Some Properties of Superplasticized and Retarding Concrete Under Effect of Accelerated Curing Methods

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ABSTRACT

In recent decades, tremendous success has been achieved in the advancement of chemical admixtures for Portland cement concrete. Most efforts have concentrated on improving the properties of concrete and studying the factors that influence on these properties. Since the compressive strength is considered a valuable property and is invariably a vital element of the structural design, especially high early strength development which can be provide more benefits in concrete production, such as reducing construction time and labor and saving the formwork and energy. As a matter of fact, it is influenced as a most properties of concrete by several factors including water-cement ratio, cement type and curing methods employed. Because of accelerated curing is deemed one of methods that achieved high early age strength of concrete and has been grown only gradually. So, the prime aim of this research work is to provide information about the some desired properties of superplasticized and retarding concrete succumbed to accelerated curing methods, such as compressive strength and water absorption and compared it with their corresponding normally curing concrete. Besides, the research discusses the influence of surface texture of aggregate and over-dosing for admixture on performance concrete in such as that conditions. The test results revealed that effect of admixture on properties of concrete are dependent upon it dosage, surface texture for aggregate and temperature used for curing.

Keywords: superplasticizer and retarding, accelerated curing, warm water, boiling water, setting time, slump, fresh density, compressive strength, water absorption

الخلاصة

في العقود الاخيرة تحققت الكثير من النجاحات فيما يخص تطوير المضافات الكيميائية لخرسانة السمنت البورتلاندي. واغلب الجهود تركزت على تحسين خصائص الخرسانة وايضا دراسة العوامل المؤثرة عليها. وبما ان مقاومة الانضغاط تعتبر الخاصية القيمة والعامل الاساس والثابت في التصميم الانشائي خصوصا تطورها في الاعمار المبكرة حيث يمكن ان توفر العديد من الفوائد في انتاج الخرسانة مثل تقليل مدة وعمل البناء و توفير القوالب. الا انها في واقع الامر كمعظم خصائص الخرسانة تتأثر بعدة عوامل بضمنها نسبة الماء الى السمنت،نوع السمنت وطرق الانضاج المتبعة. ولكون الانضاج المعجل يعتبر احد الطرق التي تحقق مقاومة عالية ومبكرة للخرسانة واصبحت تنمو بشكل تدريجي. لذا كان الهدف الرئيسي للبحث هو توفير معلومات عن بعض الخصائص المرغوبة لخرسانة الملدن المتفوق والمبطيئ والخاضعة لتاثير الانضاج المعجل مثل مقاومة الانضغاط وامتصاص الماء ومقارنتها مع خصائص الخرسانة في حالة الانضاج الاعتيادي. بجانب ذلك، يناقش البحث تاثير الملمس السطحي للركام الخشن والوزمات العالية للمضاف على اداء الخرسانة في مثل تلك الظروف. وأظهرت نتائج البحث بأن تأثير المضاف على خصائص الخرسانة يعتمد على وزمة المضاف،الملمس السطحي للركام ودرجة الحرارة المستخدمة للانضاج.

INTRODUCTION

The practical use of concrete as a construction material depends upon the fact that it is plastic in the freshly mixed state and subsequently becomes hard, with considerable strength. This change in its physical properties is due to the chemical reaction between cement and water, a process known as hydration. Hydration involves chemical changes, not just a drying out of the material, hydration is irreversible. The reaction is gradual, first causing stiffening of the concrete, and then development of strength, which continues for a very long time. Under certain ideal conditions it is probable that concrete would continue to increase in strength indefinitely. Air temperature, ground temperature and weather conditions all play major roles in the rate with which cement hydrates (Corcoran, 2004). If the hydration process is speeded up it is possible to reduce the waiting period for test results from 28 days to only 1 or 2 days. This is done by using accelerated curing methods that either supply an external source of heat or retain the heat of hydration given off when cement and water react (ASTM C 684-99). As a results, many benefits can be achieved such as ;

- The fast trend of construction progress and its economic benefits attained from accelerating the construction schedules.
- Testing for quality control purposes.
- To check the suitability of concrete mixes much earlier than the 28-days test during the design stage (Torkey, 1980)

Accelerated curing is any method by which high early age strength is achieved in concrete. These techniques are especially useful in the prefabrication industry wherein high early age strength enables the removal of the formwork within 24 hours thereby reducing the cycle time resulting in cost saving benefits (Erdem, 2003).The criterion for concrete strength requirement is always based on the characteristic compressive strength obtained after 28-days curing. This delay in testing of concrete seriously limits the control of the matrix during production and hampers quality assurance at early ages (Lamond, 1983). The use of a reliable accelerated strength testing method would add in no small measure to a better control over the properties of concrete in the field by enabling the concrete engineer to make necessary adjustment during proportioning of concrete early enough to avoid the production of sub-standard concrete (Malhotra,1981).The current speedy construction due to improved and innovative construction methods also calls for the potential strength of concrete to be determined at the earliest possible time after concrete has been placed (Tokyay, 1999). In this study, three different curing regimes were applied, normally curing, warm water method (WWM) and boiling water method (BWM).

