على العمل (فراج 1990). وتهدف الى:

1. تعزيز والمحافظة على أعلى درجة من أكتمال الصحة البدنية والعقلية والأجتماعية للعمال في جميع المهن.
2. وقاية العمال من التأثيرات الصحية الضارة التي تسببها ظروف عملهم.
3. حماية المنشأة بما في ذلك الآلات والمواد من المخاطر الممكن حدوثها كالصدم والحريق.
4. تعيين العمال في بيئة مهنية ملائمة لاحتياجاتهم البدنية والعقلية، والمحافظة على هذا الوضع.
5. جعل العمل ملائما للأنسان.
6. حماية الأفراد من أجل الوصول الى أنتاج من دون حوادث وأصابات من خلال:

أ. الحماية من المخاطر من خلال:

1. أزالة الخطر من منطقة العمل.
2. تقليل الخطر أذا لم تتم أزالته.
3. توفير معدات الحماية الشخصية مثل نظارات وقاية العين، واقيات السمع لتجنب الضجيج، الكمامات المفلترة لتجنب الغازات السامة، خوذة الرأس،....ألخ.

ب. توفير الجو المهني السليم: من حيث الأضاءة والرطوبة ودرجة الحرارة المريحة للعمل.

ثانيا: أصابات العمل

يعرف الضرر الذي يصيب العامل بسبب وقوع حادث معين بأنه (أصابة)، أي أن الأصابة هي النتيجة المباشرة للحادث الذي يتعرض له العامل. وتعرف أصابة العمل بأنها الأصابة التي تحدث للعامل في مكان العمل أو بسببه وكذلك تعتبر الأصابات التي تقع للعمال في طريق ذهابهم الى العمل أو طريق الرجوع من العمل إصابات عمل بشرط أن يكون الطريق الذي سلكه العامل هو الطريق المباشر دون توقف أو أنحراف وتعتبر الأمراض المهنية من أصابات العمل (جميل 1983). وقد تزداد عدد الأصابات مع زيادة حجم المشروع الأنشائي وبالتالي تزداد الحاجة الى وجود نظام فعال لأجراءات السلامة المهنية ومتطلبات الوقاية الشخصية (Al-Utaibi 1996).

ثالثا: الأمراض المهنية

هي أمراض محددة ناتجة عن التأثير المباشر للعمليات الأنتاجية وما تحدثه من تلوث لبيئة العمل بما يصدر عنها من مخلفات ومواد وغيرها من الآثار وكذلك نتيجة تأثير الظروف الطبيعية المتواجدة في بيئة العمل على الأفراد مثل الضوضاء، الأهتزازات، الأشعاعات، الحرارة، الرطوبة، .....ألخ. ويمكن تقسيم نتائج الأمراض المهنية الى قسمين هما (Stone2007):

1. النتائج المباشرة:

تعتبر أصابات العمل والأمراض المهنية التي تصيب العمال بالعجز الكلي أو الجزئي، وحالات الوفاة الناجمة عن حوادث العمل المختلفة هي نتائج مباشرة لظروف العمل الخطرة التي أفتقرت لأشتراطات السلامة والصحة المهنية.

2. النتائج غير المباشرة:

هذه النتائج ذات طابع أقتصادي، حيث تظهر الخسائر المادية التي تتكبدها المنشأة أو الدولة بشكل عام نتيجة حوادث العمل أو الأصابات أو الأمراض المهنية التي تنتج عن ظروف بيئة العمل غير الآمنة، ويظهر ذلك في أيام العمل الضائعة أو المفقودة بسبب أصابات العمل والأمراض المهنية.

رابعا: الحادث

يمكن تعريف الحادث على أنه حدث مفاجئ يقع أثاء العمل وبسببه، وقد يؤدي الحادث الى أضرار أو تلفيات بالمنشأة أو وسائل الأنتاج دون إصابة أحد من العاملين، أو قد يؤدي الى إصابة عامل أو أكثر بالأضافة الى تلفيات المنشأة ووسائل الأنتاج.

الحوادث في المشاريع الأنشائية

أن أسباب الحوادث في المشاريع الأنشائية كثيرة ومتنوعة ولا يستطيع أي مهندس معرفة تلك الأسباب عن طريق التخمين والتقدير، بل يجب دراسة النشاطات الأنشائية بدقة والتأكد من تطبيق أنظمة وقوانين السلامة المهنية في جميع المجالات وعلى كل المستويات.

