High Strength Lightweight Concrete, using Scoria and Mineral Admixture

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Abstracts: The purpose of this study is to investigate a high-strength lightweight concrete (HSLWC) using Scoria aggregate and mineral admixtures. The experiment findings are presented in this paper. In the concrete mix, basaltic (scoria) was used as a lightweight aggregate. A control lightweight concrete mixture made with lightweight basaltic (scoria) containing ordinary Portland cement as the binder was prepared. The control lightweight concrete mixture was modified by replacing 10% of the cement with silica fume. The control lightweight concrete mixture was also modified by replacing 10% of the cement with metakaolin. A third mixture of lightweight concrete was also prepared, modifying the control lightweight concrete by replacing 10% of the cement with metakaolin and 10% of the cement with silica fume.

Keywords: High Strength Lightweight Concrete, Structural Light Weight Concrete, Scoria Aggregate, Pozzolanic Materials.

1. INTRODUCTION

Producing lightweight concrete became an essential work in civil engineering because Dead load resulted from weight of ceilings and separation walls is among the fundamental problems in seismic design and structures implementation especially in tall buildings and spans. In this proposal, we will try to carried out to design a structural lightweight high strength concrete (SLWHSC) made with lightweight materials (basaltic-pumice (scoria)) and mineral admixtures.

In this research, lightweight concrete mixtures consisting of Scoria lightweight aggregate, ordinary cement, mineral admixtures such as metakaolin, silica fume with super plasticizers in different proportions until reaching the highest results and comparing the results of all mixtures with the basic mixture.

There are numerous studies on using lightweight aggregate either in SLWC production or lightweight concrete block. However, there are few published studies on the use of scoria in SLWHSC. Also, there is not much published material on SLWHSC made with mineral admixtures, particularly, a ternary mixture.

This study has two objectives. The first step is to create a structural lightweight concrete using scoria aggregate which has the benefit of decreasing the dead load of the structure. The second step involves using silica fume and metakaolin mineral admixtures, separately and together, to create a SHSLWC mixture that is more affordable and environmentally beneficial by obtaining more economical and greener (environment friendly) SHSLWC mixture by the use of mineral admixture metakaolin and silica fume either together or separately..

Kilic¸ et al. [1] reported that the results of experimental work show that scoria lightweight aggregate can be used in the production of SLWC. The use of nonstandard fly ash, which will reduce the cost and environmental pollution, is possible for both fly ash SLWC and ternary mixtures. It is possible to produce lightweight concrete with a 40 MPa cylinder compressive strength with the use of silica fume. Strength can be increased and dead weight can be further decreased by adding mineral additions to structural lightweight concrete. In summary, the lightweight scoria aggregate can be utilized in its locality to reduce the risk of earthquake acceleration by using it in the production of SLWC and SLWHSC.

Topc¸u [2] reported that structural lightweight concrete has its obvious advantages of higher strength/weight ratio, better tensile strain capacity, lower coefficient of thermal expansion, and better insulating qualities against heat and sound because to the air voids in the lightweight aggregate. Furthermore, it was also reported that the reduction in the dead weight of a construction by the use of lightweight aggregate in concrete could result in a decrease in the cross section of columns, beams, plates, and foundations. Reducing the steel reinforcing is another option.

Shannag, A. et al. [3] reported that the use of mineral additives in concrete such as fly ash, silica fume, natural pozzolan, metakaolin, and calcined clay has become widespread due to their pozzolanic reaction and environmental friendliness.

Rajasekhar et al. [14] reported that the density of concrete made with pumice aggregate is very much reduced as compared to nominal concrete, so the self-weight of the structure is also reduced. Concrete density decreased as we increased the replacement percentage of normal coarse aggregate with pumice aggregate. By replacing 15% and 30% of normal aggregate with pumice aggregate, the compressive strength is promising. And gives better results compared to nominal concrete. The 45% replacement of coarse aggregate with pumice aggregate gives the least compressive strength with a greater reduction in the weight of the concrete. After analysing the results of 45% replacement, we conclude that 45% replacement is effectively used for non-structural purposes only. Henceforth, 15% and 30% of the replacement can be effectively used for structural purposes.

