PROPERTIES OF PASTE AND MOTRAR MIXTURES CONTAINING SLAG AND SILICA FUME

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ABSTRACT:-

In recent years number of organization in Europe have become increasingly involved in research aimed at energy conservation in the cement and concrete industry. This, in part, is being accomplished by encouraging the use of cementitious materials such as fly ash, slag and pozzolans. Lately, some attention has been given to the use of the pozzolans, silica fume, as a possible partial replacement for portland cement. Certainly, that our earth planet is subjected to pollution hazards as a result of the advance of technology in metalurgical industries, for instance, in Egypt, It is found, the Egyptian ferroalloys and Egyptian Iron and steel companies (Edfu-Aswan & Helwan) they suffer from bounteous of silica fume and granulated blast furnace slag successively. Thereby the accumulation of silica fume and slag every year in these plants without being used represents not only a significant loss of money and energy by occupying a big area from these plants but also a negative impact to the environment.

This paper studied the usage of granulated blast-furnace slag as a ground material (% passing from size # 45um = 0.85 %, i. e. specific surface area = 2500 cm 2 | gram) with combination of silica fume in cement paste and mortar mixtures as a partial replacement for cement. This study shows that with increasing the silica fume percentage and decreasing the GGBF slag percentage, the water demand to produce the standard consistence of cement paste is sharply increased and the initial and final setting times of the paste mixtures reduced.

INTRODUCTION :-

The water demand of mortar and concrete incorporating silica fume increases with increasing amounts of silica fume. For example, at 30 percent replacement by weight of cement, for concrete with a water cement ratio of 0.64 the water demand has been found to increase by almost 30 percent 1. In order to maximize the full strength-producing potential of silica fume in concrete it should awalys be used together with a water reducer, preferably with a HRWR (High Rang Water Reducing admixture). The dosage of the HRWR will depend

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Upon the percentage of silica fume and the type of HRWR used 2. Silica fume with high range water reduces has been used to produce very high strength concrete. This type of concrete incorporates large percentages of silica fume and very high dosages of HRWR, resulting in concrete having very low permeability and high compressive strength 3.
The mortars and concretes incorporating silica fume are less permeable. It has shown that this due to a decrease in the number of coarse pores of the cement-silica fume paste system 4.

Silica fume concrete is less permeable because silica fume is a very fine siliceous material that reacts with the lime liberated during the hydration of portland cement and forms stable cementitious products. As a result, very small pores and an improved aggregate to paste interface are formed in concretes with silica fume, this leads to lower permeability and improved concrete strength 5.
In this paper, the various properties of paste and mortar mixtures such as, water demand, initial setting time, final setting time, sounds and compressive strength were discussed in order to show the best rang of combination of ground granulated blast furnace slag and silica fume as a partial replacement of ordinary portland cement from the point of view of Egyptian standard Specifications and explain the effect of combination of cement.

EXPERIMENTAL PROGRAMME :-

The type of slag used in this study was ground granulated blast furnace slag (GGBF slag) was provided from the Egyptian Iron and steel CO. (Helwan). Table1. shows the chemical analysis of this used slag with comparing to ASTM C989-89 limits and physical properties such as, fineness, surface area, specific gravity and slag activity index for evaluating the strength grade of the used slag, the slag-activity index was determined according to ASTM C989- 89 6. Silica fume used in this paper was provided from the Egyptian Ferroalloys CO. (Edfu-Aswan), the chemical analysis and physical properties of the used silica fume were completed by the laboratories of the Egyptian ferroalloys CO. as shown in table 2. The cementitious materials content (cement + GGBF slag + silica fume) assumed to take a constant value through this paper as shown in table 3.
The properties of the various combination of ordinary portland cement, GGBF slag and silica fume were determined by carrying out the water demand, initial and final setting times, soundness and compressive strength tests according to ASTM C 187- 83 3, ASTM C 191 - 827, BS: 12: 1985 8 and BS : 8110 : 1986 3. The test plan (flow chart) for experimental work and tests which were carried out on the paste and mortar of the combinations of cementitious materials used is given in fig 1.

