

Experimental Investigation on M55 Grade Concrete Using Industrial Wastes

Aparna Sasi¹ and Resmi K N²

¹*MTech Student, Federal Institute of Science and Technology*

²*Assistant Professor, Federal Institute of Science and Technology*

Abstract- The aim of this study was to use industrial by-products such as micro silica and cenosphere as replacement for cement and fine aggregate respectively to produce M55 grade concrete. One of the main problem associated with high strength concrete is autogenous shrinkage due to low water-binder ratio and hence a study was conducted by addition of non-perforated and perforated cenosphere in to M55 grade concrete mix as a replacement of fine aggregate (5% and 10%). Specimens were casted by addition of cenosphere (perforated and non-perforated) in to the control mix of M55 grade concrete obtained by addition of micro silica as cement replacement and were tested for fresh property and hardened properties after 28 days. Present investigation focuses on studying and evaluating the performance of M55 grade concrete and M55 concrete which is modified by addition of cenosphere in terms of workability, density and compressive strength. Thus exploring a new internal curing agent and this promotes sustainable development.

Index Terms- M55 grade concrete, micro silica, cenosphere, compressive strength.

1. INTRODUCTION

Concrete is a construction material which is widely used in massive volumes around the world. Recent developments in civil engineering such as high-rise buildings, tunnels and long-span bridges demands higher compressive strength concrete. In this modern era, concrete with high compressive strength is widely used due to its technical and economic advantages. Such materials exhibits improved mechanical and durability properties resulting from the use of chemical and mineral admixtures. High Compressive strength concrete are usually obtained by using materials such as Silica fume (from the reduction of high quality quartz in an electric arc furnace), along with cement. Autogenous shrinkage

is a main problem in high strength concrete due to low water to binder ratio. During the process of hydration water is rapidly drawn in to the process, hence lack of water crates fine capillaries which causes early cracking in concrete. This problem can be eliminated or reduced by introducing perforated cenosphere into the concrete. It readily releases water during the hydration process.

According to the present research data, total production of Portland cement is about 2.6 billion tones, mostly used in the production of concrete worldwide [1]. This production is responsible for 5% of all global man-made CO₂ emission, and hence is responsible factor for global warming and climate-change. A good solution for this problem is to replace cement with different types of wastes in concrete to reduce CO₂ emission which is very effective way to save natural resources and also helpful to protect environment. One such a waste product that can be used for cement replacement is Micro silica, a by-product from the manufacture of silicon metal and ferro-silicon alloys. Silica fume is a very reactive pozzolana that converts most or all of the liberated calcium hydroxide to C-S-H.

Electricity is the key for development of any country and coal is widely used as a major source of fuel to generate electricity in many countries in the world. About 41% of global electricity is produced in thermal power plants fuelled by coal and an increase to about 44% is expected by 2030 [2]. After combustion of coal, fly ash is produced as a waste product in large quantities. Different types of structures are observed in the particles in fly ash. To increase the re-use of coal fly ash several separation methods have been developed to segregate value-added components, such as alumino-silicates, magnetites, cenospheres and unburned carbon. From all mentioned components, cenospheres are one of

the most important value-added, materials found in fly ash. Instead of dumping in to environment, cenosphere can be effectively used in concrete, thus reducing the strain on the environment.

II. MATERIALS AND METHODS

A. Materials

1) *Cement*: Cement is the most important ingredient in concrete. Some of the important factors which play a vital role in the selection of cement are compressive strength at various ages, fineness, heat of hydration, alkali content, tricalcium aluminate (C₃A) content, tricalcium silicate (C₃S) content, dicalcium silicate (C₂S) content etc. It is also necessary to ensure compatibility of the chemical and mineral admixtures with cement.

For the present investigation, OPC 53 grade conforming to IS: 12269-1987 was used. Physical properties of cement are given in Table 1.

Table I. Physical properties of cement

| SI. No: | Property | Value |
|---------|----------------------|-------------|
| 1 | Standard consistency | 30% |
| 2 | Initial setting time | 115 minutes |
| 3 | Specific gravity | 3.13 |

2) *Micro silica*: Micro Silica has been recognized as a pozzolanic admixture that is effective in greatly enhancing mechanical properties. The addition of silica fume to concrete improves the latter’s durability by reducing permeability and refining pore structure, leading to a reduction in the diffusion of harmful ions and the calcium hydroxide content, resulting in greater resistance to sulfate attack. Because of its extreme fineness and very high amorphous silicon dioxide content, silica fume is a very reactive pozzolanic material.