وعن دراسة أجريت في الولايات المتحدة أشارات الى أن أكثر الحوادث في موقع العمل يعود الى خطأ بسيط أو أهمال غير متعمد، ولا تكون نتائج الأهمال عادية فأنها قد تسبب في كارثة تذهب ضحيتها الأرواح والأموال وتكلف المقاول الكثير من المال والجهد بالأضافة الى سمعته في السوق، وخاصة في العراق فأن المقال قد يتعرض أيضا الى المطالبات العشائرية.

تقارير الحوادث

يجب على أدارة المشروع أعداد تقرير بعد كل حادث يقع أثناء تنفيذ المشروع، حيث أن مثل هذه التقارير تساهم في معرفة السبب الحقيقي الذي أدى الى وقوع الحادث ومنع وقوعه مستقبلا. ويحب أن يشمل التقرير عن الحادث الأمور التالية:

1. أسم الشركة وأسم المشروع.
2. أسم العامل المصاب.
3. عمر العامل.
4. تاريخ تعينه في العمل ومدة خدمته الفعلية.
5. مهنة العامل.
6. نوع الأصابة
7. تاريخ وقوع االأصابة.
8. ما العمل الذي كان يقوم به العامل المصاب والأدوات والمعدات والمواد المستعملة عند الأصابة.
9. كيف تمت الأصابة.
10. ما التصرف الغير مأمون الذي قام به العامل أثناء العمل وأدى الى أصابته.
11. ما هي أوجه القصور التي كانت موجودة سواء في وسيلة العمل أو طريقة أداء العمل أو في محيط العمل.
12. ما هي طريقة الوقاية المناسبة التي يجب أن تستعمل لمنع الأصابة.
13. ما هي الأجراءات والتوصيات الواجب أتخاذها لمنع تكرار الحادث مستقبلا.

واجبات ادارة المشاريع :-

يجب أن يعمل مدير المشروع الإنشائى على سيادة الأمان , ومتابعة قواعد السلامة أثناء تنفيذ مختلف العمليات فى الموقع , ويجب أن يساعد مدير المشروع فى ذلك جميع مرؤسيه من مهندسين ومراقبين , كما أن على مدير المشروع أن يضع قواعد السلامة الرئيسية التى تتلائم , ونوع العمل الذى يشرف عليه , وينقلها بصورة واضحة وعملية إلى جميع العاملين فى موقع العمل.

إن المهندسين المشرفين على الموقع هم الذين يطالبون بتوضيح كافة قواعد الأمن والسلامة التى يجب أن تتم توضيحها لكل العاملين حسب نوع العمل و ظروفه , أما قواعد السلامة الرئيسية التى يجب أن يتم توضيحها لكل المسؤولين فى صناعة الإنشاء فهى تتمثل فى (غولد هابر 1977):

1. شرح أسباب الحوادث لكافة العاملين فى موقع العمل , ثم إعطائهم التدريبات اللازمة على كيفية إنجاز العمل بأمان.
2. تشجيع العاملين على تقديم التقارير عن حدوث الأخطاء والعيوب بسرعة , وبدون تردد.
3. تحذير العاملين من الأهمال والتهور والمزاح بأدوات العمل فى الموقع.
4. يجب إيصال كافة التعليمات الخاصة بقواعد الأمان والسلامة إلى كافة العاملين بمواقع العمل.

فى بعض الشركات الكبرى فى العالم يتم تعين مهندسى السلامة لمشروع الأنشاء , ويقوم مهندس السلامة بالوظائف التالية:

1. مراجعة طرق التصميم والتفيذ وتطوير مواصفات السلامة , ليتم إضافتها فى وثائق العقد.
2. وضع خطة السلامة التى تتناسب مع متطلبات المشروع.
3. مراجعة برنامج المقاول الخاص بالسلامة على ضوء برنامج مدير الإنشاء للسلامة , والحصول على موافقة صاحب العمل على خطة السلامة الخاصة بالمشروع.
4. تخطيط نظم التقيد بالخطة من قبل موظفى السلامة.
5. تنظيم لجنة سلامة للمشروع.
6. عقد إجتماع لموضوع السلامة لجميع الأطراف العاملة فى المشروع.
7. مراقبة نظام تقارير الحوادث ووضع التوصيات الخاصة بتحسن برنامج السلامة.
8. تأمين خدمات الإسعافات الأولية فى مواقع العمل.
9. تأمين الحماية من الحريق وخدمات الأمن .