RESEARCH PROGRAM

The basic objective of this present research is to study the influence of accelerated curing methods on some properties of superplasticized and retarding concrete. In this work, warm water and boiling water curing techniques according to ASTM C684-99 were applied to accelerate the strength gain of concrete. Two concrete mixes in terms of surface texture for gravel, ordinary and crushed, were considered. Superplasticizer and retarding admixture type G were also applied. The effect of surface texture for gravel, curing methods and over doses for admixture were investigated.

ACCELERATED CURING METHODS

There are several ways to cure concrete in the field. One form of curing that has become popular at precast prestressed concrete plants is accelerated curing. This type of curing is advantageous where early strength concrete gain is important (Yazdani, 2005). First, concrete elements can be removed from their forms very early after placement; currently, a 24-hour turnover period for most precast elements is standard. Second, rapidly curing concrete means that manufactures require less space reserved for the explicit purpose of curing (Vollenweider, 2004). The rate of strength gain is well known to be a consecutive property from the hydration process of the cement. Since the degree of cement hydration depends on the surrounding temperature, so the strength gain could be accelerated at early ages by using various techniques of accelerated curing such as; heat water techniques, oven curing techniques, maturity methods, pressure and elevated temperature technique and expanded polystyrene molds technique (Torkey, 1980). The ASTM C684-99 recommends three different accelerated curing techniques:

– Warm water method (WWM), the specimens were cast in steel molds and were immediately placed in the curing tank for a periods of 23½hr±30min. The curing tank water temperature was 35˚C±3˚C.The top of the molds were covered to prevent loss of mortar to the water bath. After

that, the specimens were demoulded and tested at age of 24 hr±15 min.
– Boiling water method (BWM), the specimens were cast in steel molds and were cured initially for 23hr±15min in the laboratory environment (approximate temperature 21ºC). Then, the specimens were immersed in boiling water and remained there for a period of 3½hr±5 min, cooled for 1 hr and then tested at an age of 28½hr±15 min.
– Autogenous curing method, the specimens were cast in steel molds and were placed in an insulating container and held there for 48hr±15 min and then tested at an age of 49hr±15 min (ACI 517.2 R-87, 1992).

The focus of this paper is investigated the effectiveness of the warm water and boiling water methods for accelerating curing on concrete mixtures containing superplasticizer and retarding admixture.

EXPERIMENTAL INVESTIGATIONS AND SPECIFICATIONS

Properties of Materials

Cement; one type of Portland cement; ordinary portland cement (OPC) was applied. Total percentages for its oxides, compound composition and some properties were fulfilled to the requirement of Iraqi specification No.5/1984 as denoted in Table 1 .

Aggregate; the fine aggregate used was local sand, while the coarse aggregate used was two types; ordinary and crushed gravel with maximum size 19 mm. All their met the requirements of ASTM C33-03 with respect the sieve analysis and physical properties as denoted in Table 2,3,4,5,6 and 7.

Water; Normal tap water was used as mixing water.

Admixture; synthetic based superplasticizer with a retarding effect was used. Its commercial known as Eucobet super VZ and complied to ASTM C 494 type G. Its specific gravity was 1.1 and its chloride content was claimed nil. Table 8 shows the technical description for it.

Concrete Mixes Proportion and Its Fresh Tests

Throughout the laboratory experiment, the applied eight concrete mixes were selected to cover the effect of surface texture for gravel and the dosage of admixtures on the properties of produced concrete with normally water cured and accelerated cured. Control mixes (reference) designed for 28-days characteristic strength of 25MPa according to ACI 211.1-95. For both two types of gravel, four mixes were prepared with four dosages of admixture (0, 0.8,1.6 and 2.5)% by weight of cement. All mixes were designed to have fixed proportions of total cement content of 410 kg/m^3, 710 kg/m^3 sand, 1030 kg/m^3 gravel and 190 kg/m^3 free water content. After mixing the materials, the following fresh tests were determined for each concrete mix;

- Initial setting time according to ASTM C403-99
- Slump according to ASTM C143-2000
- Fresh density according to ASTM C138-01

Preparation of Specimens and Curing

The cubical molds of size 150 mm lightly oiled were filled with fresh concrete and compacted by using vibrating table. For each concrete mix, twenty four cubic specimens were used, twelve cubic specimens for accelerated curing according to specified procedure in ASTM C 684-99 (six for the warm water curing and another six for the boiling water curing). While the remaining twelve of cubic specimens were used for normally water curing, where the molds after casting were covered with polyethylene sheet and kept in the laboratory environment for a period of 24hr. After that, the specimens were demoulded and placed in the water curing tanks up to the wanted age for test.

