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" Self-Compacting Concrete"

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***Abstract-* In this paper we study the quality of different self compacting concrete mix - cast with different materials compared with normal vibrations on concrete. In a laboratory tested program was designed to produce various mix of self compacting concrete react with different local materials. Nineteen concrete mixes sample casting with different types of cement contain with aggregates and filler types material. The test are U box test, V funnel test, Slump flow test and L box test were carried out to the behavior of the fresh mix for self compacting concrete. In the measuring of mechanical properties were flexural strength, compressive strength and impact strength. Exposure to fire or NaCl solution was also carried out to study the performance of this sample. The results shows that the lime stone filer or High Portland cement should be used successfully to the producing self-compacting concrete with increase durability, workability and reducing segregation on the mix. The addition of lime stone filler up to 20 % by cement weight reduced cost and enhanced the performance of self compacted concrete (SCC) in fresh and hardened stages. Moreover, using High Slag Portland cement obtained the high performance in several conditions in our environment. In the Self compacting concrete is a category of high grade concrete. The capability of this concrete to fill the structural elements perform, flow around restricted areas of reinforcement without needing of any external or internal vibrators. Filler materials are often used to reduce the total aggregate content and modifying viscosity.**
Keywords: Self-compacting concrete, lime stone powder, super plasticizer, modified concrete fly ash, NaCl solution, compressive strength, Split tensile strength, flexural strength and impact strength, normal compacting concrete.

I. INTRODUCTION

In few-years ago, there is a increase the use of self-compacting concrete (SCC), which increase the durability of overall structure. In the self-compacting concrete is characterized by its capacity to flow and to fill out the most restricted places of the form-work, without losing homogeneity. On the other hand, a self compacting concrete should have the capacity of self-densification, resulting in a material whose properties in the hardened state are at least the same achieved with concrete compacted by vibration. One of the employed techniques to produce a self compacting concrete is to use fine materials in the concrete, beside the cement. Those fine materials are denominated additions and they can have, or not, a chemical activity. The uses of mineral additions or powders have a purpose, besides substituting a part of the cement, it propitiate the appropriate viscosity so that the self-compaction is reached. Japan has used self-compacting concrete in bridge, building and tunnel construction since the early 1990's. In the last five years, a number of SCC bridges have been constructed in Europe. In the United States, the application of SCC in highway bridge construction is very limited at this time.

However, the U.S. precast concrete industry is beginning to apply the technology to architectural concrete. SCC has high potential for wider structural applications in highway bridge construction. The applications of SCC in Japan and Europe are covers.It discusses the potential for structural applications in the U.S. and the needs for research and development to make SCC technology available to the bridge engineers. The limestone-quarry fines and Class C fly ash have high potential for utilization in the manufacturing of self-compacting concrete (SCC). The test data collected indicate that these materials can be used in the manufacturing of economical SCC in several different ways.

When quarry fine material was used for the substitute of natural sand, it reduced the requirement of chemical admixtures, high-range water-reducing admix-ture (HRWRA) and viscosity-modifying admixture (VMA), without affecting the strength of SCC. The 28-day compressive strength of the mixtures made with sand replaced with quarry fines up to 50% was in the range of 7,500 psi and 9,000 psi, qualify-ing the mixtures to be classified as high strength SCC ($\geq$ 6500 psi). Also by using Class C fly ash for the replacement of up to 55% of total cement by mass, high-strength SCC with the 28-day strength in the range of 9,000 psi and10,000 psi was produced in an economical way.

