EXPERIMENTAL STUDY ON STRENGTH PROPERTIES OF GRAPHENE OXIDE CONCRETE WITH THE PARTIAL CEMENT REPLACEMENT BY WOLLASTONITE

Ranjini B S [1*], Usha S [2]

[1] PG Student, Department of Civil Engineering, Sri Siddhartha Institute of Technology, SSAHE, Tumakuru572105.*
[2] Assistant Professor, Department of Civil Engineering, Sri Siddhartha Institute of Technology, SSAHE, Tumakuru-572105

---***---

Abstract - *Construction uses concrete, a durable and reliable binding material. Around 1.5 tonnes of raw ingredients are required to create one tonne of cement. Less cement must be used, and more cementitious materials must be used while making concrete. Wollastonite is one such naturally occurring mineral that offers concrete additional strength. It is made when heated magmas containing silica and limestone mix to form it. Wollastonite is used in place of cement in different amounts in the current work's concrete. Graphene oxide is a remarkable nanomaterial that comes in powder, sheets, flakes, and oxide forms. It is sturdy, elastic, and light, and it was just recently accepted. It offers exceptional characteristics that are advantageous to the building sector. Graphene oxide is used to increase the strength of concrete composites. Additionally, it quickens hydration, reduces permeability, and strengthens the bond between concrete structures. In this experiment, wollastonite is utilised in place of some of the cement in the concrete at percentages of 0%, 5%, 10%, 15%, and 20% in order to evaluate the strength qualities of M25 grade concrete.*

Key Words: graphene oxide; wollastonite; strength properties; nano material

1.INTRODUCTION

The scientific term for graphene oxide is graphitic acid. In the 2D nuclear scale honeycomb cross section known as graphene, an allotrope form of carbon, one particle molds each vertex. Graphene oxide offers a number of outstanding characteristics. Graphene oxide was produced by oxidizing graphite. J. Karthikeyan and M. Devasena, 2020).

Carbon nanomaterials, such as graphene, carbon nanofiber, and graphene oxide, have lately been studied and exploited as reinforcing components for cement materials due to their distinctive properties. Numerous investigations have discovered that these nano materials improve the mechanical properties of ordinary Portland cement by halting nano-sized cracks before they may develop further. (2017) K R Mohammed Shareef et al.

A durable, flexible, and moldable construction material is concrete. Water, cement, sand, and aggregate, such gravel or crushed rock, are the main ingredients. The increased demand for concrete as a building material leads to an increase in cement production. Every year, cement production increases by around 3%. In many countries, the construction industry is rapidly growing because it uses natural resources to build better infrastructure. We can replace the pricey and depleted natural resources by adopting inventive and environmentally beneficial alternative building materials. Utilizing waste materials can help to decrease disposal difficulties while also lowering the cost of concrete. (Kshitij tikhe 2018 by Shubham Dahipale and Kabir Khan).

To overcome environmental issues, we need to find other sources. From a number of general research, we can deduce that adding mineral admixtures to concrete makes it stronger and more resistant to degradation. A naturally occurring mineral called wollastonite is produced when silica and limestone combine in molten magmas. Wollastonite, a chemically classified calcium metasilicate, was found to have reinforcing qualities and to be resistant to chemical attack even at high temperatures. CaO and Si02 make up the majority of the components in wollastonite. In a pure CaSi03, each component accounts for around 50% of the mineral by weight. It is a white mineral with a high modulus. (R S Chikkanagoudar and Suriya Xavier Lopes, 2018).

2. Materials and methodology

Worlastonite, normal Portland cement of grade 43, fine aggregate, coarse aggregate, and transportable water for mixing. Below is a mention of the section on material attributes.

2.1 Cement

Cement is a material used as a binder in the construction industry to create concrete. The substance created by heating limestone and other components in a klin is known as Portland cement (OPC), and it is most frequently used in structures.

2.2 Graphene oxide

Cementitious material is the sort of building material that is used the most frequently worldwide. They are often brittle and have very low strain capacities and tensile strengths. Making this changeover to fiber-reinforced cement is justified since the ensuing tensile strength is produced by numerous individual fibres rather than a few large pieces of steel. Many scientists who study cementitious materials are interested in nanostructures like carbon nanotubes (CNTs, both single and multiwalled), carbon nanofibers (CNFs), and graphene because of their exceptional mechanical, chemical, thermal, and electrical properties as well as their effective performance as polymeric reinforcement materials. This is so that tension inside cementitious materials is distributed more uniformly as a result of the usage of discrete fibers. Graphene is a single-layer carbon sheet with sp2 bonding that has a honeycomb crystal structure.