Hardened Concrete Tests

Compressive Strength

Compressive strength tests involve the manufacture of test specimens which were square in shape measuring 150 mm according to B.S.I 1881: part 116: 1989. For normally water curing, the specimens were tested at age of 1,3 and 28-days strength of the concrete. While for accelerated cured specimens, accelerated strength were determined at ages of 24 hr±15 min and 28½hr±15 min for WWM and BWM respectively. In each test age, the average of three specimens was adopted.

Water Absorption

The water absorption test was performed according to ASTM C 642-06 and carried out on 150 mm cube specimens at age 28-days for normally curing specimens and at age 24 hr±15 and 28½hr±15 min for WWM and BWM respectively. The average of three specimens in each age was taken. In this test, the specimens

were weighed before and after immersion in water. Water absorption was then determined as the difference in the weight of specimen before and after immersion in water relative to the weight of specimen before immersion in water, expressed in percentage.

TEST RESULTS AND DISCUSSION

1. Table 9 summarizes the results of the tested fresh concrete. The measured properties were initial setting time, slump and fresh density. The results indicated that ordinary gravel mixes with and without admixture showed increase in an initial setting time and slump versus slight decrease in fresh density compared to their corresponding crushed gravel mixes as denoted in Fig.4,5 and 6. Where as the ratios of increasing in an initial setting time and slump for control mix (M1) compared to M5 were 7.81% and 8.64 % respectively, while the reduction in fresh density was 0.13%. This may be attributed to the fineness texture for gravel used which increase the workability of concrete mix consequently, decrease the internal friction between particles of mix.
2. The measured values for initial setting time, slump and fresh density indicate that the control mixes for both two types of gravel (M1and M5) have the lowest values when compared it with their corresponding mixes that containing of SPR as represented in Fig.7 and 8. This can be ascribed to the fact that the SPR used causes an increase in set retardation by slowing down the rate of early hydration of C_3S and increasing the fluidity concrete mix. Beside, the improvement which enhancement in the SPR mixes consistency and the better compactability of such mixes (Ramachandran, 1998). For example, the reduction in initial setting time, slump and fresh density for control mix (M1) compared to M2 mix were 28.86%, 36.70% and 0.38% respectively, versus 31.18%, 35.20% and 0.55% reduction in initial setting time, slump and fresh density respectively, for control mix (M5) compared to M6 mix.
3. The results also demonstrated that the retarding tendency of the SPR admixture increased with higher admixture content for both two types of gravel, where setting times were extended when admixture was incorporated into mixes compared with it corresponding control mixes as revealed in Fig.4. The retarding effects of a admixture when added to a mix continue until it is removed from the solution by reaction with C_3A from the cement or by some other way and incorporated into the hydrated material.
4. The results denoted that the concrete mixes (M4 and M8) demonstrated decrease in fresh density compared to M3 and M7 respectively. This is may be due to the overdosing for SPR used in these mixes which produce undesirable effects such as increase the fluid of concrete mix and setting time as a results induce the onset of segregation in particles the mix. That is why usually discouraging used higher contents for admixture because of adverse effectiveness. The reduction in fresh density for M4 and M8 mixes were 0.21% and 0.42% compared to M3 and M7 mixes respectively.
5. Table 10 summarizes the results of the compressive strength and water absorption tests for normally and accelerated curing specimens. From these results, it can be seen that crushed gravel mixes with different curing methods showed higher improvement in compressive strength and more reduction in water absorption compared to their corresponding ordinary gravel mixes. This is probably due to the fact that the rough particles tend to provide stronger bond than smooth particles. As a results, rough particles tend to produce higher strength (Kaplan, 1959). The results also showed that the effect of surface texture for gravel was more noticeable in accelerated curing (WWM and BWM) than that in normally curing. Besides, the difference due to the surface texture for gravel was less in the BWM than that in the WWM. The ratios of increasing in compressive strength of control mix (M5) relative to M1mix were 4.04%, 21.74% and 11.14% versus 6.77%, 2.98% and 3.40% reduction in water absorption at 28-days normally curing, warm water method (WWM) and boiling water method (BWM) respectively.
6. The results also showed that all the concrete mixes with presence SPR admixture and under effect various curing methods exhibited slight improvement in compressive strength and noticeable reduction in water absorption compared to their control mixes. The main reason is returned to the better dispersion of the cement particles (uniform distribution of products of hydration within the paste) which resulted in higher rate of cement hydration. Furthermore, because of its effectiveness in delay setting time lead to produce a denser gel. For example, the ratio increase in compressive

strength for M2 mix compared to M1mix were 4.08%, 1.30% and 2.17% versus 21.87%, 4.67% and 10.38% reduction in water absorption at 28-days normally curing, WWM and BWM curing respectively. While the ratio increase in compressive strength for M6 mix compared to M5mix were 7.10%, 2.30% and 3.55% versus 24.02%, 6.28% and 12.75% reduction in water absorption at 28-days normally curing, WWM and BWM curing respectively.

