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Experimental investigation of geopolymer concrete

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Abstract:- This project work presents the strength characteristics of micro silica concrete. The micro silica concrete is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Use of micro silica concrete reduces the demand of Portland Cement which is responsible for high CO_2 emission. Concrete is the most versatile used material which requires the large quantity of Portland cement. But the production of Ordinary Portland Cement (OPC) generates large amount of carbon-dioxide which is polluting the atmosphere. Hence it is inevitable to find an alternative material.

Micro silica concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules .This depends upon thermally activated natural materials like fly ash, micro silica. Fly ash is a by-product of coal obtained from thermal power plants. This is rich in silica .Micro silica is the by- product of the silicon and ferrosilicon alloy production. The river is the most popular choice for the fine aggregate component of concrete. The present work involves to investigate the mechanical properties of concrete like compressive strength of cubes and spilt tensile strength .Comparing with the test results of M40grade to reduce the usage of cement. On replacement of cement with fly ash and micro silica at 10%, 20% and 30% by weight of cement. Accelerated curing and conventional curing is adopted .Accelerated curing gives early and more strength compared to normal conventional curing.

Keywords:-microsilica,fly-ash,accelerated curing,conventional curing

1.Introduction

The global use of concrete is second only to water. As the demand for concrete as a construction material increases, So also the demand for Ordinary Portland Cement (OPC). It is estimated that the production of cement will increase from about 1.5 billion tons in 1995 to 2.2 billion tons in 2010. On the other hand, The climate change due to global warming as become a major concern. The global warming is caused by the emission of greenhouse gases such as carbon dioxide (CO_2), to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The cement industry is held responsible for some of the CO_2 emissions, because the production of one tone of Portland cement emits approximately one ton of CO_2 in to atmosphere. Several efforts are in progress to reduce the use of Portland cement in concrete in order to address to global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, and the development of alternative binders to Portland cement. The advantages of using microsilica can be considerable as it reduces thermal cracking caused by the heat of cement hydration and can improve durability to attack by sulphate and acidic waters. The advantages and applications are reviewed and a number of test core illustrations are included.

Micro silica is an amorphous polymorph of silica (SiO_2 / silicon di-oxide). It is also known as silica fume or condensed silica fume. It is an ultrafine powder collected as a by-product during the production of the silicon and ferrosilicon alloys. It consists of spherical particles having an average diameter of 150nm. The main field application is as pozzolanic material for high performance concrete.

Fly ash is used as a supplementary cementitious material (SCM) in the production of portland cement concrete. A supplementary cementitious material, when used in conjunction with portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. As such, SCM's include both pozzolans and hydraulic materials.

Vol 13, Issue 01, Jan /2022
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2. Experimental Study

2.1.Materials used

2.1.1. CEMENT

The Cement used was Bharathi Ordinary Portland Cement (OPC) of grade53 conforming to IS: 12269-1987. The various laboratory tests confirming to IS: 4031-1996 (PART 1 to 15) specification was carried out.

Fig no.2.1 Ordinary Portland Cement

2.1.2. COARSE AGGREGATE

Locally available crushed stone with 20 mm graded size havebeen used as coarse aggregate

Fig no.2.2 coarse aggregate of 20 mm size

2.1.3.Microsilica

When added to the concrete mix, a small dose of micro silica introduces millions of tiny silicon dioxide particles into the concrete. It fills the gaps in wet concrete mixture and reacts chemically with Portland cement. The result is a hardened compact concrete with greatly improved strength and durability.
According to 'A.M. Nevelli' (Author of the Properties of Concrete), micro silica is a by-product obtained during the manufacturing of silicon and ferrosilicon alloys in a submerged-arc electric furnace. These alloys are produced from high-purity quartz and coal. Silica fume is also collected as a by-product during the manufacture of other silicon alloys such as ferrochromium, ferromanganese, Ferro magnesium, and calcium silicon.

