EXPERIMENTAL INVESTIGATION ON CONCRETE USING SILICA FUME AND WASTE PAPER

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Abstract-With increased environmental awareness and its potential hazardous effects, utilization of industrial byproducts has become an attractive alternative to disposal. Silica fume (SF), which is byproduct of the smelting process in the silicon and ferrosilicon industry. Silica fume is very effective in the design and development of high performance concrete. This paper presents the results of an experimental investigations carried out to find the suitability of silica fume in High Performance concrete. India is facing a serious challenge in disposing of waste in the many landfills throughout the country that are near or at capacity. The landfill situation is resulting in high disposal costs and potential environmental problems. If the current situation continues with waste production is grow by 5% each year, landfills would be at full capacity by 2020. This paper reports on the results of an experimental investigation for concrete using wastepaper as additional materials in concrete mixes to be used in housing projects, for which it must be assured that the waste paper concrete has the proper mechanical strength. Concrete mixes containing various contents of the paper was prepared and basic strength characteristics such as compressive strength, splitting tensile were determined and compared with a control mix. The concrete mixes containing of the waste material, such as conventional concrete.

Keywords- Silica Fume (Sf), Potential Hazardous Effects, Concrete Mixes, Compressive Strength, Splitting Tensile

1. Introduction

Silica fume definition The American Concrete Institute (ACI) defines silica fume as "very fine no crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon". It is usually a grey colored powder, somewhat similar to Portland cement or some fly ashes. Figure shows a typical silica fume as it appears after being collected from a furnace.

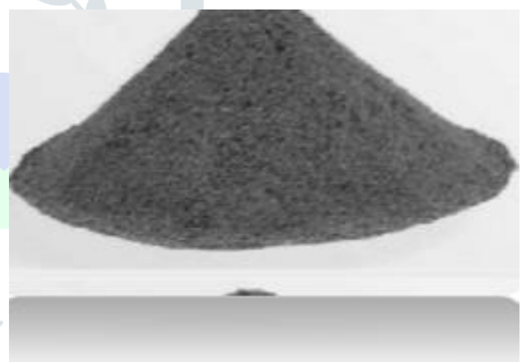


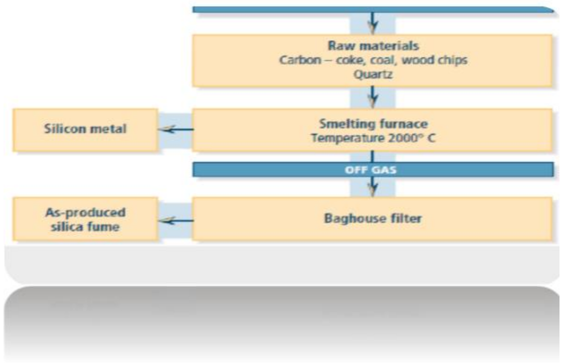
Fig 1 Silica Fume

Silica fume is frequently referred to by other names. Here are some of the other names for silica fume

- Condensed silica fume
- Microsilica
- Volatilized silica

1.1 Production

Silica fume is a by-product of producing silicon metal or ferrosilicon alloys in smelters using electric arc furnaces. These metals are used in many industrial applications to include aluminum and steel production, computer chip fabrication and production of silicones, which are widely used in lubricants and sealants. While these are very valuable materials, the byproduct silica fume is of more importance to concrete industry. The smoke leaving the plant is actually silica fume. A schematic of silica fume production is shown in the figure. The silica fume is collected in very large filters in the bag house and then made available for use in concrete directly or after additional processing.



PRODUCTION OF SILICA FUME

Fig 2 Production of Silica Fume

1.2 Silica Fume Properties and Reactions in Concrete

- **Chemical Properties**

The primary chemical properties of silica fume are shown in table. Following is a discussion of each of these properties.

This term simply means that silica fume is not a crystalline material. A crystalline material will not dissolve in concrete, which must occur before the material can react. There is a crystalline material in concrete that is chemically similar to silica fume. The material is sand. While sand is essentially silicon dioxide (SiO_2), it does not react because of its crystalline nature.