7. From Table 10, it can be seen that normally curing specimens at age 1-day have lower compressive strength than that corresponding accelerated curing specimens. This is may be strongly linked with raise the curing temperature from 21˚C for normally water curing to 35˚C and 100˚C for warm and boiling water curing respectively. On contrary, the results of normally curing specimens at age 3-days and 28-days showed higher values for compressive strength when compared it with corresponding accelerated curing specimens. This is may be associated with age of the specimens where the rate of gain of strength increase with age. On the other hand, when comparing the results of compressive strength for WWM and BWM, it can be observed that compressive strength of BWM curing specimens were higher compared to their corresponding of WWM curing specimens. This is attributed to increase the temperature for BWM than WWM, where an increasing in curing temperature has a more favorable effect on the strength gain due to the direct effect of the temperature on activating hydration (Dhir, 1988).
8. The results also demonstrate that M4 and M8 mixes in all curing methods showed slight decrease in compressive strength with slight increase in water absorption when compared it with their corresponding M3 and M7 mixes. This behavior is substantially ascribed to the discommendable influences on properties of concrete for overdosing admixture in these mixes. The reduction in compressive strength for M4 compared to M3 were 1.92%, 0.87% and 1.71% versus 6.25%, 1.28% and 2.44% increase in water absorption at 28-days normally curing, WWM and BWM curing respectively. While the reduction in compressive strength for M8 compared to M7 were 1.74%, 0.71% and 1.05% versus 4.08%, 0.91% and 1.16% increase in water absorption at 28-days normally curing, WWM and BWM curing respectively.

CONCLUSIONS

The following conclusions have been reached in this study;

1. The behavior of concrete mixes containing superplasticizer and retarding (SPR) admixture under condition of accelerated curing is effects by many factors such as dosage of admixture, surface texture of aggregate and temperature used on the rate of strength gain.
2. The surface texture for gravel was affects the properties of fresh concrete. Where, the concrete mixes was high workable and delay in setting time versus decrease in fresh density when smooth gravel used instead of rough gravel. The ratios of increasing in an initial setting time and slump for M1 mix compared to M5 were 7.81% and 8.64% respectively versus 0.13% reduction in fresh density.
3. The control mixes showed decrease in an initial setting time, slump and fresh density when compared it with their corresponding mixes containing SPR. The reduction in initial setting time, slump and fresh density for control mix (M1) compared to M2 mix were 28.86 %, 36.70% and 0.38 % respectively, versus 31.18%, 35.20 % and 0.55 % reduction in initial setting time, slump and fresh density respectively, for control mix (M5) compared to M6 mix. Furthermore, M4 and M8 mixes demonstrated decrease in fresh density compared to M3 and M7 respectively. The reduction in fresh density for M4 and M8 mixes were 0.21% and 0.42% compared to M3 and M7 mixes respectively.
4. The influence of surface texture for gravel on compressive strength and water absorption was greater demonstrated in the accelerated curing specimens than normally curing specimens. On the other hand, this influence was less in the BWM than that in the WWM. The ratios of increasing in compressive strength of control mix (M5) relative to M1mix were 4.04%, 21.74% and 11.14% versus 6.77%, 2.98% and 3.40% reduction in water absorption at 28-days normally curing, WWM and BWM respectively.
5. The values of accelerated strength with warm water method (WWM) and boiling water method (BWM) for all concrete testing specimens were greater than the strength of normally cured concrete specimens at corresponding age. While these values were less comparing to values

3-days and 28-days normally curing. Besides, BWM curing specimens were higher than that WWM curing specimens.

