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DEVELOPMENT OF SELF-COMPACTING CONCRETE WITH INDIGENOUS JORDANIAN MATERIALS USING JORPHOS AS A FILLER

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ABSTRACT

The objective of this research is to determine the effect of adding the JORPHOS (Jordanian phosphate) as filler on fresh and hardened properties of SCC. Construction companies that use SCC having trouble with importing fly ash to Jordan because it is environmental impact and prohibited from entering Jordan. The European method was used for design of SCC, fresh properties such as flow-ability, pass-ability and segregation resistance were tested. The ingredients were coarse aggregate limestone, sand, cement, water, super-plasticizer and JORPHOS. The research gave good results by addition of different percentages of JORPHOS(4%, 8%,12%,16%). It concluded that 8% of JORPHOS by volume gave the optimum value.

KEYWORDS: JORPHOS, Compressive Strength, Self-Compacting Concrete, Slump Flow, V-Funnel, J-Ring

INTRODUCTION

Self Compacting Concrete (SCC) is flowable and hence eliminates the need for vibration. It is a versatile material which increases durability and performance of the structure. The European Federation of Specialist Construction Chemicals and Concrete Systems, Self-compacting concrete (SCC) can be defined as a fresh concrete which possesses superior flow-ability under maintained stability (i.e. no segregation) thus allowing self-compaction—that is, material consolidation without addition of energy [1]. It was first developed in Japan in 1988 in order to achieve durable concrete structures by improving quality in the construction process. This was also partly in response to the reduction in the numbers of skilled workers available in the industry [2].

Al Qadi Arabi et. al. [3] developed SCC by using contrast constant factorial design to determine if adjustment of the four factors viz. cement content (C), water to powder (w/p) ratio, fly ash (FA) content, and super-plasticizer (SP) will increase the compressive strength of self-compacting concrete (SCC) by using contrast constant factorial design and response surface methodology. Their concluded were to maximized the compressive strength, variables like cement content, water to powder ratio, fly ash content, and super plasticizer dosage, should be kept at a high level and the process is relatively robust to content of super-plasticizer. The highest compressive strength is obtained when cement contents, w/p, FA contents are high and SP is low.

M. Resheidat and Alzyoud [4]presented experimental investigation on introducing the technology of SCC in Jordan using local materials. Development of SCC in Jordan is highly needed to overcome many problems in the construction sector. SCC has better finishing surfaces with less air voids on surfaces, and the similar w/c ratio, strengths of the SCC mixes, using the limestone powder as filler, were significantly lower than the mixes contain fly ash because it is coarser and its purity is low. The basic mechanism of blocking was found to depend principally on the paste volume of the concrete, and on the characteristics of coarse aggregate (size, shape and quantity) relative to the gaps through which the concrete has to flow.

Brouwers and Radix, [5] studied theoretical and experimental of SCC using Japanese and Chinese Methods are discussed, in which the packing of sand and gravel plays a major role. Here, the grading and packing of all solids in the concrete mix serves as a basis for the development of new concrete mixes. Mixes, consisting of slag blended cement, gravel three types of sand and a poly-carboxylic-ether type super-plasticizer,

Frances Yang [6] studied constitutes a self-consolidating concrete, how it Works, its applications exploring these topics includes looking at the components of SCC that make it different from normal concrete. In conclusion, self-consolidating concrete is an exciting technology that has found many successful applications. Although the concept has been around for a few decades, new products are still emerging and better mix proportioning strategies are still in development. The new generation of poly-carboxyl ate based super plasticizers has taken SCC a giant step forward. Meanwhile, multiple viscosity modifying admixtures are available, while researchers continue to seek better and cheaper recipes. While there is no set definition for SCC yet, for now the concrete construction industry generally follows certain methods of measuring mix properties to define an SCC. The absence of an established industrial standard for SCC allows more creativity in tailoring a mix to specific job requirements. At the same time, the lack of standards means devising a successful mix depends on the expertise of the producer and contractor. Therefore, it is clear that educating manufacturers and contractors is the crucial first step in expanding the use of SCC's extremely promising technology.