Obtained specific gravity of micro silica used for present study is 2.8.

Micro silica is shown in Fig. 1.



Fig. 1 Micro Silica

3) *Fine aggregate*: Fine aggregate used should be properly graded so as to provide minimum void ratio and should be free from deleterious materials like clay, silt content and chloride etc.

The fine aggregate used was M sand. Tests on fine aggregates are conducted confirming to IS 2386: 1963(part I and part III). Fine aggregate was collected from a local supplier. Fineness modulus of fine aggregate was obtained as 2.865 and it belongs to zone II as per IS 383:1970. Specific gravity of fine aggregate is 2.82.

4) *Cenosphere*: A cenosphere is a lightweight, inert, hard hollow alumino-silicate spherical particle filled with air or inert gas, typically produced as a by-product of coal combustion at thermal power plants [2]. The colour of cenosphere varies from gray to almost white as shown in Fig. 2. Cenosphere is collected from Cenosphere India Pvt. Ltd. Chemical composition of cenosphere is shown in Table 2.

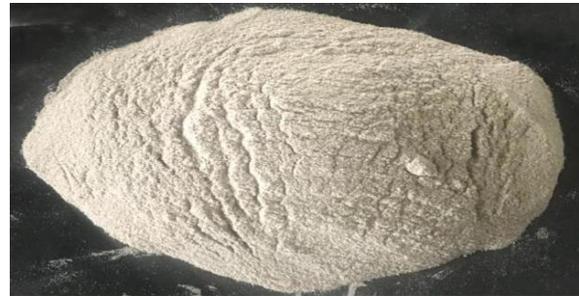


Fig. 2 Cenosphere

Table II. Chemical composition of Cenosphere

| Constituents | Content (%) |
|--------------------------------|-------------|
| SiO ₂ | 52 – 62 |
| Al ₂ O ₃ | 30 – 36 |
| CaO | 0.1 - 0.5 |
| Fe ₂ O ₃ | 1 – 3 |
| TiO ₂ | 0.8 – 1.3 |
| MgO | 1 – 2.5 |
| Na ₂ O | 0.2 - .6 |
| K ₂ O | 1.2 – 3.2 |

5) *Coarse aggregate*: Crushed stone was used as coarse aggregate which is confirming to IS: 383-1970. The maximum coarse aggregate size used is 20 mm. Tests on coarse aggregates is done confirming to IS 2386:1963 (part I and III) and the results are analyzed using IS 383:1970.

Physical properties of coarse aggregate are given in the Table 3.

Table III. Physical properties of coarse aggregate

| Size | Specific Gravity | Water Absorption (%) |
|------|------------------|----------------------|
| 20mm | 2.74 | 0.2 |
| 12mm | 2.76 | 0.4 |

6) *Superplasticizer*: Superplasticizer is an essential ingredient in the concrete mix, as they increase the efficiency of cement paste by improving workability of the mix and there by resulting in considerable decrease of water requirement.

Polycarboxylic ether based superplasticizer is used for the present study. It is a brown in colour liquid with a specific gravity of 1.145. Superplasticizer used is shown in Fig. 3.



Fig. 3 Super plasticizer

B. Methods

1) *Mix Design*: Since there is no specific mix design for M55 grade concrete, it is done based on IS: 10262-2009 and IS: 456-2000.

2) *Casting of Specimens*: Trial and error was used to obtain control mix. Total 5 mixes were made: one is the control mix with 10% micro silica (MS10), control mix with 5% and 10% non-perforated cenosphere (MS10+NCN5% and MS10+NCN10) and control mix with 5% and 10% perforated cenosphere (MS10+PCN5 and MS10+PCN10). The ingredients for the various mixes are weighed and mixing was carried out using a drum type mixer. Mixes were casted in to mould. Curing was done under water for various desired periods.

3) *Test on fresh and hardened concrete*: Slump test was carried out for fresh concrete, keeping the dosage of super plasticizer constant. For hardened properties, concrete cube compression strength test on 150 mm

size cubes at the age of 28 days were carried out using 3000kN capacity compression testing machine. The density was recorded by measuring the weight of the cube specimens, which had a known volume. Split tensile strength of cylindrical specimen of size 150mm×300mm were tested using UTM. Flexural strength of beam of size 500mm×100mm×100mm were tested using Flexural strength testing machine. The optimum percentage replacement of cement by micro silica is noted and cenosphere is added to that corresponding mix.

