Strengthening Of High-Performance Lightweight Concrete Using Cenosphere And Dolomite Hybrid Fillers

D Sri Siva Kiran Varma[1], K Urmila Devi[2]
[1] PG Student, Department of Civil Engineering, Lenora College of Engineering, Rampachodavaram
[2] Assistant Professor,Department of Civil Engineering, Lenora College of Engineering, Rampachodavaram

Abstract- *The construction industry's rapid expansion is driving an unsustainable increase in global cement production, currently exceeding 1.6 billion tons annually. This demand not only depletes natural resources but also results in significant environmental degradation due to the emission of greenhouse gases, including CO2, SO2, and NOX. To address these concerns, this study explores the utilization of industrial byproducts specifically Cenospheres and dolomite powder as sustainable additives in concrete manufacturing. Cenospheres, lightweight hollow spheres derived from coal combustion, were utilized to reduce the unit weight of the concrete, while dolomite powder was introduced as a mineral-rich cementitious material to enhance mechanical performance. This research investigates the mechanical and physical properties of M-30 grade concrete through a series of partial replacements. The experimental program evaluates varying proportions of dolomite powder (0, 10, 20 and 30% by weight of cement) in combination with cenospheres (0, 2, 4, and 6% by weight).*

The study provides a detailed experimental analysis of compressive, flexural, and split tensile strength at 7, 14, and 28 days of curing. Preliminary results aim to determine the optimal synergy between these materials to produce a structural-grade lightweight concrete that minimizes environmental impact without compromising mechanical integrity. This research contributes to the development of circular-economy-based construction materials, offering a viable pathway for reducing the carbon footprint of structural infrastructure..

Keywords- Cenosphere, Dolomite powder, workability, compressive strength, split tensile strength test, flexural stregth.

I. INTRODUCTION

The quest for the development of high strength and high performance concretes has increased considerably in recent times because of the demands from the construction indus-try. In the last three decades, supplementary cementitious materials such as fly ash, Dolomite powder and ground granulated blast furnace slag have been judiciously utilized as cement re-placement materials as these can significantly enhance the strength and durability characteristics of concrete in comparison with ordinary Portland cement (OPC) alone, provided there is adequate curing. Fly ash addition proves most economical among these choices, even though addition of fly ash may lead to slower concrete hardening. However when high strength is desired use of Dolomite powder is more useful however, this product is rather expensive. Concrete is one of the most versatile building materials. Concrete is composite material which consists of cement, coarse aggregate, fine aggregate and water in required proportions. Concrete is a material which used for the purpose of construction in now a days.

The cenosphere (spherical shape) improves the flow capacity in most applications and provides an even distribution of the composite matrix filler material. Cenospheres are 75 percent lighter than other commonly used minerals as fillers or extender. It is possible to use them in dry or wet slurry form due to the natural properties of the cenosphere. Cenosphere is easy to manage because of itsinert properties and has a low surface area-to-volume ratioand is not influenced by liquids, solvents, alkalis or acidsetc.These hollow spheres used as an extender for plasticcompounds and are compatible with thermoplastics, latex,polyesters, plastisol's, epoxies, phenolic resins and urethanes. Synthetic cenosphere foams have shown superiormechanical properties compared to those fabricatedwith microspheres.

Dolomite powders (SF) or calcined kaolin or other type of pozzolan produced by calcina-tion has the capability to replace Dolomite powder as an alternative material. In India SF can be produced in large quantities, as it is a processed product of kaolin mineral which has wide spread proven reserves available in the country. At present the market price of SF in the country is about 3 - 4 times that of cement.

The present project involves a comprehensive laboratory experimentation study for the application of new waste materials in the preparation of concrete. The main objective of investigation is to study the strength behaviour i.e. compressive strength and impact re-sistance of concrete with different percentages replacement of cement with Cenosphere and Dolomite powder.

The objective of the present study was to investigate experimentally the properties of Concrete with the following test results

1. Workability
2. Compressive strength
3. Flexure strength
4. Tensile strength

Objective of the research is to study the beneficial utilization of industrial waste as the cement replacement in construction work and to evaluate the optimum proportion of cenosphere as a beneficial replacement with cement in cement concrete.

