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EFFECT OF SUPERPLASTICIZER DOSAGE ON WORKABILITY OF SELF COMPACT CONCRETE

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ABSTRACT:- Self-compacting concrete has an enhanced ability to flow. It is known to result in an increased segregation and bleeding potential. This paper discusses the results of an experimental investigation into the properties of self-compacting concrete mixes having varying dosage of high-performance superplasticizer (Glenium 51) (0.5%-3.0%) L per 100 kg of cement material. The properties investigated are workability on the fresh state of concrete by using one mix with five superplasticizer dosage (0.5%,1.0%,1.5%,2.5% and 3.0%) is used. The workability was assessed using three tests according to the specification of self compacted concrete (slump flow ,L- box differential height and V-funnel tests. The three dosage (1.0%,1.5% and 2.5%) comply with requirement for production of SCC while 0.5% and 3.0% don't comply with specification requirement .Dosage of superplasticizer need to produce self compacted concrete range between (1.0%-2.5%) L/100 kg of cement according to the condition and material used in this paper .

Key word : Self-compacting , concrete , workability , superplasticizer dosage, Test .

1. INTRODUCTION

The term Self-Compacting Concrete (SCC) refers to a "new" special type of concrete mixture, characterized by high resistance to segregation that can be cast without compaction or vibration. The introduction of new admixtures and cementitious materials has allowed the production of SCC[1]. These materials are used to prevent segregation, bleeding, and increase flowability. The superplasticizer and mineral admixture hold the aggregates in suspension, and the combination of powder materials(limestone powder ,…) is also used to control the hardened properties, such as strength [1]. The workability of SCC is higher than the highest classes of consistence described within international standards, but a highly flowable concrete is not necessary SCC, because SCC should not only flow under its own weight but should also fill the entire form and achieve uniform consolidation without segregation [2].Workability tests for SCC can be broadly split into three categories: filling ability tests, passing ability tests and segregation resistance tests. Each test fits into one or more of these categories. Test methods for the three parameters are listed in Table (1) and recommendation of fresh SCC in Table (2) [3,4].

The slump flow increases with the increase of the superplasticizer dosage.For the slump flow range from 500 to 700 mm, the superplasticizer (Glenium 51) dosages were 0.39% and 0.54% for the self-compacting concrete[5]. Figure (1) shows the change in slump flow in relation to the superplasticizer dosage for flowing and self-compacting concretes. As expected the slump flow gradually dropped from 700mm to 650mm in 60 minutes for the mix with higher superplasticizer dosage. When the initial flow was 500mm due to reduced dosage of 0.39%, the flow dropped from 500mm to 200mm within 30 minutes. The results suggest that the superplasticizer used is capable of maintaining workability. The slump flow loss was 60mm and 180mm after 15 minutes for the lower and higher superplasticizer dosages, respectively. However, from 15 to 60 minutes, the respective flow losses were 140mm and 120mm, indicating that the stiffening process is only marginally influenced by the superplasticizer dosage [5].

Based on the experimental studies on the properties of flowing concrete and self-compacting concrete ,the parameters used in the study are dosage level of high-performance superplasticizer (Glenium 51) and effect of compaction. Since the conventional testing methods are not applicable to flowing concrete alternative test methods are needed to assess the properties of the freshly mixed self-compacting concrete and flowing concrete. Bleeding capacity for flowing and self-compacting concretes is influenced by the superplasticizer dosage. Flowability of self-compacted concrete is reduced with elapsed time, superplasticizer dosage and presence of steel reinforcement [6].

The flow properties were characterized using slump flow test,and V-Funnel test . All these tests were also used to characterize SCC with time and the change in properties of SCC with time .HRWRA(High-range water reducing admixture) is used, agitates the mix after 2-3 minutes of mixing which improves the flow properties [7] .

The effect of superplasticizer on the balance between flowability and viscosity of paste in self-compacting concrete was investigated by Ouchi (1996) et al. From experimental results, the ratio of V-funnel speed to flow area of cement paste with a fixed amount of superplasticizer was found to be almost constant, independent of the water-cement ratio. A higher amount of superplasticizer resulted in a lower ratio of V-funnel speed to flow area. The ratio was proposed as an index for the effect of superplasticizer on cement paste flowing ability and viscosity from the viewpoint of achieving self-compactability. However, the relationship between high range water reducer amount and its effect was found to differ depending on the type of cement or chemical admixture[8].

The requirements for superplasticizer in SCC as: High dispersing effect for low water/powder ratio: less than approx. 100% by volume. Maintenance of the dispersing effect for at least two hours after mixing and less sensitivity to temperature changes. The job of superplasticizer is to impart a high degree of flowability and deformability; however, the higher dosages (when compared to conventional concrete) generally associated with SCC can lead to a high degree of segregation. When a superplasticizer is only used, concrete tends to segregate due to the loss in yield stress of the concrete coupled with the fact that materials with different specific gravities reside within the mixture. One of the main characteristics of SCC is segregation avoidance, also referred to as “stability” of SCC[9] .