In conclusion, the use of quarry fines and Class C fly ash significantly reduced the amount of expensive chemical admixtures such as HRWRA and VMA in producing SCC. The alkali-silica reaction in concrete is known to result in cracking and overall expansion of structural elements. There are some examples in the literature indicating that the finest particles of alkali-reactive aggregates should not be considered dangerous in concrete. Some researchers have reported that filler particles below a critical limit, which has been reported to be in the order of 50 μm for some rocks, may give pozzolanic reactions, and consequently be beneficial. However, there have been reported cases where particles smaller than 20-30 μm gave very fast and deleterious reactions. Alkali reactive fillers from two Norwegian catalectic rocks have been investigated. The study has included fillers of Icelandic glassy rhyolite and crushed bottle glass. Non-reactive reference fillers were included in the study, as well as silica fume and fly ash known to mitigate alkali silica reactions. The main characteristics of SCC are the properties in the fresh state. These properties are filling ability (flow ability), passing ability (free from blocking at reinforcement) and resistance to seg-regation (stability). No sing test so far devised can measure all three properties. Slump flow test can provide an indication of fill-ing ability requirement, V funnel test can provide an indication of filling ability requirement and resistance to segregation requirement, U box test can provide an indication of passing ability requirement and L box test can provide an indication of passing ability

II. RESEARCH SIGNIFICANCE

This research presents the study of the results of self compacting concrete, laboratory tests such as Slump-Flow test, V-Funnel test, U box test and L box test. Self compacting concrete mixtures were produced and controlled by the mentioned tests in fresh stage; the mechanical characteristics of these concretes were studied and compared with normal compacting concrete NC. The performance of using lime stone powder or / and high slag Portland cement (HSPC) in self compacting concrete SCC mixes was also taken into consideration. Moreover, the exposure to fire and 5% NaCl solution was studied.

III. EXPERIMENTAL PROGRAM

The experimental program was designed to produce various mixes of self compacting concrete SCC made with various local ma-terials. Nineteen concrete mixes cast with different cement types and contents, aggregates types and contents, filler types and con-tents. Slump flow test, V funnel test, L box test and U box test these tests were carried out to control the consistency of the fresh mixes for SCC, Figures 1 to 3 shows the equipment for these tests. The program is extended to study the mechanical properties of the concrete mixes used in this investigation. The recorded mechanical properties were compressive strength, flexure strength and impact strength. Table 1 presents the experimental schedule.

IV. MATERIALS

The constituent materials used in this study were locally available materials specify by the following.

1. **Cement**- Ordinary Portland cement (OPC) of 350-450 kg/cm3 content and with grade42.5N was used in this investigation (Suez Company). Also, high slag Portland cement (HSPC) was used with grade52.5N as given by the manufacturer (Alex Company with trade name marine cement). Cements are confirmed the Egyptian Standard Specifications (ESS) requirements (4756-1/2007).
2. **Fine aggregates**- Medium well-graded sand of fineness modulus 2.6 was used.
3. **Coarse aggregates**- Natural well-graded gravel aggregate of 19mm maximum nominal size. It included a combination of round and angular particles. The surface of the particles was more or less smooth and regular. Natural dolomite aggregate was also used in this investigation of19mm nominal size. The dolomite was obtained from Attaka quarries its particle has a granular porous texture, rough surface and irregular. Fine and coarse aggregate confirmed the ESS requirements (1101-2002).
4. **Chemical admixtures**- High range water reducing admixtures– is a unique third generation super plasticiser with trade name GLENIUM C 315 as given by the manufacturer. It complies with BS 5075 PT 3 and EN 934-2. The amount of admixture was kept fixed for all mixes at 2.25 % of cement weight.
5. **Filler-** Silica fume SF of mineral admixtures was used as an addition 10% of cement weight. It had 150000 cm2/gm specific surface area as given by the manufacturer. Moreover, lime stone powder LF with particle passing from 0.15mm sieve size was used as an addition 10, 20 and 30 % of cement weight.