Because graphene nanoplatelets have the same chemical structure as carbon nanotubes (CNT), it is simple to chemically modify their edges for better dispersion in polymeric composites. These nanoplatelets are typically less than 5 nm thick and have lateral widths ranging from 1 to 100 microns. The usage of graphene oxide powder may enable a variety of innovative applications, including those needing high compressive and tensile strengths. Graphene oxide is a remarkable nanomaterial that comes in powder, sheets, flakes, and oxide forms. It is strong, elastic, and lightweight in nature, and has recently been employed in the construction business. It possesses great properties that are advantageous in the building sector. Graphene oxide is used to increase the strength of concrete composites. Additionally, it quickens hydration, reduces permeability, and strengthens the bond between concrete structures. In this work, several fractions of graphene oxide were tested in place of cement at a proportion of 10% by weight to determine their compressive, flexural, and tensile strengths.

2.3 Fine Aggregate

River sand that meets with zone-II of IS 383-1970 is readily available locally for use as fine aggregate. The fine aggregate is pristine and inert, free of organic elements, silt, and clay. Information on sieve analysis and fine aggregate characteristics is included in Tables 3 in that order.

Table 3. Sieve analysis results

Sieve size (mm)	Percentage passing	Zone-II gradation	Remarks
10	100	100	Conforming to grading zone II of table from IS 383-1970
4.75	95.80	95-100	
2.36	90.80	70-100	
1.18	80.20	55-90	
0.6	57.40	35-50	
0.3	23.60	8-40	
0.15	4.90	0-10	

2.4 Coarse Aggregate

Easily accessible crushed blue granite stones that meet the requirements of IS: 383-1970 for graded aggregate with a nominal size of 12.5 mm. Natural, inorganic materials large enough to pass through a 4.75mm screen are considered coarse aggregates.

Specific gravity: 2.64

Table 4. Sieve Size Analysis

Sieve size in mm	% Passin g	IS 383-1970 specificat ion		Remarks
		Graded	Singl e	
40	100	100	100	Conformin g to 20mm size aggregates
20	86	95-100	85-100	
10	4	25-55	0-20	
4.75	0.2	0-10	0-5	
PAN	-	-	-	

2.5 Wollastonite

In order to solve environmental concerns, we must explore for other sources. Furthermore, we can infer from a number of general studies that adding mineral admixtures to concrete increases its durability and resistance to the environmental variables that lead to concrete degradation. Wollastonite is a naturally occurring mineral that is formed when silica and limestone combine in molten magmas. Wollastonite was shown to possess strengthening properties and chemical resistance even at high temperatures (Ramchandra et al 1981). It is a white mineral with a high modulus. In addition to Rajasthan's Pali Sirohi Dist Udaipur, it may also be found in great quantity in Tamil Nadu, Uttarakhand, and Andhra Pradesh. It is used to minimize shrinkage cracks in refractory and ceramic tiles and to boost the tensile strength of polymers.

Wollastonite may be a mineral with improved properties, according to the study that has been done so far on it. The current work makes it possible to employ wollastonite as a new material in concrete by determining the optimal degree of replacement based on compressive strength and replacing OPC in part. Wollastonite is a calcium metasilicate mineral that may take the place of calcium and contains trace amounts of manganese, magnesium, and iron. Wollastonite powder is a calcium, silicon, and oxygen-containing mineral. Calcium metasilicate makes around 86–89% of wollastonite powder.

Colour; white

Specific gravity; 2.9

2.6 Potable Water

Typical pure water that is devoid of any impurities like organic content and turbidity was used to combine and cure the specimen.

2.7 Mix proportions

Table 5. mix proportions for casting and moulding

Sl. No	Particulars	For 1 m^3 concrete	Mix proportions
1	Cement	394 kg	1.00
2	Fine aggregates	791.54 kg	2.00
3	Coarse aggregates	1003.5 kg	2.54
4	Water	197.5 litres	0.50

2.8 Casting of Specimen

A table 3.1 was produced using the mix design calculations for the proportions of M25 grade concrete mix. Cement, aggregates, and sand are blended initially as dry components. Wollastonite and graphene oxide were added to the dry mixture for an additional minute. Following the addition of the liquid component, the dry components were combined for an additional 4 minutes. It took five minutes to combine everything. Three layers of concrete were compacted, each getting 25 strokes from a 16 mm rod. Concrete cubes that had been demolished from the mold and hardened for 24 hours in the mold were put in the curing tank until the day of testing.