II. REVIEW OF LITERATURE

A lot of work has been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete. A few inquiries were recorded concerning the physicaland mechanical properties of polymer and alloy compositesreinforced by fly ash cenosphere.

Sampathkumaran P et al have carried work on fly ash cenosphere reinforced different polymer composites, and they found that improved properties of both physical and mechanical properties with respect high density poly ethylene (HDPE) and low density poly ethylene (LDPE) polymer composites.

Divya VC et al have carried out work on the composite,with a high density polyethylene, cenosphere anmultiwall carbon nanotubes and they foundthat these composites showed better mechanical propertiesthan the composites without cenosphere and the addition of cenosphere and MWCNT increase theflammability property of the composite.

Jalageri HB et al have prepared the cenosphere/multi wall carbon nano tubes reinforced polymer composites, and they found that the composite with 0.5 wt. % exhibits higher impact strength, and for 0.1 to 0.2 wt. % were found good flexural and tensile properties.

III. MATERIALS AND METHODS

The experimental investigation work is started with various tests on the constituent materials. The constituent materials are given below.

1. Cement
2. Coarse aggregate
3. Water
4. Cenosphere
5. Dolomite powder

1. *Cement*

Ordinary Portland cement of 43 grades manufactured by Shree Ultratech Cement was used throughout the Experimental investigation. The quality of the cement was confirming to IS 8112:1989 was used in the field.

2. *Fine Aggregate*

Fractions from 4.75 mm to 150 microns are termed as fine aggregate. Locally available river sand passed through 4.75mm IS sieve is applied as fine aggregate conforming to the requirements of IS 383:1970.

3. *Coarse Aggregate*

Coarse aggregate shall be of hard broken stone of granite shall be of hard stone, free from dust, dirt and other foreign matters. The stone ballast shall be of 20mm and down and should me retained in 5mm square mesh and well graded such that the voids do not exceed 42 percent. Aggregate most of which is retained on 4.75-mmIS Sieve and containing only so much finer material as is permitted for the various types described in this standard.

4. *Cenosphere*

The Fly Ash Cenosphere is obtained from the coal power plants in the form of hol-low spherical particles by burning the coal. Fly Ash Cenosphere was started to use in early as lightweight filler material in producing composites of cementitious and at present many researchers are focusing on use of FAC as filler in polymer and metals. These particles are hollow, empty and strong and are made up of silicon dioxide aluminium oxide and iron oxide. Cenosphere compatibility, especially in cements and other building materials, such as wall coatings and composites, and also used in a wide range of other items, including sports equipment, insulation, vehicles, marine crafts, paints, and fire and heat protection devices. Due to lower production costs of cenosphere often replace mined materials. Cenosphere will support the finished product properties by increasing electrical insulation, durability and better sound proofing.

5. *Dolomite powder*

Dolomite, also known as "dolostone" and "dolomite rock," is a sedimentary rock composed primarily of the mineral dolomite, $CaMg(CO_3)_2$. Dolomite is found in sedimentary basins worldwide. It is thought to form by the post depositional alteration of lime mud and limestone by magnesium-rich groundwater. Dolomite and limestone are very similar rocks. They share the same color ranges of white-to- gray and white-to-light brown (although other colors such as red, green, and black are possible).They are approximately the same hardness, and they are both soluble in dilute hydrochloric acid. They are both crushed and cut for use as construction materials and used for their ability to neutralize acids.

IV. MIX DESIGN

The property of workability, therefore, becomes of vital importance. The mix design is done as per IS 10262-2009. Percentage dosage of super plasticizer (high range water reducers) is an additional parameter to be considered for designing an OPC mix. Percentage dosage of super plasticizer was fixed as per the mix design method described in IS 10262- 2009. Mix proportion was arrived through various trial mixes. The grade of concrete prepared for the experimental study was M30.