تقييم متطلبات السلامة والصحة المهنية في مشاريع التشييد في العراق

من خلال الزيارات الميدانية لبعض المشاريع الأنشائية في العراق، أثبتت الدراسة بأن أجراءات السلامة العامة المنصوص عليها في الأتفاقيات الدولية لحماية العنصر البشري والممتلكات الشخصية هي ضعيفة في تلك المشاريع. حيث تم خلال الدراسة أنتخاب مجموعة عشوائية من مواقع المشاريع وتم أعداد قائمة تدقيق (Check List) لمعرفة مدى تطبيق متطلبات السلامة العامة في العراق، والجدول **رقم (1)** يبين شكل قائمة التدقيق والنتائج النهائية لعملية جمع البيانات.

جدول (1): قائمة تدقيق (check list) والنتائج النهائية للبيانات.

مستلزمات وأجراءات السلامة العامة	موجودة	غير موجودة
1- خوذة الرأس	%29	%71
2- القفازات لحماية الأيدي	%63	%27
3- الواقيات والنظارات لحماية العينين والوجه	%70	%30
4- أحذية السلامة	%30	%70
5- الكمامات للحماية من تأثير الغازات والروائح السامة	%40	%60
6- أحزمة الأمان للعاملين على السقالات	%20	%80
7- وجود عامل أو أكثر مسؤول على تنظيف الموقع	%65	%35
8- وجود مرافق صحية كافية للعاملين	%50	%50
9- وجود مياه شرب صحية في الموقع	%35	%65
10- وجود خدمات طبية مثل صندوق الأسعافات الأولية والنقالات ...ألخ	%10	%90
11- وجود مستلزمات الوقاية من الحريق	%40	%60
12- وجود أنظمة ملائمة للتهوية في موقع العمل	%65	%35
13- وجود اللافتات التحذيرية في موقع العمل	%23	%77
14- وجود أنارة كافية في موقع العمل	%85	%15
15- وجود أجراءات معالجة الضجيج مث واقيات السمع	%9	%91
16- الملابس الواقية لحماية الجسم	%20	%80
17- حماية العاملين من مخاطر الكهرباء	%85	%15
18- وجود عجلات ملائمة لنقل العاملين وتأمين سلامتهم	%35	%65
19- وضع حواجز حماية أمام فتحات المصاعد والادراج وغيرها	%45	%55
20- مستلزمات حماية المجاورات	%72	%28
21- وجود سجلات خاصة بالعاملين وأعمارهم وأصابات العمل	%25	%75

من خلال المعلومات المبينة في قائمة التدقيق **(جدول رقم (1))** يتبين بأن أغلب متطلبات السلامة المهنية غير متوفرة في المشاريع الأنشائية في العراق، وهذا يرجع الى عدم أهتمام أدارة المشروع والأدارات العليا بأجراءات السلامة العامة وأجراءات الوقاية الشخصية وكيفية تطبيقها. كذلك لايوجد تنسيق واضح بين دوائر ومؤسسات الدولة والجهات الرقابية حول كيفية تطبيق متطلبات السلامة المهنية في مواقع العمل وفرض

أجراءات مشددة تلزم المقاول بضرورة تطبيق أجراءات السلامة المهنية والوقاية الشخصية لما في ذلك من حفظ لحياة الأنسان وحمايته من المخاطر والكوارث التي قد تحصل فيما لو تم الأستهانة بتلك الأجراءات. كما تم ملاحظة أثناء أجراء الدراسة الميدانية فقدان التدريب والتوعية للعاملين حول متطلبات الوقاية الشخصية والسلامة المهنية وتعريفهم بالمخاطر التي قد تصيبهم في حالة عدم ألتزامهم بتعليمات السلامة العامة.

