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. MATERIALS 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/m³ is used. The coarse aggregates
(gravel, basalt and dolomite) are used. For gravel the specific gravity was 2.55, volume weight was 1680 kg/m³, and % absorption was 0.4%. For basalt the specific gravity was 2.63, volume weight was 1610 kg/m³, and % absorption was 0.9%. For dolomite the specific gravity was 2.60, volume weight was 1560 kg/m³, 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 0.03 N/mm²/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/mm²/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>
<thead>
<tr>
<th>Mix No.</th>
<th>Group No.</th>
<th>Water (kg/m³)</th>
<th>Cement (kg/m³)</th>
<th>Sand (kg/m³)</th>
<th>Aggregate (kg/m³)</th>
<th>Limestone powder (kg/m³)</th>
<th>Superplasticizer (ViscoCrete342) (liter/m³)</th>
<th>Type of coarse Aggregates</th>
</tr>
</thead>
<tbody>
<tr>
<td>M_G</td>
<td>M_G-1</td>
<td>161</td>
<td>350</td>
<td>829</td>
<td>912</td>
<td>105</td>
<td>5.25</td>
<td>Gravel</td>
</tr>
<tr>
<td>M_G</td>
<td>M_G-2</td>
<td>168</td>
<td>400</td>
<td>796</td>
<td>875</td>
<td>120</td>
<td>6.00</td>
<td>Gravel</td>
</tr>
<tr>
<td>M_G</td>
<td>M_G-3</td>
<td>171</td>
<td>450</td>
<td>766</td>
<td>843</td>
<td>135</td>
<td>6.75</td>
<td>Gravel</td>
</tr>
<tr>
<td>M_B</td>
<td>M_B-1</td>
<td>161</td>
<td>350</td>
<td>843</td>
<td>927</td>
<td>105</td>
<td>5.25</td>
<td>Basalt</td>
</tr>
<tr>
<td>M_B</td>
<td>M_B-2</td>
<td>168</td>
<td>400</td>
<td>808</td>
<td>889</td>
<td>120</td>
<td>6.00</td>
<td>Basalt</td>
</tr>
<tr>
<td>M_B</td>
<td>M_B-3</td>
<td>171</td>
<td>450</td>
<td>779</td>
<td>856</td>
<td>135</td>
<td>6.75</td>
<td>Basalt</td>
</tr>
<tr>
<td>M_D</td>
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<td>350</td>
<td>838</td>
<td>922</td>
<td>105</td>
<td>5.25</td>
<td>Dolomite (limestone)</td>
</tr>
<tr>
<td>M_D</td>
<td>M_D-2</td>
<td>168</td>
<td>400</td>
<td>804</td>
<td>884</td>
<td>120</td>
<td>6.00</td>
<td>Dolomite (limestone)</td>
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<tr>
<td>M_D</td>
<td>M_D-3</td>
<td>171</td>
<td>450</td>
<td>777</td>
<td>851</td>
<td>135</td>
<td>6.75</td>
<td>Dolomite (limestone)</td>
</tr>
</tbody>
</table>
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).

![Fig.(1): Flexural Strength Test](image)

<table>
<thead>
<tr>
<th>Mix No.</th>
<th>Group No.</th>
<th>Compressive Strength at 7 days (kg/cm²)</th>
<th>Compressive Strength at 28 days (kg/cm²)</th>
<th>Splitting Tensile Strength at 28 days (kg/cm²)</th>
<th>Flexural Strength at 28 days (kg/cm²)</th>
<th>Type of coarse Aggregates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>W</td>
<td>P</td>
<td>A</td>
<td>W</td>
<td>P</td>
</tr>
<tr>
<td>M₅</td>
<td>M₅₁</td>
<td>197</td>
<td>199</td>
<td>193</td>
<td>283</td>
<td>270</td>
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<tr>
<td></td>
<td>M₅₂</td>
<td>302</td>
<td>317</td>
<td>306</td>
<td>429</td>
<td>366</td>
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<tr>
<td></td>
<td>M₅₃</td>
<td>333</td>
<td>332</td>
<td>327</td>
<td>447</td>
<td>404</td>
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<td>M₆₁</td>
<td>278</td>
<td>303</td>
<td>291</td>
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<td>345</td>
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<tr>
<td></td>
<td>M₆₂</td>
<td>311</td>
<td>322</td>
<td>332</td>
<td>450</td>
<td>383</td>
</tr>
<tr>
<td></td>
<td>M₆₃</td>
<td>406</td>
<td>350</td>
<td>346</td>
<td>507</td>
<td>464</td>
</tr>
<tr>
<td>M₇</td>
<td>M₇₁</td>
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<td>297</td>
<td>287</td>
<td>397</td>
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<td></td>
<td>M₇₂</td>
<td>352</td>
<td>342</td>
<td>351</td>
<td>466</td>
<td>419</td>
</tr>
<tr>
<td></td>
<td>M₇₃</td>
<td>462</td>
<td>455</td>
<td>462</td>
<td>575</td>
<td>570</td>
</tr>
</tbody>
</table>

