International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 18 (2015) pp 39196-39200

Preparation and Characterization of Self-Compacting Concrete Containing Lime Stone powder

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Abstract
This study aims at investigating the properties of self-compacting concrete (SSC) containing lime stone with the influence of different amounts of internal sulphate (CaSO4) and external salts. The effect of internal and external salts is combined with the process of wetting and drying. Three sets of mixes which are reference mix, mixes with internal sulphate and mixes exposed to external salts respectively are designed with the same mix proportion and maximum sized aggregate of 10mm. In order to determine the self compactability features, different tests are adopted such as the slump flow and the L-box test. The mechanical properties studied in this study are the compressive strength. Results show that the compressive strength of mixes with external salts is larger than mixes with internal sulphates for the ages of 28, 60, 90 and 180 days respectively except for the age of 180 days achieved a higher compressive strength. Based on the obtained results, it is clear that it is possible to produce self-compacting concrete (SCC) from local materials like limestone with good properties. The SCC is affected by salt attack and its effect by the process of wetting and drying, but despite this fact, SCC still has good properties.

Keywords: Self-compacting concrete, lime stone, fresh concrete properties

Introduction
Concrete has many qualities such as cost-effectiveness, versatility, and above all durability making it the best commonly used construction material in civil engineering. However, the production of concrete causes environmental and conservation problems due to the production of its primary component, Portland cement (PC). This is because PC production is one of the main contributors to carbon dioxide (CO_2) emissions [1]. Moreover, it consumes large quantities of fossil fuel and natural resources.
Two significant studies carried out around the mid1980s and 1990s resulted in the invention of self-compacting concrete (SCC) and high volume cement replacement (HVCR) strategy, which produces a major effect on the technique where concrete can be prepared [2]. The reason is that SCC is responsible for a variety of chances to make use of natural and by-product materials as cement substitutes, while the strategy of HVCR not just decreases the use of cement considerably but permits the production of concrete at a low cost as well.
SCC is a type of concrete which fills the formwork due to its capability to flow under its own weight completely even in the presence of dense reinforcement, with no necessity for vibration, while preserving homogeneity [3]. The self-compacting ability is accomplished by means of large paste volume [4] made possible by mixing cement with mineral additives such as limestone powder (LP), fly ash (FA), silica fume (SF), ground- granulated blast-furnace slag (GGBS), rice husk ash (RHA), meta-kaolin (MK), etc. Combining mineral additives in SCC turned out to be capable of not merely regulating the cement content but also improving the fresh state properties [5, 6].
The background study determines that CO_2 emissions caused by concrete and cement productions as the recent issue facing the construction industry. One method of solving the issue is by substituting cement with byproduct materials such as LP. In this respect, SCC is able to offer varied opportunities to use such materials efficiently. However, the research problems that need to be resolved include SCCs higher material cost compared with traditional concrete, the additives low optimal level of cement replacement with respect to the incorporation of LP in SCC due to supply and properties issue [6]. Due to its most essential ingredient, Portland cement, the concrete industry has suffered from an image of being environmentally unfriendly, because it is associated with high consumption of fossil fuel and high emissions of CO_2 into the atmosphere [7]. Nevertheless, the problem with SCC is that it is likely more expensive than traditional concrete due to using of super plasticizer (SP). Incorporating mineral additives at their optimal levels, mostly between 10- 20% [8], is insufficient at any cost increase incurred. Fortunately, most mineral additives have more than one beneficial characteristic when mixed enabling them to produce shared effects that are useful to the SCC, so at the very least they could increase the levels of cement replacement considerably. The additive of LP in this study is described to have the ability of decreasing cost and environmental impact due to it being used as a cement replacement and to improve all engineering properties [9]. They have a preference to use materials which are easily available and have been effectively used in real structural applications, such as LP, FA and SF and their bulk supply is assured. The aim of this study is to improve the SSC properties using local material Lime stone powder.

Materials and Method

A. Materials

Effective production of SCC is achieved by more strict requirements on the materials' selection, controlling and proportioning. Optimum proportions must be selected according to the mix design methods, considering the characteristics of all the materials used.