2.9 Testing of Specimen

Wollastonite additions at partial cement replacement levels of 0%, 5%, 10%, 15%, and 20% together with 0.2% by weight of graphene oxide were studied in concrete formulations. After being immersed in water for 28 days, concrete cubes formed from each combination sized 150 mm x 150 mm x 150 mm were tested for compressive strength. The compressive strength of cubes is determined using a compression testing machine (CTM) with a 2000 KN capacity. Testing is carried out to evaluate the cylinder's split tensile strength in accordance with IS: 5816 - 1999. Test specimens of 150mm in diameter and 300mm in length were used to measure the split tensile strength of concrete in both scenarios. The cylindrical specimen was positioned between the horizontal loading surfaces of the compression testing equipment, and a load was applied until the specimen broke. According to IS: 516 - 1959, the flexural strength of concrete beams with dimensions of 100 mm by 100 mm by 500 mm was assessed.

3. Results and Discussions

3.1 Tests on Concrete

3.1.1 Slump Test

Table 6 shows the slump values for m25 grade graphene oxide concrete with various percentages of wollastonite substituted cement.

Table 6. slump values

Mix Type	Graphene oxide in percentage	Wollastonite in percentage	Slump in mm
M1	0.2% added to cement	0	51
M2		5	54
M3		10	55
M4		15	57
M5		20	64

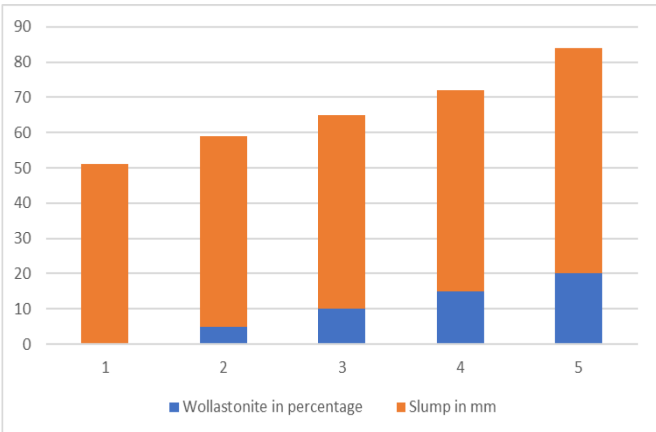

Chart 1. Comparison of slump value

3.1.2 Compaction Factor Test

The table below shows the compaction values for concrete made using m25 grade graphene oxide and different quantities of wollastonite in place of cement.

Table 7. compaction factor values

Mi x Type	Graphene oxide in percent age	Wollastonite in percentage	Compaction Factor
M1	0.2% added to cement	0	0.75
M2		5	0.79
M3		10	0.80
M4		15	0.85
M5		20	0.86

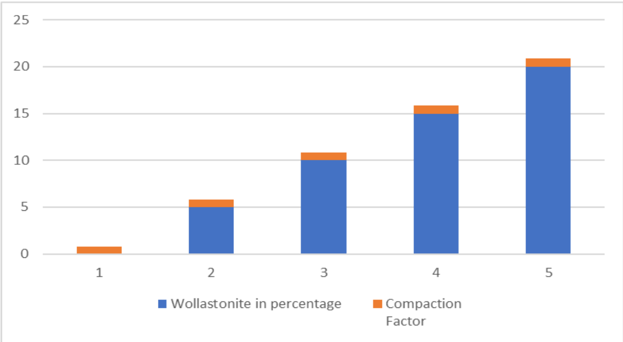

chart 2. Comparison of Compaction factor value

3.1.3 Compression Strength Test

By casting a cube specimen with varying percentages of wollastonite replaced by cement weight and an addition of 0.2% graphene oxide, the compressive strength of concrete mixtures was evaluated. An average of three samples were taken at each testing age. The results of the compressive strength test are shown in table 8.

Table 8. compression test values

Mix Type	Graphene oxide (%)	Wollastonite (%)	Average Compressive Strength (MPa)
			28 days
M1	0.2% added to cement	0	30.12
M2		5	32.24
M3		10	34.15
M4		15	35.79
M5		20	32.79

Compressive strength in graphene oxide concrete rises when Wollastonite is used at cement replacement rates of 5%, 10%, and 15%, albeit it slightly decreases at 20% replacement. The greatest compressive strength of graphene oxide concrete is achieved with a 15% Wollastonite replacement of cement. According to IS 456 (2000), the compression strength for all replacement percentages has achieved 25 MPa. Figure 3 depicts the outcomes of cube compressive strength tests for concrete mixes conducted at 7, 14, and 28 days old.

