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# Structural Lightweight Concrete Using Cured LECA

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***Abstract*— Concrete to be considered is lightweight concrete (using LECA as a coarse aggregate), that is concrete with a density in the range 1.65 - 1.85 t/m3. In order to obtain high strength concrete, LECA was treated by solution of silica fume of different concentration (10 and 20%) by weight of mixing water. Three levels of silica fume (5, 10, 15 %) and two ratios of course to total aggregate content (0.48, 0.65 by volume) were used. For this concrete, information on mechanical properties was provided. Test results proved that, using treated lightweight aggregate increase the compressive and flexural strength, the idea of using cured aggregate by pozzolanic material solution must be taken into consideration. The need of using supplementary cementitious materials such as silica fume must be detected to enhance the performance of lightweight concrete. The results indicated that cement content has a significant effect on compressive and flexural strength of Lightweight concrete. Silica fume content seems to lead to high early age strength in 7 days with relatively smaller increase in strength at 28 days. The economic silica fume content for LWC is 10%. At 0.48 coarse aggregate ratio, the compressive strength and flexural strength were higher than for 0.65 coarse aggregate ratio.***

***Index Terms*— Lightweight concrete, high strength concrete; LECA concrete; lightweight aggregate**

## I. INTRODUCTION

Recently, with the rapid development of very tall buildings, larger-sized and long-span concrete structures, the requirements for better concrete performance are higher strength, light weight, higher toughness and others. Therefore, lightweight concrete (LWC) has been used for structural purposes for several years [1–6]. The density of LWC typically ranges from 1400 to 2000 kg/m3 compared with that of 2400 kg/m3 for normal-weight concrete (NWC). The use of high-strength LWC can reduce the self-weight of structures and cross-sectional areas of structural elements. However, LWC can be considered as a brittle material. The higher the compressive strength is, the higher the brittleness is. Therefore, improving the Compressive strength is the key point to popularize the application of LWC.

Lightweight aggregates are more porous than their normal density counterparts and concrete made with the more porous aggregate will inevitably show low strength and durability. Mix design is frequently limited to empirical determination of equal compressive strengths and invariably the achievement of equal strength is at the cost of higher cement content and therefore more expensive concrete. The use of higher amounts of cement becomes even more important for the production LWC. However, the workability of these mixes has generally been obtained by increasing the cement content for constant water content so that lower w/c ratios can be achieved. The use of super plasticizer helps in reducing water content. The improvement in the quality of the LWC matrix could be partly ascribed to the use of a higher cement content combined with a lower w/c ratio. Silica fume has attained prominence in recent years because of its high reactivity potential, which is enhanced by its large specific surface area. It acts as an efficient pozzolan by reacting with the lime liberated during the hydration of Portland cement. The role of silica fume needs careful examination and also the effects of aggregate on the mechanical properties and durability. [7, 8].

In this research a new technology was developed to enhance the quality of an light weight aggregate (LECA) by immersing it in solution of silica fume in order to let the silica fume particles get through the aggregates and try to packed some voids and consequently obtain their strength, absorption and pozzolanic activity.

## II. EXPERIMENTAL PROGRAM

### *A. Materials*

Detailed information about the materials used and their characteristics are given in this section.

***Cement:*** - Portland cement has been found to be adequate for production of high strength concrete. Experience Physical and mechanical properties of cement were measured according to Egyptian standard specification (ESS 373-1963).

***Mineral admixtures:-.*** Silica fume (sf) was used in this programme and particular care was taken over curing since the pozzolanic reaction takes place over a longer time.

Aggregate The lightweight aggregates thought to be capable of producing medium strength concrete are based on expanded clay (LECA). LECA is a lightweight aggregate made of expanded clay by rotary kiln process. It has common three particle sizes up to 4 mm, 4-8 mm, and 8-12mm. One particle size of LECA 4-8 mm from the national cement company "Helwan", Egypt is used. The properties and sieve analysis of the used LECA are shown in Tables (1, 2). The water absorption after 60 min. was 12%. The fine aggregate (FA) used in concrete was desert sand. It was clean and almost free from impurities, silt, lay and saltiness. Main properties of sand were measured according to the Egyptian standard specification (ESS 1109-1971). Table (1) shows the properties of the fine aggregates.

Chemical Admixtures (Superplasticisers). High range water reducer complies with ASTM C494 type F was used.