2. MATERIALS

2.1. Cement

National Ordinary Portland Cement (OPC) was used ASTM Type I (Bani- Swif),having at 28 day 42.5 (Mpa),specific gravity of cement was 3.15 g/cm3.Intial and final setting times were 1 and 5 hours respectively. plain specific surface area was 3140 cm2/g. Chemical composition given in Table 1.

2.2. Silica Fume

The silica fume was brought from the Egyptian Company for Ferroalloys, and XRF was used to determine its components, as the analysis showed that it is rich in silica SiO_2 by up to 80%, which means that it has pozolanic properties that benefit the cement mixture, and the results are presented in Table 1.

2.3. Silica Fume

MetaKaolin was brought from Asfour Factory for Mining and Refractories in Helwan, Egypt, and XRF referral was performed to determine the components, as the analysis showed that it is rich in silica SiO_2 by up to 60%, followed by alumina by up to 30%, which means that it has pozzolanic properties that benefit the concrete mixture, and the results are presented in Table 1.

2.4. Super-Plasticizers

the super-plasticizer Sikament® -NN is added to improve the workability of the fresh concrete, and Maintaining the water to cement ratio. It decreases the risk of segregation and bleeding and helps the concrete to be easily placed without tough vibration. It also promotes the normal setting of concrete without retardation. Furthermore, it enhances the characteristics of hardened concrete. After trials and error, the optimum amount of the super-plasticizer that was found to improve the workability of the mix is 1.5% by weight of cement. The super-plasticizer is added to the mixing water and mixed thoroughly before its addition to the aggregates and cement.

Table 1 Chemical composition xrf of cement, Mk and silica fume.

Oxide composition	Cement (C)	Metakaolin (Mk)	Silica fume (SF)
SiO2	20.65	61.24	81.40
Al2O3	5.60	32.40	4.47
Fe2O3	4.13	1.47	1.40
CaO	61.87	0.68	0.82
MgO	2.60	0.11	1.48
SO3	2.79	0.08	1.35
K2O	0.83	0.19	n/a
Na2O	0.14	0.14	n/a
LOI	1.39	0.38	7.26

2.5. Aggregate

The coarse aggregate (light-weight scoria) used in this research was natural and from Saudi Arabia. volume weight, specific gravity, absorption, and crushing value of scoria were 783 kg/m3, 1.02, 6.66%, and 11.9%, respectively. The specific gravity of scoria is 2.59 g/cm3. Crushed scoria was sieved using standard sieves of 4.75 mm,10 mm,12.5 mm, 19 mm, 25 mm, and 37.5 mm; the maximum size aggregate was 10 mm.

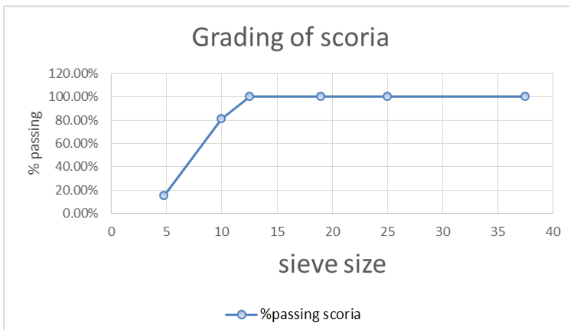

Figure 1. Sieve analysis of scoria.

2.5. Sand

The fine aggregate passing through a 4.75-mm sieve and having a specific gravity of 2.67 is used. The fine aggregate used was sand from Etfeh quarries. It was clean and free from impurities and organic material. volume weight, fineness modulus, absorption, and clay and other fine materials of sand were 1540 kg/m3, 2.67, 2.76, and 0.027, respectively. Sand was sieved using standard sieves of 150 µm, 300 µm, 600 µm, 1.18 mm, 2.36 mm, and 4.75 mm.