III. RESULTS AND DISCUSSION

A. Test Results of Fresh Concrete

1) *Workability*: The test result of workability is shown in Table 2. It was observed that the workability of concrete was increased when percentage of cenosphere was increased. This is due to its spherical particle nature.

Table IV. Slump test results

| SL No. | Replacement Level (%) | Slump (mm) |
|--------|-----------------------|------------|
| 1. | MS 10% | 90 |
| 2. | MS 10% + NCN 5% | 108 |
| 3. | MS 10% + NCN 5% | 115 |
| 4. | MS 10% + PCN 5% | 110 |
| 5. | MS 10% + PCN 10% | 120 |

B. Test Results of Hardened Concrete

1) *Density*: The density measurements are shown in Fig. 4. The density decrease was proportional to the amount of sand replaced with cenosphere. This is due to cenosphere’s light nature.

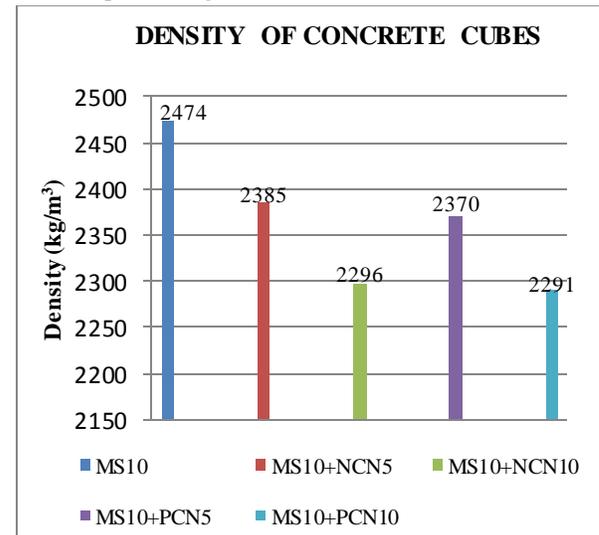


Fig. 4 28 days Density of concrete cubes

2) **Compressive Strength:** Results of compression strength are shown in Fig. 5. The optimum percentage of cement replacement by micro silica is 10% for the M55 grade concrete. This is due to the due to pozzolanic reaction and filler effects of micro silica. Addition of non-perforated cenosphere is not having any inverse effect on the cube compressive strength. Cubes with perforated cenosphere give maximum strength. Maximum value of strength, 67.12 MPa is obtained for replacement of fine aggregate with 5% perforated cenosphere.

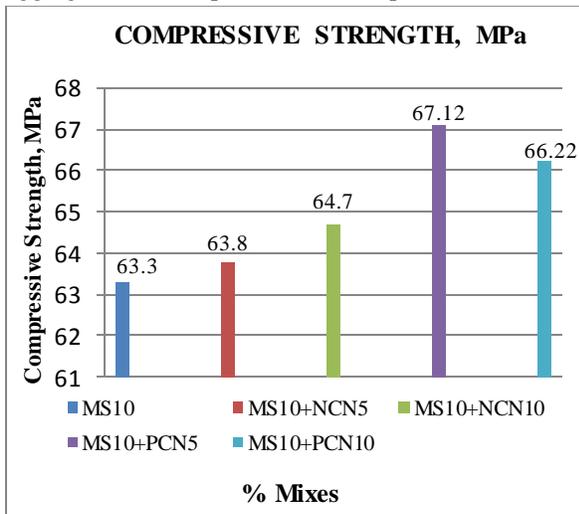


Fig 5. 28 days Compressive strength test results

IV. CONCLUSIONS

Based on the studies conducted the following conclusions are drawn:

1. The optimum percentage of cement replacement by micro silica is 10% for achieving maximum compressive strength.
2. Addition of cenosphere increases the workability of concrete due to its small spherical size. They behave just like microscopic ball bearings in a concrete mix.
3. Addition of cenosphere reduces the density of concrete due to its hollow and inert structure.
4. Compared to M55 grade concrete (control mix) with non-perforated cenosphere, control mix with perforated cenosphere gives higher compressive strength.

As a future work, cenosphere can be added in combination with other available mineral admixtures and can be optimized. Superior properties of cenosphere such as thermal insulation, acoustical

insulation can be explored. Lightweight concrete can be developed by increasing the percentage addition of cenosphere.

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