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The admixture is a brown liquid ready to use directly during concrete mixing.

**Table (1) Properties of aggregates**

| Type | Specific gravity | Unit weight (kg/m$^3$) | Void % | Fineness modulus | Max. nominal size (mm) |
|---|---|---|---|---|---|
| LECA | 1.2 | 633 | 47.25 | 5.0 | 8 |
| Sand | 2.67 | 1690 | 36.7 | 2.8 | - |

**Table (2) Sieve analysis of LECA (4-8 mm)**

| Sieve size (mm) | 10.0 | 5.0 | 2.36 | 1.41 |
|---|---|---|---|---|
| % Passing | 100 | 67 | 30 | - |

### B. *Mix design*

In designing a LWAC mix the techniques used for designing normal weight concrete (NWC) can be used, but allowing for the high water absorption of the aggregate. The effect of this factor becomes obvious knowing that the amount of water absorbed by LWA is considerably higher than that of NWA and can affect the total amount of water significantly. Therefore special attention has to be paid to the amount of water already present in the aggregates and any extra water needed to saturate the aggregate should be taken into account.

Eight mixes were selected for this study high strength lightweight concrete. These mixes have a range aggregate content; silica fume content as shown in Table (3). These mixes were used for different treated aggregate at silica fume concentration (0, 10, and 20 %).

**Table (3) Composition of high strength light weight concrete selective mixtures**

| Mix No. | c | sf/(c+sf) | w/(c+sf) | SP/(c+sf) | C/(F+C) |
|---|---|---|---|---|---|
| | kg/m$^3$ | % | | % | |
| M1 | 450 | 0 | 0.3 | 2 | 0.48 |
| M2 | 450 | 0 | 0.3 | 2 | 0.65 |
| M3 | 450 | 5 | 0.3 | 2 | 0.48 |
| M4 | 450 | 5 | 0.3 | 2 | 0.65 |
| M5 | 450 | 10 | 0.3 | 2 | 0.48 |
| M6 | 450 | 10 | 0.3 | 2 | 0.65 |
| M7 | 450 | 15 | 0.3 | 2 | 0.48 |
| M8 | 450 | 15 | 0.3 | 2 | 0.65 |

### C. *Test specimens and instrumentation*

Compressive strength:- Compression tests were carried out on 150mm cubes specimens according to British Standard BS 1881: Part 116:1983.

Flexural strength:- Tests were carried out on 100×100×500 mm beams according to British Standard BS 1881: Part 118:1983.

## III. EXPERIMENTAL RESULTS

### A. *Compressive strength*

The strength of concrete is mainly influenced by the strength of the aggregate. The development of concrete strength is possible only when the aggregates have enough strength. The effects of using cured aggregate by silica fume solution at different concentration on compressive strength of concrete made with LECA are showed in Table 4 and Fig. (1-3). From these figures, it was observed for all silica fume content the compressive strength was increased by nearly the same rate up to 28 days and at all cured aggregate. This may be due to pore filling effect of silica fume particles as an important factor enhances the strength of aggregates.

The effect of silica fume addition on compressive strength made from LECA are significant up to 10% silica fume content for all cured aggregates as shown in Fig. (4). At 15% silica fume content, the concrete gave slightly higher compressive strength than at 10% but the difference was not significant. It can be concluded that silica fume content above 10% is not worthwhile. Generally, 0.48 coarse aggregate ratio gave compressive strength higher than 0.65 by (17 -22%) at the same cured aggregate and silicafume contents. Compressive strength increases with age in the expected manner. At 10% silica fume concentration, the compressive strength is (20-25%) higher than concrete without cured aggregate, as may be seen in Fig. (5, 6). However, such increases silica fume concentration from 10% to 20 % are not as large as might be expected indicated that the compressive strength had probably reached an upper level for the cured aggregate at silica fume concentrated 10% and the strength does not benefit very much from further silica fume concentration. It can be reported that the concrete compressive strength increased by using cured aggregate, while there is no effect on the compressive strength by increasing the solution used for aggregate curing from 10% to 20%.

Most of the concrete mixes essentially stopped gaining strength between the ages of 7 and 28 days. This indicates that the compressive strength had probably reached an upper level for the aggregate, and the strength does not benefit very much from a further improvement of the matrix strength.