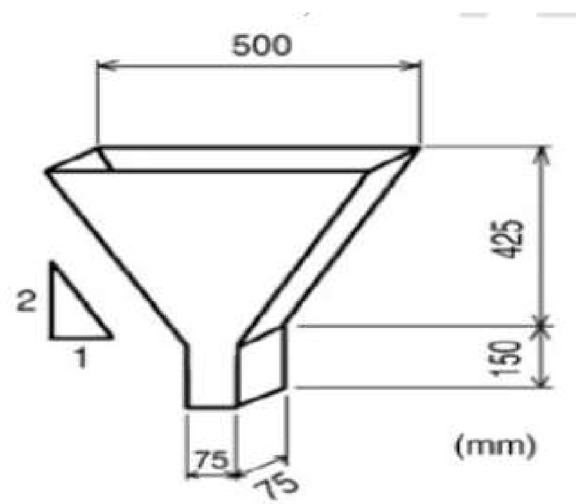

Figure 1:- V funnel

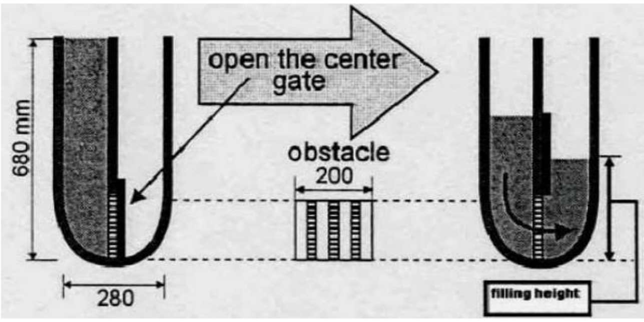

Figure 2:- U Box Test

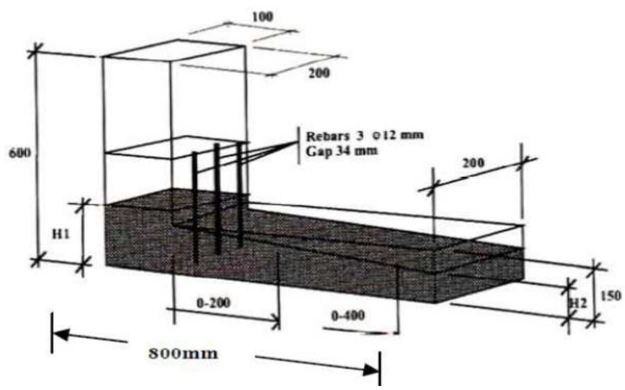

Figure 3:- L Box Test

V. MIX PROPORTIONS

Ninteen trails concrete mixes were prepared and tested for optimized mixtures of self compacting concrete SCC. Of which the suitable mixtures were selected and summarized in Table 2. Absolute volume design method was used to design these concrete mixes. Two concrete mixes (one cast with gravel and the other cast with dolomite) were proportioned without filler as a control mixes (normal compacting concrete NC). The amount of mixing water was kept fixed at 0.4 of cement weight as the control mix and the required degree of consistency was adjusted by the available test. The properties of using lime stone powder were un-known; seven mixtures were prepared to find out the suitable amount for this material and in others varied the cement types.

TABLE 1:- Proportion of concrete mix

Mix No.	Group	Cement Type	Filler %	Coarse Agg.	Cement Kg/m3	Coarse Kg/m^3	Sand Kg/m^3	Filler Kg/m^3	Water Kg/m^3	Adm. Kg/m^3
1	Gravel	OPC	-	0.67	350	1267.5	624.3	0	140	7.9
2		OPC	LF 10	0.45	400	776.7	949.3	40	160	9
3		OPC	LF 20	0.45	400	758.7	927.3	80	160	9
4		OPC	LF 30	0.45	400	740.7	905.3	120	160	9
5		OPC	SF 10	0.45	350	821.6	1004.2	35	140	7.9
6		OPC	SF 10	0.45	400	776.7	949.3	40	160	9
7		OPC	SF 10	0.55	400	932.0	793.9	40	160	9
8		OPC	SF 10	0.45	450	731.7	894.4	45	180	10.1
9		OPC	SF 10	0.55	450	878.1	748.0	45	180	10.1
10		HSPC	SF 10	0.45	350	821.6	1004.2	35	140	7.9
11		HSPC	SF 10	0.45	400	776.7	949.3	40	160	9
12	Dolomite	OPC	-	0.67	350	1267.5	624.3	0	140	7.9
13		HSPC	LF 10	0.45	400	776.7	949.3	40	160	9
14		HSPC	LF 20	0.45	400	758.7	927.3	80	160	9
15		HSPC	LF 30	0.45	400	740.7	905.3	120	160	9
16		OPC	LF 10	0.45	400	776.7	949.3	40	160	9
17		OPC	SF 10	0.45	400	776.7	949.3	40	160	9
18		OPC	SF 10	0.55	400	932.0	793.9	40	160	9
19		HSPC	SF 10	0.45	400	776.7	949.3	40	160	9

