



# Study Of Strength Parameters Of Graphene Based Concrete With Inclusion Of Industrial Waste (Cupola Slag)

Ashwini R Patil<sup>1\*</sup>, Sneha K Sawant<sup>2</sup>, Ashok B More<sup>3</sup>, Harshada Kapure<sup>4</sup>

<sup>1,2</sup>Assistant Professor, Department of Civil Engineering, D. Y. Patil College of Engineering Akurdi, Pune

<sup>3</sup>Professor, Department of Civil Engineering, D. Y. Patil College of Engineering Akurdi, Pune

<sup>4</sup>Engineer, Department of Civil Engineering, Neilsoft Pvt., Pune

\*Corresponding Author: Ashwini R Patil

\*Email :arpatil@dypcoeakurdi.ac.in

**Citation:** Ashwini R Patil, et al (2024), Study Of Strength Parameters Of Graphene Based Concrete With Inclusion Of Industrial Waste (Cupola Slag), *Educational Administration: Theory And Practice*, 30(5), 7500-7504

Doi: 10.53555/kuey.v30i5.4195

## ARTICLE INFO

## ABSTRACT

Aiming to compare microstructure and mechanical characteristics of conventional concrete with graphene reinforced concrete with 0.05% wt and partially replacement of Cupola slag as a fine aggregate concrete using Scanning Electron Microscope and various mechanical methods to identify effect of GO and cupola on concrete. The effects of the GO content, w/c ratio and cupola on mechanical properties of GO and Cupola cement composites were thoroughly investigated through experimental tests. The testing results show that with constant w/c ratio and optimum 30% cupola as replacement of fine aggregate, compressive and split tensile of concrete surprisingly enhanced as compare to convectional concrete. The investigation of the composition–microstructure–strength relationship shows that the introduction of GO could help improve the macroscopic properties for the cement-based composites via improving the microstructure of cement hydration products, refining the crystal size, and forming a denser and more uniform network structure. The filling effect, hydration effect and nucleation effect of GO could be optimized with an appropriate combination of w/c ratio and GO content.

**Keywords:** Graphene, Graphene Oxide, Nanomaterial, SEM, Durability, Cupola

## 1. Introduction

The key ingredient of concrete was patented by Joseph Aspdin named as ordinary Portland cement(OPC), which is known as world's most widely used material in construction industry. Presence of relatively large pores in OPC paste characterized by weak tensile strength may initiates the micro cracks because of its brittle nature [1]. To control cracking in fiber reinforced concrete (FRC) to enhance mechanical strength discrete short fibers have been used. Various types of fibers have been used in last few decades such as steel, glass, carbon and synthetic materials [2]. The effectiveness of FRC is highly depends on mechanical properties along with geometry of fibers [2]. Various researches from recent development have shown that Nano size fibers such as graphene have opened up to new possibilities for enhancement of strength of cement paste. Graphene is two dimensional atomic layer of carbon arranged in regular hexagonal pattern. Graphene has young's modulus of 1Tpa and core strength of 130Gpa [3]. Graphene can surely offer several advantages like high compressive strength, tensile strength, higher aspect ratio and smaller fiber spacing as compare to traditional fibers which allow them to reduce cracks at micro level [4]. One of the derivatives of graphene that have been use is graphene oxides(GO).[5] The transport properties of GO reinforced cement have shown improve in both mechanical and microstructural properties even with the small amount of incorporation [6]. This study mainly focused on properties of GO of 0.05 % reinforced with cement. One of the major challenges of our present society is the protection of environment. Some of the important elements in this respect are the reduction of the consumption of energy and natural raw materials and consumption of waste materials. It conserves natural resources and reduces the space required for the landfill disposal. Reuse of post-consumer wastes and industrial byproducts in concrete is necessary to produce even "greener" concrete.

[7] Greener concrete also improves air quality, minimizes solid wastes, and leads to sustainable cement and concrete industry. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness. Nowadays waste material is utilized in the preparation of conventional concrete. In present work another material used is Cupola which is by product of cast iron manufacturing. Cupola is partially replaced by fine aggregate in this study because cupola replaced with coarse aggregate gives less strength as compare to fine aggregate due to its metallurgical properties.