### B. *Flexural strength*

The effects of addition silica fume on flexural strength of concrete were noted. Increasing silica fume content at (5, 10%), increasing flexural strength by (30, 35%). 15% silica fume content gave a flexural strength marginally the same as 10% and the difference is not significant.

At 10% silica fume concentration, the flexural strength is (15- 20%) higher than concrete without cured aggregate, as may be seen in Table. (5). However, such increases silica fume concentration from 10% to 20 % are not as large as might be expected indicated that the flexural strength had probably reached an upper level for the cured aggregate at silica fume concentrated 10% and the strength does not benefit very much from further silica fume concentration. It can be reported that the concrete flexural strength increased

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by using cured aggregate, while there is no effect on the flexural strength by increasing the silica fume solution used for aggregate cured from 10% to 20%

At 0.48 coarse aggregate ratio, the flexural strength is higher than 0.65 ratio by (20 -27%) for the same silica fume content and cured aggregate as shown in Fig. (7).

**Table (4) Compressive strength of Light weight concrete, MPa.**

| Solution Concentration% | 0% | | | 10% | | | 20% | | | Unit weight Kg/m3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Test Age | 3 day | 7 day | 28 day | 3 day | 7 day | 28 day | 3 day | 7 day | 28 day | |
| M1 | 15.24 | 17.00 | 20.24 | 15.23 | 20.23 | 24.37 | 16.50 | 20.12 | 23.13 | 1671.05 |
| M2 | 20.12 | 23.02 | 26.58 | 21.88 | 26.68 | 30.67 | 19.36 | 24.55 | 29.58 | 1809.75 |
| M3 | 20.60 | 23.74 | 27.29 | 20.81 | 26.34 | 31.36 | 20.44 | 25.57 | 30.44 | 1681.98 |
| M4 | 26.19 | 30.48 | 34.64 | 29.13 | 32.86 | 38.66 | 26.19 | 31.17 | 37.56 | 1821.63 |
| M5 | 23.02 | 26.35 | 30.29 | 24.96 | 31.60 | 36.32 | 24.06 | 29.22 | 34.38 | 1691.95 |
| M6 | 27.64 | 30.99 | 36.46 | 29.26 | 36.94 | 42.46 | 29.17 | 36.01 | 41.39 | 1830.65 |
| M7 | 21.53 | 24.59 | 28.59 | 23.09 | 29.60 | 35.66 | 23.34 | 29.21 | 33.57 | 1702.88 |
| M8 | 26.67 | 29.91 | 35.19 | 28.02 | 35.47 | 41.24 | 27.99 | 34.09 | 40.11 | 1841.58 |

**Table (5) Flexural strength of Light weight concrete at age 28 days, MPa.**

| Solution Concentration% | 0% | 10% | 20% |
|---|---|---|---|
| M1 | 3.70 | 4.45 | 4.23 |
| M2 | 4.84 | 5.61 | 5.41 |
| M3 | 4.97 | 5.72 | 5.55 |
| M4 | 6.32 | 7.03 | 6.86 |
| M5 | 5.52 | 6.63 | 6.25 |
| M6 | 6.63 | 7.76 | 7.54 |
| M7 | 5.23 | 6.50 | 6.10 |
| M8 | 6.41 | 7.51 | 7.29 |

