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Shear Strength of Self Compacting Concrete

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Abstract: *After the complaints of Japan people from the noise of mechanical vibrators used in compaction of concrete and also the workers' complaints of frequent unhealthy use of vibrators, and with the difficulty of compaction in structural elements with heavy reinforcement and limited sections; it was necessary to find an alternative way to overcome these problems. This led to the discovery of Self Compacting Concrete (SCC) in 1988; this concrete has a high workability which can be compacted under its own weight without any need of mechanical vibrator and without segregations.*

In spite of the multiplicity of research and studies conducted in the field of SCC, the effect of the components of the mixture on the shear strength of the SCC using local materials is unavailable, which encourages study of this subject and to find a mathematical equation with compressive strength.

So it is needed to study shear strength of SCC. A new formula for shear force in the RC section with SCC is required. There are differences in results related to mechanical properties such as tensile, compressive and impact strength, as well as modulus of elasticity between the SCC and normal concrete.

The focus of the study is to replace part of the coarse aggregate by crushed aggregates with (W/C=0.45), (A/C=3.5), and MVA 0.54 % of cement. The resulting compressive strengths were between (50-65 MPa). From test results, the shear and compressive strength relationship has a clear relation as: $\sigma_{Shear} = 0.0755 f_c' + 0.5405$ *with a ratio of crushed to coarse aggregate 5 %.*

Keywords: *Self Compacting Concrete (SCC), Shear Strength, Compressive Strength, Crushed Aggregates.*

1. Introduction

Self-compacting concrete (SCC) is an innovative (developed in Japan in 1988) concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, well distributed and has the same engineering properties and durability as traditional vibrated concrete.

This type of concrete offers a rapid rate of concrete placement, with less construction time and easier flow around heavily reinforced sections than normal concrete. The fluidity and segregation resistance of SCC ensures a high level of homogeneity (well distribution of constituent materials), minimal concrete voids and uniform concrete strength, providing the potential for a superior level of finishing and durability to the structure. SCC is often produced with low water- cement ratio (W/C) providing the potential for high early strength, earlier remoulding and faster use of elements and structures [1].

The development of Self-Compacting Concrete (SCC), also referred to as “Self-Consolidating Concrete” and “High-Performance Concrete”, has recently been one of the most important developments in the building industry. It is a kind of concrete that can flow through and fill gaps of reinforcement and corners of moulds without any need for vibration and compaction during the pouring process [2].

Although the shear is as important as tensile and compressive strength, but most of studies carried out were concerned with resisting the compressive and tensile strength of concrete.

No one has studied the shear strength of self-compacting concrete in Libya yet, it is the first time to study the effect of mixture content on shear strength of SCC with local material (Libya). Since SCC considered modern discovery, the shear strength behaviour and the relation between compressive and shear strength where studied. Although there are no laboratory methods to find the value of direct shear strength for concrete, however, there is an equation to determine it.

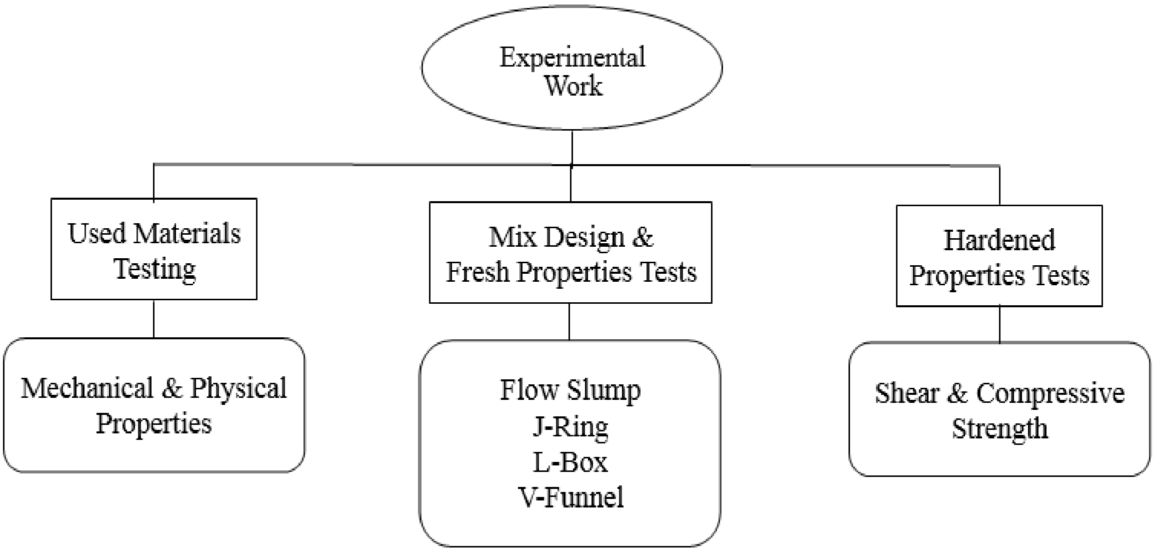
SCC was used in construction in Tripoli-Libya during 2007-2010. SCC was used in foundations in following projects [3]:-

