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THE EFFECT OF CURING TYPES ON STRENGTH OF SELF COMPACTING CONCRETE

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Abstract
The main purpose of this study is to investigate the effect of using three types of curing (water, painting, and room air) and three different types of water and cement on the strength of self-compacting concrete. Nine mixes containing different cement contents, water cement ratios, and coarse aggregates (gravel, basalt, and dolomite (limestone)) were designed. The compression, splitting tensile, and flexural strength tests were carried out on hardened self-compacting concretes after 28 days of curing by water, Painting, and room air. In the nine mixes, three cement contents (350, 400, and 450 kg/m³), three types of aggregates, and three water cement ratios (0.46, 0.42, and 0.38) were used. Results showed that water curing is the best type of curing to use in self-compacting concrete. Painting curing by Antisol_E liquid does not have effect on the strength of self-compacting concrete. The difference between Painting curing by Antisol_E liquid and having concrete on room air without any curing is very small.
Keywords : self-compacting concrete – curing – paint - gravel- basalt-dolomite

I. INTRODUCTION

Self-Compacting Concrete (SCC) is used instead of conventional concrete in heavily reinforced sections. It is highly workable concrete that can easily flow through heavily reinforcement without the need for mechanical vibration. High range water reducer chemical admixtures with minimum water content varying between 0.37 and 0.4 were used in (SSC) due to high workability requirement [1]. Limiting the w/c ratio above 0.37 prevents the development of high compressive strength and also affects the durability of self-compacting concrete mixtures. It is Known that, self-compacting concrete is considered to be a conventional concrete with a large filling ability, in spite of the differences found for both the early age behavior [2] and the hardened performance [2,3]. The main changes are due to the large amount of fine particle mineral additions used in its composition [4,5], which leads to a different speed on the plastic-to-solid evolution [2], and an increase of early age cracking risks [6]. We can get high performance concrete from self-compacting concrete due to high flow ability, passing ability through the formwork without any segregation or need of vibration [7,8], and maintaining the flow ability more than ordinary concretes[9]. Bingol and Tohumcu studied [10] the effect of air curing, water curing and steam curing on the compressive strength of self compacting concrete (SCC). Water Curing specimens gave the highest compressive strength. Air curing caused compressive strength losses in all groups. Strength of concrete with mineral admixtures was higher than that of concretes without admixtures at steam curing conditions.

II. MATERAILS USED

The cement used was ordinary Portland cement. The sand with fineness modulus of 2.57, specific gravity 2.5, and volume weight 1550 kg/m^3 is used. The coarse aggregates (gravel, basalt and dolomite) are used. For gravel the specific gravity was 2.55, volume weight was 1680 kg/m^3, and % absorption was 0.4%. For basalt the specific gravity was 2.63, volume weight was 1610 kg/m^3, and % absorption was 0.9%. For dolomite the specific gravity was 2.60, volume weight was 1560 kg/m^3, and % absorption was 1.6%. Limestones powder was used in concrete with 30% by weight of cement as filler. Sika ViscoCrete_3425 is a third generation super plasticizer for homogenous concrete and mortar was used for self compaction concrete with 1.5% liter from cement weight. Tap water was used in mixing and curing. Antisol_E liquid curing compound for preventing water loss in concrete was used for curing same samples.

III. MIX PROPORTIONS

Egyptian code and ASTM standards were used to design the mixes and test program. Nine mixes containing different types of coarse aggregates and different percentages of water and cement were designed as shown in Table (1). In Group (1), the cement content was 350 kg/m³ and (W/C) = 0.46. While, in Group (2), the cement content was 400 kg/m³ and (W/C) = 0.42, and Group (3), the cement content was 450 kg/m³ and (W/C) = 0.38**.** For each mix 18 cubes (150x150x150 mm), 9 Cylinders (150x300 mm), and 9 beams (100x100x500 mm) were prepared. Concrete samples were cured by:

- Water (6 cubes, 3 Cylinders, and 3 beams) until testing.
- Painting by Antisol_E liquid (6 cubes, 3 Cylinders, and 3 beams) after removed from molds.
- Room air without any curing (6 cubes, 3 Cylinders, and 3 beams) until testing.