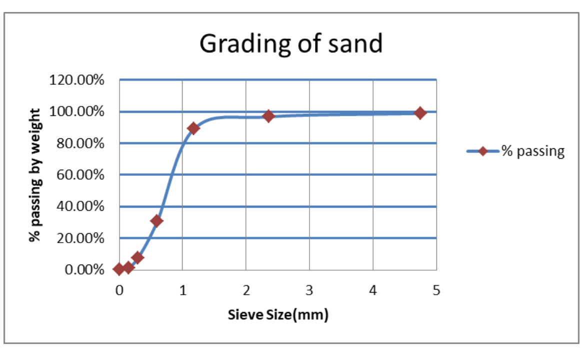

Figure 2. Sieve analysis of sand.

3. CONCRETE MIXTURE.

Table 2 Approximate concrete mixture composition Kg/m3.

Componts/mixes	CM1	M2	M3	M4
Cement	500	450	450	400
Silica fume	0	50	0	50
Water	190	190	190	190
Metakaolin	0	0	50	50
Scoria	383.50	383.50	383.50	383.50
Sand	712.22	712.22	712.22	712.22
Superplastisizer	7.50	7.50	7.50	7.5

The proportions of the control lightweight concrete CLWC mix were 1:1.4:.38 by mass of OPC, scoria, and water, respectively, and the quantity of cement was 500 kg/m3 (CM1). CLWC was modified by 10% of cement replacement by silica fume (M2); CLWC was also modified by 10% of cement replacement by Metakaolin (M3); and CLWC was also modified by 20% of cement replacement by 10% silica fume and 10% Metakaolin (M4).

Cubes sample 10*10*10 cm, and cylinders samples 20*10 cm, and beam samples (50*10*10) cm were cast from fresh concrete mixes.

After the deposition of samples, they were cured in fresh water until testing.

4. RESULTS

4.1. Slump Test

Slump test were carried out and workability was between 5.5 cm to 11 cm the control mix were the bigger value because of the superplastisizer an there was no S.F and M.K on the other hand in the mixes of S.F and M.K was average value 10cm and 7 cm respectively but the best value was at combined mix 5.5 cm.

Table 3. Slump results of concrete mix.

Mix	Slump cm
Cm1	11
M2	10
M3	7
M4	5.50

4.2. Density

Table 4 lists the average air-dry unit weights for the concrete mixtures CM1, M2, M3, and M4, along with the standard deviations. The average dead weight of HSLWC is 20% less than that of conventional concrete, according to comparisons between the air-dry unit weights of CM1, M2, M3, M4, and M4. This also implies that using HSLWC in the construction of a structure will result in a 20% reduction in seismic forces.

Table 4 Fresh density of concrete kg/m3.

Mix	Dry density kg/m^3
CM1	1793.61 ±30
M2	1781.06±30
M3	1786.59±30
M4	1774.05±30

4.3. Compressive strength.

Fig. (3) illustrates the comparison between the compressive strengths of the mixes cured in fresh water. It is recorded that the CM1 mix displayed a strength, respectively, of 29.63, 31.93, and 32.59 N/mm2 after 7, 28, and 90 days of curing with fresh water. On the other hand, mixes S.F. mix displayed a strength, respectively, of 30.46, 33.30, and 38 N/mm2 passed by 7, 28, and 90 days; M.K. mix displayed a strength, respectively, of 31.99, 35.20, and 38.38 N/mm2 passed by 7, 28, and 90 days; and finally, combined mix displayed a strength, respectively, of 32.92, 41.73, and 46.02 N/mm2 passed by 7, 28, and 90 days. It is observed that the maximum value rated for the combined mix (M4).

4.4. Splitting tensile strength.

Fig. (4) illustrates the comparison between the tensile strength of the mixes cured in fresh water in the age of 28 days. It is recorded that the CM1 mix displayed a strength of 63.8 N/mm2 after 28 days of curing with fresh water. On the other hand, mixes S.F. mix displayed a strength of 72.35 N/mm2 by 28 days, M.K. mix displayed a strength of 72.53 N/mm2 by 28 days, and finally combined mix displayed a strength of 95.57 N/mm2 by 28 days. It is observed that the maximum value rated for combined mix (M4).