- Tripoli Tower (Arab Union Construction Company, AUCC), Sika products
- Presidential Restaurant of Tripoli
- Al-Bahar Tower (Summa Company), BASF products
- Abo Nowas Tower (Summa Company), BASF products
- Borj Abolaila (Summa, Finished 2010), BASF products
- JW Marriot (Daewoo, Finished 2010), BASF products
- Tripoli Airport Road, Tower (under construction)

The objective of the paper is to study the shear strength of self-compacting concrete using local materials around Tripoli, Libya and obtain the relation with compressive strength of self-compacting concrete by replacing course aggregate with part of the crushed aggregate (Grinilia).

2. Experimental Work

Experimental work is divided into three stages. The following flow chart summarize the experimental work stages:



2.1. Materials Testing

First stage is testing the quality of constituent materials; e.g. cement and aggregates for both sizes are tested according to the Libyan specifications. Table (1) shows the physical & mechanical properties of used cement while Table (2) shows the results of cement testing. On the other hand, Table (3) & (4) shows the properties of used aggregates & used fine aggregates respectively.

Table1. *Physical and Mechanical Properties of Used Cement [4]-[5]*

Test	Result	Specification Limits
Initial setting time(Min)	162	Not less than 60 min.
Final setting time(Min)	275	-
Soundness (mm)	1	Not exceed 10mm.

Table2. *Results of Cement Testing [6]*

Days	Compressive Strength (MPa)	Standards (MPa)
After 2 days	27.99	Not less than 10
After 7 days	36.40	Not less than 16
After 28 days	51.60	Not less than 42.5 & Not exceed 62.5

Table3. *Properties of Used Coarse Aggregates [7]-[8]-[9]*

Test	Results	Standards
Impact	22.4 %	Max. 45 %
Fine10%	172.9 KN	Min.50 KN
Crushing value	21.3 %	Max. 4 5 %
Absorption	2.4 %	Less than 3 %
Unit weigh Kg/m^3	1543	1400 - 1800
Specific gravity	2.62	2.5 – 2.7

Table4. *Properties of Used Fine Aggregate [10]*

Days	Results	Standards
Unit weigh Kg/m^3	1629	1400 – 1800
Specific gravity	2.66	2.5 - 2.7
Absoption %	0.3	Less than 3 %
Fines %	0.43	Less than 4 %

2.2. Mix Design & Fresh Properties Test

The second stage was the major stage which includes mix design and testing the fresh properties of self-compacting concrete. The basic mix contents are W/C =0.45, A/C= 3.5, water = 180L and cement 400Kg per 1m3 with using Viscosity Modified Agent (VMA) BASF(G51) [11] of 0.54L/100Kg cement.

Crushed aggregates of 0% in the mix are tested in the fresh period; tests included Slump flow, J-ring, L-box and V-funnel [1]. After that, 3% of course aggregate is replaced by crushed aggregate, then again 3% is increased in each time until the percentage of non-self-compacting concrete properties are observed by testing fresh properties. Table (5) shows the mixes content used in this study.

Table5. *Mixes Content*

Mix No.	Crushed Aggregate Percentage (%)	Cement Weight (Kg/m3)	Course Aggregate Weight (Kg/m3)	Fine Aggregate Weight (Kg/m3)	Crushed Aggregate Weight (Kg/m3)	Water Weight (Kg/m3)	Additive Weight (Kg/m3)
1	0	400	868	532	0	180	2.592
2	3	400	841.96	532	26.04	180	2.592
3	6	400	815.92	532	52.08	180	2.592
4	9	400	789.88	532	78.12	180	2.592
5	12	400	763.84	532	104.16	180	2.592
6	15	400	737.8	532	130.2	180	2.592
7	18	400	711.76	532	156.27	180	2.592

2.3. Hardened Properties Test

Third stage, the hardened properties were tested for self-compacting concrete specifically shear and compressive strengths. Relation between shear strength and compressive strengths with the effect of crushed aggregate content are determined. A beam was tested to find shear by reinforcing the bending side of the beam (500x 100x 100mm) with minimum area of steel to prevent bending failure. Cubes of (150x150x150 mm) size were tested at 7 and 28 days [12].

3. Discussion of Results

Table (6) & (7) lists the test results of the fresh & hardened concrete properties respectively.