IV. TEST PROGRAM

The compressive and splitting tensile strengths of concrete were determined using compression testing machine having 2000 KN capacity. The loading rates applied in the compressive and splitting tensile tests were 0.6 and 0.03N/mm^2/sec, respectively. The compressive strength was determined by using cubes (150 mm) at the ages of 7, and 28 days while the tensile splitting strength was determined by using cylinder (150x300 mm) at 28 days. Beam specimens with size (100x100x500 mm) were used to determine the flexural strength of hardened concrete. The specimens were placed in UTM and tested for flexural strength. The loading rates applied was 0.06 N/mm^2/sec, as shown in figure (1). The average results of three samples were calculated for all tests. Figure (2) shows the slump flow shape .

Table (1): Concrete Mixes

Mix No.	Group No.		Water (kg/m³)	Cement (kg/m³)	Sand (kg/m³)	Aggregate (kg/m³)	Limestone powder (kg/m^3)	Superplasticizer (Viscocrete342) (liter/m^3)	Type of coarse Aggregates
M_G	1	M_{G-1}	161	350	829	912	105	5.25	Gravel
	2	M_{G-2}	168	400	796	875	120	6.00	
	3	M_{G-3}	171	450	766	843	135	6.75	
M_B	1	M_{B-1}	161	350	843	927	105	5.25	Basalt
	2	M_{B-2}	168	400	808	889	120	6.00	
	3	M_{B-3}	171	450	779	856	135	6.75	
M_D	1	M_{D-1}	161	350	838	922	105	5.25	Dolomite (limestone)
	2	M_{D-2}	168	400	804	884	120	6.00	
	3	M_{D-3}	171	450	777	851	135	6.75	

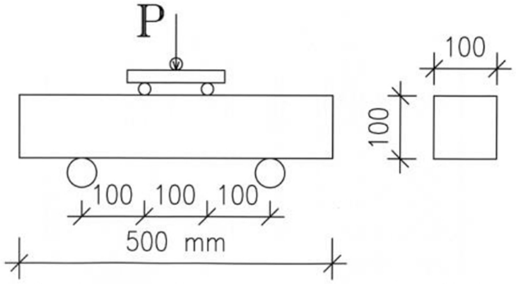

Fig.(1): Flexural Strength Test

V. RESULTS AND DISCUSSION

Results of compressive strength, splitting tensile strength, and flexural strength for the nine mixes of concrete using different types of curing (water, paint, and air) were calculated in table (2).

Table (2): Results of Compressive Strength, Split Tensile Strength and Flexural Strength Tests for Recycled Coarse Aggregates Concrete

Mix No.	Group No.		Compressive Strength at 7 days (kg/cm^2)			Compressive Strength at 28 days (kg/cm^2)			Splitting Tensile Strength at 28 days (kg/cm^2)			Flexural Strength at 28 days (kg/cm^2)			Type of coarse Aggregates
			W	P	A	W	P	A	W	P	A	W	P	A	
M_G	1	M_{G-1}	197	199	193	283	270	270	25.8	23.1	24.8	52.2	47.8	50.5	Gravel
	2	M_{G-2}	302	317	306	429	366	383	32.2	27.3	28.7	57.5	50.1	52.9	
	3	M_{G-3}	333	332	327	447	404	421	33.5	29.1	31.6	61.2	52.6	55.4	
M_B	1	M_{B-1}	278	303	291	362	345	361	31.4	29.8	30.7	58.4	50.4	55.9	Basalt
	2	M_{B-2}	311	322	332	450	383	375	36.2	32.2	31.7	62.6	57.0	58.7	
	3	M_{B-3}	406	350	346	507	464	475	38.8	36.5	36.1	77.2	68.5	70.3	
M_D	1	M_{D-1}	325	297	287	397	357	344	36.2	33.2	31.2	59.1	52.4	56.4	Dolomite (limestone)
	2	M_{D-2}	352	342	351	466	419	400	37.3	34.5	33.0	72.3	65.0	70.2	
	3	M_{D-3}	462	455	462	575	570	515	48.2	45.6	41.1	89.2	83.5	85.3	

W= Water curing, P= Painting curing, and A= without curing (room air)