Fig no.2.3 micro silica

2.1.3. Fly-ash

The potential for using fly ash as a supplementary cementitious material in concrete has been known almost since the start of the last century (Anon 1914), although it wasn't until the mid-1900s that significant utilization of fly ash in concrete began (for example, USBR 1948) following the pioneering research conducted at the University of California, Berkeley (Davis 1937). The last 50 years has seen the use of fly ash in concrete grow dramatically with close to 15 million tons used in concrete, concrete products and grouts in the U.S. in 2005 (ACAA 2006).
Fly ash is a pozzolanic material. It is a finely-divided amorphous alumino-silicate with varying amounts of calcium, which when mixed with portland cement and water, will react with the calcium hydroxide released by the hydration of portland cement to produce various calcium-silicate hydrates (C-S-H) and calcium-aluminate hydrates.

Fig no.2.4 fly ash

3.Methodology

3.1.Mix Design For Conventional Concrete(M40)

Mix design on recommended guide lines is a process of assessing the optimum combination of ingredients initially and final mix proportions is obtained only on the basis of further trial mixes. To arrive at a concrete mix design M40 concrete is carried as per IS code.

Specific gravity of cement = 3.12
Specific gravity of fine aggregate = 2.4
Specific gravity of coarse aggregate. = 2.6
Coarse aggregate = 0.5%
Fine aggregate = 1.0%
Maximum water – cement ratio =0.4
Maximum water content = 197 litres/m^3
Volume of cement = 492.5 kgs/m^3
Mass of coarse aggregate = 1035.54 kgs/m^3
Mass of fine aggregate = 681.45 Kgs/m^3

For w/c Ratio 0.4 the quantities are 1:1.3:2.10

3.2 Mix Design for fly ash Micro silica Concrete.

Amar Devendra Shitole and Sandhya Mathapati have noted that unlike conventional cement concretes Micro silica concretes are a new class of construction materials and therefore no standard mix design approaches are yet available for micro silica .
Micro silica involves more constituents in its binder, whose interactions and final structure and chemical composition are under intense research.

Assume that normal density aggregates, the combined aggregates may be selected to match the standard grading curves used in the design of Portland cement concrete mixes.

The unit weight of concrete = 2400 kg/m3
The mass of combined aggregate = 1491 kg/m3
Mass of coarse aggregate = 795 kg/m3
Mass of fine aggregate = 696 kg/m3
Mass of cement = 438 kg/m3
Mass of fly ash = 7.7 kg/m3
Mass of micro silica = 7.7 kg/m3
For w/c ratio o.45 the quantities are 1:1.5:1.8

4. Casting of cubes and cylinders

4.1 Casting of cubes

For every mix 3 cubes were casted at replacement levels of cement as

- 10% (5% fly ash + 5% micro silica)
- 20% (10% fly ash+ 10% micro silica)
- 30% (15% fly ash+ 15% micro silica)

Fig no. 4.1 casting of cubes

shows the cube having volume 150*150*150 which is casted by properly placing all the mixed material and compacted properly. The casted cube is tested for compressive strength after curing it for 28 days The cube mould plates should be removed, properly cleaned assembled and all the bolts should be fully tight. A thin layer of oil then shall be applied on all the faces of the mould. It is important that cube side faces must be parallel. The concrete sample shall be filled into the cube moulds in 3 layers, each layer approximately 5cm deep. Each layer shall be compacted either by hand or by the vibration.

4.2 Casting of cylinders

For every mix 3 cylinders were casted at replacement of cement as:

- 10% (5% fly ash +5% micro silica)

Vol 13, Issue 01, Jan /2022
ISSN NO:0377-9254

- 20% (10% fly ash+ 10% micro silica)
- 30% (15% fly ash+ 15% micro silica)

Accelerated curing and conventional curing is adopted and spilt tensile strength test results were taken. Mixing of materials like coarse aggregates, fine aggregates, cement, fly ash, micro silica and water is done. All the quantities are taken by weighting according to the mix design

4.3 Conventional and accelerated curing

Fig no. 4.2Conventional curing

Fig no. 4.3 Accelerated curing

5.TESTS ON HARDENED CONCRETE

5.1 Compressive Strength Test (IS: 516-1959)

The cubes of standard 150 x 150 x 150 mm size were cast for carrying out tests for 7,14 and 28day's . The weight of the cube is recorded for calculation of density (kg/m^3) and tested for compression strength in 300T CTM as shown in Figure

4.8 and the cube was placed in the compression testing machine and the load on the cube is applied at a constant rate up to the failure of the specimen and the ultimate (maximum) load is noted. The load at whichthe specimen fails is recorded. The experimental compressive strength was obtained by dividing the maximum load applied on the specimen during thetest by its cross sectional area. Average test results of the specimen were considered as the compressive strength (N/mm^2).