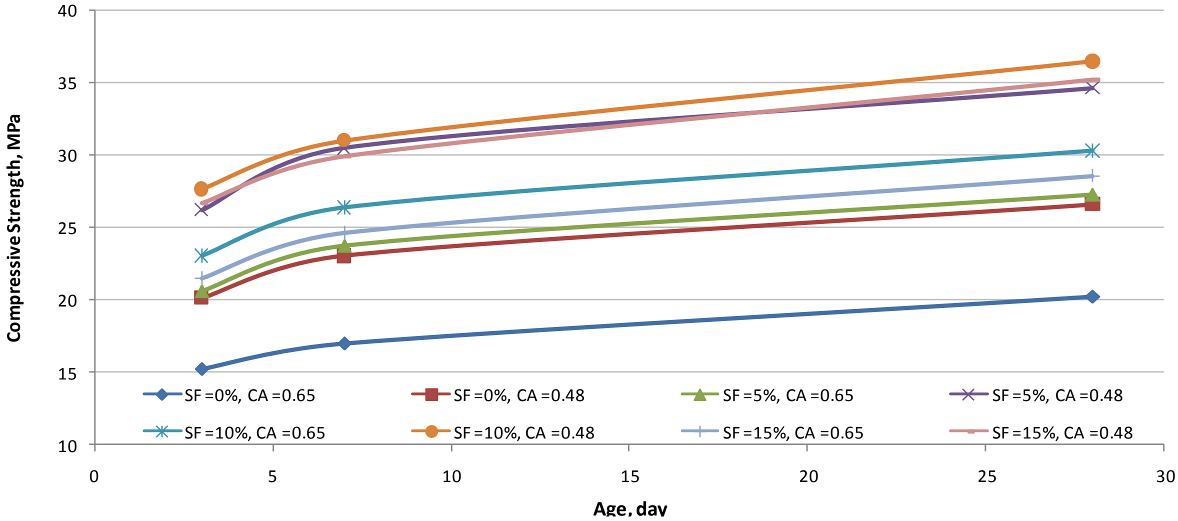


**Fig. (1) Effect of curing aggregate (0% silica fume solution) on compressive strength at different silica fume content.**

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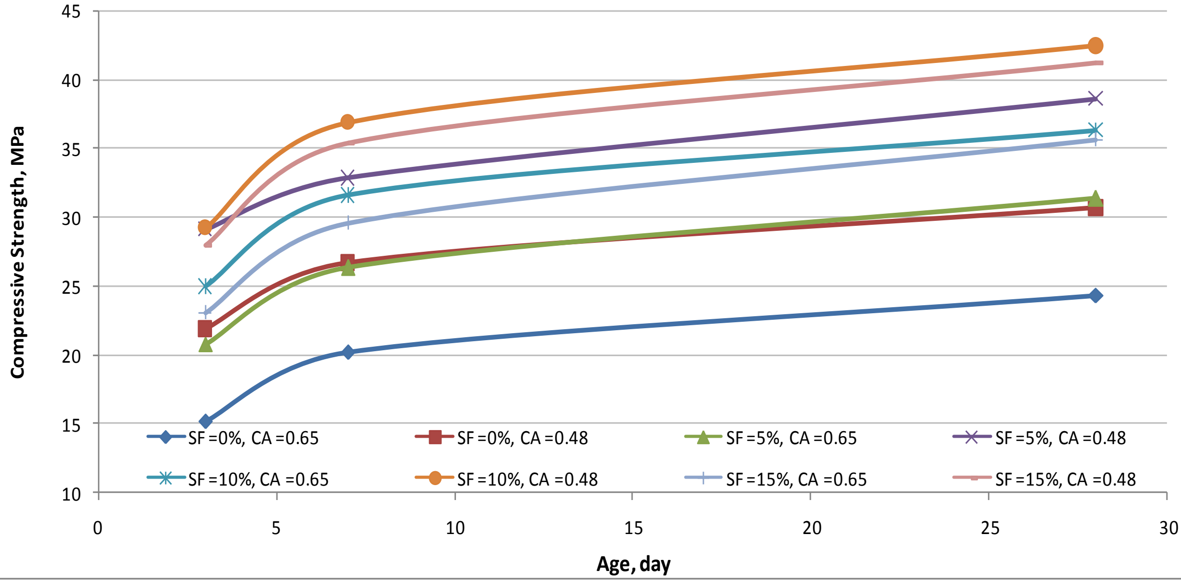


**Fig. (2) Effect of curing aggregate (10% silica fume solution) on compressive strength at different silica fume content.**