6. With presence superplasticizer and retarding (SPR) admixture and under effect various curing methods, the mixes were exhibited slight improvement in compressive strength and noticeable reduction in water absorption compared to their control mixes. The ratio increase in compressive strength for M2 mix compared to M1mix were 4.08%, 1.30% and 2.17% versus 21.87%, 4.67% and 10.38% reduction in water absorption at 28-days normally curing, WWM and BWM curing respectively. While the ratio increase in compressive strength for M6 mix compared to M5mix were 7.10%, 2.30% and 3.55% versus 24.02%, 6.28% and 12.75% reduction in water absorption at 28-days normally curing, WWM and BWM curing respectively
7. In all curing methods, the mixes incorporating higher content of SPR admixture (2.5% by weight of cement) showed slight decrease in compressive strength versus slight increase in absorption compared to their corresponding mixes that containing (1.6% by weight of cement). The reduction in compressive strength for M4 compared to M3 were 1.92%, 0.87% and 1.71% versus 6.25%, 1.28% and 2.44% increase in water absorption at 28-days normally curing, WWM and BWM curing respectively. While the reduction in compressive strength for M8 compared to M7 were 1.74%, 0.71% and 1.05% versus 4.08%, 0.91% and 1.16% increase in water absorption at 28-days normally curing, WWM and BWM curing respectively.

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Table 1 Oxides, Compound composition and Physical properties of ordinary Portland cement

<table>
<tr><th>Oxides</th><th>%</th><th>I.S.
No.5/1984</th><th colspan="2">Property</th><th>Result</th><th>I.S.
No.5/1984</th></tr>
<tr><td>SiO2</td><td>20.54</td><td>–</td><td colspan="2">Fineness, m²/Kg</td><td>341</td><td>≥230</td></tr>
<tr><td>Al2O3</td><td>5.88</td><td>–</td><td rowspan="4">Setting time, hrs:min</td><td rowspan="3">Initial set.</td><td rowspan="3">2:35</td><td rowspan="3">≥00:45</td></tr>
<tr><td>Fe2O3</td><td>3.28</td><td>–</td></tr>
<tr><td>CaO</td><td>60.78</td><td>–</td></tr>
<tr><td>MgO</td><td>1.93</td><td>≤ 5.0</td><td>Final set.</td><td>4:45</td><td>≤ 10:00</td></tr>
<tr><td>SO3</td><td>1.87</td><td>≤ 2.8</td><td rowspan="7">Compressive strength, MPa</td><td rowspan="4">3-day</td><td rowspan="4">18.8</td><td rowspan="4">≥15.00</td></tr>
<tr><td>L.O.I.</td><td>3.31</td><td>≤ 4.0</td></tr>
<tr><td>I.R.</td><td>0.15</td><td>≤ 1.5</td></tr>
<tr><td>L.S.F.</td><td>0.89</td><td>0.66-1.02</td></tr>
<tr><td>C3S</td><td>41.74</td><td>–</td><td rowspan="3">7- day</td><td rowspan="3">23.3</td><td rowspan="3">≥23.00</td></tr>
<tr><td>C2S</td><td>27.48</td><td>–</td></tr>
<tr><td>C3A</td><td>10.04</td><td>–</td></tr>
<tr><td>C4AF</td><td>9.97</td><td>–</td><td colspan="2">Expansion,%</td><td>0.03</td><td>≤ 0.8</td></tr>
</table>

Table 2 Sieve analysis of sand

Sieve size (mm)	9.5	4.75	2.36	1.18	0.30
Cumulative % passing	100	91.39	38.90	7.11	4.61
ASTM C33-03	100	85-100	10-40	0-10	0-5

Table 3 Physical properties of sand

Physical properties	Specific gravity	Sulfate content	Absorption
Test result	2.66	0.07	0.81%
I.S. No.45/1984	-	≤0.5%	-

Table 4 Sieve analysis of ordinary gravel

Sieve size (mm)	25	19	9.5	4.75	2.36
Cumulative % passing	100	97.29	46.03	8.88	2.9
ASTM C33-03	100	90-100	20-55	0-10	0-5

Table 5 Physical properties of ordinary gravel

Physical properties	Specific gravity	Sulfate content	Absorption
Test result	2.64	0.09	0.77%
I.S. No.45/1984	-	≤0.1%	-

Table 6 Sieve analysis of crushed gravel

Sieve size (mm)	25	19	9.5	4.75	2.36
Cumulative % passing	100	93.75	49.28	7.04	4.11
ASTM C33-03	100	90-100	20-55	0-10	0-5

Table 7 Physical properties of crushed gravel

Physical properties	Specific gravity	Sulfate content	Absorption
Test result	2.63	0.05	0.69%
I.S. No.45/1984	-	≤0.1%	-

Table 8 Technical description of Eucobet super VZ

Appearance	Liquid

Colour	Brown
Specific gravity	1.1
Chloride content	nil
Air entraining	Does not entrain air
Compatibility with cement	all types of Portland cement
Shelf life	Up to 2 years
Dosage	0.4-1.6% of the cement weight