Chris I. Goodier, [7] showed outlines and a brief history of SCC from its origins in Japan to the development of the material throughout Europe Research and development into SCC in the UK and Europe are discussed, together with a look at the future for the material in Europe and the rest of the world.

Khatib, [8] studied the effect of fly ash (FA) on the properties of SCC. The cement content was replaced with 0 to 80% FA, w/b ratio was kept at 0.36 for all mixes, and the mixtures tested for workability, compressive strength, ultrasonic velocity (UPV), absorption, and shrinkage. They concluded that cement replaced with 40% FA gave compressive strength of 65MPa at 56 days, but the water absorption was high with increase in FA. Also, there is a reduction in shrinkage by the increase of the fly ash content. A linear relationship was reported between FA content and shrinkage at 56. Sonebi, (2004) studied the development of medium strength of the SCC by using pulverized fuel ash (PFA) and superplasticizer (SP).

Al Qadi Arabi et al. [9] used statistical modelling to model the influence of key mixture parameters (cement, water to powder ratio, fly ash and super plasticizer) on the hardened properties affecting the performance of SCC. The models were valid for a wide range of mixture proportioning. The derived numerical models could be useful to reduce the test procedures and number of trials of mix proportioning of SCC. The researchers concluded that full quadratic models in all the responses showed the best models.

Khayat et al. [10] used a central composite response surface with 5 factors (w/c ratio (0.37 to 0.5), cement content (360 to 600), viscosity enhancing agent dosage (0.05 to 0.20% by mass of water), superplasticizer dosage (0.30 to 1.10% by mass of binder), volume of coarse aggregate (240 to 400 kg/m3) and the volume of fine aggregate content varied to achieve absolute volume. Responses studied were slump flow, rheological parameters, filling capacity, v-funnel, surface settlement, and compressive strength at 7 and 28 days. They concluded that the derived models are to better understand exchanges between mixture parameters and compare the responses obtained from various test methods.

Cheng Yeh, [11] investigated the potential of using design of experiments and neural networks to determine the effect of fly ash replacements, from 0 to 50%, on early and late compressive strength, from 3 to 56 days, of low and high-strength concrete, at water cementitious material ratios in the range of 0.3–0.7. He concluded that: Using a simplex-centroid mixture experiment design, a less number of experiments need to be performed to obtain meaningful data; the development of compressive strength and the parameters of the concrete have a high correlations of the generalization capabilities of the neural networks; and the concrete strength analyses of variance on the variables and their interactions can be performed.

The objectives of this research are to develop Self Compacting Concrete (SCC) mix design using Jordanian materials, to investigate the effect of adding the JORPHOS (Jordanian phosphate) as filler on fresh and hardened properties of SCC. Also to investigate SCC and determine whether, it can be used Jordanian materials in improving the self compacting concrete, and if the JORPHOS useful to use as filler in the mix design, to get the chemical and physical analysis for JORPHOS, limestone, and cement ingredients.

Jordan this days are concern in using the high performance concrete especially in: high rising buildings that require high bearing capacity, and of the offshore buildings which is hard to do vibration for it. Replacing the fly ash by (JORPHOS) in the mix design, help to prevent the problem for availability of fly ash and studying the environmental and economical effect of using the JORPHOS on the mix design.

EXPERIMENTAL PROGRAM

Materials Used

Portland Cement: Ordinary Portland Cement (OPC) confirming to [12] as available in the local market was used in the investigation. The cement used has specific gravity of 3.15 and Blaine's fineness (Blaine) of 4500 cm2 gm-1 as shown in Table 1.

Silica Fume: It is a byproduct manufactured of silicon or ferro-silicon metal, and is collected from flue gases of electric arc furnaces, fine powder smaller than cement. It is related to [13], used at 5 to 12% by mass of cementitious materials.