V. RESULTS AND DISCUSSIONS

This session provides an outline of the experimental results and endeavours to draw some conclusions. The take a look at result covers the workability, strength properties and sturdiness properties of concrete with and without admixtures. The results of the experimental investigation on Dolomite powder and Cenosphere concrete wherever Dolomite powder and Cenosphere has been used as partial replacement of cement in concrete mixes. On commutation cement with completely different percentages of Dolomite powder and Cenosphere the workability, compressive strength is studied the compressive strength, split tensile strength and flexural strength for various mixes then studied.

REPLACEMENT DETAILS

The replacement details of Cenosphere and Dolomite powder has been given in the below table. The replacement of cement percentages by 0, 10, 20, 30% with Dolomite powder and 0, 2, 4, 6% Cenosphere and for getting optimum percentage

5.2 VARIATION OF SLUMP VALUES FOR PERCENTAGE REPLACEMENT OF CENOSPHERE

Slump test was carried out to measure the workability of various mixes. The worka-bility of various mixes was assessed as per the IS 1199:1959 specification. The minimum workability for 30% replacement of Dolomite powder concrete may be due to the lesser fine parti-cle size of cement which can result in higher water consumption thereby reducing workability. 10%replacement mix has high workability compared to other mixes which may be due to the particle size of Dolomite powder is lesser than cement.

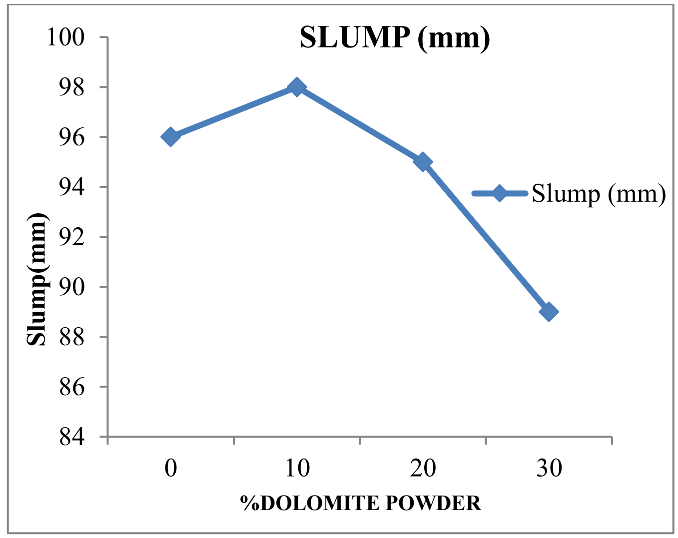

Fig 51: Plot shows the Variation of Slump Values for % replacement of Dolomite powder

5.3.1 COMPRESSIVE STRENGTH

The main function of the concrete in structure is mainly to resist the compressive forces. When a plain concrete member is subjected to compression, the failure of the member takes place, in its vertical plane along the diagonal. The vertical cracks occur due to lateral tensile strain. A flow in the concrete, which is in the form of micro crack along the vertical axis of the member will take place on the application of axial compression load and propagate further due to the lateral tensile strain.

Cubes are prepared of size 150 mm x 150 mm x 150 mm are checked for compressive strength. The specimens tested for 7, 14 and 28 days. The specimen were tested for compressive strength parallel to the plane of the board by applying increasing compressive load until failure occur. The arrangement of load is applied to the specimen by placing the specimen length vertical between the surfaces of the testing machine. Prior to that, measurement for the thickness and width was carried out in order to get the values of cross section area for the test specimens.