Compressive strength = P/A

Where, P = maximum load "kg" applied to the specimen, and

A = cross sectional area of the cube on which load

is applied(150 x 150mm)

Fig no.5.1 Compression testing machine

The results of compressive strength at 7,14 and 28 dayswere shown in results and discussion

5.2 Splitting Tensile Strength Test (IS: 5816-1999)

This test is conducted on 300T compression testing machine as shown in Figure 4.12. The cylinders prepared for testing are 150mm in diameter and 300mm long.

After noting the weight of the cylinder, then the cylinder is placed on the bottom compression plate of the testing machine. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and the load is recorded. The average test results of the specimen were considered as the splitting tensile strength (N/mm^2).

$$\textbf{Fct} = \frac{2P}{\pi \times d \times l}$$

Where, p = Maximum load **in Newton's applied to thespecimen**, d = diameter of the cylinder (150 mm), l = Length of the cylinder (300 mm),

The results of splitting tensile strength were shown in results and discussion.

Fig no.5.2 split tensile testing machine

6. Results And Discussions

This chapter presents the experimental results of the fly ash based micro silica concrete and conventional concrete. The performance of fly ash based micro silica concrete with different replacement levels of cement and with fly ash and micro silica. The compressive strength and spilt tensile of the concrete mixes using 10%, 20% and 30% replacements under accelerated curing are compared with results of conventional concrete for 28 days. The concrete mix using 30% replacement of cement (15%fly ash+ 15% micro silica) has higher compressive strength and spilt tensile strength when compared to the conventional concrete mixes at 28 days. Hence 15 specimens are tested under accelerated curing with 10%, 20% and 30% replacement of cement. And another 15 specimens are tested under conventional curing with replacement of cement with 10%, 20% and 30, 6 specimens are tested in conventional method. Comparison of strength results between micro silica concrete and conventional concrete is presented.

In the first stage of the project work, the theoretical investigation and literature review are carried out and the following results are obtained.

- The specific gravity of cement tested is 3.12
- The specific gravity of the fine aggregate tested is 2.4
- The specific gravity of coarse aggregate tested is 2.6
- The specific gravity of fly-ash is 2.1
- The specific gravity of micro silica is 2.2
- Fineness modulus of the fine aggregate tested is 2.47

- Fineness modulus of the coarse aggregate tested is 2.9
- Fineness of cement is 95%
- Fineness of fly ash is 97%
- Fineness of micro silica is 96%
- Soundness of cement is 0.53mm
- Water content for the mix is 197 L
- Bulk density of cement id 438 kg /m^3
- Bulk density of fine aggregate is 696 kg /m^3
- Bulk density of coarse aggregate is 956 kg /m^3
- The aggregate ratio of this mix is 1.40
- The mix design for m_{40}concrete arrived as1:1.6:2.2
- The mix design for fly ash based micro silica concrete arrived as 1:1.5:2.18

6.1 Test on cubes

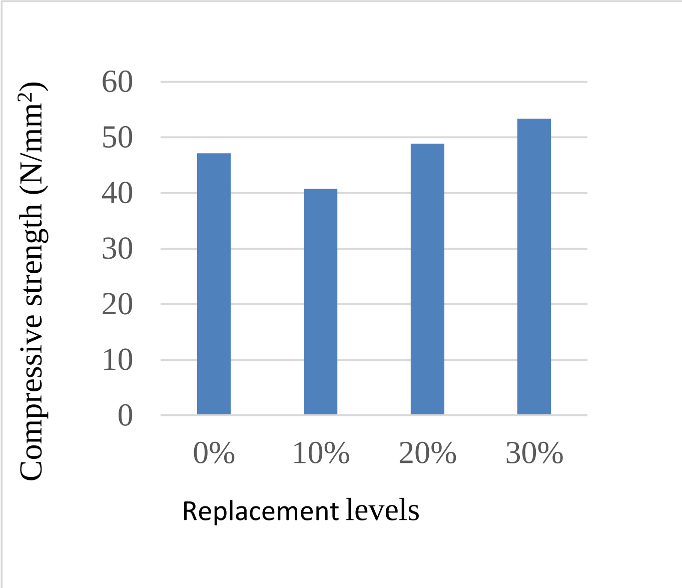
The test on cubes was conducted for its compressive strength under accelerated curing and normal curing at 28 days. The average strength of 3 cubes was recorded for each category of cement replacement

