Combined effect of fineness modulus and grading zones of fine aggregate on fresh properties and compressive strength of self compacted concrete

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ABSTRACT

Self-compacted concrete (SCC) considered as a revolution progress in concrete technology due to its ability for flowing through forms, fusion with reinforcement, compact itself by its weight without using vibrators and economic advantages. This research aims to assess the fresh properties of SCC and study their effect on its compressive strength using different grading zones and different fineness modulus (F.M) of fine aggregate. The fineness modulus used in this study was (2.73, 2.82,2.9& 3.12) for different zones of grading (zone I, zone II& marginal zone(between zone I&II)) according to Iraqi standards (I.Q.S No.45/1984).Twelve mixes were prepared, each mix were tested in fresh state with slump, V-Funnel and L-Box tests, then 72 concrete cubes of (100*100*100) mm for different mixes were tested for compressive strength after 7 and 28 days of water curing. Results indicated that the combined effect of fineness modulus and grading zone were clear on the passing ability and little effect of grading zone on flow ability and viscosity of fresh SCC properties. Compressive strength decreases with increasing F.M and no effect of grading zone for F.M higher than 2.90.

KEYWORD: fineness modulus, grading zones, self compact concrete, compressive strength, fresh tests of SCC.

التاثير المشترك لمعامل النعومة ومناطق تدرج الركام الناعم في الخواص الطرية ومقاومة الانضغاط للخرسانة ذاتية الرص

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الخلاصة:-

تعتبر الخرسانة ذاتية الرص ثورة في مجال تكنولوجيا الخرسانة نتيجة لقابليتها على الانسياب خلال القوالب ، انتشارها خلال حديد التسليح ،رصها لنفسها بتاثير وزنها وفائدتها الاقتصادية . يهدف هذا البحث الى تقييم الخواص الطرية للخرسانة ذاتية الرص ودراسة تاثيرها على مقاومة انضغاط تلك الخرسانة باستخدام مناطق تدرج مختلفة ومعامل نعومة متغير للركام الناعم المستعمل في انتاج هذه الخرسانة . معامل النعومة للركام الناعم المستخدم في هذا البحث كان متغير (2.73،2.82،2.9و3.12) ولمناطق تدرج مختلفة (منطقة تدرج رقم 1ومنطقة تدرج رقم 2ومنطقة تدرج مختلفة تقع بين المنطقتين اعلاه) وفق المواصفة القياسية العراقية رقم 45 لسنة 1984. تم تحضير 12 خلطة من الخرسانة ذاتية الرص ،فحصت بحالتها الطرية بفحوصات الهطول ، V-Funnel و L-Box وبعدها تم صب 72 مكعب خرساني بابعاد (100*100*100) ملم وتم اجراء فحص الانضغاط للخلطات المختلفة باعمار 7 و28 يوم اوضحت النتائج ان التأثيرالمشترك لمعامل النعومة ومنطقة التدرج للخرسانة ذاتية الرص في الحالة الطرية يكون اكثر وضوحا في قابلية الانسياب واقل تأثرا، قابلية الملئ واللزوجة .تقل مقاومة الانضغاط مع زيادة معامل النعومة ويقل تاثير منطقة التدرج مع زيادة معامل النعومة الى اعلى من 2.9 .

INTRODUCTION:

Self compacted concrete can be defined as a concrete that is able to flow under its own weight and completely fill the formwork, while maintaining homogeneity even in the presence of congested reinforcement, and then consolidating without the need for vibrating compaction (Rahman.M, et al 2011).Self-compacted concrete have high workability makes it flow through dense and complex reinforcement under the effect of its own weight only to fill the pores and reduce voids and with no need to use vibrators(khayat,1999),(Tvkista2000) (Raheem 2005),and it has no segregation or bleeding and no blocking tendency (Dehn 2000),(Rravindrajah2003)This distinguished properties of fresh (SCC) is due to its components which give it high workability , by using super plasticizers , and high resistance to segregation by control the aggregate grading or using fine particle materials such as fly ash , rice husk ash and blast furnace slag . It can also be regarded as "the most revolutionary in concrete construction for several decades". Originally developed to offset a growing shortage of skilled labor, it is now taken up with enthusiasm across European countries for both site and precast concrete work.