TEST RESULTS AND DISCUSSIONS:-

The results of the water demand percentage for the mixtures of cement, GGBF slag and silica fume to determine consistence of standard cementitious materials paste are indicated in table 4. It is observed that when we increase the percentage of silica fume increase, the water demand to determine the consistence of standard paste is increased. Inversely, with increasing the percentage of GGBF slag, the water demand to determine the consistence of standard paste is decreased. It is found that, with increasing the percentage of silica fume from 3% to 7%, the water demand will be increased, for example, at 6% cement, the water demand of M8 (60|35|5) equals 32% is less than M9 (60|33|7) that equals 35% (increment of water demand for M9 equals 9.4% comparing to M8 as a result of increasing the percentage of silica fume from 5% to 7%. It also evident that the water demand percent of all mixes fall within the Egyptian Standard Specifications limits (min. 25% and max. 30%) except mixes No. 3, 8 and 9.

Tables 5 and 6 show the results of setting times for the various paste mixtures. From the previous tables, it is evident that the addition of 7% silica fume to 93% cement (M3) in the paste reduces both initial and final setting times by 70 minutes approximately about M1 (100% cement). Reduction in initial and final setting times for M3 equal -46.7 % and 36.4% respectively comparing to M1. And the addition of 50% GGBF slag to 50%cement M2 increases both initial and final setting times by 50 minutes approximately about M1. Increment in initial and final setting times for M2 equal + 33.3 % and +27.3 % respectively comparing to M1. For another mixes, it is clear that with increasing the percentage of silica fume from 3% to 7% and decreasing the percentage of GGBF slag, the setting times will be reduced. The decrement in the setting times by addition of silica fume can be explained by taking into account the effect of fine particle size on the hydration process. Owing to their small size, silica fume particles fill the interstices of the cement particles and act as nucleation sites for the hydration and thus accelerate the rate of cement hydration similarly, the increment in the setting times by addition of GGBF slag can be explained by taking into account the effect of large particle size of GGBF slag comparing to silica fume and cement particles and hence reduced surface area of GGBF slag which causes it to hydrate slowly in the presence of alkaline solution formed by the dissolution of cement particels during the hydration of cement , therefore an extension in setting times will occur. Finally, it could be found that the setting times of all mixes fall within the Egyptian Standard Specifications limits (min 45 minutes for initial setting time and max. 10 hours for final setting time.).

Table7 shows the results of the soundness for the various paste mixtures. The results show that the soundness of the pastes are nearly constant regardless of the percentages of GGBF slag and silica fume, by another meaning GGBF slag and silica fume have no effect in raising the soundness of the paste, this is referred that the percentage of CaO, MgO and sulfates in GGBF slag and silica fume which raising the soundness are fall below the maximum permissible limits. It could be also found that the soundness of all mixes fall within the Egyptian Standard Specifications limit (less than 10 mm).

Table 8. and table 9. show the results of cube compressive strength for the various mortar mixtures at 3 days and 7 days. From tables {8. & 9.}, it evident that the highest mortar cube compressive strength at 3 and 7 days are 227 and 335 Kg|cm2 throughout the all mixes. These strengths were developed by M3 (93% cement + 7%silica fume) this mix recorded the highest rates of increment of compressive strength comparing to M1(100% cement) equal 2.3 % and 9.6% at 3 and 7 days respectively. The lowest compressive strength through the six mixes of combination of cement, GGBF slag, and silica fume was obtained by M4 (50% cement + 47% GGBF slag + 3% silica fume) that it contains a lower amount of cement and lowest amount of silica fume, its strengths are 136.5 and 219 Kg|cm2 at 3 days and 7 days, this mix recorded the highest rates of decrement of compressive strength comparing to M1 (through the six mixes of combinations of cementitious-materials used) equal 38.5 % and 28.4 % at 3 and 7 days respectively. It is evident

from the tables (4-5) and (4-6) the mixes which their compressive strengths cover the Egyptian specifications limits are M1 and M3, this does not mean that the other mixes are rejected or low-grade mixes because there will be possibility of increasing of their strengths at later ages. Finally, it could be said that the mixes no. 7, 8 and 9 recorded the satisfactory values of mortar cube compressive strength comparing to other mixes, or by other meaning, the best range of combination of ground granulated blast - furnace slag and silica fume that gives high compressive strength is as much as 37 % GGBF slag and as low as 3% silica fume with 60% ordinary portland cement.