2. MATERIALS AND EXPERIMENTAL WORK:

The original objective of this study is to determine the relative behavior of SCC when five different ratio dosages of superplasticizer are added to the mixture .The tests are conducted in order to view the differences in behavior made during the fresh state only. The Slump flow, L-box and V-funnel are performed during the fresh state.

2.1 Materials :

Effective production of SCC is achieved by more stringent requirements on materials selecting, controlling and proportioning all of the ingredients. Optimum proportions must be selected according to the mix design methods, considering the characteristics of all materials used.

2.1.1 Cement: -

Ordinary Portland cement produced at northern cement factory (Tasluja-Bazian) was used throughout this investigation. The cement was stored in air-tight plastic containers to avoid the harmful effects of humidity. Analysis of chemical composition and physical properties of this cement were made at the engineering consultancy bureau at college of engineering /Al-Mustansiriya University. The results are shown in Tables (3) and (4) respectively. Results showed that the cement conformes to the Iraqi specification No. 5/1984(10).

2.1.2 Fine Aggregate:

The grading and particle shapes of fine aggregate are significant factors in the production of SCC. Fine aggregate with rounded particle shape and smooth textures requires less mixing water in concrete and for this reason is preferable in SCC. Natural sand is used in this work. Table (5) and Fig. (2) show the grading of the fine aggregate and the limits of the Iraqi specification No.45/1984 [10].

2.1.3 Coarse Aggregate: -

Crushed gravel of maximum size(12.5) mm is used. Table (6) and Fig. (3) show the grading of this aggregate, which conforms to the Iraqi specification No.45/1984 [10].

2.1.4 Superplasticizer: -

One of the new generations of copolymer-based superplasticizer, designed for the production of High Performance Concrete is used (Glenium 51). Table (7) contains the properties of this product. The dosages used in the mix were (0.5 ,1.0, 1.5 ,2.0,2.5 and 3.0 %) respectively liters / 100 kg of cement (cementitious material). In this work, no changes are made to all materials except the dosages of superplasticizer and the test is limited to properties of fresh concrete.

2.1.5 Mineral Admixtures: -

Limestone Powder (LSP) :-

one locally available type of mineral admixtures is used for the purpose of this study. Limestone powder is produced locally. This material is locally named as “Al-Gubra”. It is a white grinding material from lime-stones excavated from different regions in Iraq, and usually used in the construction processes. In this work, a fine limestone powder, grinded by blowing technique, has been used. The cost of grinding is very low, and the fineness of the gained material is very high. The chemical composition of LSP is listed in Table (8).

2.2 Determining of Mix Design Method :

Depending on the required modification on the ACI 211.1 method to be used for production of self-compact concrete. The properties of Five dosage (Tr1,Tr2,Tr3,Tr4 and Tr5) were concluded and shown in Table (9).

2.3 Test Procedures of Fresh Concrete

After determining a suitable mixture proportioning method and the materials for this study, the experimental process begins. The experimental equipment used to evaluate the fresh concrete properties (the Slump flow, L-box and V-funnel) are fabricated according to the specifications and requirements (JSCE). The first priority is to determine if the equipment works as expected. Table (10) contains the first data set created during this study. The data represent concrete mixes designed to be SCC with the single variable of superplasticizer dosage. The dosages range from 0.50 to 3.0 % liters per 100 kg of cement .Mineral admixture has been used in this stage. The data are taken from the results of slump flow, L-box and V-funnel tests Figure (4).

3-RESULTS AND DISCUSSION

3.1 Tests of Fresh SCC

Testing of concrete in its fresh state is a major focus of this study. SCC is defined by its behavior when it is in the fresh state, and it is determined whether concrete meets certain requirements, Table (2), while fluid is paramount in qualifying concrete as SCC or not. The slump flow, L-box and V-funnel are all used for all mixes of this study.

Table (10) shows that as the dosage of superplasticizer increases, the slump flow increases. This is expected because as the superplasticizer dosage increases the fluidity of the concrete also increases. The L-box values increase as superplasticizer dosage increases; this translates that as the dosage increases, concrete is more able to flow through reinforcement. The V-funnel values are the most variables of the tests. These values display a trend of decrease in time to flow through the orifice with the increases in superplasticizer dosage, but due to the lack of a viscosity modifying admixture, the values increase after optimal dosage because of blocking behavior of coarse aggregate. From these data sets, it is decided that could be associated with these apparatus, and it is decided that this study could progress with confidence that meaningful data could be gathered.