A. COMPRESSION STRRENGTH AT 7 DAYS

The results of compressive strength test at 7 days for the nine mixes with different cement contents and types of curing are shown in Figures (3 to 5). It is observed that the compressive strengths at 7 days for all types of curing do not have big change. Strength of gravel concrete was (197, 302, and 333 kg/cm^2) for water, (199, 317, and 332 kg/cm^2) for painting, and (193, 306, and 337 kg/cm^2) for air. Basalt concrete strength was (278, 311, and 406 kg/cm^2) for water, (303, 322, and 350 kg/cm^2) for painting, and (291, 332, and 346 kg/cm^2) for air. Dolomite concrete strength was (325, 352, and 462 kg/cm^2) for water, (297, 342, and 455 kg/cm^2) for painting, and (287, 351, and 462 kg/cm^2) for air.

B. COMPRESSION STRRENGTH AT 28 DAYS

The results of compressive strength test at 28 days for the nine mixes with different cement contents and types of curing are shown in Figures (6 to 8). It is observed that the compressive strength at 28 days for all types of curing have big changes. Water results are the highest values and the difference between painting and air is small. Gravel concrete has strength values of (283, 429, and 447 kg/cm^2) for water, (270, 366, and 404 kg/cm^2) for painting, and (270, 383, and 421 kg/cm^2) for air. Basalt concrete has strength values of (362, 450, and 507 kg/cm^2) for water, (345, 383, and 464 kg/cm^2) for painting, and (361, 375, and 475 kg/cm^2) for air. Dolomite concrete has strength values of (397, 466, and 575 kg/cm^2)

for water, (357, 419, and 570 kg/cm^2) for painting, and (344, 400, and 515 kg/cm^2) for air.

Relation between compressive strength at 28 days and compressive strength at 7 days for the nine mixes with different cement contents and types of curing are shown in Figure (9). It is observed that:

- For water curing

f_{cu} at 7 days ≈ 0.7610 f_{cu} at 28 day

- For painting curing

f_{cu} at 7 days ≈ 0.8133 f_{cu} at 28 day

- For room air curing

f_{cu} at 7 days ≈ 0.8197 f_{cu} at 28 day

Where: $f_{cu=}$ compressive strength

C.SPLITTING TENSILE STRRENGTH

The results of splitting tensile strength test at 28 days for the nine mixes with different cement contents and types of curing are shown in Figures (10 to 12). It is observed that splitting tensile strength for all types of curing have big change. Water results are the highest values and the difference between painting and air is small. Gravel concrete has strength values of (25.8, 32.2, and 33.5 kg/cm^2) for water, (23.1, 27.3, and 29.1 kg/cm^2) for painting, and (24.4, 28.7, and 31.6 kg/cm^2) for air. Basalt concrete has strength values of (31.4, 36.2, and 38.8 kg/cm^2) for water, (29.8, 32.2, and 36.5 kg/cm^2) for painting, and (30.7, 31.7, and 36.1 kg/cm^2) for air. Dolomite concrete has strength values of (36.2, 37.3, and 48.2 kg/cm^2) for water, (33.2, 34.5, and 45.6 kg/cm^2) for painting, and (31.2, 33.0, and 41.1 kg/cm^2) for air.

Relation between splitting tensile strength and compressive for the nine mixes with different cement contents and types of curing are shown in Figure (13). It is observed that:

- For water curing $f_t \approx 0.0812 f_{cu}$

- For painting curing $f_t \approx 0.0810 f_{cu}$

- For room air curing $f_t \approx 0.0809 f_{cu}$

Where: f_t = splitting tensile strength.

D.FLEXURAL STRRENGTH

The results of flexural strength test at 28 days for the nine mixes with different cement contents and types of curing are shown in Figures (14 to 16). It is observed that splitting tensile strength for all types of curing have big change. Water results are the highest values and the difference between painting and air is small. Gravel concrete has strength values of (52.2, 57.5, and 61.2 kg/cm^2) for water, (47.8, 50.1, and 52.6 kg/cm^2) for painting, and (50.5, 52.9, and 55.4 kg/cm^2) for air. Basalt concrete has strength values of (58.4, 62.6, and 77.2 kg/cm^2) for water, (50.4, 57.0, and 68.5 kg/cm^2) for painting, and (55.9, 58.7, and 70.3 kg\cm^2) for air. Dolomite concrete has strength values of (59.1, 72.3, and 89.2 kg/cm^2) for water, (52.4, 65.0, and 83.5 kg/cm^2) for painting, and (56.4, 70.2, and 85.3 kg/cm^2) for air.

