A Study on Mechanical Properties of Self-Compacting Concrete by Partial Replacing Cement with Pozzolanic Materials Fly Ash, Silica Fume and Lime Sludge

M. Venkateswari
PG Student
Department of Civil Engineering
DNR College of Engineering & Technology Bhimavaram, Andhra Pradesh, India

Mrs J. Keerthana
Assistant Professor
Department of Civil Engineering
DNR College of Engineering & Technology Bhimavaram, Andhra Pradesh, India

Mr. M. K. M. V. Ratnam
Assistant Professor
Department of Civil Engineering
DNR College of Engineering & Technology Bhimavaram, Andhra Pradesh, India

Dr. U. Ranga Raju
Professor
Department of Civil Engineering
DNR College of Engineering & Technology Bhimavaram, Andhra Pradesh, India

Abstract

Now a days the production of cement is highly coastly and significantly affects the environment. the CO2 has increased manifold over the last decade or so leading to global warming .thus it is the need of the how to contro the usage of cement so that its production can be reduced optimal usage the present study has been done to find the optimal usage industrial by products fly ash, silicafume, limesludge to be as substitutes of cement Fly ash, a byproduct from the thermal power plant and it is a pozzolanic material. Silica fume as very fine non crystalline silica produced in blast furnace as by product of the production of elemental silicon or alloys containing silicon .Lime sludge is generated from paper, acetylene, sugar, fertilizer, sodium chromate and soda ash industries Attempts have been made to study the properties of self-compacted concrete and to investigate properties of fly ash, silica fume, lime sludg and its suitability of those properties to enable them to be used as partial replacement materials for cement in concrete Experimental investigation on strength aspects like compressive, flexural, and split tensile strengths of self-compacting concrete (SCC) containing different levels of flyash, silica fumes, lime sludge, and workability tests for different mineral admixtures (slump, L –box, V-funnel and T50) are carried out .the methodology adopted is that mineral fly ash is replaced by ((5%,10%,15%,20%,25%,30%), silica fume (5%,10%,15%,20%,25%,30%), lime sludge (5%,10%,15%,20%, 25%,30%) in cement and performance is measured and compared. Hardned tests carried out by two different combinations of these three pozzolanic materials 1.(flyash+silica fume+limesludge) is replaced by(25%+5%+0%, 20%+5%+5%, 15%+5%+10%, 10%+5%+15%) in cement and performance is measured. 2. (silica fume+fly ash) is replaced by (2.5 %S+5%F, 5%S+10%F , 7.5%S+15%F, 10%S+20%F, 12%S+15%F) in cement and performance is measured.

Keywords: Self-Compacting Concrete, Fly Ash, Silica Fume and Lime Sludge

I. INTRODUCTION

Concrete technology has under gone from macro to micro level study in the enhancement of strength and durability properties from 1980's onwards. Till 1980 the research study was focused only to flow ability of concrete, so as to enhance the strength however durability did not draw lot of attention of the concrete technologists. This type of study has resulted in the development of self compacting concrete (SCC), a much needed revolution in concrete industry. Self compacting concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of form work under its self weight only (Okamura 1999) . Thus SCC eliminates the needs of vibration either external or internal for the compaction of the concrete without compromising its engineering properties. Compaction for conventional concrete is done by vibrating. Over vibration can easily cause segregation. In conventional concrete, it is difficult to ensure uniform material quality and good density in heavily reinforced locations. If steel is not properly surrounded by concrete it leads to durability problems.

The SCC concept can be stated as the concrete that meets special performance and uniformity requirements that cannot always be obtained by using conventional ingredients, normal mixing procedure and curing practices. The SCC is an engineered material consisting of cement, aggregates, water and admixtures with several new constituents like colloidal silica, pozzolanic materials, and chemical admixtures to take care of specific requirements, such as, high-flow ability, compressive strength, high workability, enhanced resistances to chemical or mechanical stresses, lower permeability, durability, resistance against

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segregation, and possibility under dense reinforcement conditions. The properties, such as, fluidity and high resistance to segregation enables the placement of concrete without vibrations and with reduced labour, noise and much less wear and tear of equipment. Use of SCC overcomes the problem of concrete placement in heavily reinforced sections and it helps to shorten construction period. Self-compacting concrete is growing rapidly, especially in the precast market where its advantages are rapidly understood and utilized. in view of global warming ,efforts are on to reduce the emission of carbon di oxide to the environment .cement industry is amajor contributor in the emission of carbon di oxide as well as using up high levels of energy resources in the production of cement .by replacing cement with a material of pozzolanic characterstic ,such as industrial wastes fly ash ,silica fumes ,lime sludge (these are industrial wastes and recently, agricultural wastes are also being used as pozzolanic materials in concrete) ,the cement and concrete industry together can meet the growing demand in the construction industry as well as help in reducing the environmental pollution.