Self- compacted concrete can be used in precast concrete or in situ concrete or to be mixed in central mixers and transformed by vehicles or pumped by pumps, three basic characteristics that are required to obtain SCC are high deformability, restrained flow ability and a high resistance to segregation. High deformability is related to the capacity of the concrete to deform and spread freely in order to fill all the space in the formwork. It is usually a function of the form, size, and quantity of the aggregates and the friction between the solid particles, which can be reduced by adding a high range water-reducing admixture (HRWR) to the mixture. Restrained flow represents how easily the concrete can flow around obstacles, such as reinforcement, and is related to the member geometry and the shape of the formwork. Segregation is usually related to the cohesiveness of the fresh concrete, which can be enhanced by adding a viscosity-modifying admixture (VMA) along with a (HRWR) by reducing the free-water content, by increasing the volume of paste, or by some combination of these constituents(Venkateswara Rao,et al 2010).

The guiding principle behind self compacting concrete is that the sedimentation velocity of a particle is inversely proportional to the viscosity of the floating medium in which the particle exists (Venkateswara, et al 2010),

The disadvantages of SCC are: The production of SCC requires more experience and care than the conventional vibrated concrete. SCC mixes must be properly designed and tested to assure compliance with the project specifications. The mixing time of SCC may be longer than that for conventional vibrated concrete to ensure homogeneity because the difference in raw materials (Emborg, M 2000) (Chopin, et al, 2004), SCC is more sensitive to the total water content in the mix. The effect of changing fineness modulus of fine aggregate on SCC properties is not clear on hardened concrete, while it is more clear on fresh concrete, it has been noticed that concrete mixes prepared with 10 mm maximum size aggregate lead to higher strength about 18%for compressive strength and the fineness modulus of 3.1 gives higher results than other fineness modulus (Ali Hussain, Z.M. 2008).From several trial mixes of SCC it has been shown that a suitable mix for adequate compressive strength can be formulated with marginal aggregate of fine/coarse aggregate ratio of 1.1 that will satisfy flow ability criteria (Shamsad A, et al 2008).The most important issue in producing SCC is the providing of sufficient amount of fine materials, thus increase the viscosity of mortar and thereby decrease the segregation risk as well as minimize the friction between coarse aggregate particles and give better flow ability. Increasing fine aggregate content up to 53% by volume of mortar improves the flow ability and decrease its tendency to segregation (Shakir,A., et al 2009).

2. RESEARCH SIGNIFICANT

This research aims to study the combined effect of varying fineness modulus F.M (2.73, 2.82, 2.9 & 3.12) and gradation zones (zone I, zone II, marginal zone (between zone I&II)) on fresh properties of SCC and compressive strength of (100x100x100) mm cubes after 7 &28 days of water curing.

3. MATERIALS

Cement: Ordinary Portland cement manufactured by Taslujah factory confirms to I.Q.S. NO.5/1984 was used in this research, the physical and chemical properties of this cement were listed in tables 1&2.

Fine aggregate: Natural sand from Al_Ukhaider region was used in this research. The specific gravity of the used sand is 2.63 with SO3 content 0.33%. different fineness modulus with different grading were used, 2.73(zone I, zone II , marginal zone (between zone I&II)) ,2.82(zone I, zone II , marginal zone (between zone I&II)) 2.9(zone I, zone II , marginal zone (between zone I&II))and 3.12(zone I, zone II , marginal zone (between zone I&II)) . Table (3) show the grading of fine aggregate used in this research, tables (4, 5&6) shows some international specifications for grading of fine aggregate.

Coarse aggregate: Rounded coarse aggregate with maximum size (10) mm used in this research. Tables (7&8) show the physical properties and grading of coarse aggregate.

Mineral admixtures: silica fume, a by-product from the electrical arc furnace, was used in this research with 3% by weight of cement. Table (9) show chemical and physical properties of silica fume.

Chemical admixture: Viscosity modifying agent (VMA) used in this research was (Glenium 51) with 0.9 % by weight of cement. This consists of (Carboxylic Ether polymer) that have long chain which designed to give the mix rehoplastic properties which is desired in SCC mixes.

4. EXPERIMENTAL PROGRAM

The experimental program was designed to study the role of fineness modulus and grading zone of fine aggregate on fresh and compressive strength of SCC. The SCC mixes were designed according to (The European Guidelines for Self Compacting Concrete 2005). The mix proportion for SCC mixes were (1:1.67:1.83) and w/p ratio was 0.91 by volume. The silica fume (S.F.) was 3%by weight of cement and the super plasticizer (SP) was 0.9% by weight of cement. Twelve mixes were poured in 72 cubes of (100x100x100) mm and were tested after 7&28 days for compressive strength, the averages of three cubes were taken for each mix.