CONCLUSIONS:-

When ordinary portland cement is partially replaced with a combination of ground granulated blast - furnace slag (GGBF slag) and silica fume to get a cementitious - materials paste and mortar, the following effects had been observed:

1- With increasing the percentage of silica fume from 3% to 7% and decreasing the amount of GGBF slag, the water demand to maintain the consistence of standard paste is sharply increased. Mix no.3 (93|0|7) that contains 93% cement with 7% silica fume (maximum amount of silica fume) recorded the highest rate of increment of water demand (through the all mixes) is +57.7 % comparing to control mix M1 (100 % cement). M9 (60|33|7) that contains maximum amount of silica fume (7%), minimum amount of GGBF slag (33%) with 60 % cement attained the highest rate of increment of water demand (through the six mixes of combinations of cementitious materials used) is + 34.6 % comparing to M1 (100 cement). The highest rate of decrement of water demand (through the all mixes) realized by M2 (50|50|0) which contains maximum amount of GGBF slag 50% with 50 % cement is - 7.7% comparing to M1(100% cement).

2- With increasing the silica fume percentage form 3% to 7% and decreasing the amount of GGBF slag, the initial and final setting times reduced, M3 (93|0|7) recorded the highest rates of decrement of initial and final setting times (through the all mixes) are -30% and -27.3% respectively comparing to M1 (100 cement). M2 achieved the highest rates of increment of initial and final setting times (through the all mixes) are 33.3 % and 27.3 % respectively comparing to M1.

3- There is no effect of free lime in GGBF slag and silica fume on blended cement paste, because the soundness of the all pastes is to be constant nearly and range from 2 to 3 mm regardless of the percentage of combination GGBF slag and silica fume.

4- With increasing the silica fume percentage from 3 % to 7 % in mortar and decreasing the amount of GGBF slag, the early compressive strength at 3 and 7 days increased. M3 (93|0|7) recorded the highest rates of increment of compressive strength at 3 and 7 days(through the all mixes) equal 2.3 % and 9.6 % respectively comparing to M1 (100 % cement). M9 (60|33|7) attained the lowest rates of decrement of compressive strength at 3 and 7 days (through the six mixes) equal -24% and -14.9% respectively comparing to M1 (100 % cement).

5- The best rang of combinations of GGBF slag and silica fume that satisfies with high degree for requirements of Egyptian Standard Specifications is as much as 37 % GGBF slag and as low as 3% silica fume with 60% cement.

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Table 1 Chemical analysis and physical properties of ground granulated blast furnace slag.

Description of test		
1-Chemical analysis,%	Test results	ASTM C98-89 limits
Silicon Dioxide (SiO_2)	34.05	------
Aluminum Oxide (Al_2O_3)	13.35	------
Ferric Oxide (Fe_2O_3)	1.19	------
Calcium Oxide (CaO)	37.2	------
Magnesium Oide (MgO)	4.54	------
Sulfur (S)	1.44	Max. 2.5 %
Sulfur Trioxide (SO_3)	3.6	Max. 4.0 %
Loss on igrition (L.O.I)	0	------
Manganese Oxide (Mn O)	2.92	------
Sodium Oxide (Na_2O)	o.4	------
Potassium Oxide (K_2O)	0.10	------
Barium Oxide (BaO)	3.95	------
2-Physical Properties	Test results	ASTM C 989-89 limits
-Fineness:		
45um (passing) %	85	Min. 80 %
Surface area :		
Blaine (cm^2/gm)	2500	------
Specific Gravity	2.9	------
Slag activity index ,(%)		
at 7 days	70.2	Min. 70 % for grad 100
at 28 days	95.2	Min. 90 % for grad 100