Table 9 Results of fresh tests for concrete mixes

Type of gravel	No. of Mix	SPR %	Initial setting time hr:min	Slump mm	Fresh density Kg/m^3
Ordinary	M1	0	4:36	88	2329
	M2	0.8	6:28	139	2338
	M3	1.6	13:05	180	2344
	M4	2.5	22:01	225	2339
Crushed	M5	0	4:25	81	2332
	M6	0.8	6:12	125	2341
	M7	1.6	12:33	168	2354
	M8	2.5	21:23	211	2344

ng and accelerated curing specimens

Accelerated curing	BWM	Absorption %	5.60	5.02	4.51	4.62	5.41	4.72	4.31	4.39

Type of gravel	No. of Mix	SPR %	Normally curing						
							WWM		
			Compressive strength MPa			Absorption %	Compressive strength MPa	Absorption %	Compressive strength MPa
			1-day	3-days	28-days	28-days			
Ordinary	M1	0	5.29	12.15	25.96	1.92	5.38	7.71	10.14
	M2	0.8	5.40	13.81	27.02	1.50	5.45	7.35	10.36
	M3	1.6	5.62	15.90	29.14	1.12	5.70	7.01	11.11
	M4	2.5	5.54	14.14	28.58	1.19	5.65	7.10	10.92
Crushed	M5	0	6.47	13.42	27.01	1.79	6.55	7.48	11.27
	M6	0.8	6.64	15.06	28.93	1.36	6.70	7.01	11.67
	M7	1.6	7.00	17.31	31.54	0.98	7.03	6.62	12.39
	M8	2.5	6.88	16.31	30.99	1.02	6.98	6.68	12.26