Cube compressive strength = loadarea

Where

Load = Load at failure of cube in N

Area = Application area = 150mm *150mm= 22500 mm^2

Fig 5.2: Compressive Strength Testing machine

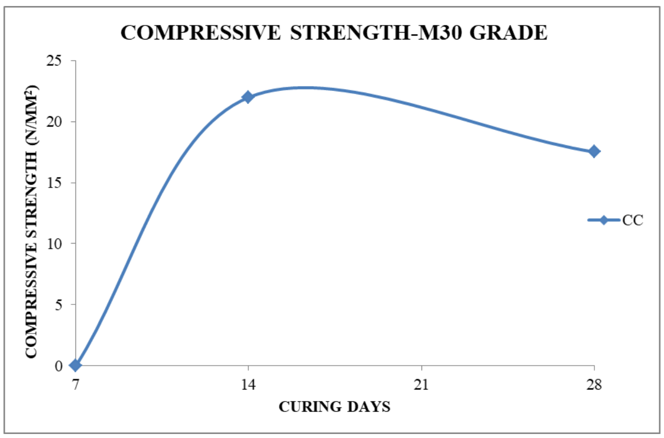

Fig 5.3: Plot shows the Variation of Compressive strength of conventional concrete

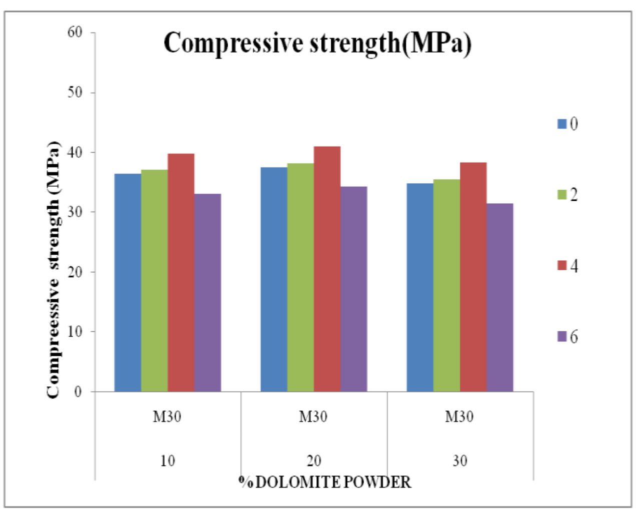

Fig 5.4: Plot shows the variation in compressive strength for different percentages of Cenosphere at 10% Dolomite powder-M30 Grade

The significance of test results of obtained from the average of three samples. It is observed from the results that the specimens containing particles show an increase in compressive strength when compared with the conventional concrete. The results exhibits that the concrete modified by 20% Dolomite powder and of 4% Cenosphere enhances the compressive strength compare to Normal concrete for 28 days. The enhancement of compressive strength of concrete can be mainly due to that Nano particles act as nuclei in promoting the cement hydration and filling up of pores to increment in the compressive strength of concrete. The influence of Cenosphere particle and Dolomite powder in concrete improves the low early age compressive strength in concrete.

5.3.2 SPLIT TENSILE STRENGTH

The size of specimens 150 mm dia and 300 mm length was used and the specimens were cured in normal water. Concrete specimen cubes are used to determine compressive strength of concrete and were tested as per as per IS 516 (1959) and IS 5816 (1999).

Table shows variation of Split tensile strength for conventional concrete

S.No	Curing Days	Split Tensile Strength, (MPa)
1	7 Days	2.51
2	14 Days	3.15
3	28 Days	3.73

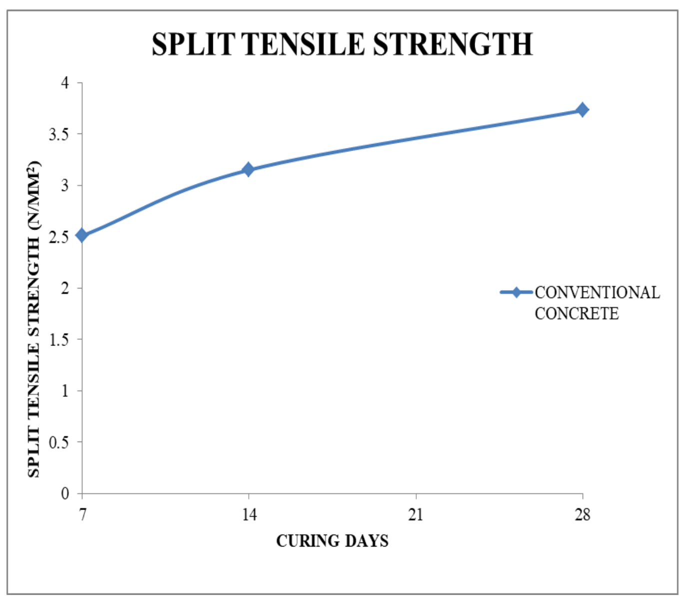

Fig 5.5: Plot shows the Variation of Split tensile strength of conventional concrete-M30 Grade