When pozzolanic materials are incorporated to concrete, the silica present in these materials react with the calcium hydroxide released during the hydration of cement and forms additional calcium silicate hydrate (C – S – H), which improve the mechanical properties of concrete.

The purpose of this research was to study the application and utility of these industrial wastes as a cementitious/pozzolanic material in construction Industry.

II. Literature review

Cengiz (2005) used fly-ash with SCC in different proportional limit of 0%, 50% and 70% replacement of normal Portland cement (NPC). He investigated the strength properties of self compacted concrete prepared using HVFA (high volume fly ash). Concrete mixtures made with water-cementitious material ratios ranged from 0.28 to 0.43 were cured at moist and dry curing conditions. He investigated the strength properties of the mix and developed a relationship between compressive strength and flexural tensile strength. The study proved that it is possible to convert an RCC (zero slump) concrete to a workable concrete with the use of suitable superplasticizer.

E. Sureshkumar et al (2013), this paper examines the possibility of using copper slag as partial replacement of sand and Nano Silica as partial replacement of cement and super plasticizer and Viscosity Modifying Agent are used in self compacting concrete, in order to overcome problems associated with cast-in-place concrete. Self compacting concrete does not require skilled labours. The percentage of copper slag to be added is 10%, 20%, 30% of total weight of sand. The percentage of Nano Silica to be added is 2%, 4%, 6%, and 8% of total weight of cement. According to ACI: 211.4R code of practice, control specimen is casted for M40. Finally the workability and strength characteristics of concrete have been compared with conventional concrete

III. Experimental analysis

A. *Cement: (ANJANI cement of 53grade ordinary Portland cement was used)*

The cement used for the investigation was Ordinary Portland cement .the cement is fresh and is of uniform colour and consistency.it is free from lumps and foreign matter. The cement The cement procured was tested for physical requirements in accordance with IS : 12269-1987 and for chemical requirements in accordance with IS: 4032-1977.The cement conforms to 53 grade

B. *Fly Ash*

Fly ash is one of the types of coal combustion by- products .The use of these by-products offers environmental advantages divert the material from the waste stream, reduce the energy used in processing virgin materials, use of virgin materials, and decreases pollution.in this experimental investigation the fly ash used confirming to IS: 3812-2003 part- II.

C. *Silica Fume*

Silica fume as very fine non crystalline silica produced in blast furnace as by product of the production of elemental silicon or alloys containing silicon. Silica fume is usually categorized as a supplementary cementitious material. It has excellent pozzolanic properties. in this experimental investigation the silica fume is in white colour powder form.

D. *Lime Sludge*

Lime sludge is generated from paper, acetylene, sugar, fertilizer, sodium chromate and soda ash industries. Approximately 4.5 million tons of sludge in total are generated annually from these industries. The lime sludge from paper industry has been found suitable as blending material for manufacture of masonry cement in the proportion of up to 30 percent conforming the Indian Standard specification of IS:3466-1988.

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E. Fine Aggregate (Sand)

The fine aggregate used in this experimental investigation is river sand confirming to zone-II as per IS:383:1970. The sand is free from clay, silt and organic impurities. sand which is passing through 600micron sieve is taken and The sand is tested for various properties like specific gravity, bulk density etc., and in accordance with IS 2386-1963.

F. Coarse Aggregate

The coare aggregate used, was from an established quarry satisfying the requirements of IS:383:1970. In this experimental investigation Machine crushed angular granite metal of 20mm nominal size from the local source is used as coarse aggregate .It is free from impurities such as dust, clay particles and organic matter etc. The coarse aggregate is also tested for its various properties specific gravity, bulk density and fineness modulus of coarse aggregate were found to be 2.74, 1580kg/m3 and 7.17 respectively.