Jordanian Phosphate: The specific gravity is 2.8 done according to [14], while chemical composition of JORPHOS was sown in Table 1 as follows.

Table 1: Chemical Composition of JORPHOS and Cement

Type	JORPHOS(%)	Cement (%)
Tri Calcium Phosphate (TCP)	58.44	
Acid Insoluble Resolution (cilia Air)	11.64	
Loss of Ignition (LOI)	9.41	1
CO_2	7.74	-
CaO	46.27	51.3
MgO	0.49	4.1
Fe_2O_3	0.37	4.5
Cl	0.142	-
Al_2O_3	0.86	5.8

Table 1: Contd.,		
CO_3	1.5	-
Na_2O_3	0.68	-
K_2O	0.075	0.6
Organic Matter	0.18	

Crushed Aggregate: Crushed angular limestone material of 20 mm nominal size from a local source was used as course and medium aggregate, while fine aggregate crashed silica sand with a combined of aggregate (28% coarse aggregate, 38% medium aggregate and 34% fine aggregate) all of these aggregate are oven dry weight. Figure 1and Table 2 shows the sieving analysis according to [15]. Specific gravity for combined aggregate was 2.534 and the absorption value was 1.751% conforming to [16].

Table 2: Sieving Analysis of Combined Coarse, Medium and Fine of Limestone Aggregate

Sieve Size		Combined Percentage Passing (%)	Grading Limits	
			Upper(%)	Lower(%)
1 "	25.4mm	100	100	90
3/4"	19mm	92.72	100	70
1/2"	12.5mm	74.53	88	60
3/8"	9.5mm	62.27	75	50
No. 4	4.75mm	35.62	60	35
No. 8	2.36mm	34.43	45	27
No. 16	1.18 mm	33.57	35	20
No. 30	0.6mm	25.25	25	12
No. 50	0.3mm	8.69	15	5
No. 100	0.15mm	2.39	5	1
No. 200	0.075mm	1.33	5	0

Figure 1: Sieve Size with % Passing of Combined Aggregate Related to Specified Limit

Super-Plasticizer: Polycarboxylic polymer based free flowing liquid having specific gravity of 1.09, light yellow liquid colour, freezing point -10oC, and air entrainment less than 2%, with a dosage of 0.3 to 1.7 liter per 100kg cementitious materials in the mixture conforming to[17].

Potable Tap Water: Water conforming to was used for mixing and curing [18].

MIX PROPORTION AND TEST SPECIMENS

The control mixture contains only the base components for any mixture without any additives (except super-plasticizer) which are cement, water, aggregate, and super-plasticizer. It will be the reference for all other mixtures that contains additives or replacement materials of cement. To achieve a high performance concrete depend on the European Guideline by weight or volume of components for the related mixtures. Table 3and Table 4 showed the mixture proportions.

Table 3: Mixture Proportion of SCC with Silica Fume and JORPHOS as Fillers

	Trial Mix			
Component (0.03m^3)	**PC Control**	**PC with Silica Fume**	**PC with JORPHOS**	**PC with (JORPHOS + Silica Fume)**
Coarse Aggregate (Kg)	5.810	5.770	5.770	5.770
Medium Aggregate (Kg)	14.250	14.160	14.160	14.160
Fine Aggregate (Kg)	11.160	11.540	11.540	11.540
Silica sand (Kg)	21.110	20.980	20.980	20.980
Cement (Kg)	12.60	11.590	11.590	11.590
Water (Kg)	4.650	4.650	4.650	4.650
JORPHOS (Kg)	0.000	0.000	1.010	0.505
Silica fume (Kg)	0.000	1.010	0.000	0.505
Super-plasticizer(L)	0.150	0.150	0.150	0.150