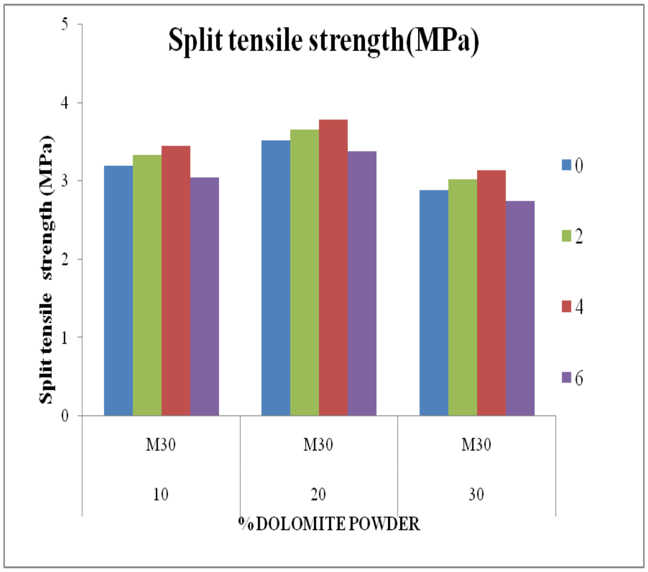

Fig 5.6: Plot shows the summarized results of split tensile strength for different percentages of Cenosphere and Dolomite powder

The significance of test results of obtained from the average of 3 samples. It is observed from the results that the specimens containing Nano particles show an increase in split strength when compared with the conventional concrete. The results exhibits that the concrete modified by 20% Dolomite powder and of 4% Cenosphere shows an enhancement in split tensile strength of concrete.

5.3.4FLEXURAL STRENGTH

In the flexural strength test theoretical maximum tensile stress reached at the bottom fibers of the test beam is known as the modulus of rupture. When concrete is subjected to bending stress, compressive as well as tensile stresses are developed at top and bottom fibers respectively. If the largest nominal size of aggregate does not exceed 20mm, the dimension of specimen may be 150mm×150mm×700mm.

6.5.1 VARIATION OF FLEXURAL STRENGTH FOR DIFFERENT MIXES AND GRADES

The Flexural strength of the concrete mix for different grades with partial replacement of cement by Dolomite powder and Cenosphere respectively.

Table 6.1shows variation of flexural strength for conventional concrete

S.No	Curing Days	Flexural Strength, (MPa)
1	7 Days	2.69
2	14 Days	2.91
3	28 Days	3.21