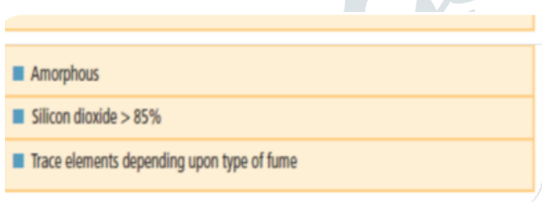


Fig 3 Silicon Dioxide

➢ **Silicon dioxide (SiO_2)**

This is the reactive material in silica fume. There may be additional materials in silica fume based upon the metal being produced in the smelter from which the fume was recovered. Usually, these materials have no impact on the performance of silica fume in concrete. Standard specifications may put limits on some of the materials in this category.

➢ **Physical Properties**

The primary physical properties of silica fume are shown in the table. Following is a discussion of each of these properties.

➢ **Particle size**

Silica fume particles are extremely small, with more than 95% of the particle size being less than 1μm. Particle size is extremely important for both the physical and chemical contribution of silica fume in concrete.

➢ **Bulk density**

This is another term for unit weight. The bulk density of the as produced silica fume depends upon the metal being made in the furnace and upon how the furnace is operated. Because the bulk density of the as produced fume is usually very low, it is not very economical to transport it for long distances.

➢ **Specific gravity**

It is a relative number that tells how silica fume compares to water, which has a specific gravity of 1.00. This number is used in proportioning concrete. Silica fume has a specific gravity of about 2.2, which is somewhat lighter than Portland cement, which has a specific gravity of about 3.15. Thus adding silica fume to concrete mixture will not density the concrete in terms of increasing the density of the concrete.

➢ **Specific surface**

It is the total surface area of a given mass of a material. Because the particles of silica fume are very small, the surface area is very large. We know that water demand increases for sand as the particles become smaller; the same happens for silica fume. This fact is why it is necessary to use silica fume in combination with a water reducing admixture or super plasticizer. A special test called BET method or nitrogen adsorption method must be used to measure the specific surface of silica fume. Specific surface determinations based on sieve analysis or air permeability testing are meaning less for silica fume.

2. Background

R. Srinivasan, K. Sathiya & M. Palanisamy reported on "Experimental investigations in developing low cost concrete from paper industry waste". Over 300 million tons of industrial wastes are being produced per annum by chemical and agricultural process in India. These materials pose problems of disposal and health hazards. The wastes like phosphor gypsum and red mud contain obnoxious impurities which adversely affect the strength and other properties of building materials based on them. **A Balwaik & SP Raut** reported on "Utilization of waste paper pulp by partial replacement of cement in concrete". The use of paper-mill pulp in concrete formulations was investigated as an alternative to landfill disposal. The cement has been replaced by waste paper sludge accordingly in the range of 5% to 20% by weight for M-20 and M-30 mix. By using adequate amount of the waste paper pulp and water, concrete mixtures were produced and compared in terms of slump and strength with the conventional concrete. **Verma ajay et al**. have studied the effect of micro silica and the strength of concrete with ordinary Portland cement. They observed that silica fume increases the strength of concrete and reduces capillary pores. **Dilip Kumar Singha** Roy has investigated on the strength parameters of concrete made with partial replacement of cement by Silica Fume. **T. Shanmugapriya** studied the influence of silica fume on M60 concrete and found that 7.5% of silica fume replacement increases the maximum compressive strength, split tensile strength and flexural strength. **H. Katkhuda, B. Hanayneh & N. Shatarat** reported on "The effects of silica fume on compressive strengths on high strength lightweight concrete". They carried out by replacing cement with different percentages of silica fume at different constant water-binder ratio keeping other mix design variables constant. The silica fume was replaced by 0%, and 8% for a waterbinder ratios ranging from 0.26 to 0.42. For all mixes, compressive strength was determined at 7& 28 days. The results showed that the compressive strengths increased with silica fume incorporation but the optimum replacement percentage is not constant because it depends on the water cementitious material (w/c) ratio of the mix. Based on the results, a relationship between compressive strengths of silica fume concrete was developed using statistical methods.

3. Materials and Methodology

3.1. Materials Used andTesting

3.1.1 Portland cement

The cement used was commercially available TCI 43 grade. This cement complies with the requirements of IS: 8112-2013 for ordinary Portland cement 43 grade.