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

A. COMPRESSION STRENGTH 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/cm²) for water, (199, 317, and 332 kg/cm²) for painting, and (193, 306, and 337 kg/cm²) for air. Basalt concrete strength was (278, 311, and 406 kg/cm²) for water, (303, 322, and 350 kg/cm²) for painting, and (291, 332, and 346 kg/cm²) for air. Dolomite concrete strength was (325, 352, and 462 kg/cm²) for water, (297, 342, and 455 kg/cm²) for painting, and (287, 351, and 462 kg/cm²) for air.

B. COMPRESSION STRENGTH 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/cm²) for water, (270, 366, and 404 kg/cm²) for painting, and (270, 383, and 421 kg/cm²) for air. Basalt concrete has strength values of (362, 450, and 507 kg/cm²) for water, (345, 383, and 464 kg/cm²) for painting, and (361, 375, and 475 kg/cm²) for air. Dolomite concrete has strength values of (397, 466, and 575 kg/cm²).
for water, (357, 419, and 570 kg/cm²) for painting, and (344, 400, and 515 kg/cm²) 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 \( \approx 0.7610 \ f_{cu} \) at 28 day

- For painting curing  
  \( f_{cu} \) at 7 days \( \approx 0.8133 \ f_{cu} \) at 28 day

- For room air curing  
  \( f_{cu} \) at 7 days \( \approx 0.8197 \ f_{cu} \) at 28 day

Where: \( f_{cu} \) = compressive strength

C. SPLITTING TENSILE STRENGTH

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/cm²) for water, (23.1, 27.3, and 29.1 kg/cm²) for painting, and (24.4, 28.7, and 31.6 kg/cm²) for air. Basalt concrete has strength values of (31.4, 36.2, and 38.8 kg/cm²) for water, (29.8, 32.2, and 36.5 kg/cm²) for painting, and (30.7, 31.7, and 36.1 kg/cm²) for air. Dolomite concrete has strength values of (36.2, 37.3, and 48.2 kg/cm²) for water, (33.2, 34.5, and 45.6 kg/cm²) for painting, and (31.2, 33.0, and 41.1 kg/cm²) 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  \( f_t \approx 0.1498 \ f_{cu} \)

- For painting curing  \( f_t \approx 0.1467 \ f_{cu} \)

- For room air curing  \( f_t \approx 0.1560 \ f_{cu} \)

where: \( f_t \) = flexural strength

D. FLEXURAL STRENGTH

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/cm²) for water, (47.8, 50.1, and 52.6 kg/cm²) for painting, and (50.5, 52.9, and 55.4 kg/cm²) for air. Basalt concrete has strength values of (58.4, 62.6, and 77.2 kg/cm²) for water, (50.4, 57.0, and 68.5 kg/cm²) for painting, and (55.9, 58.7, and 70.3 kg/cm²) for air. Dolomite concrete has strength values of (59.1, 72.3, and 89.2 kg/cm²) for water, (52.4, 65.0, and 83.5 kg/cm²) for painting, and (56.4, 70.2, and 85.3 kg/cm²) 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  \( f_t \approx 0.1498 \ f_{cu} \)

- For painting curing  \( f_t \approx 0.1467 \ f_{cu} \)

- For room air curing  \( f_t \approx 0.1560 \ f_{cu} \)

where: \( f_t \) = flexural strength
Fig. (4): Relation between Cement Content and Compressive Strength at 7 days for Basalt Using Different Types of Curing

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

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

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

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

Fig. (9): Relation between Compressive Strength at 7 and 28 Days for Self-Compacting Concrete
Fig. (10): Relation between Cement Content and Splitting Tensile Strength at 28 days for Gravel Using Different Types of Curing

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

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

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

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

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