5. Results and Discussion

5.1 Properties of fresh SCC

Fresh SCC must confirm the major properties including flow ability, passing ability and resistance to segregation. Flow ability refer to the ability of SCC to flow in formwork spaces horizontally and vertically under its own weight only and without leaving air entrapped inside or on surface of SCC. Figure (1) and table (10) shows the results of slump test with different fineness modulus and grading zones. This figure show that the slump increase with increasing of fineness modulus because increase of fineness modulus means decreasing in surface area of fine particles that leads to have more free water from the mix therefore provides more flow ability, and grading zone (1) have higher slump than zone (2) .Marginal zone show higher slump because it has less interfere between particles, this can obviously noticed with fineness modulus higher than (2.9). The increasing ratio range is (0.7-5) %. According to (The European Guidelines for Self Compacting Concrete 2005), all mixes, except mix (12), have slump flow class SF1 (550-650) mm which use in housing slab, tunnel lining, piles and some deep foundation. Mix (12) has slump –flow class SF2 (660-750) mm which can use it in walls and columns. Same indication can be notice in figure (2) & table (10) which refer to the results of T500 time with different fineness modulus and grading zones. This test assesses the flow ability and viscosity of SCC. Figure (2) indicated that the flow ability time of fresh SCC decreases with increasing of fineness modulus, marginal zone has less flow ability time due to less interfere between particles and reduction ratio range is (2-33) %. Figure (3) & table (10) shows the results of V-Funnel test with different fineness modulus and grading zones. This test assesses the viscosity of SCC. Results show that with increase of fineness modulus there is a decreasing in the time need to flow through the V-Funnel. This may be because of high friction between coarser particles which decrease the viscosity of SCC, and this confirm with (Shakir,A., et al 2009).According to (The European Guidelines for Self Compacting Concrete 2005), all mixes have class VF1 because all mixes have V-funnel time less than 8 sec. Figure (4) & table (10) refers to the results of L-Box test for different fineness modulus and grading zones. This test assesses the passing ability of SCC. Figure (4) indicates that as the fineness modulus increases the blocking ratio (H2/H1) (passing ability) decrease due to the friction between the particles that obstruct the flow of the fresh SCC mix through the reinforcement bars. According to (The European Guidelines for Self Compacting Concrete 2005), conformity to the passing ability of fresh SCC, is confirmed if the (H2/H1) equal or greater than (0.75), hence mixes with F.M less than (2.9) show class PA1 while poor passing ability with F.M equal or greater than (2.9) for all zones, this may be due to high coarse particles percent in mixes with high F.M (The European Guidelines for Self Compacting Concrete 2005).

5.2 Hardened properties of SCC

Table (11) & figures (5&6) show the results of compressive strength for hardened SCC. Results show that the compressive strength decreases with increasing F.M. Interlocking of the aggregate and the hydrated cement paste is an important factor in the strength of concrete. When F.M increase, the surface area of fine aggregate bonding with hydrated cement paste, will decrease this leads to decreasing in compressive strength. But with F.M equal or higher 2.9 the coarser particles may be act as crack arresters (Neville 1995). The effect of grading zone obviously shows when using F.M (2.73-2.82).The compressive strength of zone (2) mixes are higher than zone (1) and marginal zone mixes with 40% and no effect of grading zone with F.M. higher than 2.9.

Relying on the results of this research ,using C and M grading zone of B.S. specification 882:1992 is suitable for SCC mixes but dependence (Total limit) only , which has a wide range of F.M varying from(4.01) to (1.15) need more restrictions to dependence it in SCC mixes because the clear effect of F.M on properties of SCC.

ASTM specification C33-1993, which has F.M varying from (3.38) to (2.25), show same indication .One grading zone may be insufficient to judge the possibility uses of fine aggregate in SCC mixes.

6. CONCLUSIONS:

1-It can be possible to produce SCC with satisfied flow ability by using fine aggregate with F.M (2.73, 2.82, 2.9&3.12).

2-The flow ability and viscosity of fresh SCC mixes decreases with the increase of the F.M with little effect of grading zone

3- The passing ability of fresh SCC mixes decreases with the increase of the F.M and poor passing ability with F.M equal or greater than 2.9 for all grading.

4- Compressive strength decreases with increasing F.M and higher compressive strength show with zone (2) and no effect of grading zone for F.M higher than 2.9.

5- B.S and ASTM specification, concerning with fine aggregate grading, needs more restrictions to dependence of them on SCC mixes.