Relation between flexural strength and compressive for the nine mixes with different cement content and types of curing are shown in Figure (17). It is observed that:

- For water curing $f_f \approx 0.1498 f_{cu}$

- For painting curing $f_f \approx 0.1467 f_{cu}$

- For room air curing $f_f \approx 0.1560 f_{cu}$

where: f_f = flexural strength

Fig.(2): Shape of Concrete Slump Flow

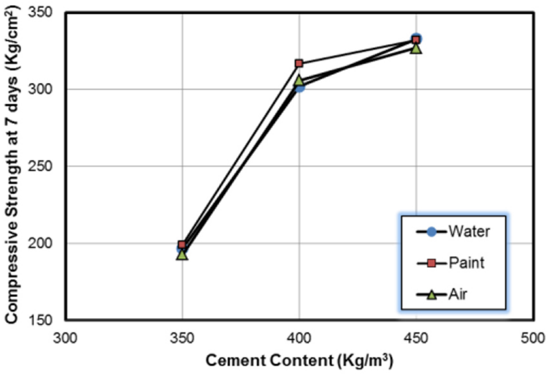

Fig.(3): Relation between Cement Content and Compressive Strenghth at 7days for Gravel Using Different Types of Curing

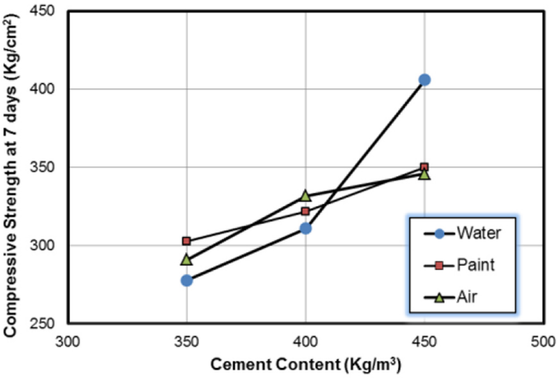

Fig.(4): Relation between Cement Content and Compressive Strenghth at 7days for Basalt Using Different Types of Curing

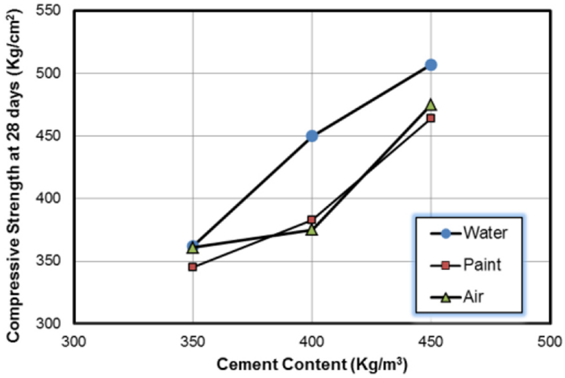

Fig.(7): Relation between Cement Content and Compressive Strenghth at 28 days for Basalt Using Different Types of Curing

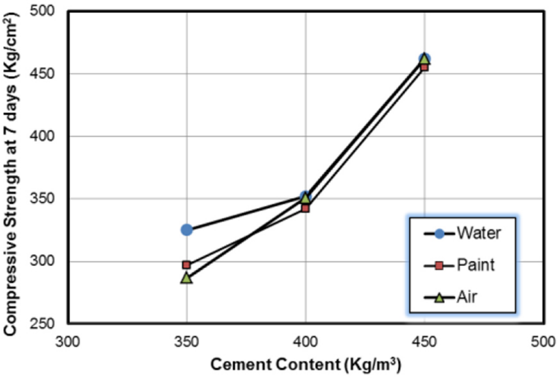

Fig.(5): Relation between Cement Content and Compressive Strenghth at 7days for Dolomite Using Different Types of Curing