B. Cement

The cement used in this study is Ordinary Portland Cement (OPC) type (I) produced according to the Malaysian Standard MS 522, and agrees with BS EN 196.

C. Fine Aggregate

The amount, grading and partial shapes of fine aggregate are significant factors in the production of SCC. Fine aggregate with rounded particles shape and smooth texture requires less mixing water and for this reason is preferable in SCC. Local washed river sand as fine aggregate materials is used in this work. Sand sieve analysis was performed in accordance with B.S.887:1992

D. Salt water solution

Ordinary treated water obtained from the main supply line of Perlis and Pinang is used throughout this work in mixing of concrete. In curing mixes with internal salt water is used, and in external salts water with amount of salts is used

E. Sulphates

Natural lumps of sulphate were used. They were dried to about 105 C^0 for 24 hours, cooled to room temperature, crushed by hand compactor, then sieved using a No.4 sieve. Sulphate amounts in concrete were changed by the addition of different weights of the previous mixture to get 1.2, 1.3, 2.3 and 3.4 percent of SO_3 by weight of sand.

F. Superplasticizer

ADVD 181 is a high range water-reducing polymer-based admixture, which according to Grace Construction Products was formulated in accordance with BS5075 part 3:1985. The specific gravity of ADVD 181 is 1.2 and the addition rates vary from 195 ml to 375 ml per 100 kg of binder materials [10].

G. Lime stone powder

The limestone powder (LP) passing a 0.075 mm sieve is used in this study. The cement in SCC mixes is generally partially replaced limestone powder in order to improve certain properties of concrete.

H. Concrete Mixes

In order to achieve the scopes of this study, the work is divided into three sets which are shown in Table 1. These sets include nine mixes that depend on one reference mix, in order to show the effect of internal and external salts.

TABLE 1. Mixture components and description

No.	Mix Symbol	Mix Description
1	L_1	reference Mix without internal or external salts
2	L_2	Mix with internal salt 3.4%of sand weight
	L_3	Mix with internal salt 2.3% of sand weight
	L_4	Mix with internal salt 1.3% of sand weight
	L_5	Mix with internal salt 1.2% of sand weight
3	L_6	Mix with external salt Na_2Cl_2 1.4%
	L_7	Mix with external salt $NaSo_4$ 0.97%
	L_8	Mix with external salt $MgSo_4$ 0.97%
	L_9	Mix with external salt $CaCl_2$ 1.4%

Results and Discussion

A. Fresh properties of SCC

Workability tests are made on fresh concrete immediately after mixing, including slump flow and L-box. SCC should possess at some level both filling and passing abilities as well as the resistance to segregation.

i. Slump Flow and T50 cm Test

Table 2 shows the results of slump flow test. The values of (D) represent the maximum spread (slump flow), while the values of T50 represent the time required for the concrete flow to reach a 50cm diameter circle. The flowing ability of fresh concrete is described with slump flow investigated with the Abrams cone. The low water/powder ratio and the high fineness of limestone powder form a paste with high viscosity. During flowing, neither segregation nor bleeding occurs. It is very clear from the results that all mixes are assumed to have a good consistency and workability from the filling ability point of view. However, these results show a wide range of variation. This variation illustrates the effects of the changes that are made in the mixes on the filling ability of SCCs. The T50 cm for all mixes is between (3-5) sec indicating a good deformability. This agrees with the EFNARC 2002 [3].