4.5. Flexural strength.

Fig. (5) illustrates the comparison between the flexural strengths of the mixes cured in fresh water in the age of 28 days. It is recorded that the CM1 mix displayed a strength of 3.75 N/mm2 after 28 days of curing with fresh water. On the other hand, mixes S.F. mix displayed a strength of 4.41 N/mm2 by 28 days, M.K. mix displayed a strength of 4.39 N/mm2 by 28 days, and finally combined mix displayed a strength of 4.56 N/mm2 by 28 days. It is observed that the maximum value is rated for the combined mix (M4).

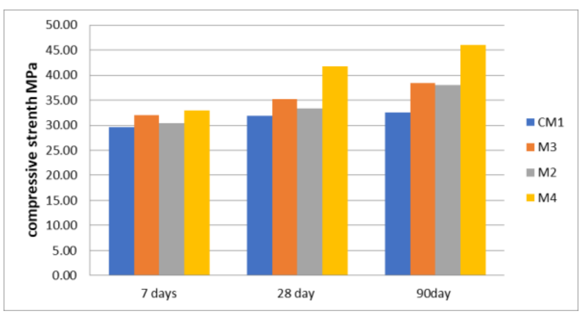

Figure 3. Compressive Strength after 7, 28, and 90 Days.

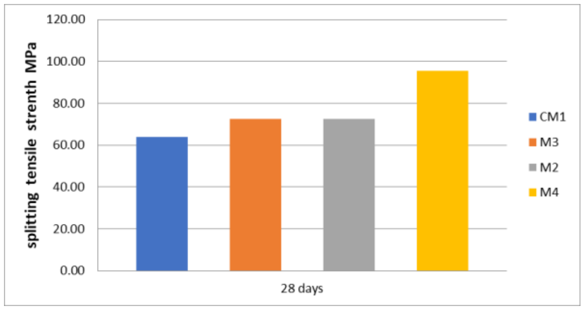

Figure 4. Splitting tensile strength after 28 days.

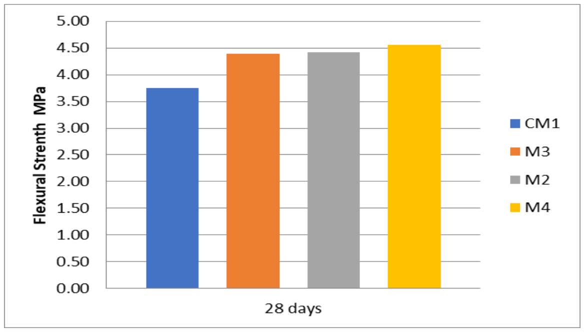

Figure 5. Flexural strength after 28 days.

4.6. Micro Structure of Control Mix.

Fig (6) Shows SEM microscopic images of the control mix, which shows that good bond between scoria and cementious paste but there are capillary pores and nonuniform of hydration components and low amount of CSH (Calcium silicate hydrate), low denser more than other mixes.

4.7. Micro Structure of Silica Fume Mix.

Fig (7) Shows SEM microscopic images of the silica fume mix, which shows a good bond between scoria and cementious paste, but silica improved the composition of the cement paste and increased the CSH content, and decreased capillary pores. Therefore, the silica sample was relatively better than the control mixture, as the sample became denser than the control sample.

4.8. Micro Structure of Metakaolin Mix.

ig (8) Shows SEM microscopic images of the Metakaolin mix, which shows that good bond between scoria and cementious paste, but Metakaolin improved the composition of the cement paste and increased the CSH content, and decreased capillary pores compared to the previous two mixes (silica mix and control mix). Therefore, the Metakaolin sample was relatively better than the two mixes. As the structure of concrete is somewhat more homogeneous, there is regularity in the distribution of hydration products, and the capillary pores are relatively less than before.

4.9. Micro Structure of Combined Mix.

Fig. (9) Shows SEM microscopic images of the combined mix, which contains metakaolin and silica fume, which shows that the mix is the best one because it improves the composition of the cement paste due to increased CSH content, which is the main phase responsible for strength properties, and decreases capillary pores more than the previous mixes. Therefore, the combined sample was the best one than the three mixes, as the structure of concrete is more compacted and homogeneous.