REFERENCES:

Ali Hussain Z.M., (the effect of grading of aggregate on properties of self -compacted concrete) M.Sc. Thesis, college of engineering, civil engineering department, Al-Mustensirya University, January 2008.

Chopin D, De Larrad CF, Cazacliu B, (why do HPC and SCC require longer mixing time?),cement and concrete research,2004, No.34, Vol.12, pp. 2237-2243.

Dehn F., Holschemacher K., Weibe D., (self- compacting concrete time-development of the material properties and the bond behavior), LACER, No.5, 2000, pp. 115-124.

Emborg M., 2000, final report of task 8.1 mixing and transport.

Khayat K. H., (workability, testing and performance of self -compacting concrete), 1999, ACI materials journal, No.3, Vol.96, pp.346-353.

Nevill, A, M. (properties of concrete), fourth and final edition, England, 1995.pp. (117) and (287).

Rahman M., Rashid M., Hossain M., Adrita F., Hossain T., (mixing time effects on properties of self- compacted concrete), ARPN journal of engineering and applied science,2011, No.8, Vol.6, pp.108-114.

Raheem J.O., (the influence of volume ratio and size of coarse aggregate on the properties of self -compacted concrete), M.Sc. thesis, civil engineering department, AL-Mustansiriya University, 2005.

Shakir A.AL-Mishhadani, Mays F. (a data base for self -compacting concrete in iraq), eng. &tech. journal, 2009.No.6, Vol.27, pp.1203-1218.

Shamsad A., Abul Kalam Azad, Mohammed Abdul Hameed,(a study on self-compacting concrete made with marginal aggregate), the Arabian journal of science and engineering,2008,No.2B,Vol.33,pp.437-442.

“The European Guidelines for Self Compacting Concrete specification, production and use” May 2005, www.efnarc.org.

Tviksta Lars Goran ,(quality control guidlines), 2000, Brite Eu Ram project No.BE96-3801.

Venkateswara Rao S., Seshagiri Rao M.,Rathish Kumar P.,(effect of size of aggregate and fines on standard and high strength self -compacting concrete),2010,journal of applied science research, No.5, Vol.6,pp.433-442.

Walraven J., (self –compacting concrete in Netherlands),2002,first north American conference on the design and use of self- compacting concrete,Illinois, hanley wood,pp.355-359.

Table (1) physical properties of cement

Physical properties	Test result	Limit of Iraqi specification No.5/1984
Specific surface area, Blain's method, m²/kg	290	≥ 230
Soundness, Autoclave's Method, %	0.03	< 0.8
Setting time, Vicat's method Initial setting hr:min Final setting hr:min	 2:35 4:45	 ≥ 45 min ≤ 10 hours
Compressive strength 3 days N/mm² 7 days N/mm²	 18.8 23.3	 ≥ 15 ≥ 23

Table (2) chemical properties of cement

Oxide	% by weight	Limit of Iraqi specification No.5/ 1984
CaO	60.78	--------
SiO2	20.54	--------
Al2O3	5.88	--------
Fe2O3	3.28	--------
MgO	1.93	≤ 5.0
SO3	1.87	≤ 2.80
Na2O	0.28	--------
K2O	0.54	--------
Loss on ignition	3.47	≤ 4.0
Insoluble residue	0.15	≤ 1.5
Lime saturated Factor	0.85	0.66 - 1.02
Main compounds (Bogue's equations)		
C3S	41.74	--------
C2S	27.65	--------
C3A	10.04	--------
C4AF	9.97	--------

Table (3) %passing of fine aggregate used in this research

Sieve size(mm)		4.75	2.36	1.18	0.6	0.3	0.15
F.M	Grading						
2.73 Mix1	Zone I	98	95	70	34	20	10
2.82 Mix2		97	92	67	33	19	10
2.90 Mix3		94	92	70	41	11	2
3.12 Mix4		92	77	60	32	18	9
2.73 Mix5	Zone II	92	90	73	40	25	7
2.82 Mix6		92	80	60	48	30	8
2.90 Mix 7		94	92	70	41	11	2
3.12 Mix8		93	80	60	40	10	5
2.73 Mix9	Marginal zone	94	90	82	31	21	9
2.82 Mix10		96	85	68	30	29	10
2.90 Mix11		94	92	70	41	11	2
3.12 Mix12		91	68	54	48	20	7