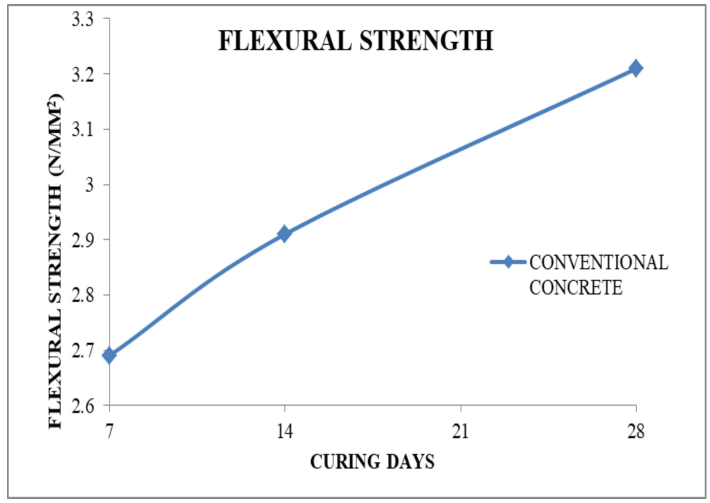

Fig 5.7: Variation of Split tensile strength of conventional concrete-M30Grade

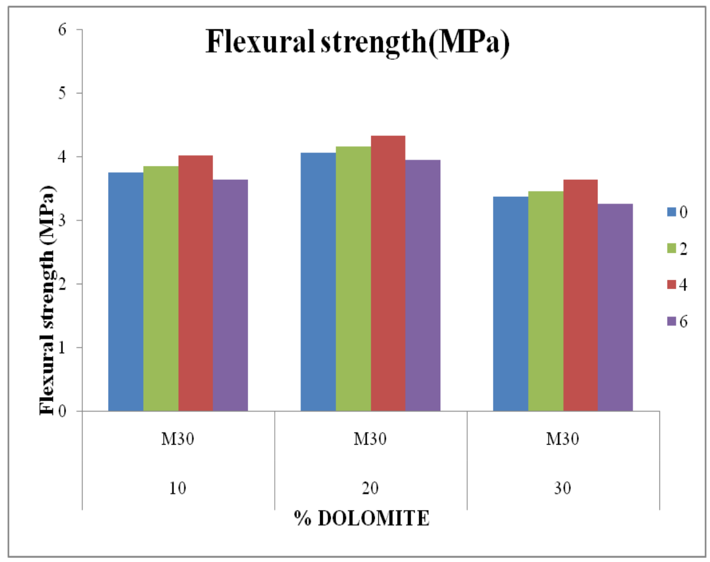

Fig 5.8: Plot shows the summarized results of flexural strength for different percentages of Cenosphere and Dolomite powder

The The significance of test results of obtained fromthe average of 3 samples. It is ob-served from the results that the specimens containing Nano particles show an increase in flexural strength when compared with the conventional concrete. The results exhibits that the concrete modified by 20% Dolomite powder and of 4% Cenosphereshows an improvement results in flexural strength compare to normal concrete for 28 daysfor M30 grade. The en-hancement of split tensile strength of concrete can be mainly due to that Nano particles act as nuclei in promoting the cement hydration and filling up of pores to increment in the flexural strength of concrete. The influence of Cenosphere particle and Dolomite powder in concrete improves the low early age flexural strength in concrete.

VI. CONCLUSIONS

Based on the experimental results provided in the study, the conclusions regarding the performance of M-30 grade concrete modified with Dolomite powder and Cenosphere are summarized below:

Workability Observations

Water Demand: Data from the Slump Cone Test shows that workability decreases as the percentage of Dolomite powder increases, indicating that higher levels of this additive increase the water demand of the concrete mix.

Particle Size Influence: While 10% replacement of Dolomite powder showed higher workability—likely due to the finer particle size of the powder compared to cement—higher replacement levels (e.g., 30%) led to reduced workability due to the increased specific surface area, which results in higher water absorption.

Optimal Mix Composition: The experimental data indicates that the concrete mix modified with 20% Dolomite powder and 4% Cenosphere provides the most significant enhancement in mechanical properties compared to conventional concrete.

- **Mechanical Strength Improvements:**
  - **Compressive Strength:** The incorporation of these particles improves compressive strength, particularly noted at the 28-day curing period. This is attributed to the nanoparticles acting as nuclei that promote cement hydration and fill pores within the concrete matrix.
  - **Split Tensile Strength:** Specimens containing these particles demonstrated higher tensile strength compared to conventional concrete. The 20% Dolomite and 4% Cenosphere modification showed a marked enhancement in split tensile capacity.
  - **Flexural Strength:** Similar to compressive and tensile results, the 20% Dolomite and 4% Cenosphere mix showed an improvement in flexural strength (modulus of rupture) over normal concrete at 28 days. This improvement is linked to the refinement of the microstructure and pore-filling effects.

- **Early Age Performance:** The influence of Cenosphere and Dolomite powder particles contributes to improving the typically low early-age strength of concrete.

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