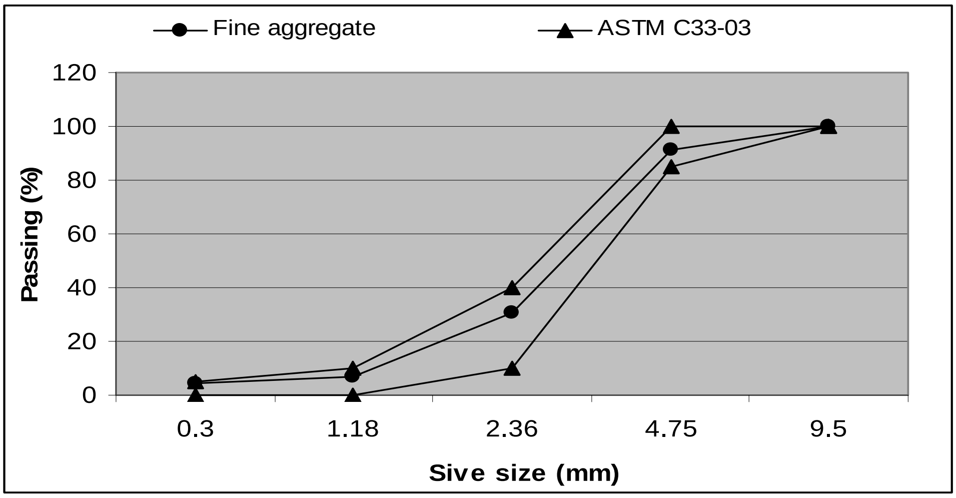

Fig.1 Grading curve for sand

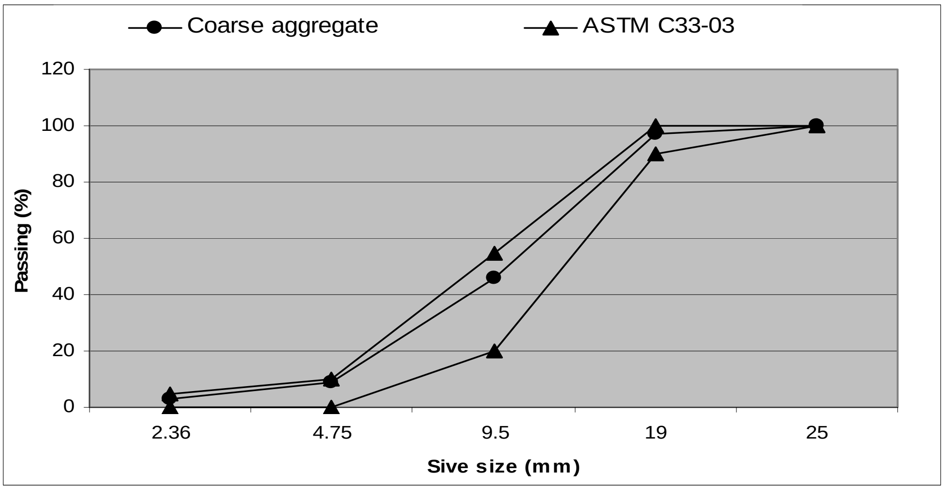

Fig.2 Grading curve for ordinary gravel

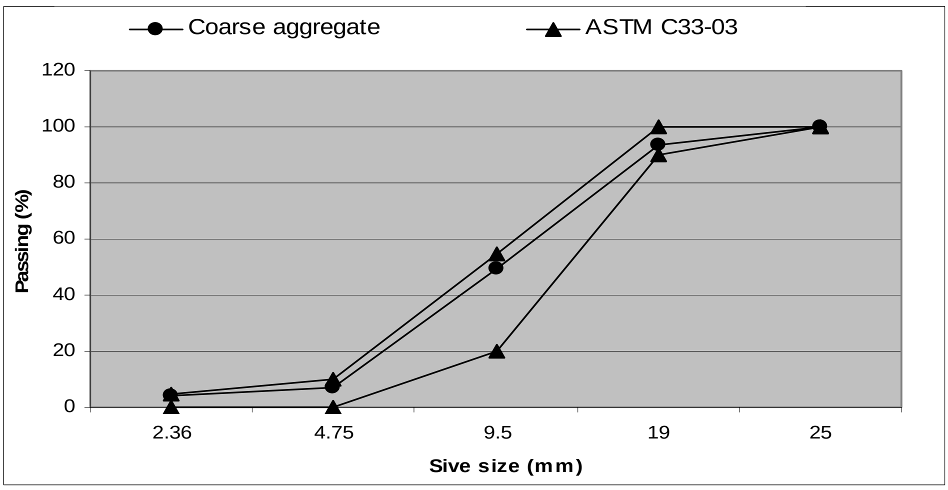

Fig.3 Grading curve for crushed gravel

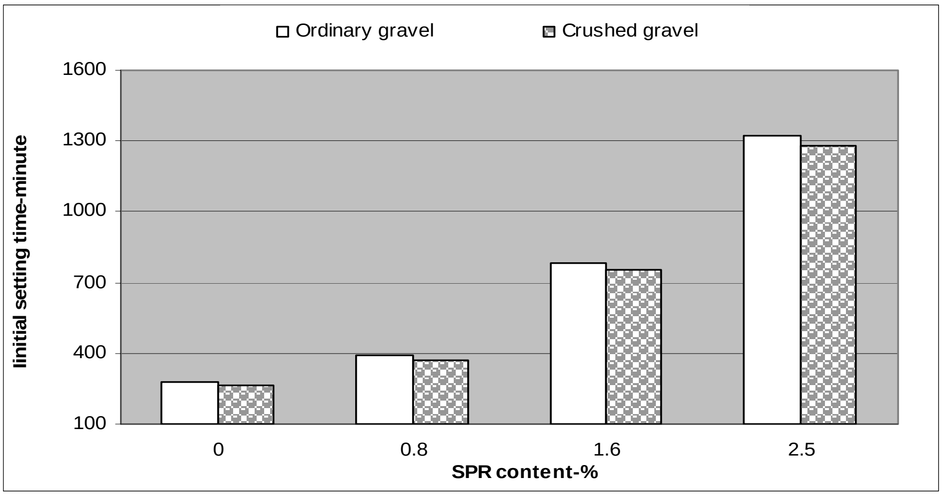

Fig.4 Initial setting time for mixes relative to type of gravel used at different SPR dosages