Table 2 Chemical analysis and physical properties of silica fume

Description of test	test results %	ASTM.limits
1- Chemical analysis		
Silicon Dioxide (SIO_2)	97	------
Aluminum Oxide (AL_2O_3)	0.2	------
Ferric Oxide (Fe_2O_3)	0.5	------
Calcium Oxide (CaO)	0.2	------
Magnesium Oxide (MgO)	0.5	------
Sulfur Trioxide (SO_3)	0.15	------
Loss on ignition (L.O.I)	0.7	------
Sodium Oxide (Na_2O)	0.2	------
Potassium Oxide (K_2O)	0.5	------
Total Carbon	0.5	------
Chlorides	< 0.01	------
2-physical properties		
-Fineness:		
45 um(passing) .%	99.75	------
- Surface area :		
(by nitrogen adsorption method),		
cm^2/gm	167000	------
Specific Gravity	2.3	------

Table 3 The percentages of combinations of cement, GGBF and Silica fume.

	Mix no.	OPC	GGBFslag	Silica fume
Control mixes	M1	100%	0%	0%
	M2	50%	50%	0%
	M3	93%	0%	7%
50% Cement group	M4	50%	47%	3%
	M5	50%	45%	5%
	M6	50%	43%	7%
60% Cement group	M7	60%	37%	3%
	M8	60%	35%	5%
	M9	60%	33%	7%