3.2 Superplasticizer Dosages (SPD)

3.2.1 Slump flow tests :Table (11) shows the results of slump flow tests. D and T50 are plotted in a descending manner in Figs. (5) and (6) respectively. It is very clear from the results that same of the mixes satisfy the requirements of SCC illustrated in section (1) Table (2). Thus, mixes (Tr2,Tr3,Tr4) have a good consistency and workability from the filling ability point of view, but Mixes (Tr1 and Tr5) have low consistency and low workability. However, these results show a wide range of variation. This variation illustrates the effects of the changes that are made in the mixes on the filling ability of SCC.

Fig.(6) show the effect of dosage of the superplasticizer on the flow ability of fresh concrete ,while Figs.(5) and (6) illustrated that the filling ability increment with increase of dosage but not exceed the passable limitation because of cause segregation in fresh concrete ,and weakly the concrete. (Tr1) do not reaches to range diameter (500 - 700)mm, and (Tr5) exceed the limitation and this mixes do not classify as a self-compact concrete (SCC). The mixes (Tr1,Tr3,Tr4) became in the limitation range and this can be classified as self-compact concrete (SCC).

3.2.2 L-box Tests : With the L- box test, it is possible to measure the filling ability and the passing ability of the mixes. The L-box results are listed in Table (11). The values of (H2 / H1) represent the blocking ratio (BR). The values of T20 and T40 represent the times of the concrete flow to reach 20 and 40 cm respectively. The values of BR are illustrated in Fig. (7) in a descending manner, and the values of T20 and T40 are plotted in Fig. (8).The L-box results indicate good flow ability for mixes(Tr2, Tr3 , Tr4 and Tr5). Also, they show that the BR values for this mixes are greater than or equal to 0.80 (which is often considered in the literature as the critical lower limit). The mixes (Tr2, Tr3 , Tr4 and Tr5) show excellent deformability, without blockage, through the closely spaced obstacles. Two comparisons are made through Figs. (9) and (10) between the results of slump flow tests (D and T50) and the results of L-box tests (BR and T40). The comparisons show that the trend of the results of these two tests is close. Thus, it can be said that what have been inferred from the behavior of these mixes in slump flow tests seem to be adequate to explain the behavior of these mixes in L-box test .These two figures show that there are variations between the behavior of these mixes in slump flow tests and their behavior in L-box tests. These variations are very clear at the results of this mixes.

Empirical relationships between the results of slump flow tests and those of L-box tests are illustrated in Fig. (11) where T50 is plotted with T40.

3.2.3 V-funnel Tests : Table (11) shows the results of V-funnel tests. The values of Tv represent the ability of the concrete to flow out of the funnel, while Tv5 values represent the same ability but after refilling the funnel and allowing concrete to discharge after 5 minutes from the refilling. The results are within the limits pointed out in the literature Table (2). No blocking or segregation behavior is observed for all mixes. Figure (12) shows the results of Tv and Tv5 in an ascending manner. The results clearly show the effects of the changes that are made in the mixes on the viscosity of the mixes. SCC mixtures are often characterized by their funnel time Tv (which is often used as a degree of the apparent viscosity of mix) and their spread diameter D which stands for the filling ability [6]. The relationship between the flow times is plotted in Fig. (13). Based on the high degree of correlation coefficient (R = 0.9321), it can be assumed that this relationship is reliable. The nature of the relationship between these two parameters is clearly defined by this figure. The highly degree of correlation between the results demonstrates that mixes of this study are homogenous and SCC mixes.

4. CONCLUSIONS

Taking into account the findings from this study, the following conclusions can be drawn:

1-It has been verified that by using the slumpflow, L-box, U-box and V-funnel tests, SCC (produced by using locally available materials) achieves consistency and self-compactability under its own weight, without any external vibration or compaction. Also, SCC can be obtained in such a way, by adding superplasticizer dosage and very fine mineral admixtures. These two materials provide sufficient balance between the yield and viscosity of the mix .

2- The workability of studied mix (Tr1) is poor, with slump flow diameter less than to 500 mm, blocking ratio less than (0.80), and flow times less than 6 to 12sec. ,Therefore it does not satisfy the properties of self compacting concrete .

3-The workability of studied mixes(Tr2,Tr3and Tr4) is excellent according to EFNARC limitation , with slump flow diameter greater than or equal to (500 mm), blocking ratio greater than or equal to (0.80), and flow times range (6 to 12sec.) On the fresh properties.

4- From the statistical analysis and the empirical relationships made in this study, it can be concluded that the slump flow test is enough to evaluate the SCC with maximum size of coarse aggregate equal to 12.5mm.