6.1.1 Compressive strength of cubes

Sr.No	Replacement levels	Compressive strength for 7days (N/mm²)	Compressive strength for 28days (N/mm²)	Compressive strength for accelerated curing (N/mm²)
1	0%	30.62	47.11	32.45
2	10%	34.9	40.74	37.81
3	20%	35.1	48.88	39.80
4	30%	35.9	53.33	43.61

Table 6.1.1 compressive strength of cubes

From the table 5.1 the compressive strength values for 30% (15%fly ash+15% micro silica) replacement for 28 days is having higher result value compared to conventional concrete cubes and accelerating curing cubes.



Figno. 6.1 variation of compressive strength of cubes

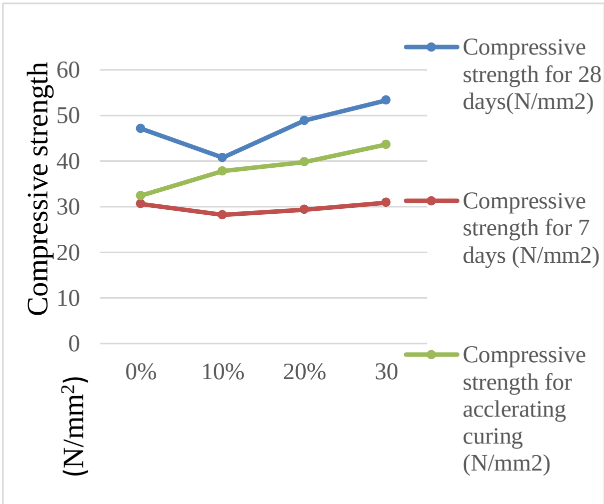


Fig no. 6.2 Compressive strength of concrete cubes for 28 days

Vol 13, Issue 01, Jan /2022
ISSN NO:0377-9254

6.1.2 Comparison of compressive strength of cubes

Fig 6.1 and 6.2 shows compressive strength test results of conventional and micro silica concrete cubes for accelerated curing, normal curing and conventional curing at 7 and 28 days at various mix proportions. It can be seen that 30% (15% fly-ash+15% micro silica) cement, having high compressive strength. The strength is increased by 13.5% when compared to other concrete mixes and also with conventional concrete at 28 days and accelerating curing.

6.2 Tests On Cylinders

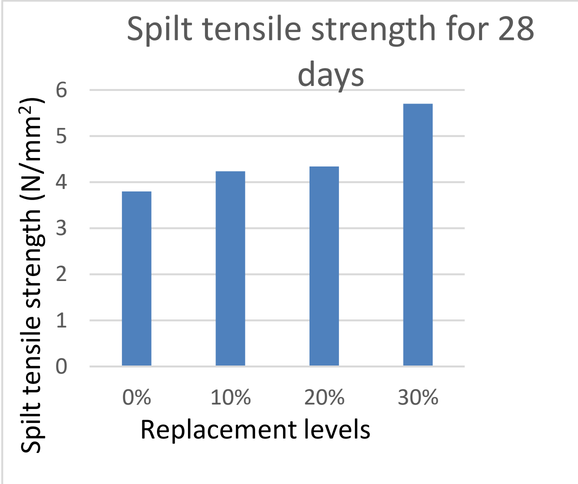
The test on cylinders was conducted for its split tensile strength under accelerated curing and normal curing. The average strength of 3 cylinders was recorded for each category of cement partial replacement along with micro silica and fly-ash

6.2.1 Split tensile strength of Cylinders

Sr. No	Replacement levels	Split tensile strengthfor7days (N/mm^2)	Splittensile strengthfor 28days (N/mm^2)	Splittensile strengthfor accelerated curing (N/mm^2)
1	0%	3.01	3.80	2.89
2	10%	3.15	4.24	2.01
3	30%	3.28	4.34	2.85
4	30		3.40	4.70 3.30