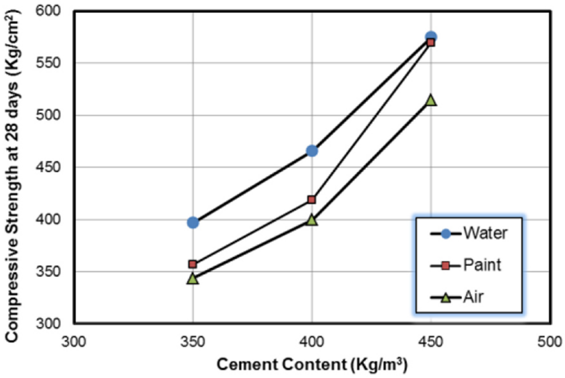

Fig.(8): Relation between Cement Content and Compressive Strenghth at 28days for Dolomite Using Different Types of Curing

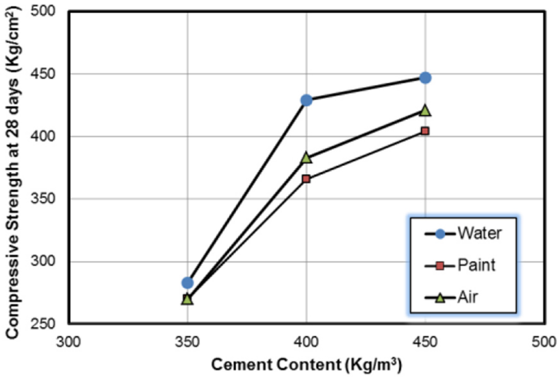

Fig.(6): Relation between Cement Content and Compressive Strenghth at 28 days for Gravel Using Different Types of Curing

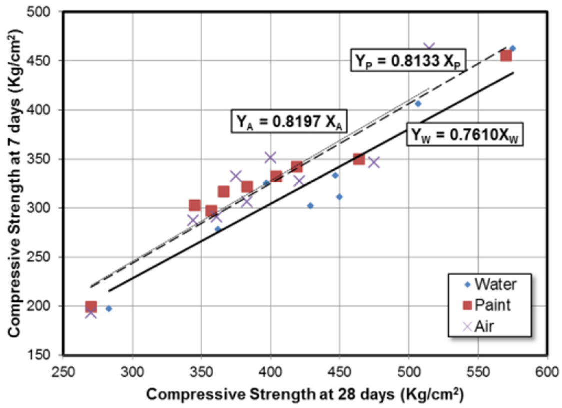

Fig.(9): Relation between Compressive Strength at 7and 28 Days for slef Compacting Concrete

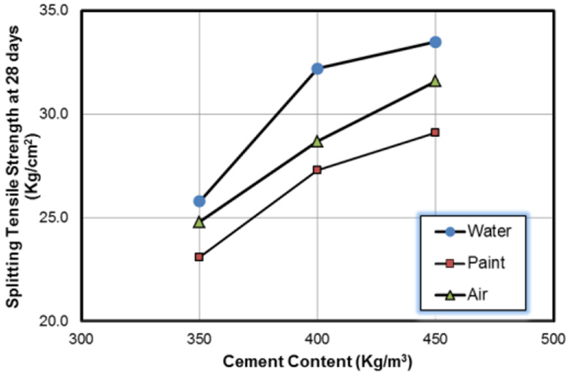

Fig.(10): Relation between Cement Content and Splitting Tensile Strenghth at 28 days for Gravel Using Different Types of Curing

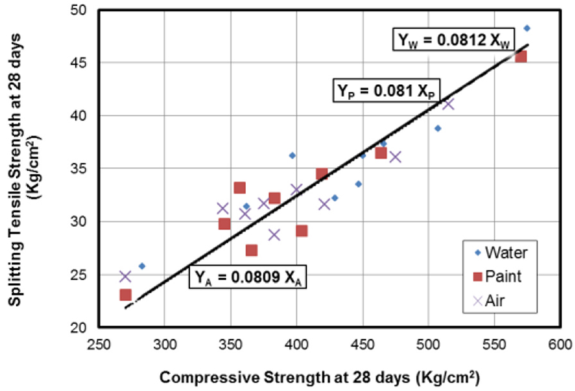

Fig.(13): Relation between Splitting Tensile Strength and Compressive Strength for slef Compacting Concrete