Table 4: Mix Proportions of SCC with Different Percentages of JORHPOS

Mix No.	C (kg)	W (kg)	CA (kg)	FA (kg)	Sand (kg)	W/P	Super-Plasticizer (L)	JORHPOS Volume (%)	JORHPOS. Weight(kg)
PC control	420.00	155.00	193.67	847.00	703.67	0.37	5.00	0%	00.00
MJ4	403.20	157.85	483.20	655.77	586.74	0.38	8.06	4%	14.93
MJ8	386.40	164.49	478.72	649.69	581.31	0.40	7.73	8%	29.87
MJ12	369.60	171.14	474.24	643.62	575.87	0.41	7.39	12%	44.80
MJ16	352.80	177.78	469.76	637.54	570.43	0.43	7.06	16%	59.74
MJ20	336.00	184.43	465.29	631.46	564.99	0.45	6.72	20%	74.67
MJ24	319.20	191.08	460.81	625.38	559.55	0.47	6.38	24%	89.60
MJ28	302.40	197.72	456.33	619.30	554.11	0.49	6.05	28%	104.54

The mix proportions that were used in the investigation is presented in Table 3 and Table 4 along with the response. All concrete mixes were prepared in 40 L batches in a rotating planetary concrete mixer. The batching sequence consisted of homogenizing the sand and coarse aggregate for 30 seconds, then adding about half of the mixing water into the mixer and continuing to mix for one more minute. The mixer was covered with a plastic cover to minimize the evaporation of the mixing water and to let the dry aggregates in the mixer absorb the water. After 5 minutes, the cement and silica fume and JORPHOS were added and mixed for another minute.

Finally, the SP and the remaining water were introduced and the concrete was mixed for 3 minutes. A concrete mix can be classified as SCC if the requirement for all fresh properties are conformed to [1]; filling ability under own weight SCC flow in all spaces within the framework. Tests, such as slump flow, V-funnel are used for measuring filling ability. Slump flow, T50 tests were used to test the filling ability of SCC [19]. Compressive strength tested using a 2000 kip (4448.2216 kN) capacity compression machine. according to the [20]. Compressive strength was determined by using cubic specimens of 150x150x150 mm that were cast for 1 day then removed from the molds, cured in water at 20oC for 28 days, the surfaces were then smoothed by grinding to achieve a leveled appearance then tested for strength, average of three results are reported in the investigation.

METHODS OF ANALYSIS

Experimental procedure will include four tests for fresh self compacting concrete, which is recommended for

European Standardization methods; slump flow test (total spread and T50 time):Primarily to assess filling ability, L-Box test: primarily to asses passing ability, J-Ring test: primarily to assess passing ability, V-funnel primarily to assess filling ability.

RESULTS AND DISCUSSIONS

The following results of SCC as shown in Table 5 through Table 7 indicate the fresh and hardened properties of SCC with Silica fume and JORPHOS as filler materials in the constitiuos of the concrete. The fresh properties were slump flow, T50, J-Ring, L-Box and V-Funnel found. Also hardened property compressive strength was calculated.

Table 5: Fresh and Hardened Properties of SCC with Silica fume and JORPHOS as Fillers

Mix Type	Tests type						
	Slump Flow (mm)	T50 (Sec.)	J-Ring (mm)	L-Box Ratio (H2/H1)	V-Funnel (Sec.)	Density (kg/m^3)	Compressive Strength (MPa)
PC control mix	740.5	5.4	700.5	0.944	13.4	2.46	63.9
PC with Silica Fume	770.0	3.2	700.5	0.966	9.5	2.45	57.1
PC with JORPHS	695.0	7.00	630.0	0.815	23	2.48	56.8
PC with Silica fume and JORPHS	730.0	5.00	650.0	0.965	14	2.45	68.2