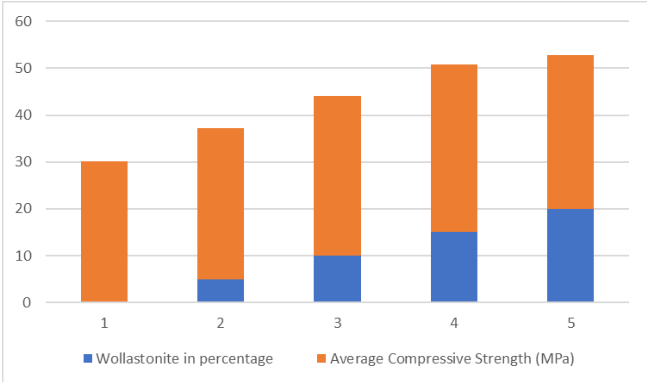

Chart 3. Comparison of Compressive Strength for 28 days

3.1.4 Split Tensile Strength

The split tensile strength of concrete mixes including various percentages of wollastonite in place of cement was evaluated in this study, as well as the effect of adding 0.2% graphene oxide as an additive to cement and measuring the results after 7, 14, and 28 days. Three samples were obtained for each age group, and the average and total were computed. The results of the tensile strength test are shown in Table 9.

Table 9. tensile strength values

Mix Type	Graphene oxide (%)	Wollastonite (%)	Average Split Tensile Strength (MPa)
			28 days
M1	0.2% added to cement	0	3.16
M2		5	3.23
M3		10	3.5
M4		15	3.67
M5		20	3.54

When 5%, 10%, and 15% of the cement in graphene oxide concrete is replaced by wollastonite, the tensile strength increases; however, when 20% of the cement is substituted, the tensile strength somewhat decreases. The greatest tensile strength of graphene oxide concrete is seen at a cement replacement rate of 15% wollastonite. Figure 4 shows the results for concrete mix tensile strength at 7, 14, and 28 days.

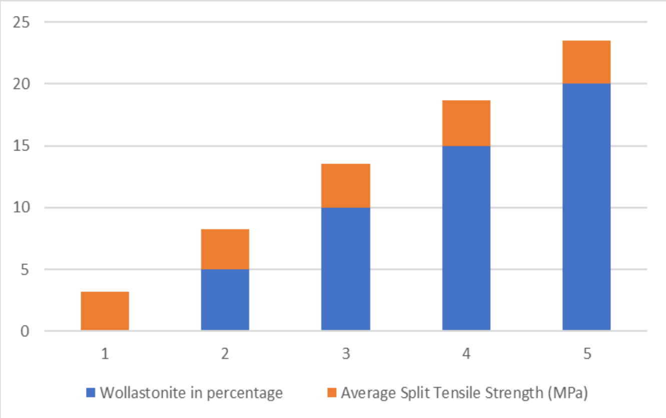

Chart 4. Comparison of Split Tensile Strength for 28 days

3.1.5 Flexural Strength Test

Flexural strength of concrete mixes made with various amounts of wollastonite content replaced by cement weight was assessed at 7, 14, and 28 days after cure using a prism mould specimen containing 0.2% graphene oxide as an addition to cement. An average of three samples were taken at each testing age. Table 10 displays the outcomes of the flexural strength test.

Table 10. flexural strength values

Mix Type	Graphene oxide (%)	Wollastonite (%)	Average flexural Strength (MPa)
			28 days
M1	0.2% added to cement	0	4.7
M2		5	5.21
M3		10	5.6
M4		15	5.66
M5		20	5.37

When cement is replaced by 5%, 10%, or 15% wollastonite content, the flexural strength of graphene oxide concrete increases; however, when cement is substituted by 20%, it slightly decreases. The highest flexural strength in graphene oxide concrete is achieved when 15% Wollastonite is used in place of cement. According to the codal criteria of IS 456 (2000), flexural strength has surpassed the projected strength of 3.83 MPa for all replacement percentages. Figure 5 shows the results for the flexural strength of the concrete mix at 7, 14, and 28 days.