Table (4) Iraqi specification (I.Q.S No.45/1984) %passing of fine aggregate

Sieve No.(mm)	Zone 1	Zone 2	Zone 3	Zone 4
4.75	90-100	90-100	90-100	95-100
2.36	60-95	75-100	85-100	95-100
1.18	30-70	55-90	75-100	90-100
0.6	15-34	35-59	60-79	80-100
0.3	5-20	8-30	12-40	15-50
0.15	0-10	0-10	0-10	0-15

Table (5) ASTM specification C33-93 %passing of fine aggregate

Sieve No. (mm)	% passing of fine aggregate
4.75	95-100
2.36	80-100
1.18	50-85
0.6	25-60
0.3	10-30
0.15	2-10

Table (6) B.S. specification 882:1992 %passing of fine aggregate

Sieve No.(mm)	% passing of fine aggregate			
	Total limit	Grading zone limits		
		C (coarse grading)	M(medium grading)	F(fine grading)
10	100	-	-	-
5	89-100	-	-	-
2.36	60-100	60-100	65-100	80-100
1.18	30-100	30-90	45-100	70-100
0.6	15-100	15-54	25-80	55-100
0.3	5-70	5-40	5-48	5-70
0.15	0-15	-	-	-

Table (7) physical properties of coarse aggregate

Type of aggregate	Bulk Specific Gravity	Density(kg/m^3)	Absorption %	SO3 %
Rounded coarse aggregate	2.56	1600	1	0.06

Table (8) grading of coarse aggregate

Sieve size (mm)	% Passing by weight	Limits of the Iraqi specification No. 45/1984 (5-20)mm
20	100	95-100
10	45.7	25-55
5	3.6	0-10

Table (9) chemical and physical properties of silica fume

Oxide	% by weight
SiO_2	94.8
Al_2O_3	0.15
CaO	0.08
Fe_2O_3	0.004
SO_3	0.07
Specific surface area m^2/kg	18000
Bulk Density kg / m^3	650

Table (10) Results of testes of fresh SCC

Mixes	Slump (mm)	Slump Flow class*	slump@T500 (sec.)	V funnel (sec.)	Viscosity class*	L-Box (H_2/H_1)	Passing ability class*
Mix 1	633	SF1	5	6.8	VF1	0.8	PA1
Mix 2	635	SF1	4.5	6.2	VF1	0.75	PA1
Mix 3	640	SF1	4.3	5.25	VF1	0.74	Not confirm
Mix 4	645	SF1	4.2	5.18	VF1	0.714	Not confirm
Mix 5	630	SF1	5	6.82	VF1	0.802	PA1
Mix 6	632	SF1	4.8	6.7	VF1	0.77	PA1
Mix 7	632	SF1	4.6	5.56	VF1	0.76	PA1
Mix 8	635	SF1	4.5	5.5	VF1	0.74	Not confirm
Mix 9	635	SF1	4.9	6.9	VF1	0.87	PA1
Mix 10	640	SF1	4	6	VF1	0.8	PA1
Mix11	642	SF1	3.8	5.8	VF1	0.73	Not confirm
Mix12	670	SF1	3	5.3	VF1	0.625	Not confirm

*specification according to (The European Guidelines for Self Compacting Concrete 2005)

Table (11) average compressive strength results for SCC mixes

Mixes	compressive strength @age 7 days(Mpa)	compressive strength @age28 days (Mpa)
Mix 1	24.2	37
Mix 2	23.8	36.2
Mix 3	20.6	30
Mix 4	17.5	28.7
Mix 5	35	50.5
Mix 6	26	38.7
Mix 7	21	32
Mix 8	20	30
Mix 9	25	38
Mix10	20.7	30
Mix11	20	30
Mix12	19	29.4