Table6. *Results of Fresh Properties Tests*

Mix No.	Crushed Aggregate Percentage (%)	Slump Flow(mm)	J-ring (mm)	L-box (%)	V-funnel (sec)
1	0	680	9	0.80	10
2	3	750	7	0.89	7.2
3	6	755	5	0.92	7.5
4	9	730	7.5	0.88	7.3
5	12	690	9	0.81	8.9
6	15	560	11	0.77	12
7	18	495	15	0.71	15

Table7. *Shear and Compressive Strengths*

Mix No.	Crushed Aggregate Percentage (%)	Compressive Strength at 7 days (MPa)	Compressive Strength at 28 days (MPa)	Shear Strength at 7 days (MPa)	Shear Strength at 28 days (MPa)
1	0	44.60	57.41	4.00	5.00
2	3	47.34	62.00	4.62	5.19
3	6	47.83	62.45	4.73	5.30
4	9	45.94	61.95	4.53	5.00
5	12	43.92	58.82	4.56	4.83
6	15	41.51	51.44	4.51	4.67
7	18	37,00	50.67	3.87	4.06

Workability is decreased when the crushed aggregate (Grinilia) reached to the ratio of 15%. While the crushed aggregate (Grinilia) ratio reached to 18% the workability continues in decreasing where the concrete become as a normal concrete with a slump flow diameter less than 500mm.

The relationship between the content of crushed aggregate& shear strength are shown in Figure 1, while Figure 2 shows the relationship between the content of crushed aggregate& compressive strength. The best ratio of crushed aggregate is found to be between 3% to 6% and it is about 5%.

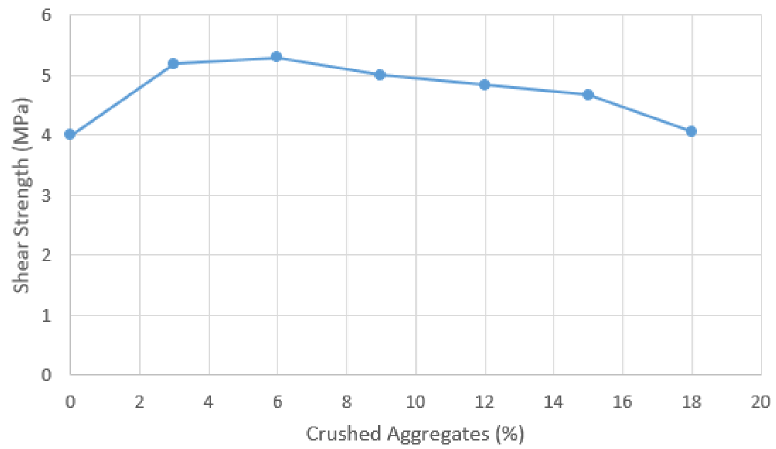


Figure1. *Relation between shear strength and percentage of crushed aggregate*

The strength of concrete found to be increasing with workability. Where, the best value of shear and compressive strength was with a highest value of flow slump without the use of electric vibrator. The relation between shear and compressive strengths shown in Figure 2 with a good correlation coefficient $R^2 = 0.809$.

The relation between shear and compressive strength is presented by the equation:

$$\sigma_{Shear} = 0.0755 f_c^{'} + 0.5405$$

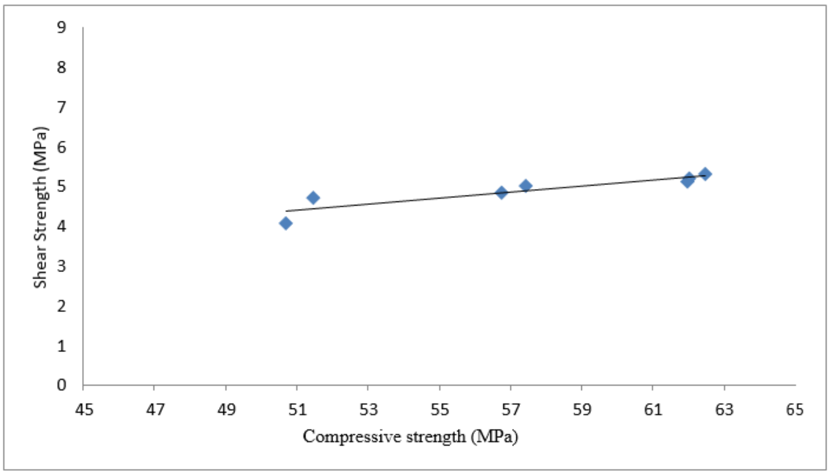


Figure2. *Relation between shear strength and compressive strength*

4. Conclusion

From the study the following can be concluded:

1. The relation between shear and compressive strengths can be expressed as:

$$\sigma_{Shear} = 0.0755\, f_c' + 0.5405$$

2. The best compressive strength and flow ability was within 3% - 6% ratio of crushed aggregate.
3. The proportion of shear to compressive strength of self-compacting concrete between 8% to 9%.
4. The highest value of shear strength was accompanied with the highest value for the compressive strength, 62 MPa.

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Author's Biography

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