3.2 Coarse Aggregates:

The coarse aggregate used were boulder crushed. Two types of coarse aggregates were used, 20 mm and 10 mm nominal size. The specific gravity of coarse aggregates was 2.71.

3.3 Test on Coarse Aggregates

3.3.1 Sieve Analysis

The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate which we call gradation. The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm ,10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron. The aggregate fraction from 80 mm to 4.75 mm are termed as coarse aggregates and those fraction from 4.75 mm to 150 micron are termed as fine aggregates. Grading pattern of a sample of CA or FA is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with large sieve at the top. The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above. Sieving can be done either manually or mechanically. In the manual operation the sieve is shaken giving movements in all possible directions to give chance to all particles for passing through the sieve. Operation should be continued till such time that almost no particle is passing through. From the sieve analysis the particle size distribution in a sample of aggregate is found out. In this connection a term called fineness modulus is being used. It is a ready index of coarseness or fineness of the material .It is an empirical factor obtained by adding the cumulative percentage of aggregates retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by an arbitrary umber 100 .The larger the figure, the coarser is the material.

3.3.2 Fine Aggregates

The fine aggregates used in all the mixes was a natural sand conforming to grading zone II after sieve analysis as per IS-383-1970. Its bulk specific gravity at SSD was 2.65 and its fineness modulus ranged from 2.9-3.2.

4. Result and Discussion

It is quite evident from the test results that there is increase in the compressive strength (both 7 Day and 28 Day Compressive Strength) of the silica fume concrete as compared to the compressive strength of the conventional concrete. It is found that the compressive strength (both 7 day and 28 day) increased with the increase in the dosage of silica fume upto certain limit of replacement of cement by silica fume and waste paper. When the dosage of waste paper was further increased after 15%, it showed dip in the compressive strength of Silica Fume & waste paper Concrete. Thus 15% is the optimum dosage of incorporation of waste paper in Concrete. However, the incorporation of waste paper in concrete reduced the workability of the concrete. It is quite evident from the test results that there is increase in the compressive strength (both 7 Day and 28 Day Compressive Strength) of the silica fume concrete as compared to the compressive strength of the conventional concrete. It is found that the compressive strength (both 7 day and 28 day) increased with the increase in the dosage of silica fume upto certain limit of replacement of cement by silica fume and waste paper. When the dosage of waste paper was further increased after 15%, it showed dip in the compressive strength of Silica Fume & waste paper Concrete. Thus 15% is the optimum dosage of incorporation of waste paper in Concrete. However, the incorporation of waste paper in concrete reduced the workability of the concrete.

Also, Silica Fume being finer then cement, demands for more water as its specific surface area is quite large then the cement. Thus at constant water cement ratio, workability of the mix is reduced. To overcome the above stated problem, that is, to enhance the workability of mix at the optimum dosage of incorporation of Silica Fume and waste paper in Concrete, Plasticizer having sufficient plasticity to improve the workability of the mix.

Addition of Plasticizer, at the optimum dosage of incorporation of Silica Fume and waste paper, gives great results for both compressive strength and even for the workability.

4.1 Remedy for enhancing workability

It was seen that with increase in the dosage of waste paper in concrete the workability of concrete was reduced. In order to increase the workability of concrete at optimum dosage of 20% replacement of cement by 5% silica fume and 15% waste paper we added plasticizer Master Polyheed 8101 at the dosage of 0.7% replacement of cement by the said plasticizer:

Table 1. Trial mix with 15 % waste paper, 5% of silica fume and 0.7 % of plasticizer

Grade of Concrete: M30								
Water Cement Ratio: 0.45								
Description	**Cement**	**Sand**	**CA10mm**	**CA-20mm**	**Water**	**Silica fume**	**Master polyheed**	**Waste paper dosage**
Standard Quantities	**350.17**	**674.17**	**459.16**	**688.74**	**197.00**	**5%**	**0.7%**	**15%**
Moisture Content	-	2.56	0	0	-	-	-	
Water absorption	-	1.40	1.10	0.47	-	-	-	
%ofadjustment	-	1.16	-1.10	-0.47	-	-	-	
Correction Required	-	7.82	-5.50	-3.24	0.47	-	-	