VI. SPECIMEN PREPARATION AND TESTING

The dry materials required for each batch were weighted and mixed using a mechanical concrete mixer. The water in addition to admixture and cement or cement- filler was mixed for a half minute to ensure the uniformity of the constituents. Sand was simultaneously charged into the mixer and was mixed for a half minute and then coarse aggregate was added and mixing at least for two minutes. Slump test was carried out according to the British standard specification to control the consistency of the fresh mixes for normal compacting concrete NC. Fresh concrete for self compacting concrete SCC was subjected to evaluate the slump flow (flow ability), passing ability and segregation potential. Slump flow test, V funnel test, U box test and L box test was carried out according to[9-11] to control the consistency and workability of the fresh mixes of SCC. Standard slump cone (200mm by 100mm by300mm) was filled with concrete and required both time (T50cm) take for concrete to reach a500mm slump flow diameter and the mean diameter D of the spread lifting the cone. Funnel test was used to determine the segregation potential. The bottom opening has the dimension of 75mm by 75mm to a depth of150mm. The funnel is filled with concrete and time T taken for the concrete to leave the funnel is measured. Then, the funnel is refilled with the same concrete and allowed to settle for 5 minutes. The new time T5min required for the concrete to leave the funnel is measured. The difference in time is a measure of segregation resistance of the concrete mix.

The L box test is another test method, in which the vertical part is first filled with concrete then a hatch is removed and concrete flows out between rebar. The height level of the concrete on each side H1 and H2 of the L box are measured and calculate H2/H1. Moreover, in U box, the left hand section is filled with concrete and then lifted the gate and concrete flow upwards into the other section. After the upwards into the other section. After the concrete has come to rest required the height in two places H1 and H2 and calculate (H1-H2).

Standard cubes (15x15x15cm) of concrete mix were prepared to measure compressive and tensile splitting strength. Standard beams(10x10x50cm) were prepared to measure flexural strength and impact strength. Figure 5 shows the test apparatus for the impact test. A hydraulic compression testing machine of total capacity 15oo kN was used for compression and splitting test, while, the Universal testing machine of total capacity 300 kN was used for flexural test.

Moreover, the influence of exposure to fire after 28 days in compressive strength was investigated on cubes l5xl5xl5cm. The concrete cubes were put on fire chamber at 400 °C for two hours and left in laboratory temperature up to cold, after then the speci-mens applied to compressive test. Comparative study for corrosion resistance of concrete specimens "lollipop" of 10cm diameter and 20cm height concrete cylinder in which steel reinforcement bars 10mm diameter and35cm length were imbedded in concrete cylinder. Each steel reinforcement bar was weighted firstly and embedded to 15cm length in concrete cylinder keeping 20cm over length out of the cylinder. An accelerated test for corrosion was applied by using power supply at constant current and switch to maximum voltage. Stainless steel bar with 10mm diameter was used as a cathode and the steel bar act as the anode. The lollipop specimens was cured in water, 20 °C, for 14 days and then immerged in fiber glass container to half depth in 5% NaCl solution at age of 14 days to still to another 14 days in the solution, Figure 6 shows the accelerated corrosion cell. After then the specimens leave the container and the steel reinforcement pull out from cylinder by pull out test using the hydraulic testing machine of total capacity 300 kN or crushing the concrete cylinder and then cleaned carefully to cut the rust from the steel, the steel reinforcement weighted and calculate the percent of weigh loss W.