علاقة بين عمر العامل وعدد الأصابات

لتوضيح تأثير العمر للعامل على عدد الأصابات في المشاريع الأنشائية، كان لابد من جمع المعلومات التي تتعلق بهذا الموضوع، حيث تم أعداد أستمارة أستبيان تتضمن معلومات حول موضوع السلامة المهنية وأصابات العمل وتم أختيار عينة من المهندسين ومدراء المشاريع للأجابة عن الأسئلة والمعلومات التالية:

1. هل يوجد شرط أو فقرة في عقد المقاولة تشير الى ضرورة وجود أجراءات السلامة العامة في موقع العمل؟
2. ما مدى تطبيق أجراءات السلامة المهنية في موقع العمل؟
3. هل توجد برامج تدريب وتوعية للعاملين في مواقع العمل بأجراءات السلامة المهنية؟
4. هل يوجد نظام توثيق لأصابات العمال والحوادث وأجراءات السلامة المتبعة في المشروع؟
5. معلومات عن عدد الحوادث أو الأصابات خلال تنفيذ المشروع.
6. معلومات عن عمر المصاب ومهنته وخبرته ونوع ومكان الأصابة وسببها وتأثيرها على سير العمل في الموقع.

التحليل الأحصائي

من خلال المعلومات المثبتة في أستمارات الأستبيان المستلمة من الأشخاص الذين تم توزيعها عليهم، أتضح أن أغلب المشاريع الأنشائية قد حدثت فيها أصابات وحوادث للعاملين في الموقع، وأن تلك الحوادث شملت أعمار مختلفة من العاملين ما بين (17 – 55) سنة. كانت عدد الأستمارات الفعلية المستلمة من المستبينين هي (65) أستمارة، حيث تم تنظيم المعلومات والبيانات المدونة في تلك الأستمارت بشكل جدول تكراري بعد حساب عرض الفئة التكرارية من خلال القانون التالي:

$$W = \frac{R}{K} \quad \text{.....Eq(1).}$$

حيث أن:

W = عرض الفئة التكرارية (Class Width).

R = المدى (Range).

K = عدد الفئات (No. of Classes).

ولحساب عرض الفئة يجب أولاً أن نحسب كل من المدى (R) وعدد الفئات (K) وكما يلي:

R = maximum value – minimum value …….Eq(2).

R = 55 – 17 = 38

K = 1+ 3.322 log (N) ……Eq(3).

حيث أن (N) تمثل عدد البيانات أو القراءات الملاحظة وهي (65) قراءة.

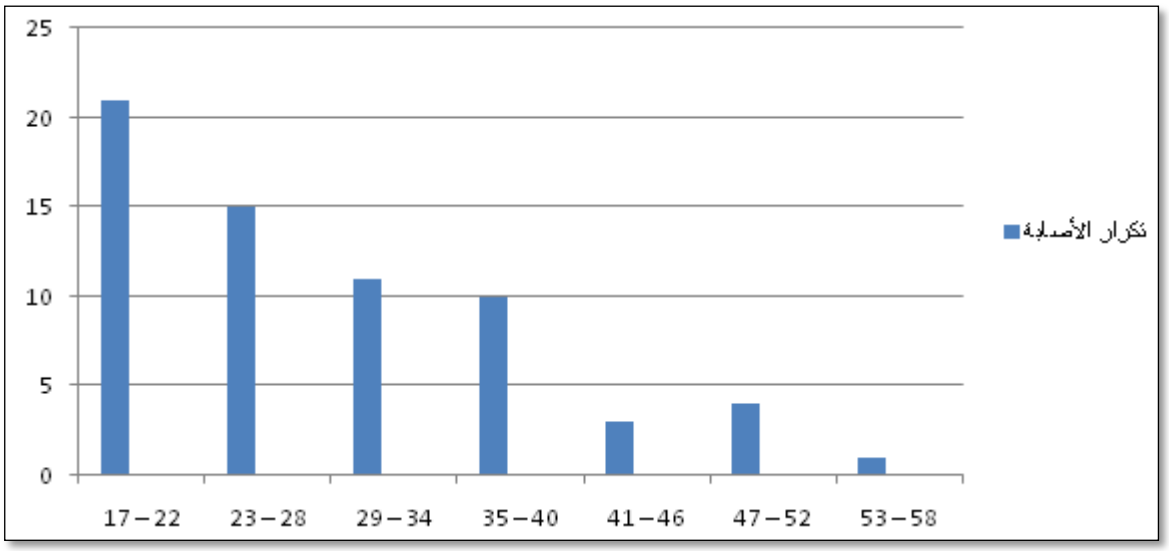
K = 1+ 3.322 log (65) = 7

$$W = \frac{38}{7} = 5.43 \approx 5$$

بعد أكمال الحسابات أعلاه تم تنظيم البيانات بشكل جدول تكراري **(جدول رقم 2)** يوضح العلاقة بين عمر العامل وعدد الأصابات التي تحدث في موقع العمل، والشكل **رقم (1)** يوضح العلاقة بين العمر للعامل وعدد الأصابات.