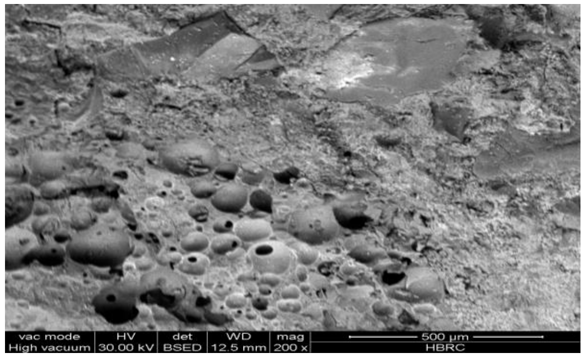

Figure 6. SEM of control mix CM1.

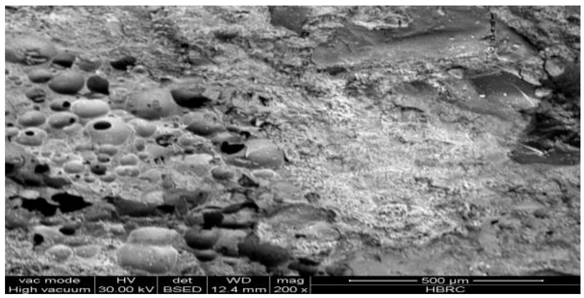

Figure 7. SEM of S.F mix M1.

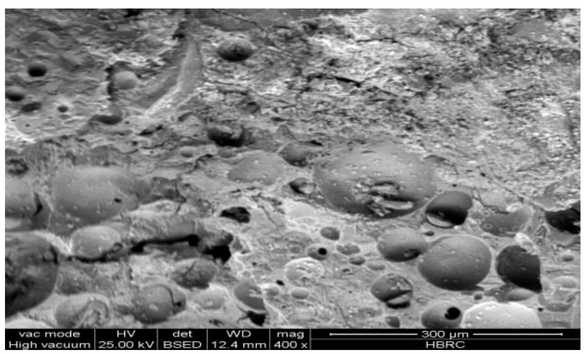

Figure 8. SEM of M.K mix M2.

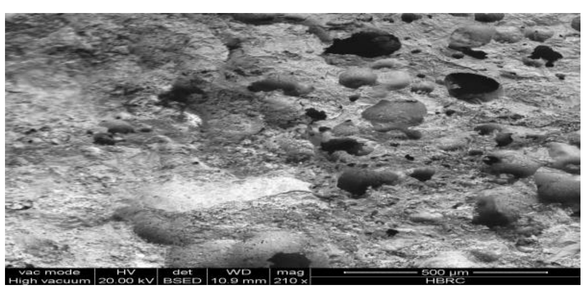

Figure 9. SEM of compind mix M3.

CONCLUSIONS

We can obtain high strength light weight HSLWC concrete by using SCORIA and mineral admixture. The quantity used of metakaolin and silica fume was 10%, 15%, and 20% of S.F. and M.K. separately, and we found that 10% of mineral admixture is a suitable amount of replacement for cement. When using 10% S.F. + 10% M.K. + scoria, the results were the best, and we reached up to 40 MPa at 28 days.

Using light weight concrete LWC is essential in High-rise buildings because dead load of LWC is 20% less than that of conventional concrete due to decrease in density because of use of light weight aggregate.

Microscopic images of the mixes Shows that the mix that contains silika fume and metakaolin is the best one because it improves the composition of the cement paste due to increased CSH (Calcium silicate hydrate) content, which is the main phase responsible for strength properties, and decreases capillary pores more than other mixes. Therefore, the compind sample was the best of the three mixes, as the structure of concrete is more compacted and homogeneous.

Based on the out findings of this experimental research, the following is recommended for further exploration work:

•Use Nano silica for obtaining ultra-high strength light weight concrete.

•Use combined aggregate to obtain lightweight concrete.

•The role of silica fume, metakaolin on the slump of mix needs more emphasis on research.

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