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Table (1): List of test methods for workability properties of SCC. [3]

Method	Property
Slump - flow by Abrams cone	Filling ability
T50cm slump-flow	Filling ability
V-funnel	Filling ability + Segregation resistance
Ormit	Filling ability
J-ring	Passing ability
L-box	Passing ability
U-box	Passing ability
Fill-box	Passing ability
GTM screen stability test	Segregation resistance
V-funnel at T5minutes	Segregation resistance

Table (2): Acceptance criteria for Self-compacting Concrete .[4]

Method	Typical range of values					
	Maximum		Minimum		Symbol	Unit
Slump flow by Abrams cone	750		500*	600**	D	Mm
T50cm slumpflow	5*	25**	2*	3**	T50	Sec
V-funnel	12		6		T	Sec
Time increase, V-funnel at T_5minutes	+3		0		T5	Sec
L-box	1.0		0.8		Blocking Ratio (h2/h1)	-
U-box	0		30*	50**	ΔH	Mm

* EFNARC ** JSCE

Table (3): Physical Properties of the Cement Used in this Work.

Physical properties	Test Results	Limit of Iraqi specification No. 5/1984
Specific Surface area (Blaine Method , cm^2/gm)	3329.0	≥ 2300.0
Setting time (Vicats Method) Initial Setting time, hrs. : min Final Setting time, hrs. : min	 2:10 3:45	 ≥ 45 min ≤ 10:00
Compressive strength of mortar 3- days, N / mm^2 7- days, N / mm^2	 32.4 40.5	 ≥ 15 ≥ 23

Table (4): Percentage of Oxide Composition and Main Compounds of Cement Used Throughout this Work.

Oxide composition	Abbreviation	Content (percent)	Limit of Iraqi specification No.5/1984
Lime	CaO	63.19	---
Silica	SiO_2	20.60	---
Alumina	AL_2O_3	4.10	---
Iron Oxide	Fe_2O_3	4.48	---
Sulphate	SO_3	1.98	< 2.8%
Magnesia	MgO	2.28	≤ 5%
Loss on Ignition	L.O.I	2.45	≤ 4%
Insoluble residue	I.R	0.47	≤1.5%
Lime saturation factor	L.S.F	0.94	0.66-1.02
Main compounds (Bogue's equations)			
Tricalcium Silicate	C_3S	57.11	
Di Calcium Silicate	C_2S	16.23	
Tri Calcium Aluminate	C_3A	8.39	> 5%
Tetra Calcium Alumina Ferrite	C_4AF	13.62	

Table (5): Grading of Fine Aggregate.

Sieve size (mm)	% Passing by Weight	Limits of the Iraqi specification No.45/1984 (zone 2)
4.75	100	90-100
2.36	93.3	75-100
1.18	84.0	55-90
0.60	57.2	35-59
0.30	27.5	8-30
0.15	8	0-10
Fineness Modulus = 2.33		

Table (6): Grading of Coarse Aggregate.

Sieve size (mm)	% Passing by Weight	Limits of the Iraqi specification No.45/1984
12.5	100	100
10	88.6	85-100
5	10.8	0-25
2.36	0	0-5

Table (7): Typical properties of the admixtures

Main action	Concrete Super plasticizer
Subsidiary effect	Hardening retarded
Form	Viscous liquid
Color	Light brown
Relative Density	1.1 at 20 C
Viscosity	128 ±30 CPS AT 20 C
PH.Value	6.6
Transport	Not classified as dangerous
Labeling	NO hazard table required

Table (8): Chemical Composition and Physical Properties of LSP.

Chemical Properties	
Oxides	Content %
SiO_2	1.38
Fe_2O_3	0.12
Al_2O_3	0.72
CaO	56.1
MgO	0.13
SO_3	0.21
L.O.I	4.56
Physical Properties	
Fineness (Blain)	2800

Table (9): Mix design properties

Symbols Dosage	Cement kg/m^3	Water kg/ m^3	Limestone powder kg/m^3	w/c %	w/p %	Fine aggregate kg/m^3	Coarse aggregate kg/m^3	Dosage Of S.P %
Tr 1-5	345	190	204	0.55	0.346	693	884	Variable

Table (10): Data of Initial Investigations.

SR .NO	Trial dosage	Dosage Of S.P	Slump flow (mm)	T50cm ((sec))	V-funnel T_f (sec)	V-funnel T5min (sec)	L –box Ratio (H_2/H_1)	Indication of segregation
1	Tr1	0.5	470	-	9.58	7. 38	0.095	NO
2	Tr2	1.0	631	4.27	7.51	9.1	.803	NO
3	Tr3	1.5	674	3.20	6.60	8.66	.821	NO
4	Tr4	2.5	680	2.11	6.23	8.41	0.88	NO
5	Tr5	3	814	1.94	5	3.32	0.921	Yes

Table (11): Results of Slump flow Tests , L-box Tests and V-funnel test.