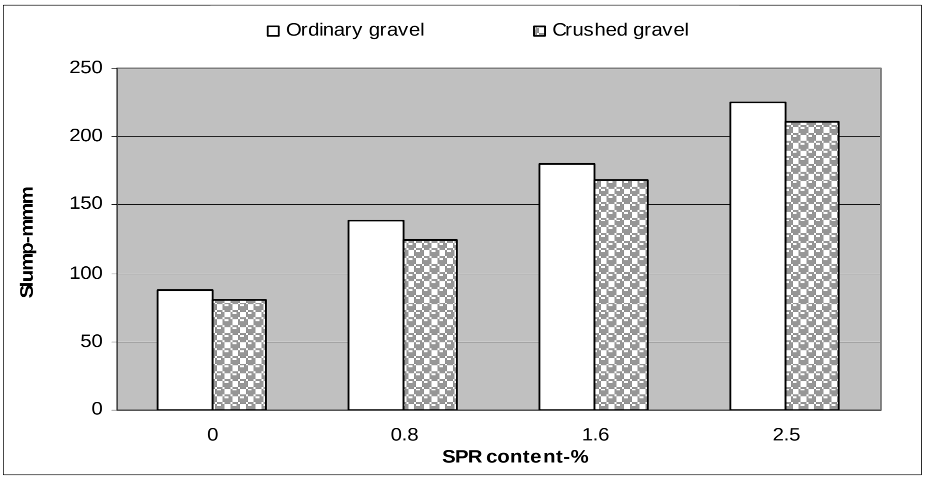

Fig.5 Slump of mixes relative to type of gravel used at different SPR dosages

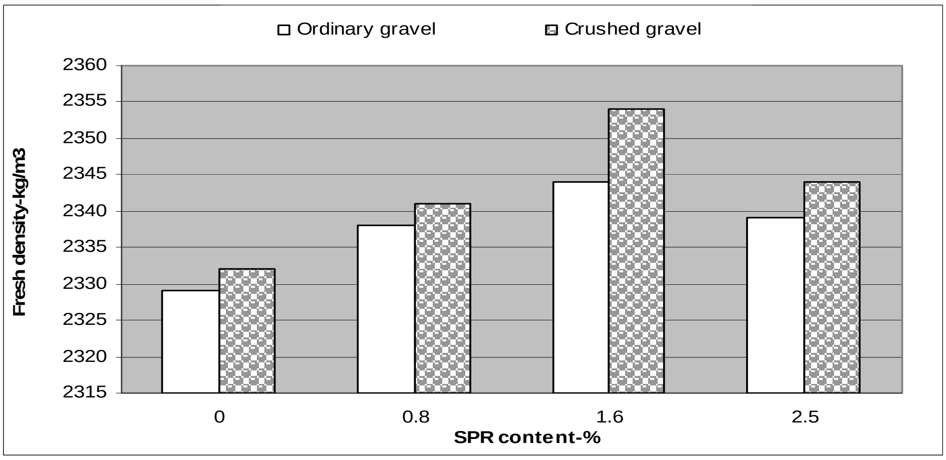

Fig.6 Fresh density for mixes relative to type of gravel used at different SPR dosages

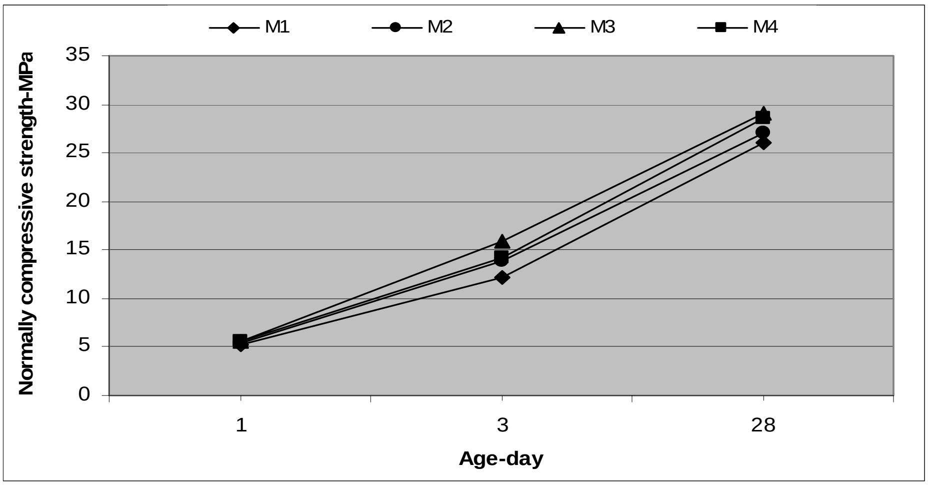

Fig.7 Normally compressive strength for ordinary gravel mixes at different SPR dosages

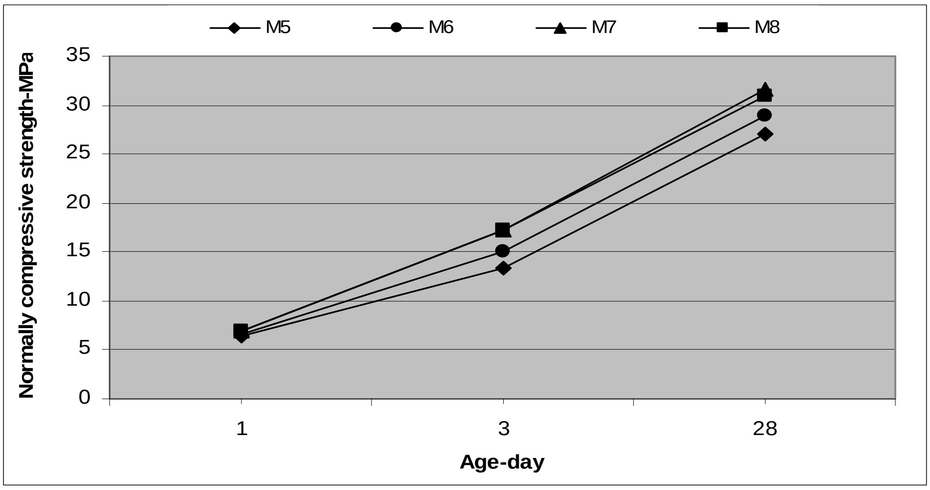

Fig.8 Normally compressive strength for crushed gravel mixes at different SPR dosages