## 2. Materials and Method

### 2.1 Materials:

**Graphene Oxide:** The graphene derivative graphene oxide (GO), which possesses a substantial specific surface area, ultrahigh strength, and flexibility, has demonstrated tremendous potential for usage in cementitious materials. [8] Numerous oxygen functional groups in GO make it simple to dissolve in water and form stable dispersions. Additionally, composite materials made of ceramics and polymer materials may be produced using it. The goal of this study was to enhance the microstructure of concrete using GO as a reinforcing material. This was made possible by GO's distinctive structure and remarkable application capabilities

**Cupola Slag:** Cupola slag is a cast iron by product generated while the molten steel separates from impurities in a cupola furnace [9]. This slag forms when a hot liquid melts and then cools before solidifying. It is a complicated mixture of oxides and silicates. For every tonne of molten metal generated in a cupola furnace, 50 kg of slag are produced. Cupola was employed in the present research as a substitute for some of the fine aggregate.

### 2.2 Method:

Three cement paste mixtures with a 0.45 water to cement ratio (w/c) were made. One mixture contained 30% replacement of cupola as a fine aggregate and 0.05% by weight of GO by the weight of the cement. 30% of the cupola in the second mix was replaced with ordinary cement paste as fine aggregate. A simple cement mix was also provided as a comparison. After mixing, some of the mixtures were utilized to perform the mini slump test while the remaining mixes were cast into moulds then compacted properly using a rod. The samples were demolded and cured in a water bath at 20°C after the moulds were maintained for 24 hours. After demolding following tests are conduct on concrete cubes.

### 1. Workability

To ensure the uniform distribution of engineering qualities in concrete, an excellent flow ability and modest viscosity are required. At the same time, appropriate cohesion stability must be maintained. Table 2 compares and measures the workability using the slump cone test. Workability is decreased by the extra cupola and 0.05% of GO. The slump is reduced by 23% with the addition of 0.05% GO. This outcome may be caused by a GO's huge surface area, which reduces the amount of water that can be added to fresh mix by saturating the GO. Low concrete workability is typically correlated with poor compaction, which can result in non-homogeneity because of trapped big air holes that are maintained in composite [12]. due to poor compaction at a low workability level. Steel fiber-cement composites showed a similar behavior as well [13]. Air voids were identified in the current investigation using ultrasonic pulse velocity measurements.

**Table 1.** Slump cone test result

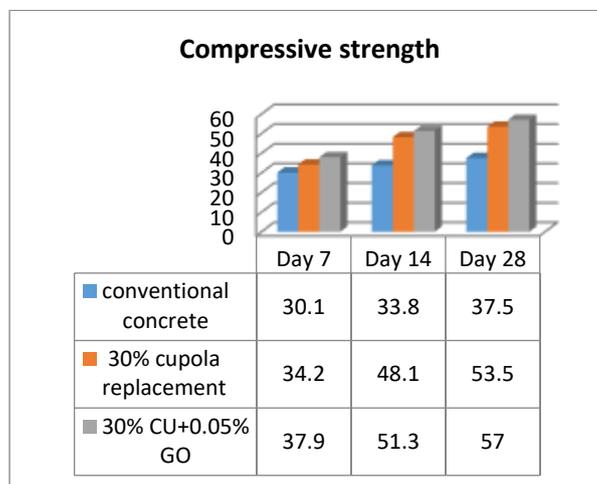
Sample	Slump Cone Result (mm)
CC M30	125
30% Cupola Slag	120
30% Cupola Slag in FA with 0.05% GO (Optimum)	100

### 2. Compressive strength

The compressive strength of cement samples with fine aggregate replacements of 10%,20%,30%,40%, and 50% cupola slag noted. Then the cupola's optimal mix was applied, along with 0.05% GO. To determine the true impact on the concrete's compressive strength, these mixtures are compared to normal concrete at various ages. It was found that, as predicted, the compressive strength of both mixes increased with respect to sample age. According to the findings, samples reinforced with GO and cupola regularly display a better compressive strength than regular concrete. At day 28, the concrete's strength was 46.6 Mpa without the cupola replaced, 44.4 Mpa with it, and 53.5 Mpa with it (the maximum). After 40% and 50% cupola replacement, it fell by 33.7 and 35.5 Mpa, respectively. Further 30% optimum result of compressive strength of material reinforced with 0.05% of GO. Strength of this mixture is obtained 57 Mpa which is almost 41% as compared to conventional concrete. following table shows comparison of conventional concrete, cupola based concrete and cupola with GO concrete.