G. Chemical Admixture

Chemical admixture reduces the cost of construction the cost of construction, modify the properties of concrete and improve the quality of concrete during mixing, transportation, placing, and curing.

IV. TESTS CONDUCTED

A. Fresh Concrete Tests

For determining the self-compatibility properties (slump flow, t50 time, v-funnel flow time, l-box blocking ratio) tests were performed on all mixtures the order of testing was:

1) Slump flow test and measurement of T50 time
2) V-funnel flow test
3) L- box blocking test ,respectively.

The tests were performed according with EFNARC standards.

1) Slump flow test and measurement of T50 time

a) Filling Ability

Self-compacting concrete must be able to flow into all the spaces within the formwork under its own weight. This is related to workability, as measured by slump flow test and slump flow T50cm test shown in Fig.3.

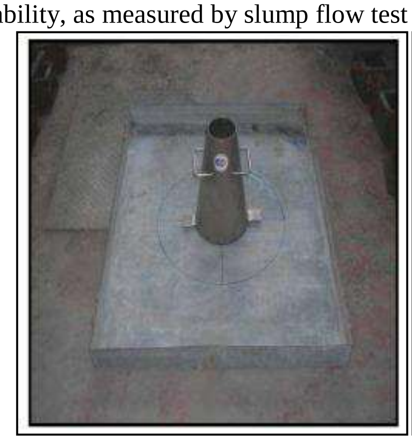

Fig. 1: Slump flow

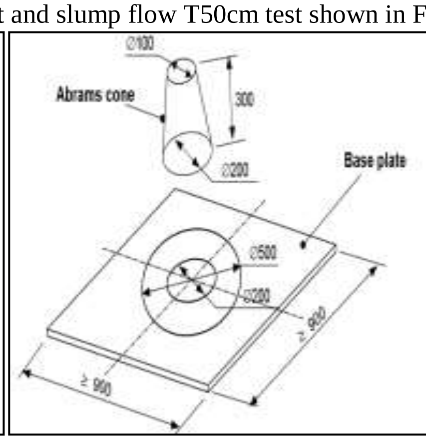

Fig. 2: Dimensions of base plate

Fig. 3: Slump Flow Test

The fresh concrete poured into a cone as used for slump test when the cone is withdrawn upwords the time from commencing upword movement of the cone to when concrete has flowed to a diameter of 500mm is measured ,this is the T_{50} time the largest diameter of the flow spread of the concrete and the diameter of the spread at right angles to it are then measured and the mean is the slump flow

2) V-Funnel Flow Test

a) Resistance of Segregation

Resistance to the segregation is the property that characterizes the ability of the SCC to avoid the segregation of its components, such as the coarse aggregates. The V- Funnel T5min test is the most common method used to assess this property.

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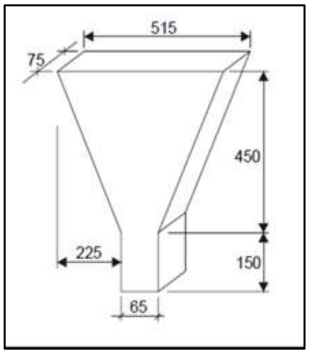

Fig. 4: Dimensions of v-funnel test

Fig. 5: V- Funnel test

Fig. 6: V- Funnel flow

A 'V'shaped funnel is filled with fresh concrete and the time taken for the concrete to flow out of the funnel is measured and recorded as the V-funnel flow time.

3) L- box text

a) Passing Ability

Self compacting concrete must flow through tight openings such as spaces between steel reinforcing bars under its own weight. The mix must not 'block' during placement. L-Box test are the most common methods used to assess this property.

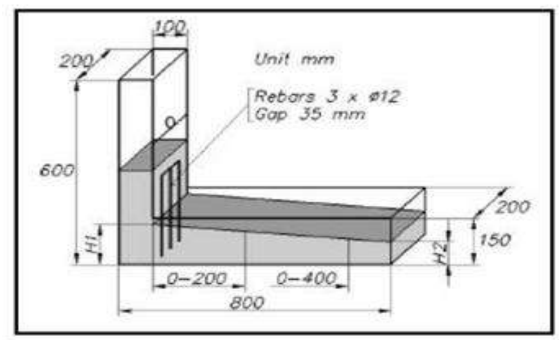

Fig. 7: Dimensions of L-Box

Fig. 8: Flow through rebar in L-Box

A measured volume of fresh concrete is allowed to flow horigontally throw the gaps between vertical, smooth reinforcing bars and the height of the concrete beyond the reinforcement is measured.