TABLE 2. Results of the slump flow tests

Set No.	Mix Symbol	D(mm)	T50(sec.)
1	L1	760	5
2	L2	743	4.5
	L3	750	4.5
	L4	761	3.5
	L5	746	4
3	L6	773	3.5
	L7	779	3
	L8	791	3
	L9	744	5

TABLE 3. L-box test results

Set No.	Mix Symbol	Blocking Ratio	T20(sec)	T40(sec)
1	L1	0.91	1.5	3.5
2	L2	0.91	2.5	4.0
	L3	0.86	3.5	6.5
	L4	0.91	2.5	3.0
	L5	0.86	3.5	6.5
3	L6	0.84	4.0	7.5
	L7	0.83	4.5	8.5
	L8	0.95	1.5	2.5
	L9	0.85	4.5	7.5

ii. L-Box Test

L-box test is used to measure the filling ability and the passing ability of the mixes. The L-box results are listed in Table 3. The value of (H**2**/H**1**) represents the blocking ratio. The values of T**20** and T**40** represent the times of the concrete flow to reach 20 and 40 cm respectively. The blocking ratio values for all mixes are greater than 0.8 which is often considered in the EFNARC 2002 as the critical lowest limit [3].

B. Hardened SCC Properties

Since no segregation or bleeding is shown with the fresh state, SCC mixes should, theoretically, have improved hardened properties. In order to study these hardened properties of SCC developed in this study, 549 specimens of various types are cast after a series of fresh self-compactability concrete tests. All the concrete specimens are cast in molds without being mechanically consolidated. All of the samples are demolded after 24 hours then either cured in water, water solution and exposed to cycles of wetting and drying until the date of testing.

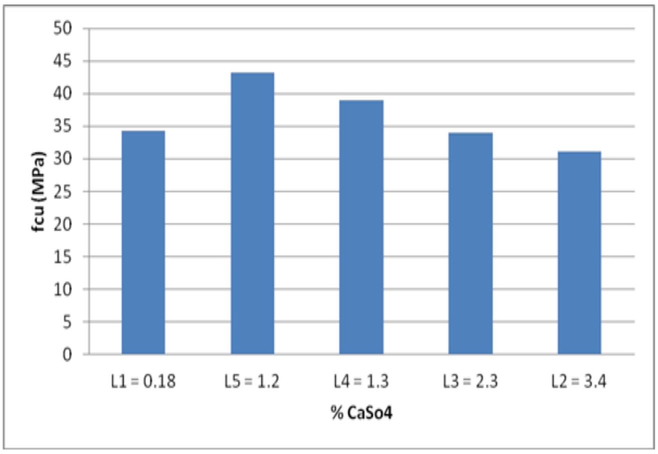

Fig. 1. Compressive Strength of Cubes (fcu) internal sulphates and L1 at 28 days.

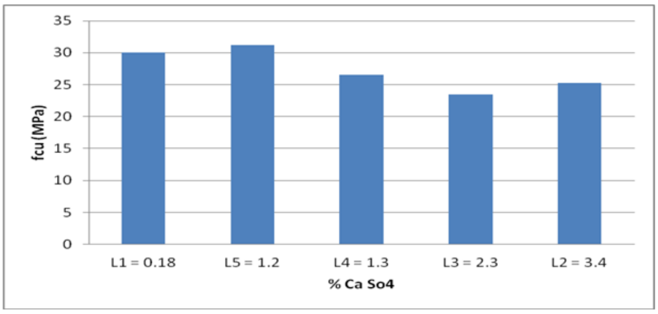

Fig. 2. Compressive Strength of Cubes (fcu) internal sulphates and L1 at 60 days.

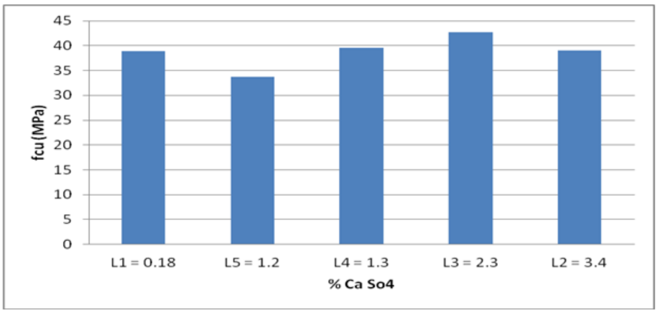

Fig. 3. Compressive Strength of Cubes (fcu) internal sulphates and L1 at 90 days.