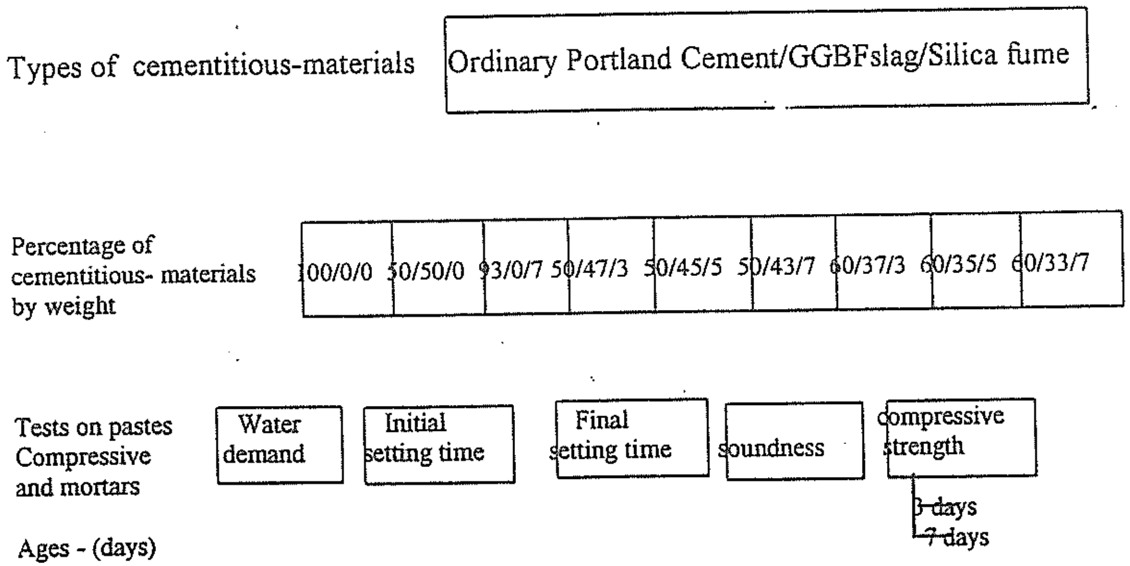

Fig. 1 Flow chart of test plan of paste and mortar mixtures

Test plan flow chart

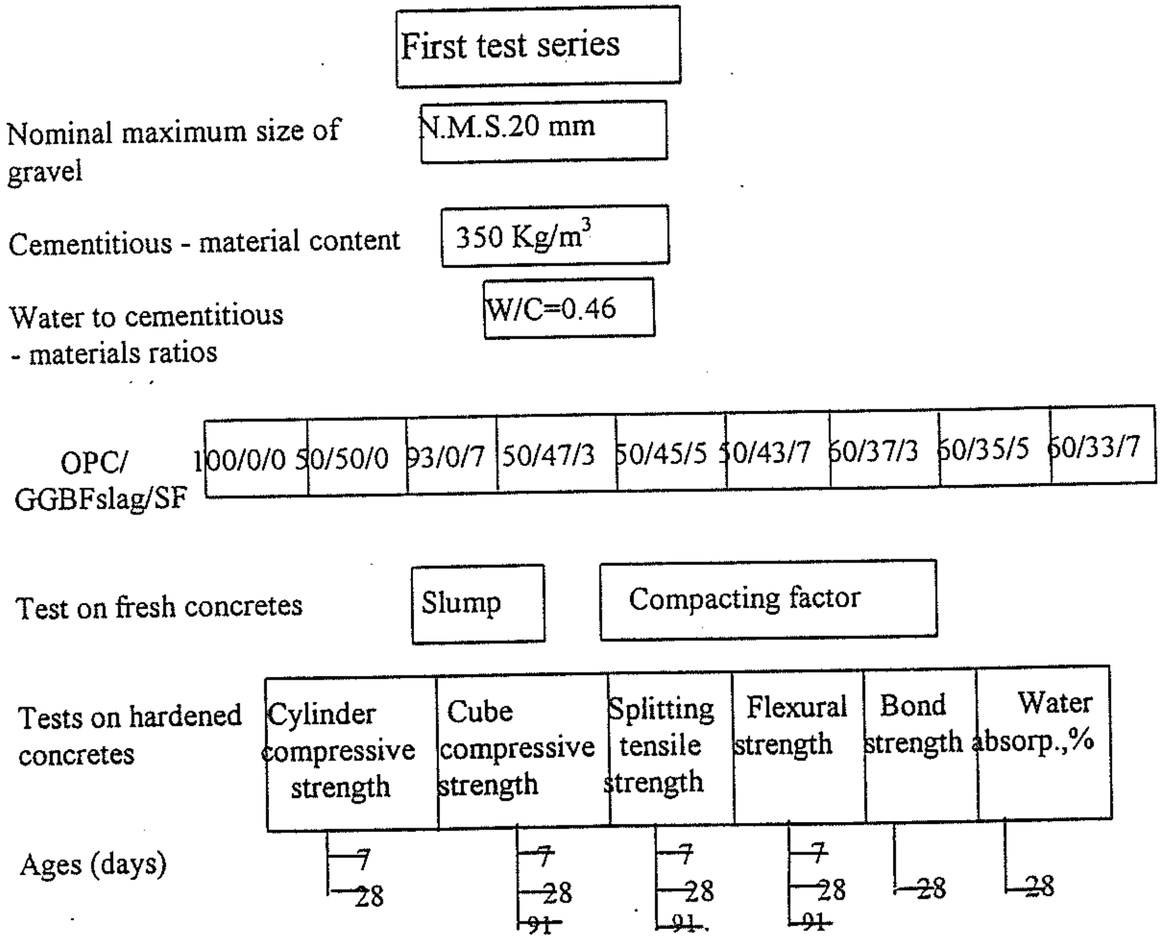

Fig. 2 Flow chart of test plan of concrete mixes for first test se...

Table 4 The water demand of the various combinations of cementitious-materials paste