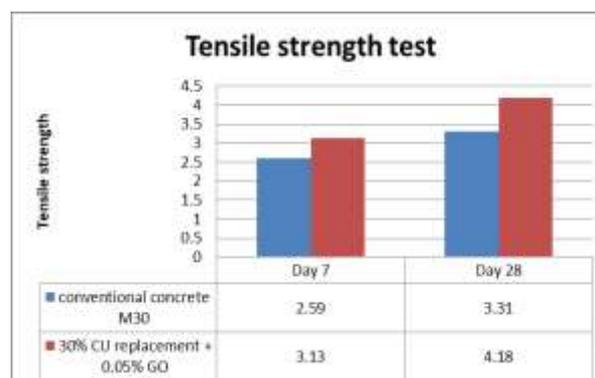
**Fig 1.** Compressive Strength Test



**Fig 2.** Compressive Strength Test Result

### 3. Split Tensile strength

To determine the tensile strength of concrete, three test methods are typically used: the direct tension test, the test for flexural strength, & the tensile splitting test. The tensile splitting test can yield more accurate findings than direct tension and flexural testing in order to determine the concrete's tensile strength when subjected to uniform stress at the top and bottom throughout the diameter of each of the cylinder specimens. [10] According to the test results, the conventional concrete and values recommended by Indian norms had a higher split tensile strength than the 30% cupola replacement without GO. However, the astounding outcomes of the 30% cupola replacement with 0.05% incorporation of GO eliminated Flaws. By adding GO, tensile strength increased by over 24% as compared to regular concrete



**Fig. 3.** Split Tensile Strength Results

#### 4. Ultrasonic Pulse Velocity (UPV)

An accessible pulse meter with a connected transducer pair was used to measure the ultrasonic pulse velocities in direct transmission mode. Transducers (150mm x 300mm) were positioned on either side of the cylinder and lightly lubricated. The distance between the specimen's opposite surfaces, which was measured using a Vernier caliper with an acceptable reading of 0.01 mm, is therefore the travelling distance of the ultrasonic pulse. The measured travel time (t) can be used to compute the pulse velocity (v), where  $v = D/t$ , where D is the ultrasound's travel route length in the specimen, and the concrete quality for all three mixes showed good results. Concrete with 30% cupola replacement and no GO has a somewhat lower pulse velocity than other mixes.



Fig. 4. Ultrasonic Pulse Velocity (UPV) test

Table 2. Ultrasonic Pulse Velocity Test Results on Cylinders of length 300mm

Sample at 28 days	Travel time (in $\mu$ sec)	Pulse velocity (in km/sec)
CC M30	$66 \times 10^{-6}$	4.49
30% cupola replacement with 0.05% GO	$63 \times 10^{-6}$	4.91

#### 5. Rapid chloride permeability test (RCPT)

The RCPT method is the quickest approach used for quality control and specification [11]. This technique is used to evaluate the concrete's permeability. Age causes concrete's permeability to diminish. The age during which a permeability test is tested can be specified with the help of this method. A permeable material is far more susceptible to chemical and ion attack. If adequately cured, concrete loses some of its permeability. With the use of a DC supply, a NaCl and NaOH solution, and concrete, this test assists in determining the permeability of concrete. Equipment for the Rapid Chloride Permeability Test is used to conduct this test. There are two reservoirs in it. One reservoir contains 3.0% NaCl solution, while the other contains 0.3M NaOH solution. As a test specimen, concrete with a 90-100mm diameter and a 50mm thickness is used. Rapid chloride permeability testing of concrete samples containing cupola slag replacement with graphene oxide revealed that specimens under channels 1 and 2 passed with 1640.9 Coulombs and 1283.16 Coulombs, respectively, falling within the range of low chloride ion permeability.



Fig. 5. Rapid chloride permeability test

#### 6. Scanning Electron Microscopy (SEM)

SEM investigations yield information that is helpful for describing the microstructure of cement, concrete, and aggregate and for identifying the reasons for failure. SEM images can be used to identify various-sized and higher-resolution slurry of cement products as well as to investigate and study microstructural processes. [14]. The microstructural features of the elements used to create cement have been proved to draw advantages from GO, which reduces matrices permeability and increases the pore structure. Overall the microscopic properties of GO-based concrete, such as energy consumption and durability, have undergone substantial improvements. Some outcomes, nevertheless, seem suspect. The primary factor driving the need

for more research on the effect using Graphene Oxides upon small-size cement composites is the potential for conflicts resulting from equipment distribution, GO performance, process planning, and building.