جدول (2): العلاقة بين عمر العامل وعدد الأصابات.

الفئة العمرية للعمال	التكرار أو عدد الأصابات
22 – 17	21
28 – 23	15
34 – 29	11
40 – 35	10
46 – 41	3
52 – 47	4
58 – 53	1
مجموع التكرارت	65



شكل (1): العلاقة بين عمر العامل وعدد الأصابات.

أن الهدف الرئيسي لهذه الدراسة هو أثبات أن عدد الأصابات تتركز في الأعمار الصغيرة للعمال (فئة الشباب) حيث تركزت الأصابات بين الأعمار (17 – 34) وكان عددها هو (47) أصابة من مجموع (65) أصابة أي بنسبة (72%) وكالاتي: –

1. من خلال المعلومات المبينة في الجدول **رقم (2)** نستنتج بأن فئة الشباب هم أكثر عرضةً للمخاطر وأصابات العمل التي قد تحدث في المواقع ويرجع ذلك لأسباب كثيرة منها:

- أن الكثير من المقاولين وأصحاب العمل يفضلون فئة الشباب للعمل في المشروع لسرعتهم في العمل وقوة أجسامهم ونشاطهم العالي، أي أن أغلب العاملين في مواقع العمل هم من فئة الشباب.
- أن الشباب وخاصة المبتدؤن في العمل هم أقل خبرة ممن هم أكبر منهم سناً، لذا فهم أكثر عرضةً للأصابة.
- كثرة المزاح أثناء العمل بين صفوف الشباب، وهذا يؤدي غالباً الى حدوث الأصابة.
- غالباً ما توكل الأعمال التي تحتوي على خطورة الى فئة الشباب مثل الأعمال على مرتفعات عالية وحمل الأوزان الثقيلة وغيرها.
- لايوجد برامج تدريبية على متطلبات السلامة للعاملين وخاصة المبتدؤن بالعمل وهم فئة الشباب لغرض توعيتهم وتحذيرهم من المخاطر التي قد يواجهونها في مواقع العمل في حالة عدم ألتزامهم بمتطلبات السلامة المهنية.

2. أثبتت الدراسة بأن أنواع أصابات العمل هي متباينة حسب نوع العمل الذي يقوم به العامل كما موضح في جدول **رقم (3)**، ولكن أكثرها تحدث لعمال البناء حيث بلغت نسبة أصابات العمل لديهم (57%)، ويرجع ذلك لأسباب كثيرة منها:

- أن المشروع الأنشائي يحتوي عل الكثير من الأنشطة وأن أكثر الأنشطة توكل الى عمال البناء وغالباً ما تكون تلك الأنشطة محتوية على بعض المخاطر التي قد تؤدي الى حدوث الأصابة.
- غالباً ما يكون عامل البناء هو شخص بسيط يبحث عن أي عمل يمتهنه للحصول على المال وليس لديه خبرة في المجالات الأخرى مثل الحدادة والنجارة وغيرها، لذا فأنه يوكل بأعمال التي تخص عملية البناء مثل حمل المواد الأنشاية، مساعدة العامل الماهر، تنظيف الموقع.....ألخ.
- عدم توفير متطلبات السلامة العامة للعاملين مثل ملابس الوقاية الشخصية ووسائل حماية بيئة العمل وغيرها.
- لايوجد برامج تدريب وتوعية للعاملين على متطلبات السلامة المهنية.

جدول (3): العلاقة بين مهنة العامل وعدد الأصابات.