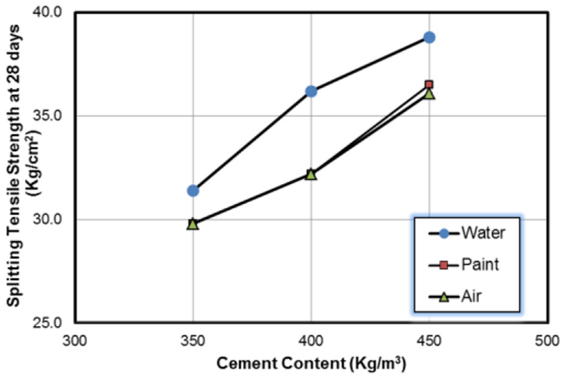

Fig.(11): Relation between Cement Content and Splitting Tensile Strenghth at 28 days for Basalt Using Different Types of Curing

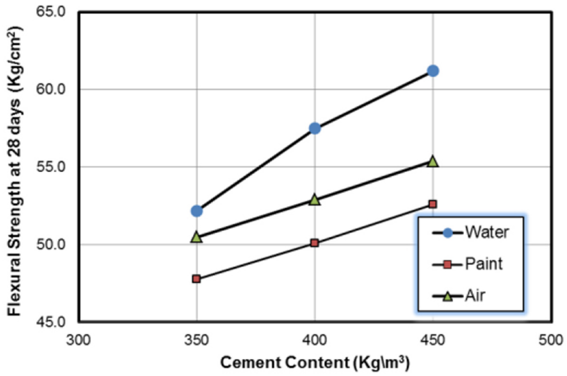

Fig.(14): Relation between Cement Content and Flexural Strenghth at 28 days for Gravel Using Different Types of Curing

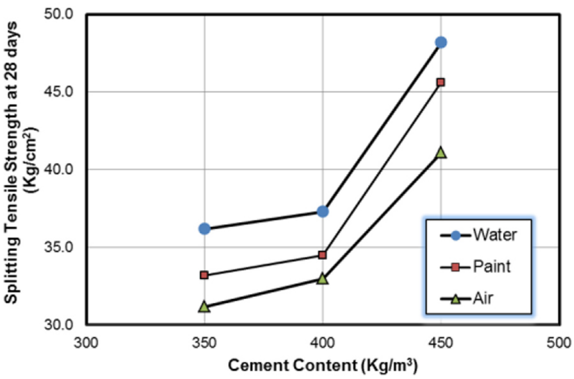

Fig.(12): Relation between Cement Content and Splitting Tensile Strenghth at 28 days for Dolomite Using Different Types of Curing

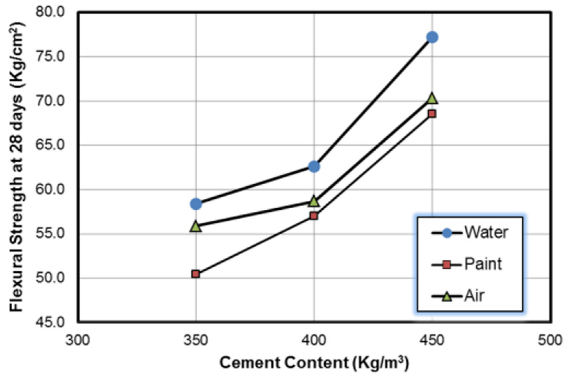

Fig.(15): Relation between Cement Content and Flexural Strenghth at 28 days for Basalt Using Different Types of Curing

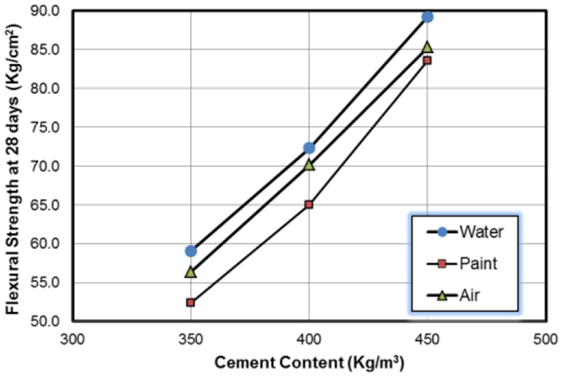

Fig.(16): Relation between Cement Content and Flexural Strenghth at 28 days for Dolomite Using Different Types of Curing