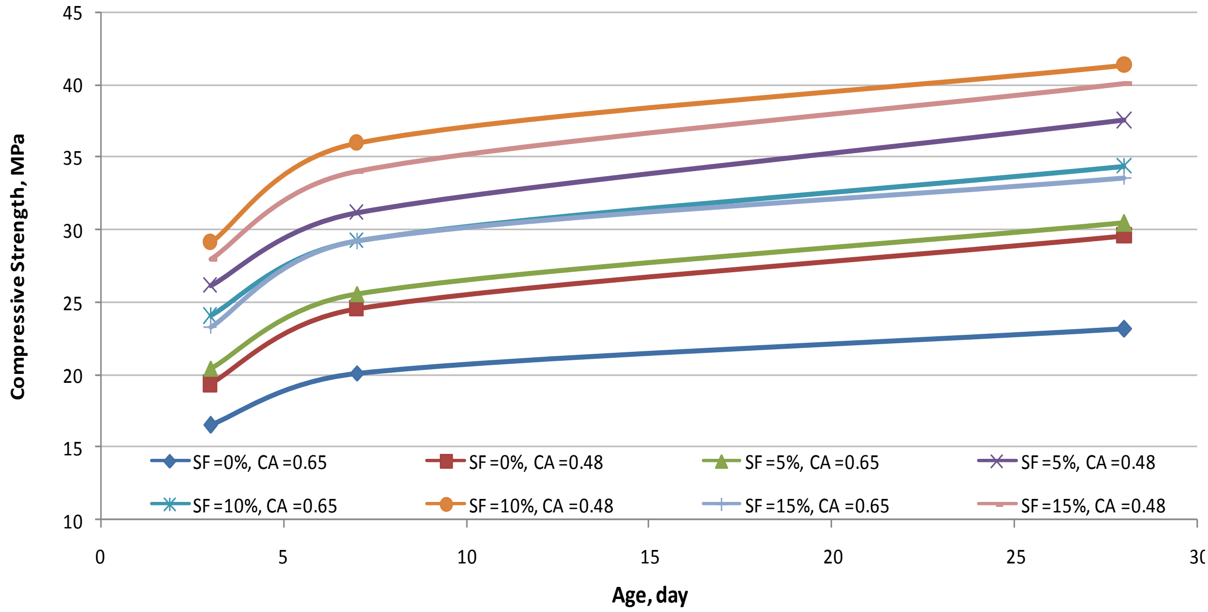


**Fig. (3) Effect of curing aggregate (20% silica fume solution) on compressive strength at different silica fume content.**