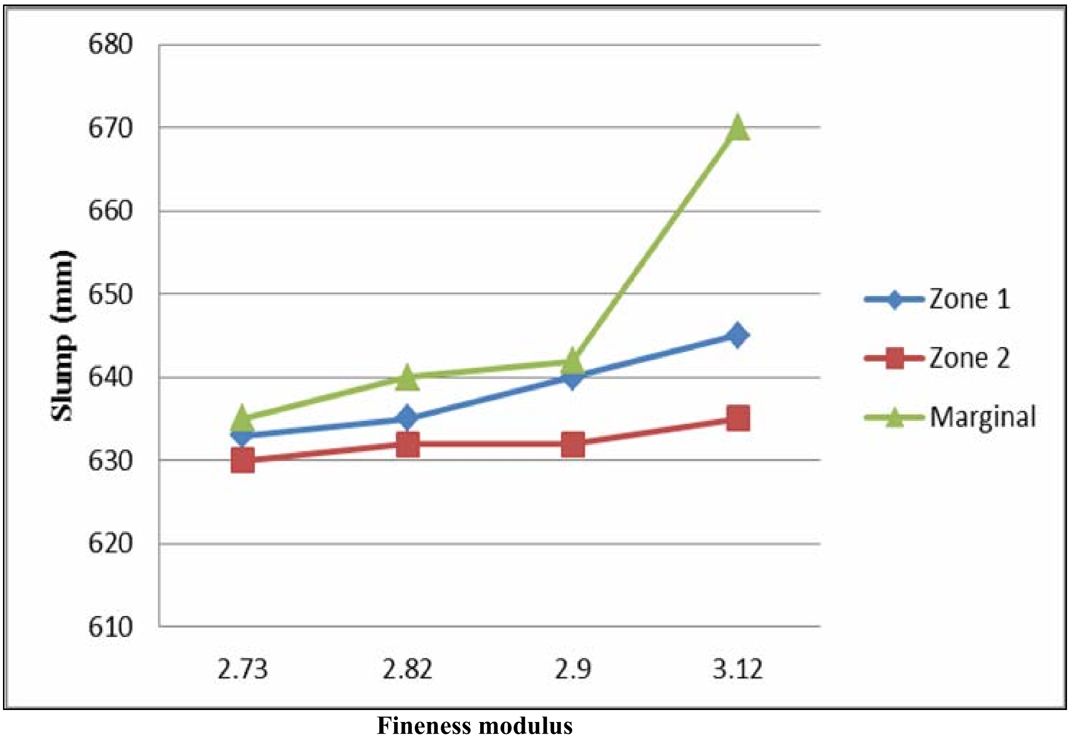


Figure (1) Slump (flow ability) test of fresh SCC with different fineness modulus