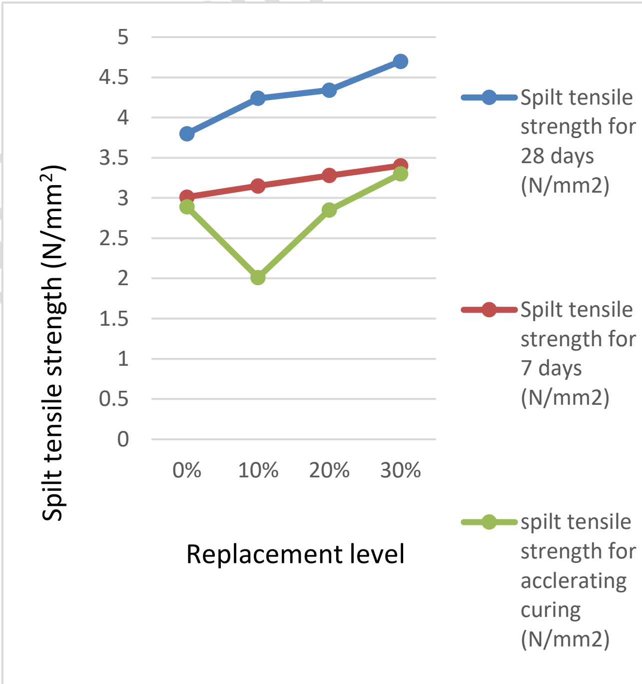
Table no.6.2.1 Split tensile strength of Cylinders

From the table 6.2.1 the split tensile strength values for 30% (15% fly ash+ 15% micro silica) replacement for 28 days is having higher result value.it was found that the strength has been increased by 10.4% when compared to other concrete mixes and also with conventional concrete at 28 days and accelerating curing cylinders.



Figno. 6.3 variation of split tensile strength of cylinders

Figno. 6.4 split tensile strength of concrete cylinders



for 28 days

6.2.2 Comparison of Spilt tensile strength of cylinders

From figures 6.3 and 6.4 spilt tensile strength test results for 7 and 28 days are shown for cylinders. The spilt tensile strength test results of conventional and fly-ash based micro silica concrete cylinders for 7 and 28 days at various mix proportions. It can be seen that for 30% (15% fly-ash+ 15% micro silica) cement replacement having high compressive strength of cylinders.

- Experimental investigation was carried out on conventional and fly- ash based micro silica concrete.
- Tests were carried for compressive strength of cubes and spilt tensile cylinders are calculated at various mix proportions.
- And it was found that for 30%(15%fly-ash+15% micro silica) cement replacement with fly- ash and micro silica having high compressive strength and spilt tensile strength at 28 days curing.

7. CONCLUSIONS

The strength of fly-ash based micro silica concrete for 28 days curing is more when compared to accelerating curing and conventional concrete of grade M40.

- The fly-ash based micro silica concrete mix cubes using 30% replacement of cement with (15% fly ash+ 15% micro silica) for 28 days curing has higher compressive strength.
- It was found that the compressive strength increased by 13.5% when compared to other concrete mixes and also with conventional concrete at 28 days and accelerated curing.
- The fly-ash based micro silica concrete mix cylinders using 30% replacement of cement with (15% fly-ash+15%micro silica) for 28 days curing has higher spilt tensile strength.
- It was found that spilt tensile strength increased by 10.4% when compared to other concrete mixes and also with conventional concrete for 28 days curing and accelerated curing.

7.1 Recommendations

- In the short term, there is large potential of fly-ash based micro silica concrete applications for bridges, such as precast structural elements and decks as well as structural retrofits using different composites.
- Fly-ash based micro silica technology is most advanced in precast applications due to the relative ease in handling sensitive materials.
- Other potential near-term applications are pre-cast pavers and slabs for paving, bricks and pre-cast pipes.
- Furthermore, the low drying shrinkage, low creep, excellent resistance to sulfate attack, good acid resistance and excellent fire resistance offered by fly-ash based micro silica concrete may yield additional economic benefits when it is utilized in infrastructure applications.

7.2 Future Scope

All the above aspects prove that fly ash based micro silica concrete to be highly beneficial in the construction industry.

- Fly –ash based micro silica concrete has high fire resistance, different elevated temperature for different molarities can be studied.

- Replace sand by quarry dust to increase the strength results and economic in construction.
- This can be improved in the further studies.

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