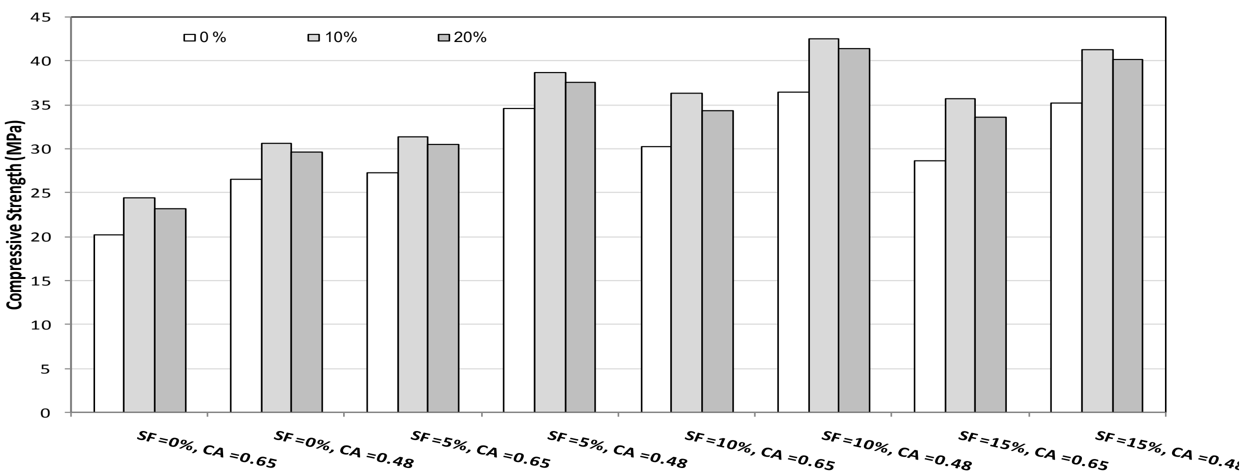


**Fig. (4) Effect of silica fume on Compressive Strength of lightweight concrete for different cured aggregate**

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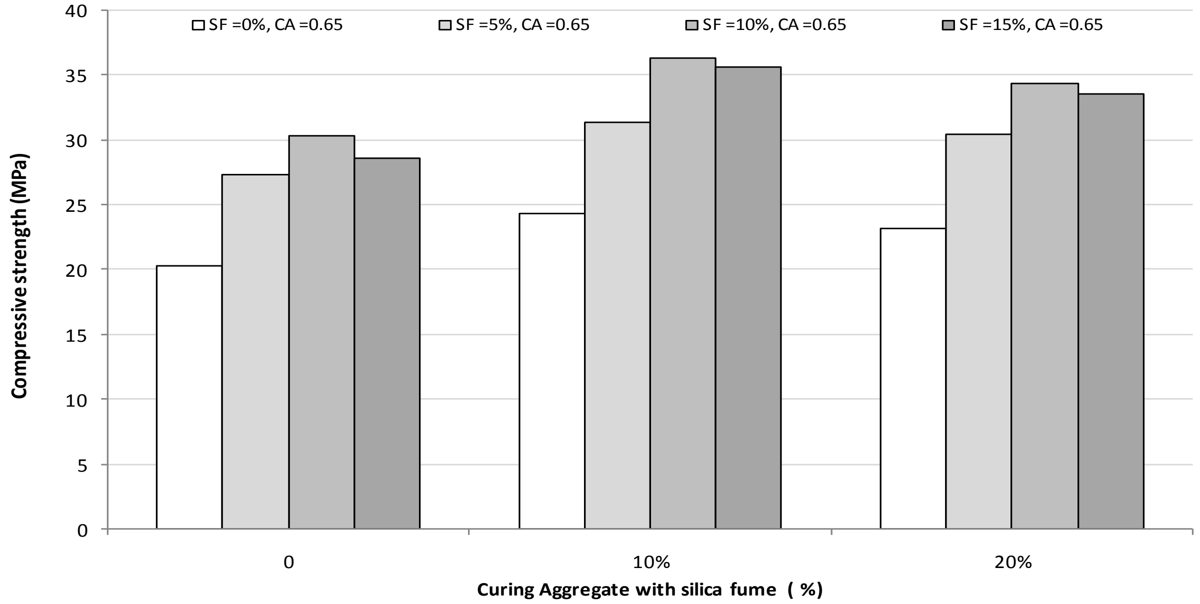


**Fig. (5) Effect of curing aggregate with silica fume on compressive strength for light weight concrete at 0.65 coarse aggregate ratios.**

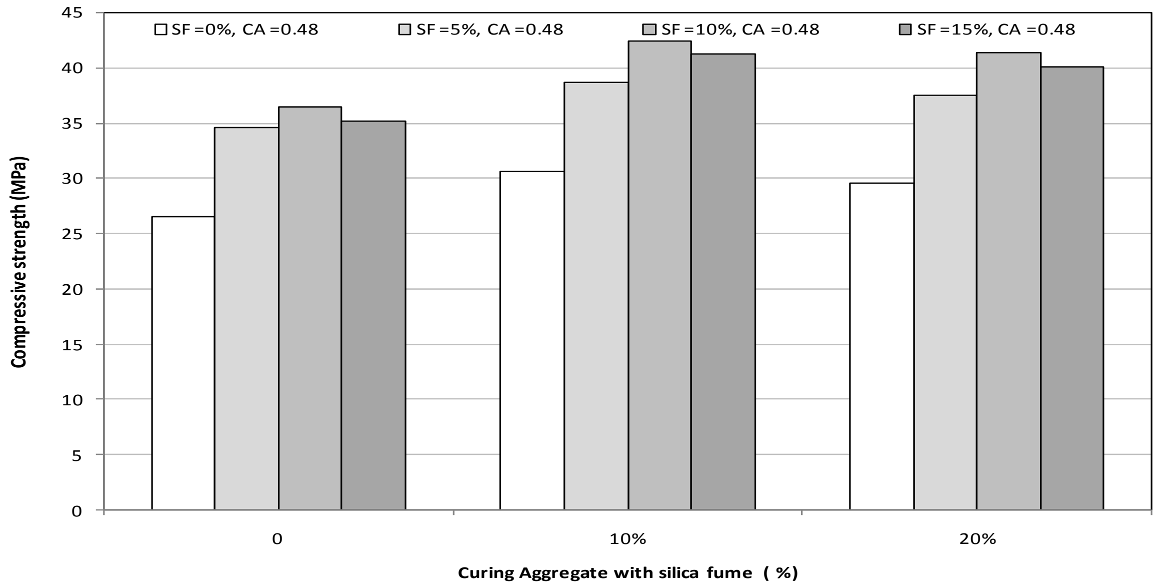


**Fig (6) Effect of curing aggregate with silica fume on compressive strength for light weight concrete at 0.48 coarse aggregate ratios.**