S.D. Mix	dosage of sp %	Slump flow (mm)	L-box ratio (H2/H1)	T20 (sec)	T40 (sec)	V-funnel Tv (sec)	V-funnel Tv5 (sec)
Tr1	0.5	470	0.095	3.55	7.31	9.58	38.7
Tr2	1	631	0.803	2.02	3.53	7.51	9.1
Tr3	1.5	674	0.821	1.57	3.41	6.6	8.66
Tr4	2.5	680	0.880	1.11	2.21	6.23	8.41
Tr5	3	814	0.99	0.52	1.58	5	3.32

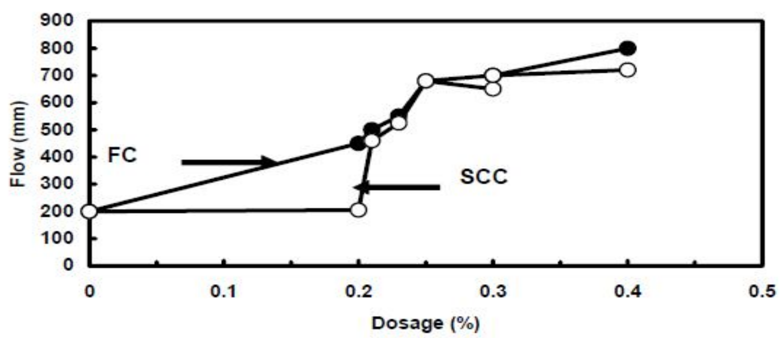


Fig.(1): Effect super plasticizer dosage on flow concrete and self compacted concrete. (5)

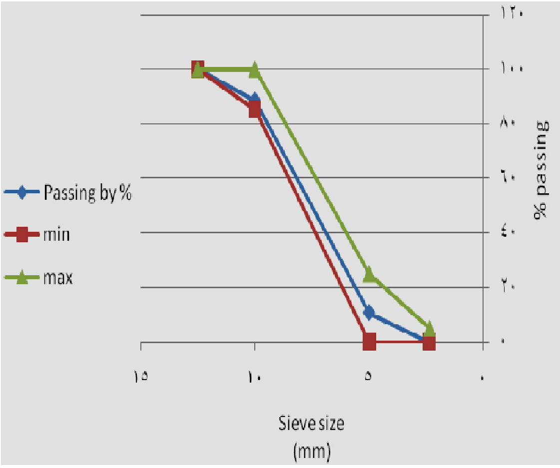


Fig.(2): Grading Curve for Coarse Aggregate.

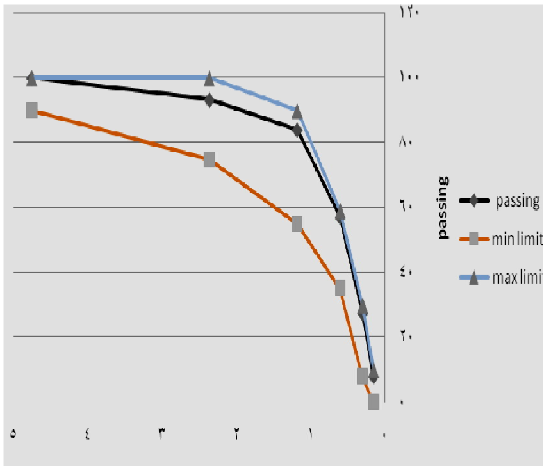


Fig.(3): Grading Curve for Fine Aggregate with grading limits in zone

Fig.(4) :slump flow ,L-box and V-funnel tests.

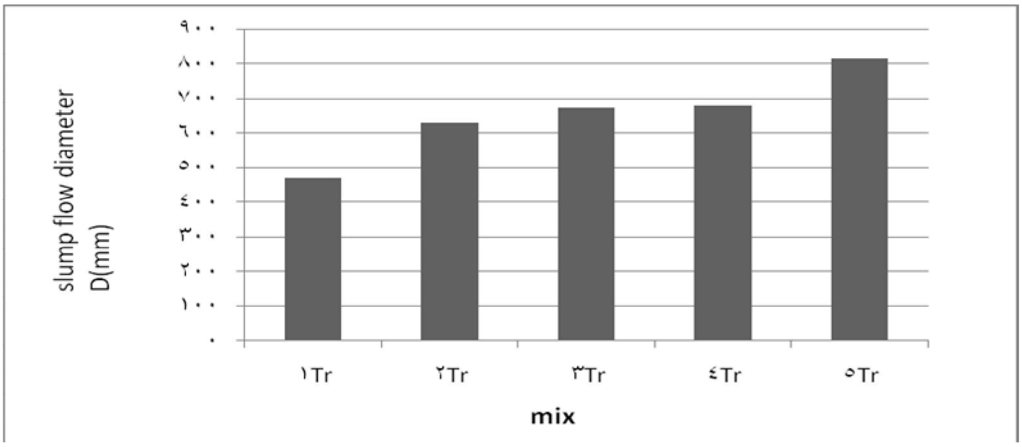


Fig.(5): slump flow diameter D (mm).