B. Hardened Tests

- Compressive Strength
- Split Tensile Strength
- Flexural Strength

Compressive, flexural strength tests were performed as per Indian standards 516:1959, split tensile strength test was performed as per Indian standards 5816:1970.

1) Compressive Strength

Compressive strength can be defined as the measure maximum resistance of a concrete to axial loading. The specimens used in the compressive test are: 150 mm x 150mm x 150mm

Fig. 9: Compression Testing Machine

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The compression testing machine used for testing the cube specimens is of standard make.the capacity of testing machine is 3000KN. The machine has a facility to control the rate of loading with a control valve.the plates are cleaned before the testing of cubes.

Note down the ultimate load at the failure of specimens , when the load is applied

Compressive Strength = Max. Load/Area = (W/A)

2) Split Tensile Strength

The tensile strength one of the basic and importent properties of the concrete .the determination of tensile strength of concrete is necessary to determine the load at which the concrete member may crack. The cracking is a form of tension failure.

The split tensile strength of concrete is determined by casting cylinders of size 150 mm X 300 mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at the age of 28,60&90 days of moist curing and tested after surface water dipped down from specimens. This test was performed on Testing Machine as shown in fig.

Fig. 10: Split Tensile Strength

The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formula

Split Tensile Strength in N/mm^2 (T)= 0.637P/DL

P = Applied load,
D = Diameter of Concrete cylinder sample in mm.
L = Length of Concrete cylinder sample in mm.

3) Flexural Strength

It is the ability of a beam or slab to resist failure in bending. Flexure specimens shall be beams whose cross section is a square with a side length not less than three times the maximum coarse aggregate size and not less than 100 mm. The beam length shall be at least 80 cm longer than three times the side length of the cross-section.The standard cross-sectional size of flexure specimens is 100 by 100 mm or 150 by150 mm

Fig. 11: Flexure specimens

Relation between compressive and flexural strength of concrete:

The Indian standard IS 456-2000 gives the following relationship between the compressive strength and flexural strength flexural strength = $0.7\sqrt{fck}$

V. CONCLUSIONS

based on the experimental study on the SCC for M20 ,M25, M30 ,grades the following conclusions are drawn :

1) the workability tests on fresh concrete such as Slump flow , V-funnel , L-box are measured .as the percentage replacement of fly ash, silica fumes , lime sludge is increasing in cement from 5% -30% . fly ash is increasing in cement from 5% - 20% the slump flow value is also increasing at 30% increase of fly ash in cement the slump flow value is decreased. Silica fume is increasing in cement from 5% - 15% the slump flow value is also increasing at 30% increase of silica fume

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in cement the slump flow value is decreased. Lime sludge is increasing in cement from 5% - 20% the slump flow value is also increasing at 30% increase of lime sludge in cement the slump flow value is decreased.

2) For 5% -15% increasing of fly ash in cement values v-funnel and l-box tests are decreasing ,at 30 % of increase in fly ash has shown maximum flow value , l-box blocking ratio and minimum V- funnel flow time .simialarly For 5% -10% increasing of silica fume in cement values v-funnel and l-box tests are decreasing ,at 30 % of increase in silica fume has shown maximum flow value , l-box blocking ratio and minimum V- funnel flow time. And 5% -15% increasing of lime sludge in cement values v-funnel and l-box tests are decreasing ,at 30 % of increase in lime sludge has shown maximum flow value , l-box blocking ratio and minimum V- funnel flow time
3) As the replacements levels of fly ash (5%,10%,15%,20%,25%,30%), silica fumes (5%,10%,15%,20%,25%,30%), lime sludge(5%,10%,15%,20%,25%,30%),in cement is increasing the compressive strength ,split tensile strength & flexural strength are decreasing.
4) High percentages of fly ash (more than 30%) ,silica fume (more than 15%),lime sludge (more than 20%) can not be used to produce self compacting concrete. and 20% replacements of fly ash, 5% silica fume ,10% lime sludge exhibited the high compressive strengths , splitting tensile strengths and flexural strengths and the replacements of 20% of fly ash ,5% silica fume and combining fly ash10% +silica fume 5% can be recommended for usage without compromising in strength parameters.

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