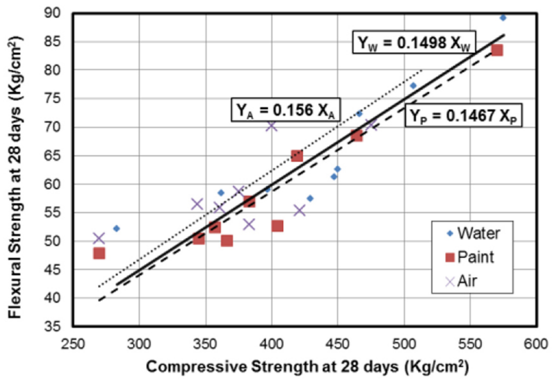

Fig.(17): Relation between Flexural Strength and Compressive Strength for slef Compacting Concrete

VI. CONCLUSIONS

The main conclusions according to the experimental results presented in this paper are as follows:

1-Water curing increases the compressive strength for self-compacting concrete mix at 7 days more than the other types of curing. For basalt the painting and room air decreased by 2.01%, and 2.61% than water, and for dolomite the painting and room air decreased by 3.95%, and 3.42% than water. For gravel the difference between the types of curing is very small.

2-Water curing increases the compressive strength for self-compacting concrete mix at 28 days than the other types of curing. For gravel the painting and room air decreased by 10.27%, and 7.33% than water, for basalt the painting and room air decreased by 9.63%, and 8.19% than water, and for dolomite the painting and room air decreased by 6.40%, and 12.45% than water.

3-Water curing increases the splitting tensile strength for self-compacting concrete mix at 28 days than the other types of curing. For gravel the painting and room air decreased by 13.11%, and 6.99% than water, for basalt the painting and room air decreased by 7.42%, and 7.80% than water, and for dolomite the painting and room air decreased by 6.90%, and 13.48% than water.

4-Water curing increases the flexural Strength for self-compacting concrete mix at 28 days than the other types of curing. For gravel the painting and room air decreased by 11.94%, and 7.08% than water, for basalt the painting and room air decreased by 11.25%, and 6.71% than water, and for dolomite the painting and room air decreased by 8.93%, and 3.94% than water.

5-The results show that water curing was the most effective type of curing to be used in self-compacting concrete.

VII. REFERENCES

[1] EFNARC ," Specification and guide lines for self-compacting concrete," www.efnarc.org. , 2002.

[2] Barluenga, G., Palomar, I., and Puentes, J.," Early age monitoring and hardened properties of SCC with limestone filler and active mineral additions," Fifth North American conference on the Design and Use of Self-Consolidating Concrete, Chicago, 2013.

[3] Bermejo, E. B., Moragues, A., Galvez, J. C., and Fernandez Canovas, M, " Permeability and pore size distribution in medium strength self-compacting concrete," Materiales de Construcción, 60 (299), 37–51, 2010.

[4] Ye, G., Liu, X., Poppe, A. M., and et al., " Numerical simulation of the hydration process and the development of microstructure of self-compacting cement paste containing limestone as filler,"

Materials and Structures, 40 , 865–875, 2007.
[5] Darquennes, A., Khokhar, M. I. A., Rozière, E., and et al., "Early age deformations of concrete with high content of mineral additions," Construction and Building Materials, 25 ,1836–1847, 2011.
[6] Barluenga, G., and Hernandez-Olivares, F., "Cracking control of concretes modified with short AR-glass fibers at early age," Experimental results on standard concrete and SCC. Cement and Concrete Research, 37 (12), 1624–1638, 2007.
[7] Khayat KH, Manai K., and Trudel A., "In-situ mechanical properties of wall elements cast using self-compacting concrete," ACI Mater J 1997;94(6):491–500.
[8] Khayat KH, and Guizani Z., "Use of viscosity modifying admixtures on enhance stability of fluid concrete," ACI Mater J 1997;94(4):332–40.
[9] Skarendahl A., and Petersson O., "State of the art report of RILEM technical committee 174 – SCC, Self-Compacting Concrete," Report no. 23, 141; 2010.
[10] A. Ferhat Bingol and IlhanTohumcu, "Effect of Different Curing Regimes on the Compressive Strength Properties of self compacting Concrete Incorporating Fly Ash and Silica Fume," Materials & Design Journal V. 51, P. 12-18, 2013.