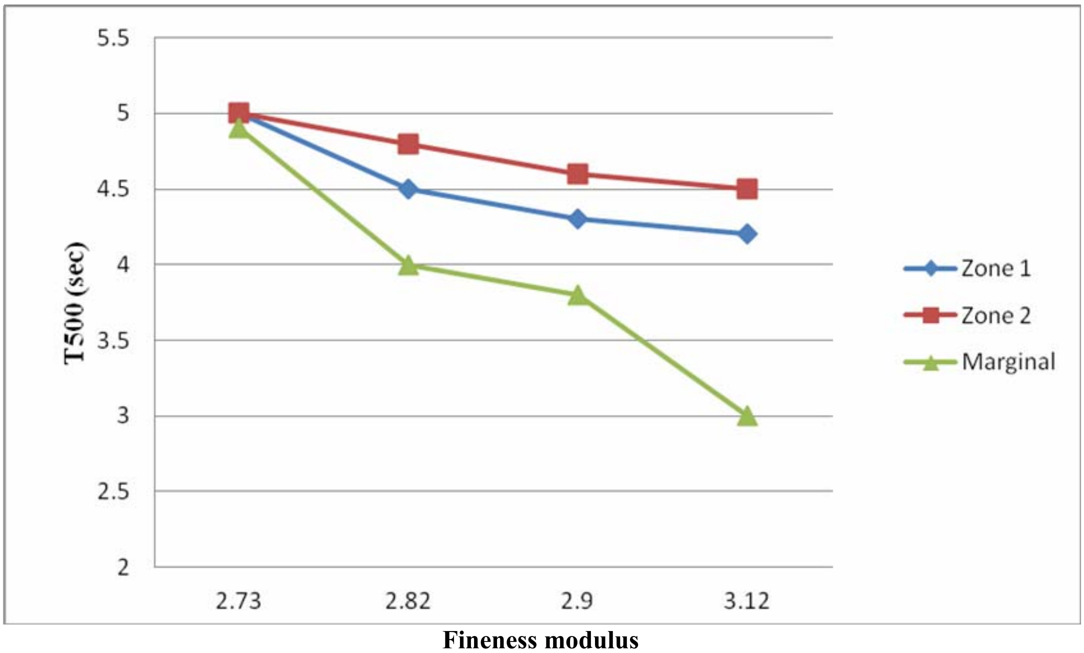
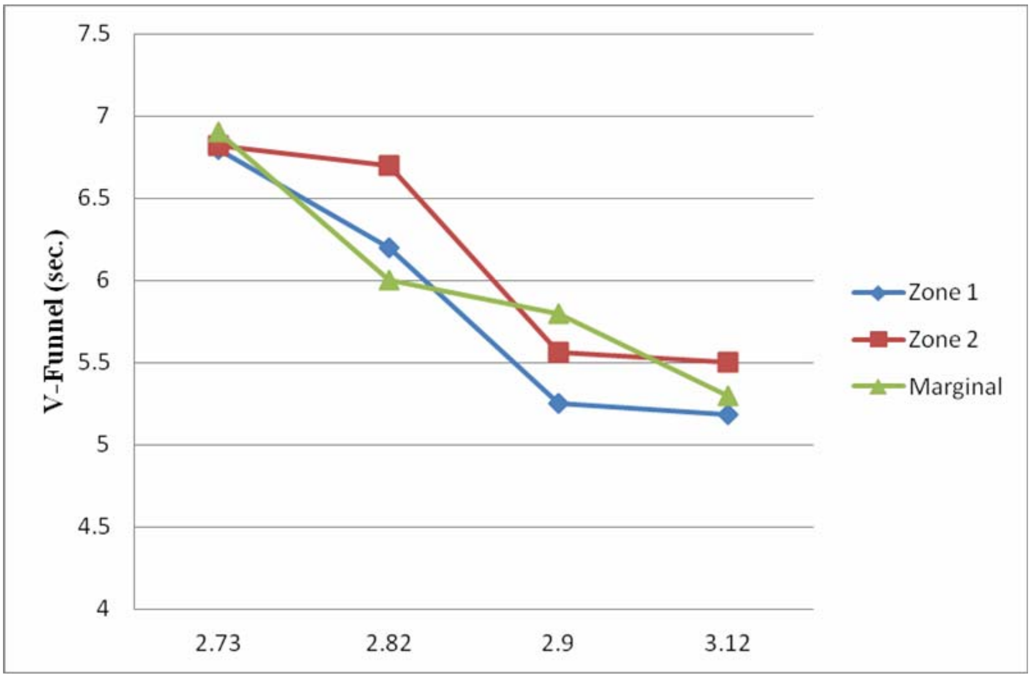
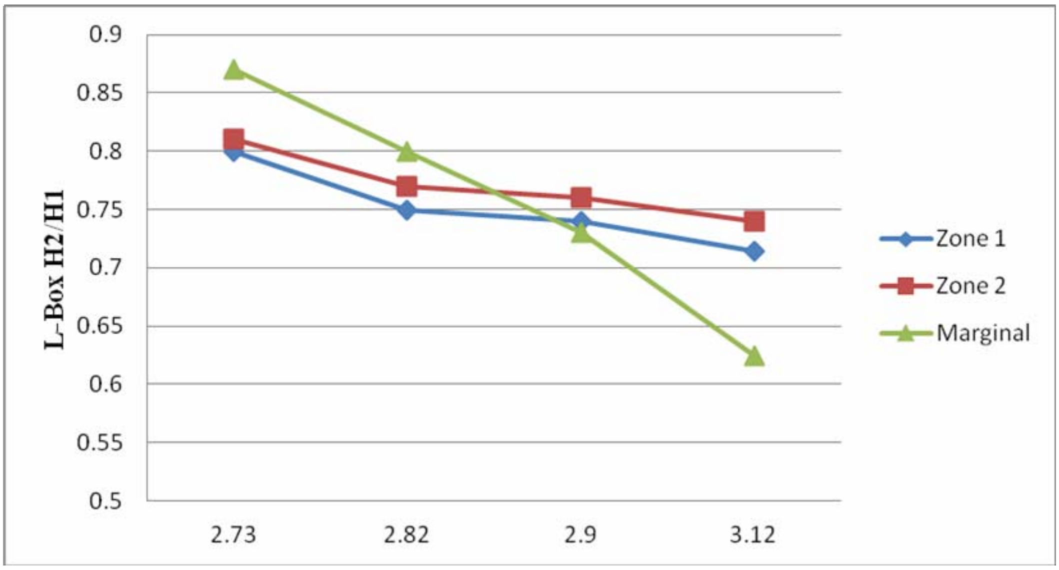


Figure (2) Slump flow time (sec.) (flow ability) test@T500mm diameter of fresh SCC



Fineness modulus

Figure (3) V-Funnel time (sec.) (viscosity) test with different fineness modulus of fresh SCC