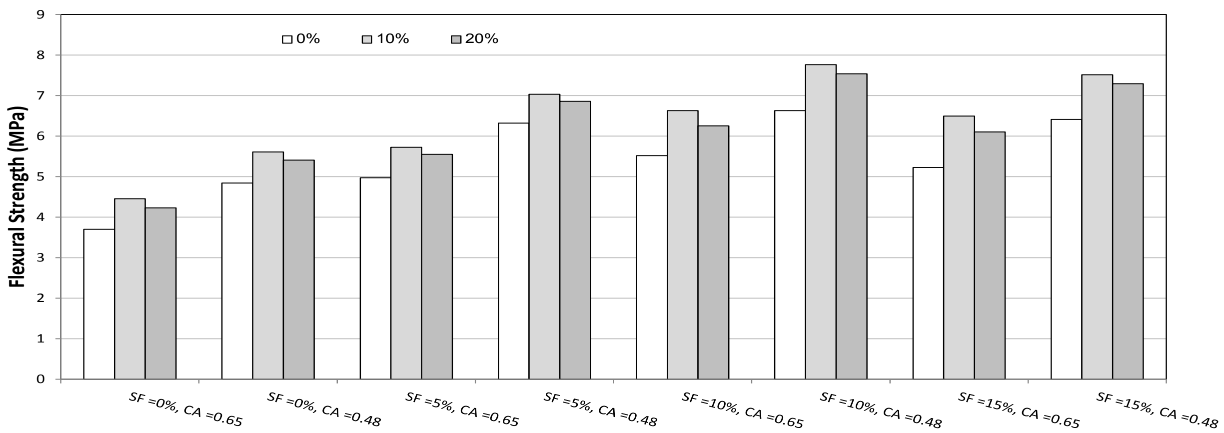


**Fig. (7) Effect of silica fume on Flexural Strength of light weight concrete for different cured aggregate solution concentration.**

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## IV. CONCLUSIONS

Based on the results from the tests reported here, the following general conclusions may be drawn in relation to lightweight, high strength concrete.

1) The compressive strength increases with silica fume content. The effect of silica fume on compressive strength is fairly marginal and certainly no benefit is to be gained from contents above 10%. This is also more generally true of flexural strength.
2) Using cured lightweight aggregate (LECA) increase the compressive and flexural strength of concrete.
3) The effect of increase the concentration of silica fume solution for 10 to 20% on strength of concrete can be negligible.
4) Coarse aggregate content has a considerable effect on mechanical properties with all being significantly greater at 0.48 coarse aggregate ratio than for a ratio of 0.65. A balance between strength and density needs to be considered according to individual applications.

## REFERENCES

[1] J. Gao, W. Sun, K. Morino, Mechanical properties of steel fiberreinforced, high-strength, lightweight concrete, Cem. Concr. Compos. 19 (4) (1997) 307– 313.

[2] R. Wasseman, A. Bentur, Effect of lightweight fly ash aggregate microstructure on the strength of concrete, Cem. Concr. Res. 27 (4) (1997) 525–537.

[3] O. Kayali, M.N. Haque, B. Zhu, Some characteristics of high strength fiber reinforced lightweight aggregate concrete, Cem. Concr. Compos. 25 (2) (2003) 207–213.

[4] R.V. Balendran, F.P. Zhou, A. Nadeem, A.Y.T. Leung, Influence of steel fibres on strength and ductility of normal and lightweight high strength concrete, Build. Environ. 37 (2002) 1361– 1367.

[5] T. Merikallio, R. Mannonen, V. Penttala, Drying of lightweight concrete produced from crushed expanded clay aggregate, Cem. Concr. Res. 26 (9) (1996) 1423– 1433.

[6] G.C. Mays, R.A. Barnes, The performance of lightweight aggregate concrete structures in service, Struct. Eng. 69 (20) (1991) 351– 361.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 5, Issue 9, March 2016

[7] Zhang M. H., Gjorv O. E., (1992), "Development of high strength lightweight Concrete", ACI SP121-34 , American Concrete Institute, , 1992, PP. 667-675.

[8] Floyd O. S., Arthur H. N., Salvador M., (1986), "Mechanical Properties of High-strength Lightweight Concrete", ACI Material Journal, American Concrete Institute, July-August, 1986, PP. 606-613.

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