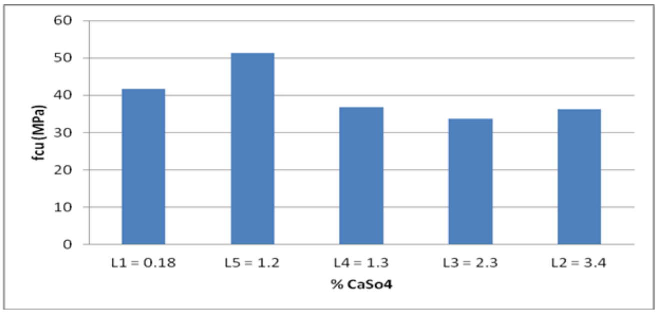

Fig. 4. Compressive Strength of Cubes (fcu) internal sulphates and L1at 180 days.

i. Compressive Strength

The compressive strength is one of the most important properties of hardened concrete. National and international codes generally use the value of compressive strength for the classification of concrete.

In order to study the effect of internal and external salts combined with cycles of wetting and drying on the compressive strength of SCC, standard cubes measuring 150mm and cylinders measuring (150x300) mm are used. Each compressive strength reading is the average reading of three tested samples. The compressive strength results are shown in Fig. 1-8, which show test at 28, 60, 90 and 180 days gained from cylinders and cubes respectively. The value of compressive strength for cylinders is less than for cube because of slenderness of the specimens.

It appears that the compressive strength of mixes with external salts is larger than mixes with internal sulphates by about (2.7

%), (15 %), and (5.4%) for 28, 60, and 90 days respectively. At age 180 days, the compressive strength of mixes with internal sulphates is larger than mixes with external salts by about (4.5) % while the reference mix (L1) shows results lower than the mixes in Set (No.1) and Set (No.2). At age 28 to 60 days it is clear there is reduction in compressive strength. This is due to the essence of sulphate attack which leads to the formation of calcium sulphates (gypsum) and calcium sulpho-aluminate (ettringate). Both products occupy a greater volume than the compounds which they replace so that the expansion of hardened concrete takes place reducing the compressive strength for the mixes. For 60 to 90 days there is an increase in compressive strength because the presence of hydration products fill the pores of concrete and that will reduce the effect of salts attack and mitigate the damages caused by salts attack. For the age of 180 days, there is a continuity of strength increase except for L2, L3 and L4 where a reduction in compressive strength is exhibited because the amount of sulphate in these mixes is greater than the other mixes. In addition, the effect of wetting and drying effect on the samples at early ages is greater than the later ages.

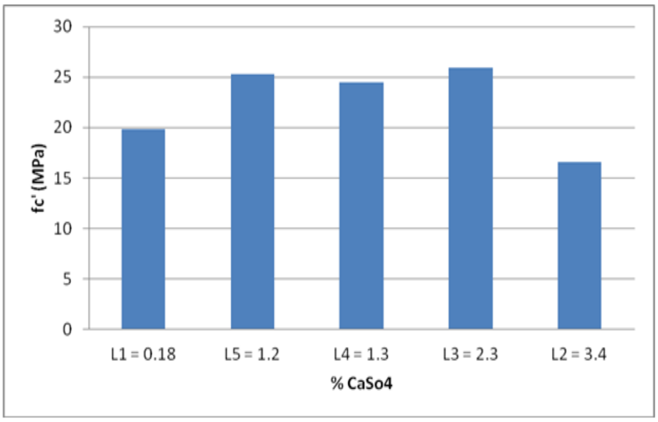

Fig. 5. Results of Compressive Strength of Cylinder (fc/) internal sulphates and L1 at 28 days.