Table 6: Fresh and Hardened Properties of SCC with JORPHOS as Fillers

Mix Type	JORPHOS (%)	Slump Flow (mm)	T50 (Second)	J-Ring (mm)	L-Box Ratio (H2/H1)	V-Funnel (Second)	Compressive Strength (MPa)
JOM0	0	740.5	5.4	700.5	0.944	13.4	61.0
JOM1	4	730.0	4.5	640.0	0.850	23.0	54.4
JOM2	8	753.0	3.0	697.0	0.870	17.0	45.0
JOM3	16	730.0	3.6	643.0	0.940	25.0	42.9
JOM4	32	723.0	3.2	653.0	0.730	9.4	39.0

Table 7: Fresh and Hardened Properties of Control Pc Silica Fume and JORPHOS

Mix Type	Tests Type						
	Slump Flow (mm)	T50 (Second)	J-Ring (mm)	L-Box Ratio (H2/H1)	V-Funnel (Second)	Free Weight Density (kg/m3)	Compressive Strength (MPa)
PC control mix	740.5	5.4	700.5	0.944	13.4	2.46	63.9
PC with Silica Fume	770.0	3.2	700.5	0.966	9.5	2.45	57.1
PC with JORPHS	695.0	7.0	630.0	0.815	23	2.48	56.8
PC with Silica fume and JORPHS	730.0	5.0	650.0	0.965	14	2.45	68.2

Figure 2 demonstrate the slump flow for different percentages of JORPHS. It indicate that the 8% of JORPHS by volume had the highest value of slump, which was 753.4 mm than other percentages.

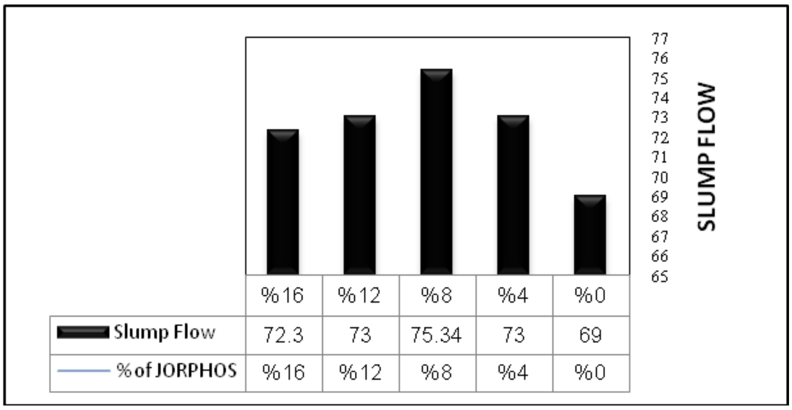

Figure 2: Slump Flow for different Percentages of JORPHOS

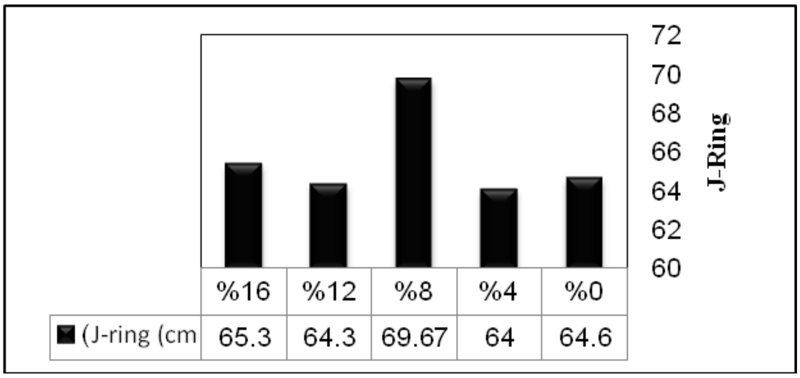

Figure 3: J-Ring for different Percentages of JORPHOS

As seen in Figure 3 the 8% of JORPHS by volume is indicate the highest value 696.7mm than other values Percentages of JORPHOS.