Corrected quantity	**350.17**	**681.99**	**454.11**	**685.50**	**197.47**	**21.88**	**3.06**	**65.65**

Table 2. Test Result for workability

Workability	Slump value	Compacting factor
	160mm	0.95

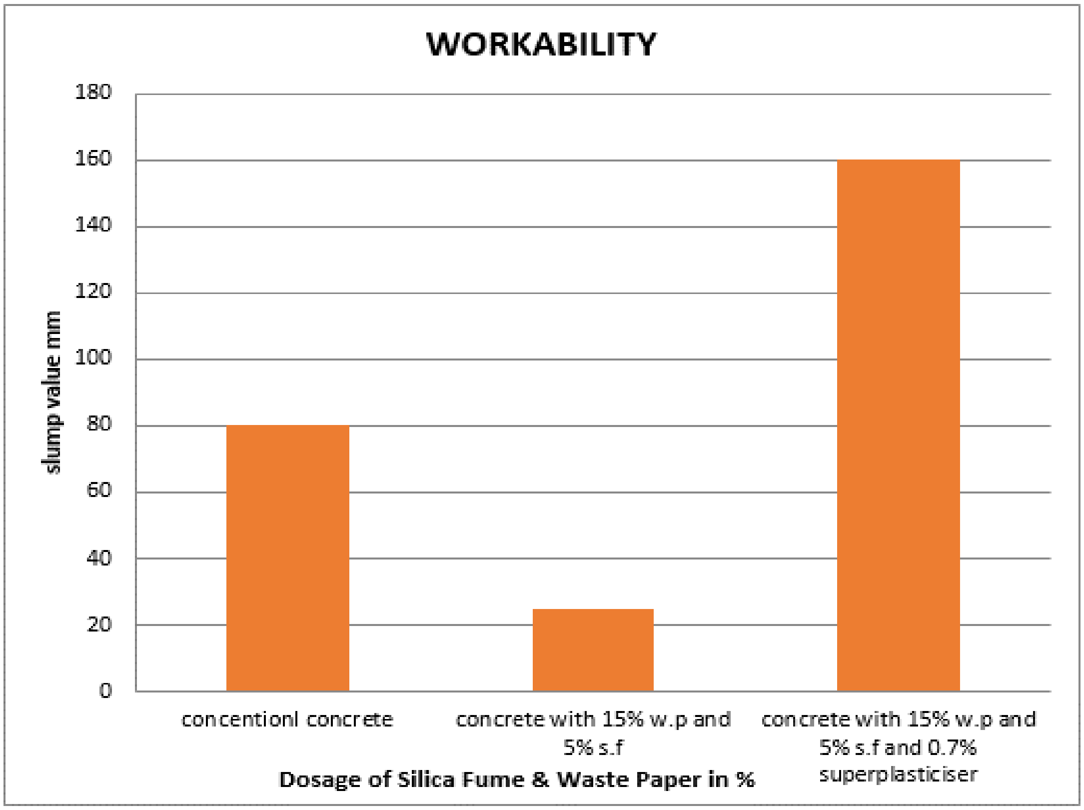