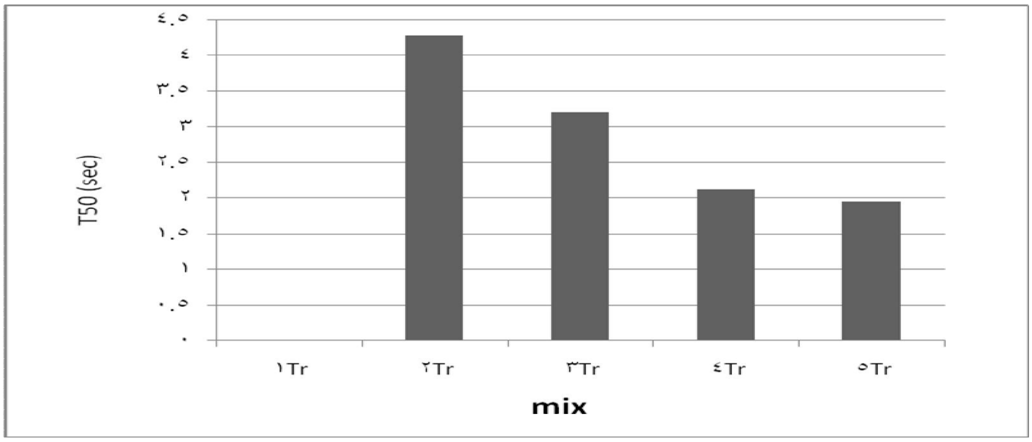


Fig.(6): Time required to pass (500 mm dia.)circle (T50) .

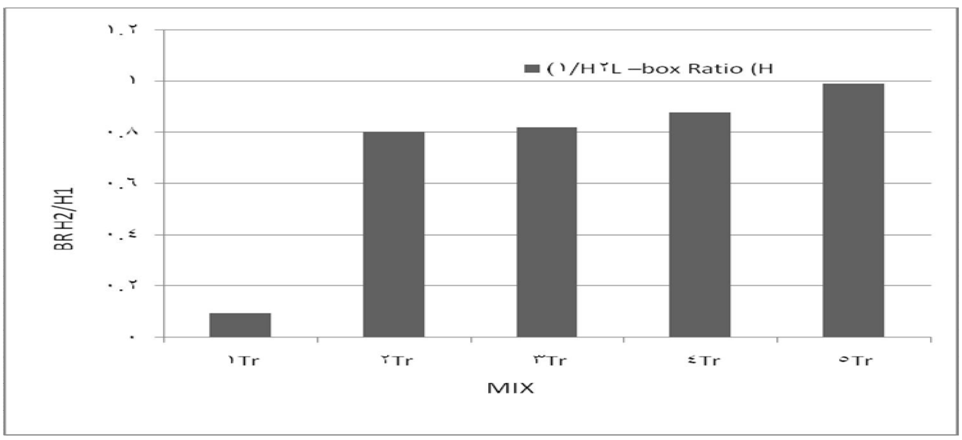
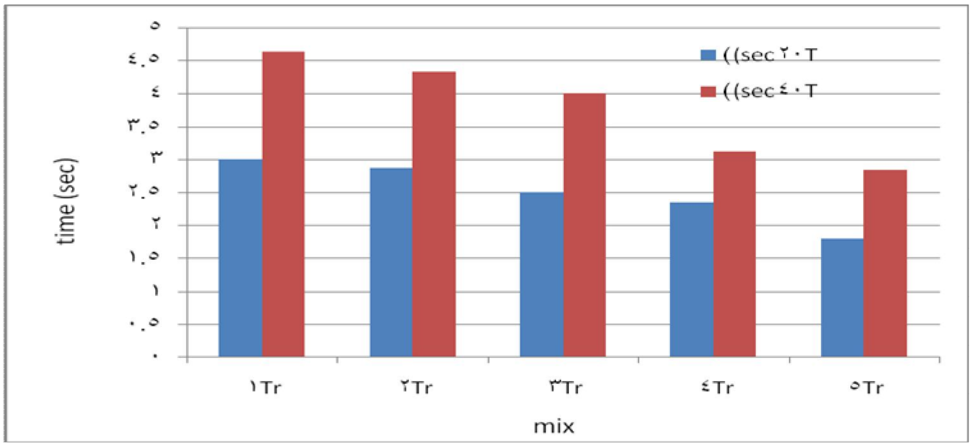


Fig.(7): Results of blocking ratio (BR) (H2/H1).



Fig(8): Results of T20 & T40 of L-box.