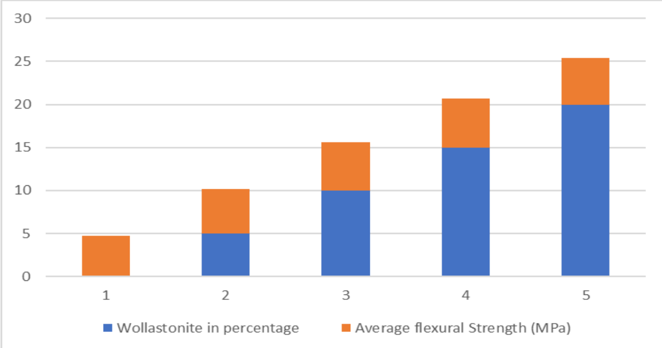

Chart 5. Comparison of Flexural Strength for 28 days

4. Conclusion

- The workability reaches its peak at 20% replacement, and the wollastonite content in concrete of M25 grade increases with slump and compacting factors.

- Compressive strength of graphene oxide concrete increases when Wollastonite is used in lieu of 5%, 10%, and 15% of the cement, although it slightly decreases at 20% substitution.

- The maximal compressive strength of graphene oxide concrete is achieved with a 15% Wollastonite cement substitute.

- Flexural and split tensile strength in graphene oxide concrete rise for cement substitutions of 5%, 10%, and 15% Wollastonite; however, at 15% replacement, both flexural strength and split tensile strength somewhat decrease. The highest flexural and split tensile strength is observed at 15% Wollastonite replacement. Thus, we may deduce from the results that adding 15% wollastonite to cement increases the strength of the graphene oxide concrete. The studies' findings demonstrated that wollastonite may successfully substitute cement without affecting the concrete's mechanical qualities. The lifespan of concrete structures will increase even if 15% of the cement is changed. As a viable building material, wollastonite will contribute to the country's sustainable growth by reducing greenhouse gas emissions and resource depletion.

REFERENCES

1) Akhil Karunakaran, B Mary Sonia George (July 2020), "Study of Mechanical Performance of Concrete with the Addition of Graphene oxide as Admixture", International Research Journal of Engineering and Technology (IRJET), Vol.07, pp. 3948 - 3952.

2) IS 456 (2000), "Plain and Reinforced Concrete–Code of Practice", Bureau of Indian Standards, New Delhi, India.

3) IS 383 (2016), "Coarse and Fine Aggregate for Concrete–Specification", Bureau of Indian Standards, New Delhi, India.

4) Vijay Bhudiya, Abbas Jamani (June2020), "Experimental Study on Mechanical Properties of Concrete Containing Wollastonite and Ground Granulated Blast Furnace Slag as a Partial Replacement of Cement", International Research Journalof Engineering and Technology (IRJET), Vol. 07, pp. 4559- 4567.

5) Vikas Kumar, Devander Kumar "Study on Strength of Concrete by Partial Replacement of Cement to Wollestonite and make Concrete Economical" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 24566470, Volume-6, Issue-4, June 2022, pp.1664

6) URL: www.ijtsrd.com/papers/ijtsrd 50359.pdf

7) Vikrram Singh Meena (Dec 2017), "Wollastonite: An Energy Efficient Building Material", International Journal of Trend in Scientific Research and Development (IJTSRD), Vol. 02, pp. 195-198.

8) Preethi G R, R S Chikkanagoudar (Oct 2020), "A Study on Influence of Graphene oxide Powder on Compressive Strength of Concrete", International Research Journal of Engineering and Technology (IRJET), Vol. 06, pp. 23- 32.

9) IS 10262 (2009), "Concrete Mix Proportioning–Guidelines", Bureau of Indian Standards, New Delhi, India.

10) IS 8112 (2013), "Ordinary Portland Cement–Specification", Bureau of Indian Standards, New Delhi, India.

11) Pus ms. Thnu A r, prof. Shivraju G D (march 2022), "study on effect of curing for red soil based geopolymer bricks". International Research Journal of Engineering and Technology (IRJET).

12) A. Mrs. Roopakala C. G1, B. Shivaraju G.D2, C. Mrs. Usha S(sep 2021) "Experimental study on properties of self-curing concrete incorporated with PEG and PVA" IJIRT 152881 INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN TECHNOLOGY.

13) PRAJWAL M. 1, USHA S. 2, SHIVARAJU G D3, S. R RAMESH. 4(sep 2022) "Evaluating the Strength and Durable Parameters of C&D Waste Replaced Bricks". The International journal of analytical and experimental modal analysis.

14) Usha, S., Shivaraju, G. D., Mallesh, T. V., Prathibha, R. T., & Navya, S. M. (2022). Performance assessment of fly-ash aggregates in concrete. International Journal of Health Sciences, 6(S9), 3858–3864