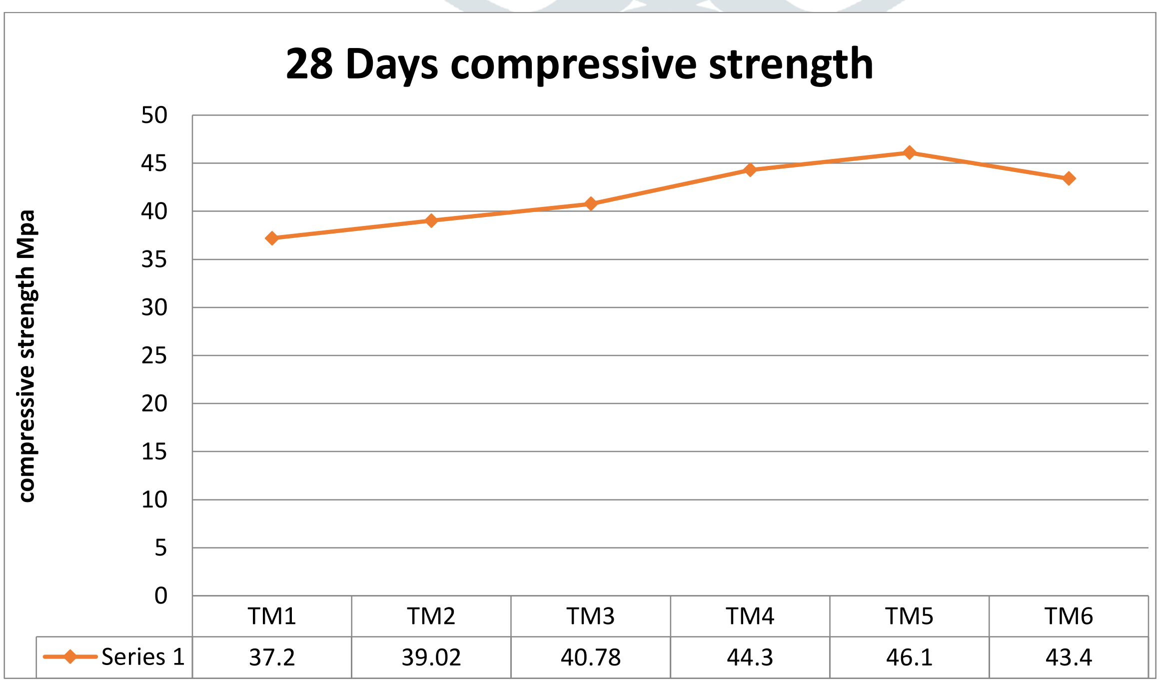
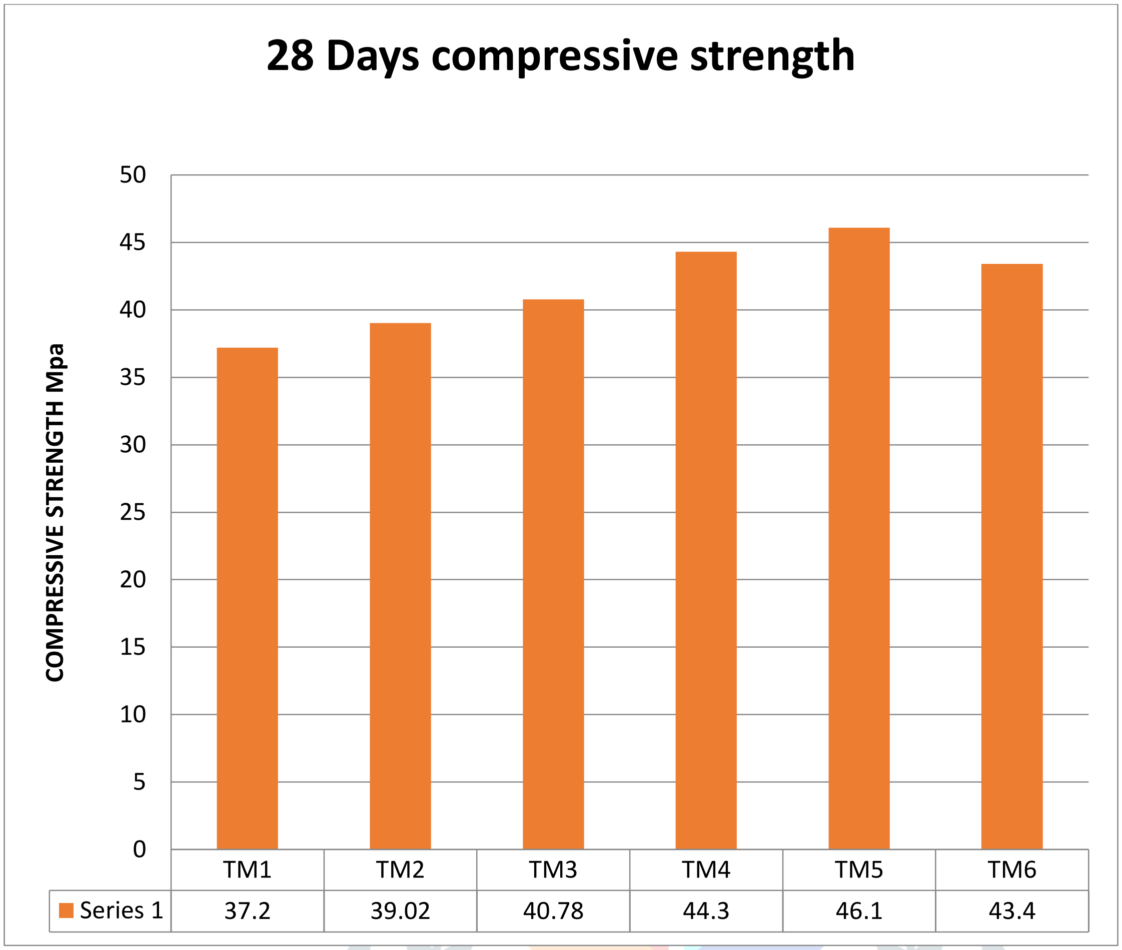
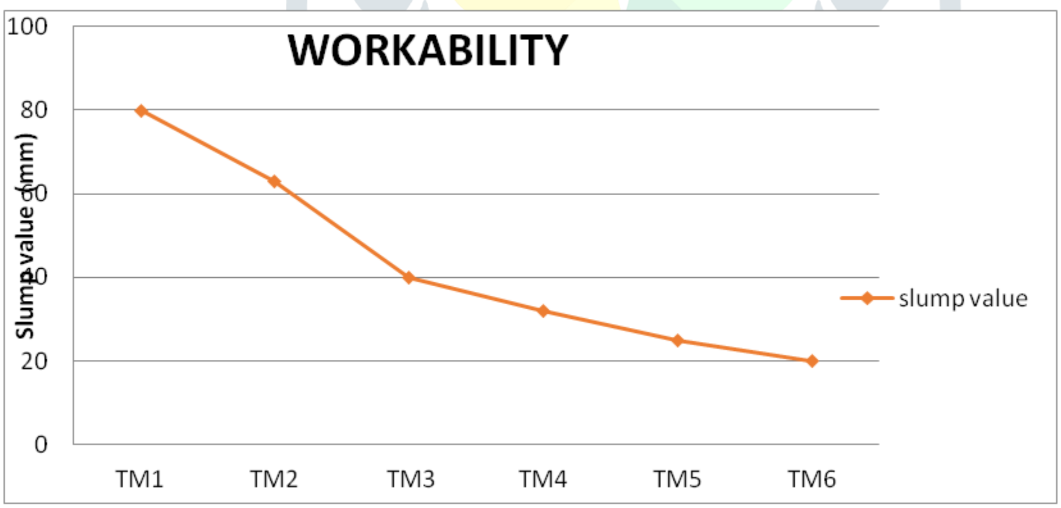