الفئة العمرية	الأختصاص						المجموع	النسبة %
	عامل بناء	نجار	حداد	حفار	لحام	حارس		
22–17	13	6		2			21	32,3
28–23	10	3	2				15	23,1
34–29	4	3	4				11	16,9
40–35	7	2	1				10	15,4
46–41	1	2					3	4,6
52–47	1		2			1	4	6,2
58–53	1						1	1,5
المجموع	37	16	9	2	0	1	65	
النسبة %	56,9	24,6	13,9	3,1	0	1,5		100

يلي عمال البناء من حيث تعرضهم للأصابة هم النجارين، حيث بلغت نسبتهم حوالي (25%) ويرجع ذلك لأسباب منها:

- أن عمال النجارة يستعملون الكثير من الأدوات الخطرة مثل المطرقة والمسامير والمناشير وغيرها وهي أدوات قد تؤدي الى حدوث الأصابة في حالة الأهمال وسوء أستخدامها.
- قد يعمل النجارين على أماكن مرتفعة، لذا فهم عرضة للأصابة والسقوط من المرتفعات في حالة تجاهلهم وأهمالهم لمتطلبات السلامة العامة مثل أحزمة الأمان وخوذة الرأس والقفازات اليدوية وغيرها.
- أن مهنة النجارة تحتاج الى الخبرة والممارسة، حيث أن نقص الخبرة والتدريب في هذا المجال قد يؤدي الى حدوث الأصابة.

3. يوضح جدول **رقم (4)** أنواع أصابات العمل ونسبها بين صفوف الفئات العمرية المختلفة للعاملين، حيث نستنتج بأن أكثر الحوادث التي تقع للعاملين هي الجروح والكسور، وهما يشكلان حوالي نسبة (57%) من أنواع الحوادث التي تقع في مواقع المشاريع الأنشائية. أما بقية الأنواع المختلفة من أصابات العمل مثل الحروق وخطر الكهرباء والتسمم فهي غالباً ما تنتج عن الأهمال وعدم أتباع أو الأفتقار للعلامات والأرشادات التي تتبع لمنع وقوع تلك الحوادث، أما الوفاة فهي قليلة الحدوث وهي ناتج خطر كبير لأي نوع من أنواع أصابات العمل التي تم ذكرها.

جدول (4): أنواع أصابات العمل وعددها.

الفئة العمرية	نوع الأصابة							المجموع	النسبة %
	كسر	حرق	رضوض	جرح	تسمم	وفاة	أخرى		
22–17	5			9	2	2	3	21	32,3
28–23	5	1	1	4		3	1	15	23
34–29	2	1	1	3		2	2	11	17
40–35		1	1	3	2	2	1	10	15,4
46–41	1		1			1		3	4,6
52–47	1			3				4	6,2
58–53	1							1	1,5
المجموع	15	3	4	22	4	10	7	65	
النسبة %	23	4,6	6,2	33,8	6,2	15,4	10,8		100

4. بينت الدرسة بأن أغلب المشاريع الأنشائية في العراق تفتقر لأجراءات السلامة العامة، حيث كان رأي المستبينين بأن حوالي (75%) من مواقع المشاريع الأنشائية لاتوجد فيها أجراءات متبعة للسلامة المهنية

ولايوجد تدريب وتوعية للعاملين حول الأجراءات الصحيحة والمتبعة دولياً للسلامة المهنية وتأثيرها في حماية العنصر البشري من حوادث العمل.

الأستنتاجات

نستنتج من هذه الدراسة الأمور التالية بموضوع ادارة السلامة المهنية:

1. هناك نقص شديد وعدم أهتمام بعلم السلامة المهنية ومتطلبات الوقاية الشخصية في مواقع المشاريع الأنشائية في العراق.

2. غياب الجهات الحكومية قي العراق التي تعنى بأمور السلامة المهنية وضعف التنسيق بين دوائر الدولة مثل دائرة الصحة ودائرة الضمان الأجتماعي وغيرها حول تسجيل وحفظ بيانات حول الأصابات التي تحدث للعاملين في مواقع العمل، وهذا يعلل سبب نقص البيانات التي تخص العمال المصابين مثل أسمائهم، أعمارهم، الحالة الأجتماعية، نوع الحادث، مكان الأصابة، وسببها،...ألخ. كما لايوجد تنسيق بين الجهات الحكومية وغير الحكومية حول وضع ستراتيجيات وقوانين تضمن للعامل سلامته وحقوقه وتلزم أصحاب العمل بضرورة حماية العمال وتأمين سلامتهم من خلال توفير متطلبات السلامة المهنية والوقاية الشخصية.

3. غياب التدريب والتوعية للعاملين حول أجراءات السلامة العامة والمخاطر التي قد تصيبهم فيما لو أهملوا أجراءات السلامة المهنية.