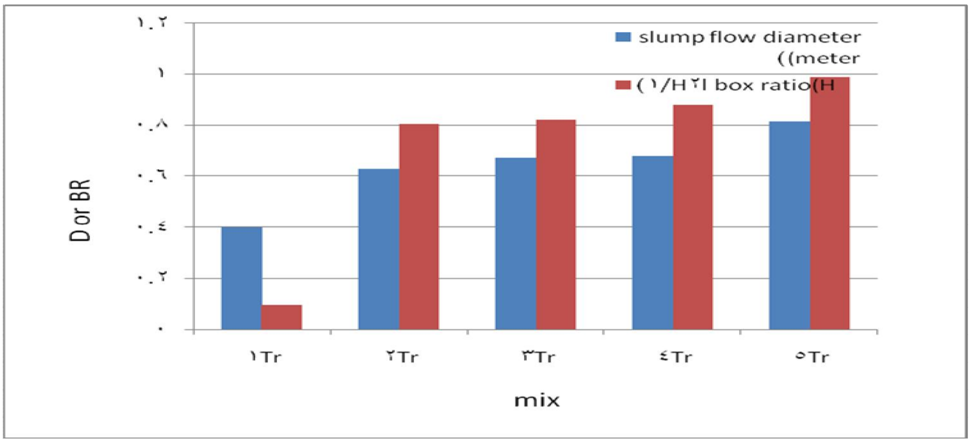


Fig.(9): Comparison between slump flow (D) and blocking for all mix.

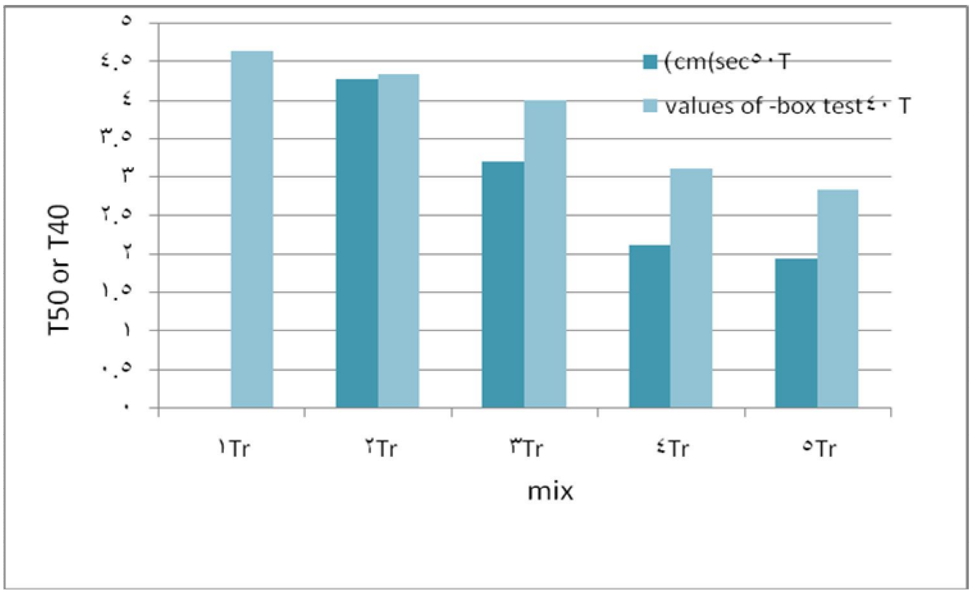


Fig.(10): Comparison between slump flow and blocking for all mix T50 & T40 Results for mixes.

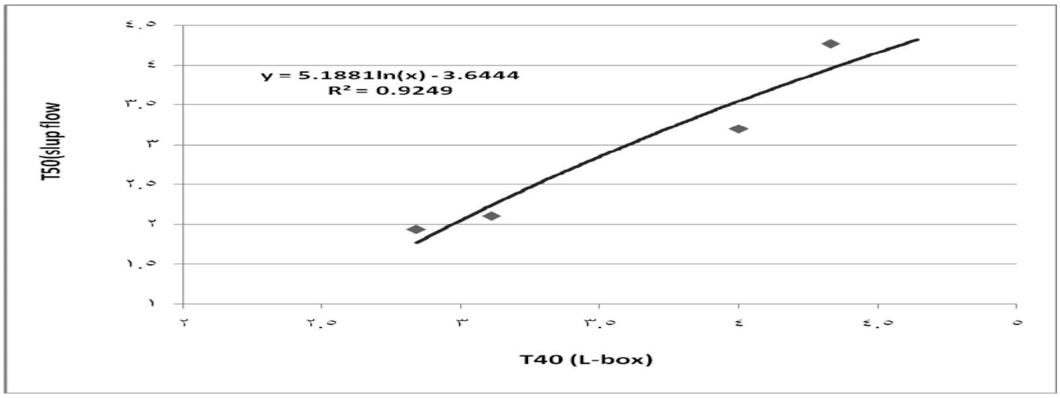


Fig.(11): Relationship between T40 of L-box and slump flow T50.