Mix	OPC/GGBF slag/SF	Water demand (%)	%Rate of change of water demand comparing to:								
			M1	M2	M3	M4	M5	M6	M7	M8	M9
M1	100/0/0	26	0%	+8.3	-36.6	0	-7.1	-13.3	-10.3	-18.7	-25.7
M2	50/50/0	24	-7.7	0%	-41.5	-7.7	-14.3	-20	-17.2	-25	-31.4
M3	93/0/7	41	+57.7	+70.8	0%	+57.7	+46.4	+36.7	-41.4	+28.1	-17.1
M4	50/47/3	26	0	+8.3	-36.6	0%	-7.1	-13.3	-10.3	-18.7	-25.7
M5	50/45/5	28	+7.7	+16.6	-31.7	+7.7	0%	-6.7	-3.4	-12.5	-20
M6	50/43/7	30	+15.4	-25	-26.8	+15.4	+7.1	0%	+3.4	-6.2	-14.3
M7	60/37/3	29	+11.5	-20.8	-29.3	+11.5	+3.6	-3.3	0%	-9.4	-17.1
M8	60/35/5	32	+23	+33.3	-21.9	+23.1	+14.3	-6.7	+10.3	0%	-8.6
M9	60/33/7	35	+34.6	+45.8	-14.6	+34.6	+25	+16.7	+20.7	+9.4	0%
Egyptian Standard Specifications		Min.25% Max.30%									

Table 5 The initial setting time of the various combinations of cementitious-materials pastes

Mix	OPC/GGBF slag/SF	Initial setting time(min.)	%Rate of change of initial setting comparing to:								
			M1	M2	M3	M4	M5	M6	M7	M8	M9
M1	100/0/0	150	0%	-25	+87.5	-13.3	-3.2	+9.5	+3.4	+20	+42.9
M2	50/50/0	200	+33.3	0%	+150	+15.6	+29	+46	+37.9	+60	+90.5
M3	93/0/7	80	-46.7	-60	0%	-53.7	-48.4	-41.6	-44.8	-36	-23.8
M4	50/47/3	173	+15.3	-13.5	+116.2	0%	+11.6	+26.3	+19.3	+38.4	+64.8
M5	50/45/5	155	+3.3	-22.5	+93.7	-10.4	0%	+13.1	+6.9	+24	+47.6
M6	50/43/7	137	-8.7	-31.5	+71.2	-20.8	-11.6	0%	-5.5	+9.6	+30.5
M7	60/37/3	145	-3.3	-27.5	+81.2	-16.2	-6.4	+5.8	0%	+16	+38.1
M8	60/35/5	125	-16.7	-37.5	+56.2	-27.7	-19.3	-8.8	-13.8	0%	+19
M9	60/33/7	105	-30	-47.5	+31.2	-39.3	-32.3	-23.3	-27.6	-16	0%
Egyptian Standard Specifications		Min.45min									

Table 6 The final setting time of the various combinations of cementitious-materials pastes

Mix	OPC/GG BFslag/SF	Final setting time (min.)	% Rate of change of final setting time comparing to :								
			M1	M2	M3	M4	M5	M6	M7	M8	M9
M1	100/0/0	220	0 %	-21.4	+57.1	-10.2	-1.8	+15.8	+4.8	+18.9	+37.5
M2	50/50/0	280	+27.3	0%	+100	+14.3	+25	+47.4	+33.3	+51.3	+75
M3	93/0/7	140	-36.4	-50	0%	-42.9	-37.5	-26.3	-33.3	-24.3	-12.5
M4	50/47/3	245	+11.4	-12.5	+75	0%	+9.4	+28.9	+16.7	+32.4	+53.1
M5	50/45/5	224	+1.8	-20	+60	-8.6	0%	+17.9	+6.7	+21.1	+40
M6	50/43/7	190	-13.6	-32.1	+35.7	-22.4	-15.2	0%	-9.5	+2.7	+18.7
M7	60/37/3	210	-4.5	-25	+50	-14.3	-6.2	+10.5	0%	+13.5	+31.2
M8	60/35/5	185	-15.9	-33.9	+32.1	-24.5	-17.4	-2.6	-11.9	0%	+15.6
M9	60/33/7	160	-27.3	-42.9	+14.3	-34.7	-28.6	-15.8	-23.8	-13.5	0%
Egyptian Standard Specifications		Max.10 hours									

Table 7 The soundness of the various combinations of cementitious-materials pastes .