Fineness modulus

Figure (4) Passing ability test for different fineness modulus

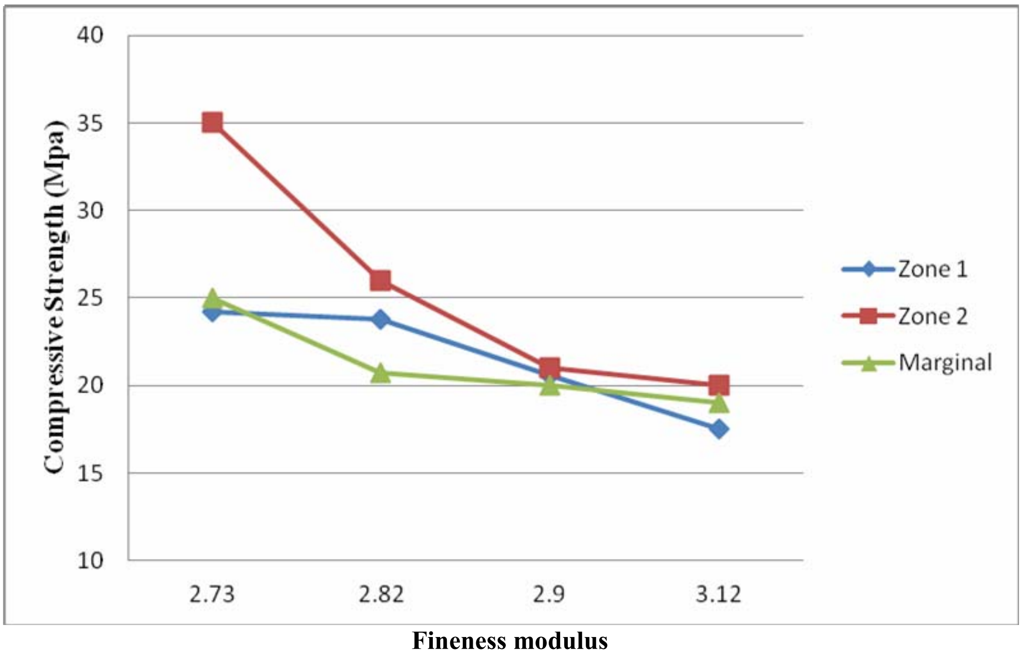


Figure (5) Compressive strength test of hardened SCC @7days age of curing with different fineness modulus

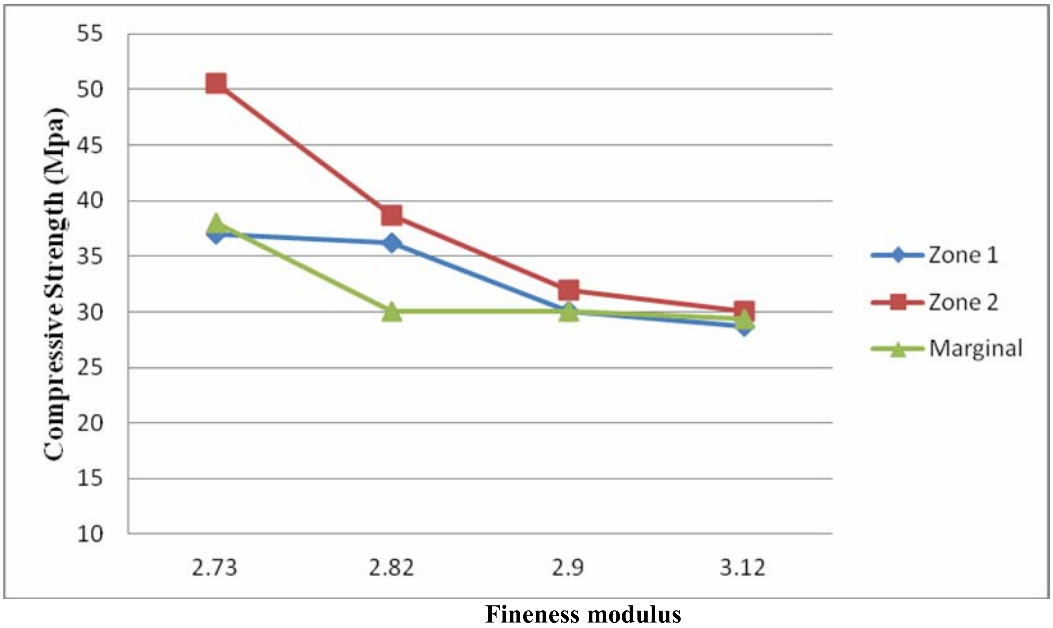


Figure (6) Compressive strength test of hardened SCC @28days age of curing with different fineness modulus