Fig 4. Comparative results of workability

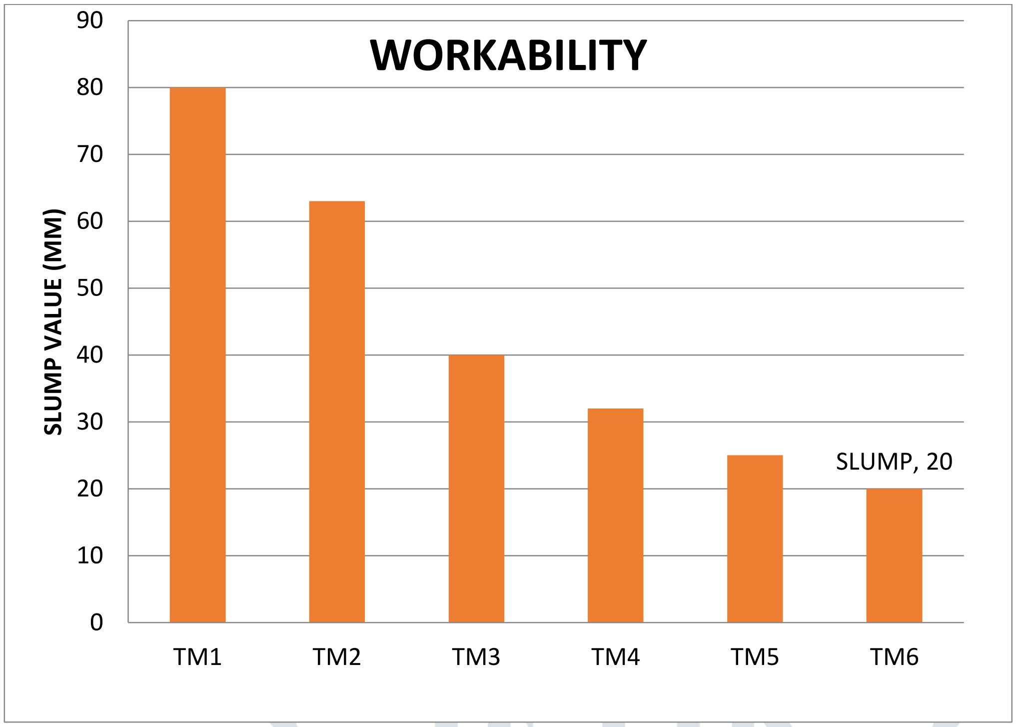


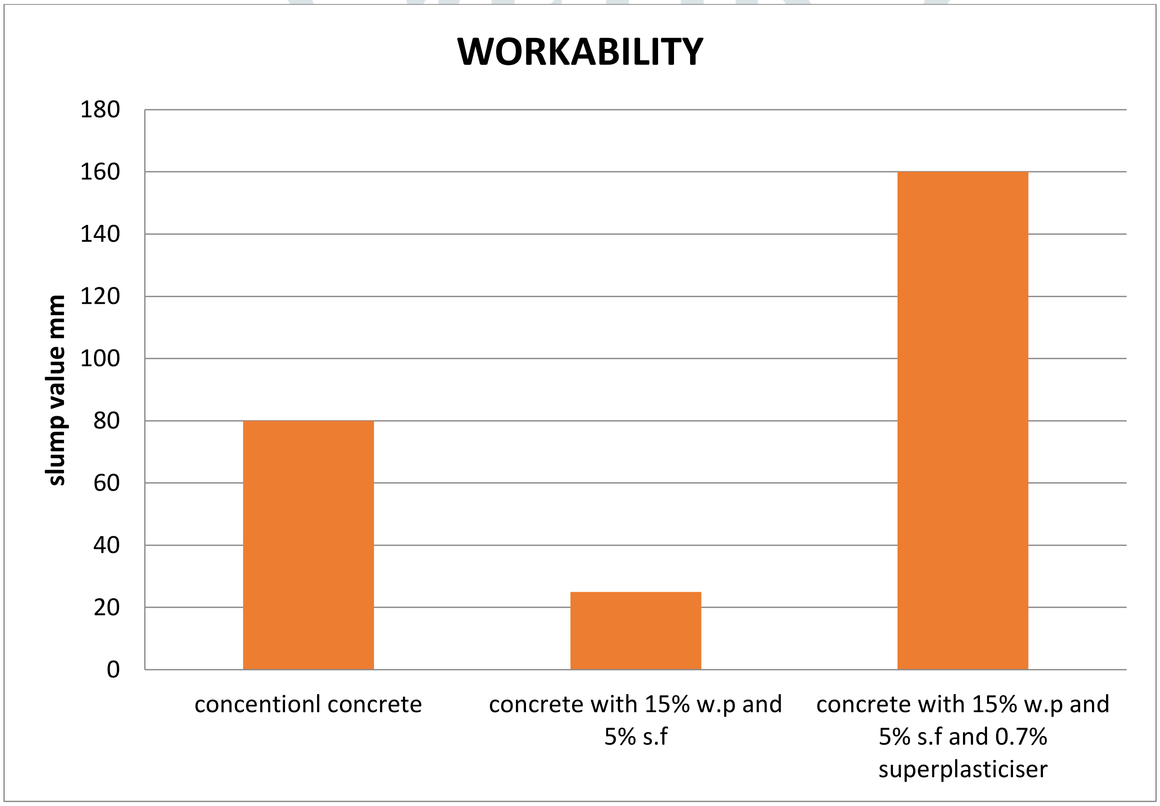


Compressive Strength After 28 Days



Workability For Trial Mixes





Comparative results of workability.