**Funding Information:** Authors do acknowledge that there is no funding involved in present research work.

**Author Contribution:** Corresponding author has formulated research statement and guided for manuscript writing and second author contributed for all experimental work.

## 7. Conclusion

- Graphene Oxide powder and cupola can be used in combination as a Supplementary Cementitious Material (SCM) to replace partial of the cement in a construction project.
- Both the durability and strength of concrete are increased for all ages when this mixture is used as a partial replacement for cement.
- Split tensile strength test shown that almost more 24% of tensile strength was gained by addition of GO comparatively to that of conventional concrete
- The concrete quality for all three mixes shown excellent results. The pulse velocity of concrete with 30% cupola replacement without GO slightly less than other mixes. Overall concrete casted with good workmanship and precision
- The effects of GO on the microstructure of cement composites are unknown, however it has been shown to strengthen cement composites, encourage cement hydration, increase pore structure, microstructure, and matrix-interfacial bonding. It appears to be pretty obvious.
- Percentage increases in Cupola results in decrease of strength parameter i.e combination having 40%, 50% replacement of Cupola as a fine aggregate gives decreases in results for this mix proportion.

## References

1. Birchall, J., Howard, A., and Kendall, K. (1981). "Flexural strength and porosity of cements." *Nat. Lett.*, 289(5796), 388–390
2. Bentur, A., and Mindess, S. (2006). *Fibre reinforced cementitious composites*, Taylor and Francis, Milton Park, Abingdon, U.K
3. Lee, C., Wei, X., Kysar, J. W., and Hone, J. (2008). "Measurement of the elastic properties and intrinsic strength of monolayer graphene." *Science*, 321(5887), 385–388
4. Konsta-Gdoutos, M. S., Metaxa, Z. S., and Shah, S. P. (2010b). "Highly dispersed carbon nanotube reinforced cement based materials." *Cem. Concr. Res.*, 40(7), 1052–1059.
5. Mohammed, A., et al., *Incorporating graphene oxide in cement composites: A study of transport properties*. *Construction and Building Materials*, 2015. 84: p. 341-347.
6. Li, X., et al., *Improvement of mechanical properties by incorporating graphene oxide into cement mortar*. *Mechanics of Advanced Materials and Structures*, 2016(just-accepted): p. 00-00.
7. Lewis, W.D. *Properties and uses of iron and steel slag*. National Slag Association Presented at Symposium on Slag National Institute for Transport and Road Research South Africa, (2011) February, 1982, MF 182-6
8. Li, X., Lu, Z., Chuah, S., Li, W., Liu, Y., Duan, W.H., Li, Z., *Effects of graphene oxide aggregates on hydration degree, sorptivity, and tensile splitting strength of cement paste*, *Composites: Part A* (2017), doi: <http://dx.doi.org/10.1016/j.compositesa.2017.05.002>
9. R. Balaraman and S. Anne Ligeria. (2015) utilization of cupola slag in concrete as fine and coarse aggregate Volume 6, Issue 8, pp. 06-14, Article ID: IJCIET\_06\_08\_002
10. Rocco, C., et al., *Review of the splitting-test standards from a fracture mechanics point of view*. *Cement and concrete research*, 2001. 31(1): p. 73-82.
11. Shashikant Kumar, Baboo Rai, Rahul Biswas, Pijush Samui, Dookie Kim, *Prediction of rapid chloride permeability of self-compacting concrete using Multivariate Adaptive Regression Spline and Minimax Probability Machine Regression*, *Journal of Building Engineering*, Volume 32,2020, 101490,ISSN 2352-7102, <https://doi.org/10.1016/j.job.2020.101490>
12. Tu C, Lin Z, Tao H. *Formation for Air Bubble in Cement Paste and Its Influence on The Strength*. *Cem Eng*. 2001;2001(2):42-5
13. Dawood ET, Ramli M. *High Strength Characteristics of Cement Mortar Reinforced with Hybrid Fibres*. *Constr Build Mater*. 2010;25(5):2240-7.
14. Paul E. Stutzman *Building and Fire Research Laboratory National Institute of Standards and Technology Gaithersburg, MD 20899 USA Scanning Electron Microscopy in Concrete Petrography*.