VII. RESULTS AND DISCUSSION

According to the experimental program, the test results of fresh concrete and hardened concrete were summarized in Tables 3 and 4 respectively.

Table 2:- Test Results of fresh Concrete mixes

Mix No.	Group	Cement Type	Filler %	Coarse Agg.	Cement Kg/m3	Slump Flow		V Funnel		U Box	L Box
						T50	D	T0	T5min	H2/H1	H2/H1
1	Gravel	OPC	-	0.67	350	-	-	-	-	-	-
2		OPC	LF 10	0.45	400	3	650	7	10	10	1
3		OPC	LF 20	0.45	400	4	650	9	11	10	1
4		OPC	LF 30	0.45	400	5	670	11	12	20	0.85
5		OPC	SF 10	0.45	350	4	650	7	10	20	0.85
6		OPC	SF 10	0.45	400	3	650	5	7	10	1
7		OPC	SF 10	0.55	400	2	650	5	8	0.0	1
8		OPC	SF 10	0.45	450	2	750	4	6	0.0	1
9		OPC	SF 10	0.55	450	2	800	4	7	0.0	1
10		HSPC	SF 10	0.45	350	4	650	6	9	3.0	0.8
11		HSPC	SF 10	0.45	400	3	650	5	7	20	1
12	Dolomite	OPC	-	0.67	350	-	-	-	-	-	-
13		HSPC	LF 10	0.45	400	4	650	9	11	30	1
14		HSPC	LF 20	0.45	400	4	650	11	13	40	1
15		HSPC	LF 30	0.45	400	5	650	12	15	45	0.8
16		OPC	LF 10	0.45	400	4	650	10	13	30	1
17		OPC	SF 10	0.45	400	3	700	6	9	20	1
18		OPC	SF 10	0.55	400	2	700	6	9	10	1
19		HSPC	SF 10	0.45	400	3	650	6	9	15	1

FRESH CONCRETE

The use of gravel recorded more workability with less homogeneous for self compacted concrete than dolomite according to the test measured in this work. The flow ability, passing ability and segregation resistance of SCC measured by slump flow, V funnel, U box and L box test. Dolomite is recommended than gravel to enhance the workability problems and maintain the homogenous of SCC. Increase in cement content decrease the flow time and increase the passing ability by U and L box, and the use of HSPC recorded the same trained of OPC. The increase in coarse aggregate content from0.45 to 0.55 decrease the flow time while the segregation resistance decreases by about 12.5% measured by V funnel T5min (mix 7 compared with mix 6, content 400 kg/m3 cement) and by 14.3 % (mix 9 compared with mix 8, content 450 kg/m3 cement), this results recorded for more flow able mix cast with gravel. The deference between SF and LF filler up to 10% addition of cement weight not remarkable. These results go to use the lime stone filler as use silica fume. On the other hand, the increase in lime stone filler resulted in reduction in flow ability of mixes and with regard to mixes cast with gravel the flow time for mix 2, mix 3 and mix 4 were 3, 4 and 5 sec., for 10 %, 20 % and 30 % addition lime stone filler by cement weight OPC, respectively. While, the flow time for mix 13, mix 14 and mix 15 were 4, 4 and 5 sec., for 10 %, 20 % and 30 % lime stone filler addition of cement weight HSPC, and using dolomite, respective-ly.

Figure 5:- Impact Apparatus Test

HARDENED CONCRETE

The compressive strength is the most common limit used to characterize concrete and a base for specification and quality control. The compressive strength for all mixes of SCC at varies ages were higher than NC. Tables 4 and 5 illustrate the test results and the effect of using SCC on mechanical properties.