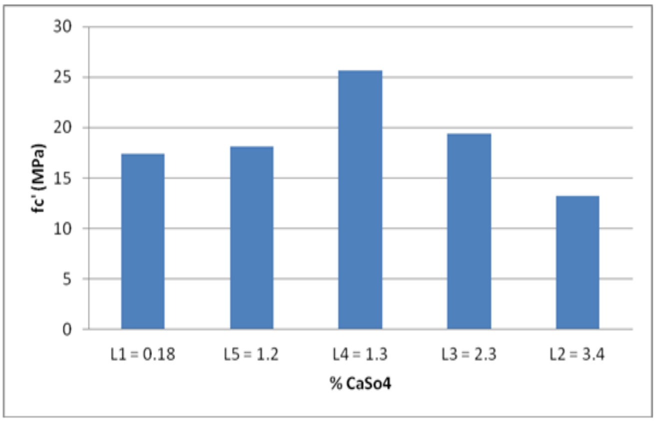

Fig. 6. Compressive Strength of Cylinder (fc/) internal sulphates and L1 at 60 days.

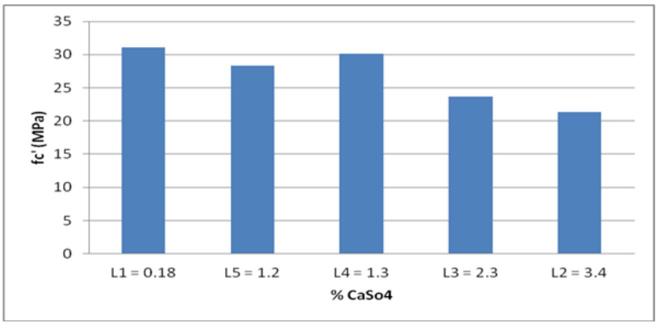

Fig. 7. Compressive Strength of Cylinder (fc/) internal sulphates and L1 at 90 days.

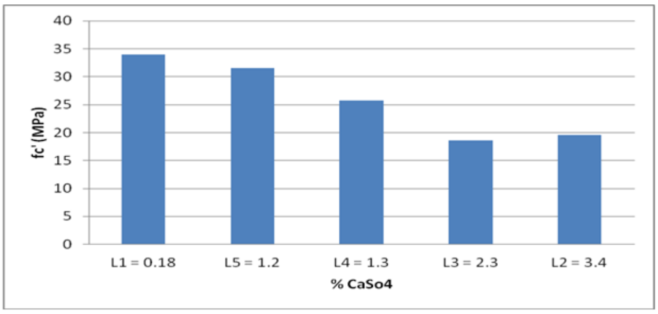

Fig. 8. Compressive Strength of Cylinder (fc/) internal sulphates and L1 at 180 days.

Conclusion

Based on the experimental results of this work and in view of the experimental conditions, limitations of the laboratory circumstances of the local materials used, the following conclusions can be drawn from this work:

i. It has been verified, by using the slump flow and L-box, that SCC mixes achieve consistency and self-compactable under their own weight, without any external vibration or compaction. The ranges of slump flow diameters and T_{50} times for all mixes are between 743-791 mm and 3-5 sec. respectively. L-box results are in the ranges 0.83-0.95, (1.5-4.5) sec for blocking ratioT_{20} whereas 2.5-8.5 sec forT_{40}.

ii. When SCC is properly proportioned and controlled, the fresh concrete will flow to great distances and remains homogeneous without segregation and there is no need for SCC to undergo troweling or finishing.

iii. The values of compressive strength for cube (fcu) for internal sulphates are about 31.15-43.72, 23.15-31.24, 33.75-42.66, and 33.68-51.25 Mpa at 28, 60, 90 and 180 days respectively. For external salts, the values are about 23.81-44.09, 32.71-36.57, 39.61-44.78 and 45.86-49.96 Mpa for the same ages. While the values of reference mix L1 are 334.30, 30, 38.95 and 41.77Mpa at the same ages above.

iv. Self-compacting concrete can be produced with locally available materials. Self-compacting concrete has sufficient flowability and workability to obtain its self-compactable performance concrete self-compacting.SCC flows into formwork and through reinforcement under its own weight so no external vibration is required. SCC needs careful proportioning and batching.

Acknowledgment
Duha Abdalla Najm would like to thank School of Housing, Building and Planning, Universiti Sains Malaysia for all kinds of lab facilities and support.

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