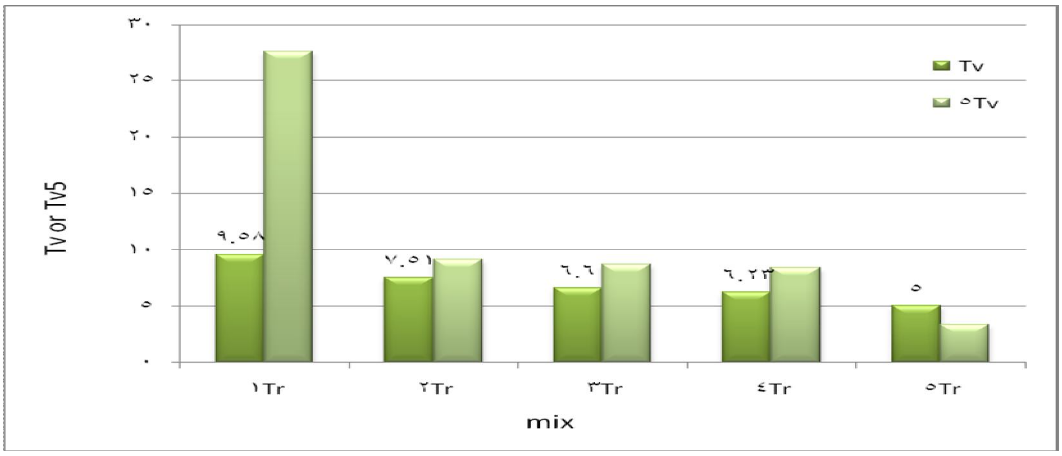


Fig.(12): Comparison between time V-funnel and time V-funnel 5 all mix (Tv & Tv5) (sec.).

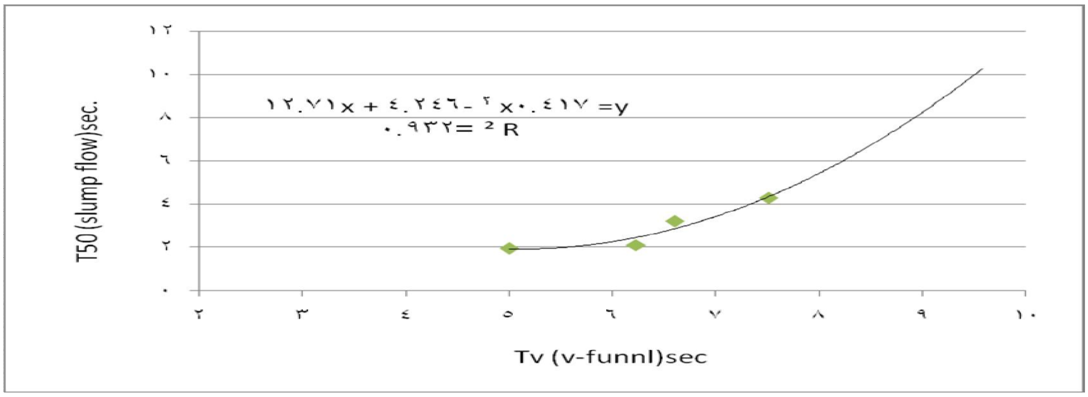


Fig.(13): Relationship between slump flow T50 and V-funnel test (Tv).

تأثير جرعة المضاف على قابلية التشغيل للخرسانة ذاتية الرص

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الخلاصة

تمتلك الخرسانة ذاتية الرص القدرة على الجريان والزيادة الكامنة للانعزال والنضح .إن البحث المقدم يناقش نتائج عملية لخلطة خرسانية ذاتية الرص مختلفة الجرعات للمضاف عالي الأداء نوع (Glenium 51) وبنسبة تراوحت (0.5%− 3%) لتر / 100 كغم سمنت .الخواص الطرية للكونكريت التي فحصت باستخدام خمس جرعات للمضاف (0.5%,1.0%,1.5%,2.5% and 3.0%) بالتتابع . قابلية التشغيل قيمت باستخدام ثلاث فحوص لكل جرعة من المضاف للخلطة وحسب مواصفات الخرسانة ذاتية الرص (slump flow , L-box differential height and V-funnel tests). ثلاث نسب من المضاف (Tr2,Tr3 and Tr4) حققت متطلبات الخرسانة ذاتية الرص والنسبتان (Tr1 and Tr5) لم تحقق متطلباتها لذلك أفضل جرعة من المضاف حققت متطلبات الخرسانة ذاتية الرص تراوحت مابين (1.0%-2.5%) لتر لكل 100 كغم سمنت حسب الظروف والمواد المستخدمة في البحث .

مفاتيح الكلمات : خرسانة ذاتية الرص ،قابلية التشغيل ،جرعة مضاف ، فحص .