Conclusion

Test Results from the present study, combined with collected data from the literature, were analytically evaluated and following conclusions was drawn. The study on M30 grade of concrete at 0.45 water cement ratio yielded the following results; Compressive strength of concrete increases with increase in the percentage of waste paper. At 0% dosage of silica fume and 0% dosage of waste paper, the compressive strength was found to be 37.2 Mpa. As the silica fume waste paper is introduced into the concrete the strength increases. The optimum dosage of silica fume & waste paper by weight of cement was found to be 5% &15% resp. The compressive strength at this dosage came out to be 46.1 Mpa. This means a strength of concrete increases by 9

Mpa. To increase in compressive strength is not indefinite but upto a particular dosage of silica fume and waste paper which in our research came out to be 5% and 15% resp. The compressive strength at this dosage reduced to 43.4 Mpa. The workability of concrete however decreases with the increase in the dosage of waste paper.This was remedied by adding some optimum d0sage of super plasticizer. Thus by all the results and economic analysis carried out, it is concluded that use of silica fume and waste paper is economical for partial replacement of cement in concrete. This will further help in reducing environmental pollution.

Future Work

Following are few recommendations that can be done to further enhance the usefulness of the experiment.

1. The work was carried out in winter without the use of accelerators. Accelerators can be added which could further enhance the strength of concrete.
2. Different super plasticizers can be added to enhance the workability and the super plasticizer which increases the workability to required value at minimum dosage may be adopted.
3. Accurate optimum dosage of silica fume and waste paper can be obtained by decreasing the dosage difference.
4. The experiment can be proceeded to dosage of wste paper beyond 20% to see if the trend remains the same or changes.
5 .Different zones of sand and grades of aggregates can be used to carry out the experiment.
6. Ultra high strength concrete can be obtained using different chemical and mineral admixtures.
7. Work can be carried out to determine the effect of silica fume on the permeability of concrete.

References

1. Igarashi S, Watanabe A and Kawamura M., Evaluation of capillary pore size characteristics in high-strength concrete at early ages. Cement and Concrete Research, 35(3), 2005, 513- 519.
2. Bhanja,s. and Sengupta,B.(2002).”Investigations on the composite structure ofsilica fume concrete using statisticalmethods”, Cement and Concrete Research,Vol.32, pp.1391-1394.
3. Australian Bureau of Statistics (2013), “Waste Account, Australia, Experimental Estimates”, Australian Bureau of Statistics, 4602.0.55.005, Catalogue, http://www.abs.gov.au [accessed on 31st August 2013].
4. Elhakam, A., Mohamed, A., Awad, E., (2012) “Influence of self-healing, mixing method and adding silica fume on mechanical properties of recycled aggregates concrete”, Construction and Building Materials, Vol. 35, pp. 421-427.
5. Roy, D. K. (2012). Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete. International Journal of Emerging Technology and Advanced Engineering, 2(8), 472-475.
6. Amarkhail, N. (2015). EFFECTS OF SILICA FUME ON PROPERTIES OF HIGH-STRENGTH CONCRETE. International Journal of Technical Research and Applications, 13-19.
7. Sharma, a. &Seema (2012). Effect of partial replacement of cement with silica fume on compressive strength of concrete. International journal of research in technology and management, 1 (1), 34- 36
8. Ghutke, Prof. Pranita S. Bhandari, “Influence of silica fume on concrete”, IOSR Journal of Mechanical and Civil Engineering 2014.
9. Mohammad Iqbal Khana and Rafat Siddiqueb, Utilization of silica fume in concrete: Review of durability properties, Resources, Conservation and Recycling, 2011, 57, 30–35
10. Aitcin, P.C., and Laplante, P. (1990),“Long-term compressive strength of silicafume concrete”, Journal of Materials in CivilEngineering, Vol. 2, No. 3, pp. 164-170
11. Mohammad Panjehpour, Abang Abdullah, Abang Ali, Ramazan Demirboga "A review for characterization of silica fume and its effects on concrete properties ".
12. Mr.R.Balamurugan, Mr.R.Karthickraja "An experimental investigation of partial replacement of cement by industrial waste (Hypo Sludge)". ISSN : 2248-9622, Vol. 4, Issue 4(Version 1), April 2014, pp.430-435.