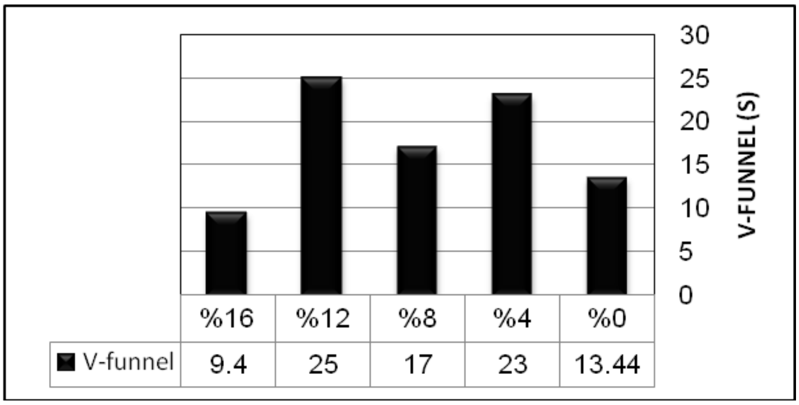

Figure 4: V- Funnel for Different Percentages of JORPHOS

As shown in Figure 4 for V-Funnel test with different percentages of JORPHOS the 12% indicate 17 second, the highest value with respect to the previous percentages.

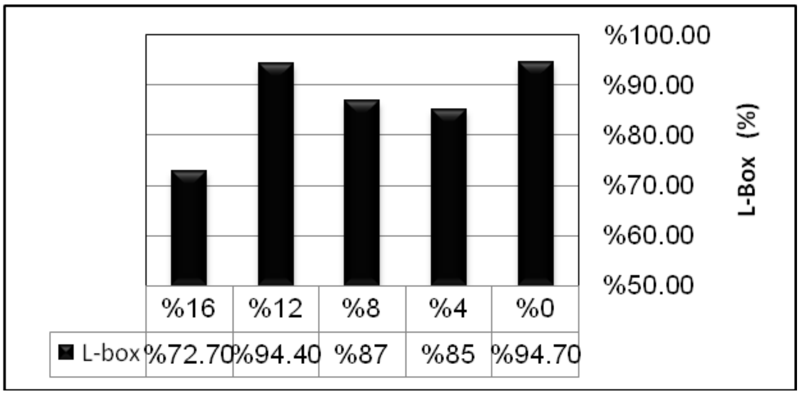

Figure 5: L- Box for Different Percentage of JORPHOS

Therefore, Figure 5 demonstrate that 12% of JORPHOS with 94.4% for L-Box, than other percentages of JORPHOS.

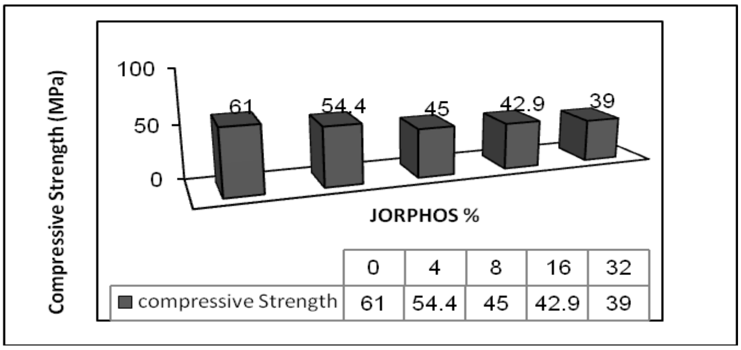

Figure 6: Compressive Strength at Different Percentages of JORPHOS

CONCLUSIONS

The following conclusions can be drawn from the investigation:

- Fresh properties tests of slump, T50, L-Box, V-funnel and J-ring of SCC show that 8% JORPHOS achieved the best results compared with other JORPHOS concrete mixtures.
- Hardened properties of compressive test at 28 day shows that the best result achieved good value at 0% and 4% in JORPHOS and 8% in micro silica mixes.

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