4. أن أصابات العمل لا تتوزع بصورة طبيعية بين الأعمار المختلفة للعمال، حيث أثبتت الدراسة بأن الحوادث وأصابات العمل تكثر لدى فئة الشباب وخاصة العمال التي تقل أعمارهم عن 29 سنة لأسباب كثيرة منها نقص الخبرة لديهم وتوكيلهم بأعمال تناسب أعمارهم والمزاح والأهمال أثناء العمل.

5. من خلال مشاهدة بعض مواقع العمل في العراق، تم ملاحظة بأن أكثر العاملين هم من فئة الشباب وهم مفضلين لدى أصحاب العمل لقوة أجسامهم وتحملهم أعباء العمل المختلفة، وهو ما يفسر كثرة الأصابات بين صفوف الشباب العاملة في مواقع العمل، حيث يتم تشغيلهم مباشرة بدون أي تدريب على الأعمال التي توكل لهم، مما يجعلهم عرضة للأصابة.

6. بينت الدراسة بأن أنواع أصابات العمل هي متباينة حسب طبيعة العمل الذي يقوم به العامل، كما بينت الدراسة بأن أكثر الأصابات في المواقع الأنشائية هي تحدث لعمال البناء أكثر من غيرهم من الأختصاصات الأخرى مثل النجار والحداد وغيرهم، لأن عملية البناء تحتوي على تفاصيل وفقرات كثيرة يكون فبها عامل البناء عرضة للأصابة فيما لو أهمل متطلبات السلامة المهنية والوقاية الشخصية.

التوصيات

1. يجب على الجهات المختصة بشؤون العمل والعمال مثل دائرة العمل والضمان الأجتماعي ونقابة العمال وضع الشروط والقوانين التي تكفل ضمان حياة العامل ومستحقاته وتوفير ظروف الأمان والسلامة العامة أثناء قيامه بعمله، وتوفير الجهات الرقابية لمراقبة والتأكيد على المقاولين وأصحاب العمل على ضرورة توفير متطلبات السلامة المهنية والوقاية الشخصية للعاملين في موقع العمل. كما توصي هذه الدراسة بضرورة تفعيل القوانين العراقية الخاصة بموضوع السلامة المهنية مثل قانون العمل رقم (71) لسنة 1987 (وطفة 2001)، قانون الصحة العامة رقم (89) لعام 1981، قانون التقاعد والضمان الأجتماعي للعمال رقم (39) لعام 1971....ألخ.

2. من خلال عملية الأستبيان، تبين بأنه لاتوجد فقرة في عقد المقاولة تنص على وجوب توفير أجراءات السلامة المهنية وحماية العاملين من المخاطر، لذا لابد من تضمين فقرة ضمن فقرات عقد المقاولة تلزم المقاول توفير الأجراءات الضرورية للسلامة المهنية قي مواقع العمل.

3. يجب توفير برامج تدريبية للعاملين في مواقع العمل وخاصة فئة الشباب الذين غالباً ما يفتقرون للخبرة، من أجل تعريفهم بالأعمال التي سيقومون بها في الموقع والمخاطر التي قد تصيبهم في حالة أهمالهم لمتطلبات السلامة المهنية. كما يجب توعيتهم بالأرشادات والتعليمات الخاصة بالسلامة المهنية وتنبيههم حول العقوبات التي قد يواجهونها في حالة أخلالهم بتلك التعليمات.

4. التأكيد على توفير متطلبات الأسعافات الأولية في موقع العمل مثل صندوق الأسعافات الأولية وتعين أو تدريب شخص على كيفية أسعاف العامل المصاب.

5. يجب على كافة الجهات الحكومية وغير الحكومية تنظيم سجلات لتدوين وحفظ للمعلومات التي تتعلق بالحوادث وأصابات العمل وكذلك معلومات عن العامل المصاب وتنظيم أستمارة يطلق عليها (تقرير حادث) يبين فيه معلومات عن الشخص المصاب وعمره وسبب الأصابة ومكانها من أجل دراسة تلك الحوادث والتقليل منها مستقبلاً.

6. التأكيد على توفير قسم خاص بالسلامة المهنية في شركات المقاولات وتفعيل دورها الرقابي على مواقع العمل ووضع الخطط التي تسهم في تجنب وتقليل الخطر وتوفير الجو الآمن للعاملين من أجل زيادة أنتاجيتهم في العمل.

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