Mix	OPC/G GBFslag /SF	Soundness (mm)	% Rate of change of soundness comparing to:								
			M1	M2	M3	M4	M5	M6	M7	M8	M9
M1	100/0/0	2	0%	-33.3	0	-33.3	0	0	-33.3	0	0
M2	50/50/0	3	+50	0%	+50	0	+50	+50	0	+50	+50
M3	93/0/7	2	0	-33.3	0%	-33.3	0	0	-33.3	0	0
M4	50/47/3	3	+50	0	+50	0%	+50	+50	0	+50	+50
M5	50/45/5	2	0	-33.3	0	-33.3	0%	0	-33.3	0	0
M6	50/43/7	2	0	-33.3	0	-33.3	0	0%	-33.3	0	0
M7	60/37/3	3	+50	0	+50	0	+50	+50	0%	+50	+50
M8	60/35/5	2	0	-33.3	0	-33.3	0	0	-33.3	0%	0
M9	60/33/7	2	0	-33.3	0	-33.3	0	0	-33.3	0	0%
Egyptian Standard Specifications		Max. 10mm									

Table 8 The 3day - compressive strength of the various combinations of cementitious materials mortars .

Mix	OPC/GGBF slag/SF	3day-compressive strength (Kg/cm^2)	% Rate of change of compressive strength comparing to:								
			M1	M2	M3	M4	M5	M6	M7	M8	M9
M1	100/0/0	221.8	0%	+66.8	-2.3	+62.5	+57.5	+45.9	+50	+45.2	+31.6
M2	50/50/0	133	-40	0%	-14.4	-2.6	-5.5	-12.5	-10.1	-13	-21.1
M3	93/0/7	227	+2.3	+70.7	0%	+66.3	+61.2	+49.3	+53.5	+48.6	+34.7
M4	50/47/3	136.5	-38.5	+2.6	-39.9	0%	-3	-10.2	-7.7	-10.7	-19
M5	50/45/5	140.8	-36.5	+5.9	-38	+3.1	0%	-7.4	-4.8	-7.8	-16.4
M6	50/43/7	152	-31.5	+14.3	-33	+11.3	+7.9	0%	+2.8	-0.5	-9.8
M7	60/37/3	147.9	-33.3	+11.2	-34.8	+8.3	+5	-2.7	0%	-3.2	-12.2
M8	60/35/5	152.8	-31.1	+14.9	-32.7	+11.9	+8.5	+0.5	+3.3	0%	-9.3
M9	60/33/7	168.5	-24	+26.7	-25.8	+23.4	+19.7	+10.8	+13.9	+10.3	0%
Egyptian Standard Specifications		Min. 180 Kg/cm^2									

Table 9 The 7day -compressive strength of the various combinations of cementitious- materials mortars

Mix	OPC/GGBF slag/SF	7day-compressive strength(Kg/cm2)	%Rate of change of compressive strength comparing to:								
			M1	M2	M3	M4	M5	M6	M7	M8	M9
M1	100/0/0	305.7	0%	+42.4	-8.7	+39.6	+37.4	+29.5	+33.3	+29.9	+17.6
M2	50/50/0	214.6	-29.8	0%	-35.9	-2	-3.5	-9.1	-6.4	-8.8	-17.5
M3	93/0/7	335	+9.6	+56.1	0%	+53	+50. 6	+41.9	+46.1	+42.3	+28.8
M4	50/47/3	219	-28.4	+2	-34.6	0%	-1.6	-7.2	-4.5	-7	-15.8
M5	50/45/5	222.5	-27.2	+3.7	-33.6	+1.6	0%	-5.7	-3	-5.5	-14.4
M6	50/43/7	236	-22.8	+10	-29.5	+7.8	+6.1	0%	+2.9	+0.2	-9.2
M7	60/37/3	229.3	-25	+6.8	-31.5	+4.7	+3.1	-2.8	0%	-2.6	-11.8
M8	60/35/5	235.4	-23	+9.7	-29.7	+7.5	+5.8	-0.2	+2.7	0%	-9.5
M9	60/33/7	260	-14.9	+21.1	-22.4	+18.7	+16.8	+10.2	+13.4	+10.4	0%
Egyptian Standard Specifications		Min.270 Kg/cm^2									