Table 3:- Test Results of Mechanical Properties of Concrete

Mix No.	Group	Cement Type	Filler %	Coarse Agg.	Cement Kg/m3	Compressive Strength MPa		Flexural Strength MPa	Impact Strength No. of Blows
						14	28	28	28
1	Gravel	OPC	-	0.67	350	22	26	6	5
2		OPC	LF 10	0.45	400	25	27.5	4.8	3
3		OPC	LF 20	0.45	400	24	29	5.8	4
4		OPC	LF 30	0.45	400	28	30	5.3	4
5		OPC	SF 10	0.45	350	23	25	4.8	4
6		OPC	SF 10	0.45	400	25	28	5	4
7		OPC	SF 10	0.55	400	31.5	36	5.8	4
8		OPC	SF 10	0.45	450	34	39.5	6.5	17
9		OPC	SF 10	0.55	450	33	37	7.3	3
10		HSPC	SF 10	0.45	350	22	28	5	3
11		HSPC	SF 10	0.45	400	29	32	5.3	7
12	Dolomite	OPC	-	0.67	350	25	30	6.5	5
13		HSPC	LF 10	0.45	400	29	35.5	7.5	8
14		HSPC	LF 20	0.45	400	26	37.5	7.3	7
15		HSPC	LF 30	0.45	400	32.5	33	7	5
16		OPC	LF 10	0.45	400	28.5	35.5	7.8	5
17		OPC	SF 10	0.45	400	25	32.5	7	5
18		OPC	SF 10	0.55	400	38.5	42	7.8	6
19		HSPC	SF 10	0.45	400	33.5	38	7.3	10

Table 4:- Effect of using SCC on Mechanical Properties

Mix No.	Group	Cement Type	Filler %	Coarse Agg.	Cement Kg/m3	Compressive Strength MPa		Flexural Strength MPa	Impact Strength No. of Blows
						14	28	28	28
1	Gravel	OPC	-	0.67	350	22	26	6	5
2		OPC	LF 10	0.45	400	25	27.5	4.8	3
3		OPC	LF 20	0.45	400	24	29	5.8	4
4		OPC	LF 30	0.45	400	28	30	5.3	4
5		OPC	SF 10	0.45	350	23	25	4.8	4
6		OPC	SF 10	0.45	400	25	28	5	4
7		OPC	SF 10	0.55	400	31.5	36	5.8	4
8		OPC	SF 10	0.45	450	34	39.5	6.5	17
9		OPC	SF 10	0.55	450	33	37	7.3	3
10		HSPC	SF 10	0.45	350	22	28	5	3
11		HSPC	SF 10	0.45	400	29	32	5.3	7
12	Dolomite	OPC	-	0.67	350	25	30	6.5	5
13		HSPC	LF 10	0.45	400	29	35.5	7.5	8
14		HSPC	LF 20	0.45	400	26	37.5	7.3	7
15		HSPC	LF 30	0.45	400	32.5	33	7	5
16		OPC	LF 10	0.45	400	28.5	35.5	7.8	5
17		OPC	SF 10	0.45	400	25	32.5	7	5
18		OPC	SF 10	0.55	400	38.5	42	7.8	6
19		HSPC	SF 10	0.45	400	33.5	38	7.3	10

VIII. CONCLUSIONS

Based on the experimental results and the previous discussion, the following conclusions can be drawn:

- Self compacting concrete mixes SCC show better improvement in compressive strength compared to normal compacting con-crete NC at various ages.
- Dolomite was recommended than gravel to enhance the workability problems and maintain the homogenous of SCC.
- The use of high slag Portland cement HSPC improved the performance of SCC in sever environment exposure to fire or expo-sure to5 % NaCL solution compared to ordinary Portland cement OPC.
- The addition of lime stone powder LF up to20 % by cement weight reduced cost and enhanced the performance of self com-pacted concrete SCC in fresh and hardened stages, and the improved increases in sever condition for concrete cast with high slag Portland cement.

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