Experimental Study on Nano Engineered Concrete With Graphene Oxide

J.Sakthishanmugavel[1], P.Andavar[2]
[1]Dept of Civil Engineering
[2]Assistant Professor, Dept of Civil Engineering
[1, 2] Government College of Technology, Coimbatore,

Abstract- *Concrete is the most widely used man-made construction material in the world. It is obtained by mixing cementing materials, water and aggregates, and sometimes admixtures, in required proportions. In this fast pace of world the requirement for the construction industry is heavily focused on producing conservative materials which is strong in their engineering properties and flexible to the production environment. In the construction industry requirement of the concrete is greatly increased, but the cement emits higher CO2 during calcinations which is harmful to the environment. So, reducing the need of cement is important. The use of Nano particles has received particular attention in the application of construction material especially in cement mortar concrete. The application of Nano materials in construction is new alternative to enhance mechanical properties of the concrete. One of the most interesting nanomaterial's which still require detailed investigation is Graphene and Graphene Oxide. In this project, Graphene was added as an additional material in the concrete. The Graphene Concrete are experimentally investigated and compared with the conventional concrete to identified the parameters influencing its strength (compression, split tensile and flexural) respectively. The optimum percentage of graphene was found 3 % to the volume of water.*

Keywords- Cement, Fine Aggregate, Coarse Aggregate, Concrete, Graphene Oxide, Compressive Strength.

I. INTRODUCTION

Concrete is composed principally of aggregates, Portland cement, and water, and many contain other cementitious materials and/or chemical admixtures. It will contain some amount of entrapped air and may also contain purposely entrained air obtained by use of admixture or air-entraining cement. Chemical admixtures are frequently used to accelerate, retard, improve workability, reduce mixing water requirements, increase strength, or alter other properties of the concrete.

Workability: The property of the concrete that determines its capacity to be placed and consolidated properly and be finished without harmful segregation.

Consistency: It is the relative mobility of the concrete mixture, and measured in terms of the slump; the greater the slump value the more mobile the mixture.
Strength: The capacity of the concrete to resist compression at the age of 28 days.

Water-cement ratio: Defined as the ratio of weight of water to the weight of cement, or the ratio of weight of water to the weight of cement plus added Pozzolana. Either of these ratios is used in mix design and considerably controls concrete strength.

Durability: Concrete must be able to endure severe weather conditions such as freezing and thawing, wetting and drying, heating and cooling, chemicals, deicing agents, and the like. An increase of concrete durability will enhance concrete resistance to severe weather conditions.

Density: For certain applications concrete may be used primarily for its weight characteristics. Examples are counterweights, weights for sinking pipelines under water, shielding from radiation, and insulation from sound.

Graphene: It is an allotrope of carbon consisting of a single layer of Graphite (pure crystalline carbon) arranged in a hexagonal lattice. A modern material with unique physical properties that could reshape our future. While not a new building material, graphene has been impractical to use in construction since its discovery. In theory, it is an excellent material, as it is incredibly lightweight while being stronger and stiffer than both steel and carbon fiber. Potentially, it could be combined with more traditional materials to create stronger beams and cables, allowing for more impressive structures. However, graphene is so difficult to produce that builders have rarely been able to use more than a few flakes of it's per project**.**

Generation of heat: If the temperature rise of the concrete mass is not held to a minimum and the heat is allowed to dissipate at a reasonable rate, or if the concrete is subjected to severe differential or thermal gradient, cracking is likely to occur

HIGH STRENGTH CONCRETE

In the early 1970s, experts predicted that the practical limit of ready-mixed concrete would be unlikely to exceed a compressive strength greater than 11,000 pounds square inch (psi). Over the past two decades, the development of high-strength concrete has enabled builders to easily meet and surpass this estimate. Two buildings in Seattle, Washington, contain concrete with a compressive strength of 19,000 psi. The primary difference between high-strength concrete and normal- strength concrete relates to the compressive strength that refers to the maximum resistance of a concrete sample to applied pressure. Although there is no precise point of separation between high-strength concrete and normal-strength concrete, the American Concrete Institute defines high-strength concrete as concrete with a compressive strength greater than 6,000 psi. Manufacture of high- strength concrete involves making optimal use of the basic ingredients that constitute normal-strength concrete. Producers of high-strength concrete know what factors affect compressive strength and know how to manipulate those factors to achieve the required strength. In addition to selecting a high-quality Portland cement, producers optimize aggregates, then optimize the combination of materials by varying the proportions of cement, water, aggregates, and admixtures. When selecting aggregates for high-strength concrete, producers consider the strength of the aggregate, the optimum size of the aggregate, the bond between the cement paste and the aggregate, and the surface characteristics of the aggregate. Any of these properties could limit the ultimate strength of high- strength concrete. High-strength concrete is specified where reduced weight is important or where architectural considerations call for small support elements. By carrying loads more efficiently than normal-strength concrete, high-strength concrete also reduces the total amount of material placed and lowers the overall cost of the structure.

GRAPHENE

It is an allotrope of carbon consisting of a single layer of Graphite (pure crystalline carbon) arranged in a hexagonal lattice. A modern material with unique physical properties that could reshape our future. While not a new building material, graphene has been impractical to use in construction since its discovery. In theory, it is an excellent material, as it is incredibly lightweight while being stronger and stiffer than both steel and carbon fiber. Potentially, it could be combined with more traditional materials to create stronger beams and cables, allowing for more impressive structures. However, graphene is so difficult to produce that builders have rarely been able to use more than a few flakes of its per project. Until now, that is, as the US' Oak Ridge National Laboratory has developed a new way of producing it using a technique known as chemical vapor deposition.

Graphene can be seen with the help of

1. Transmission electron microscopy
2. Electron microscopy
3. Optical microscopy

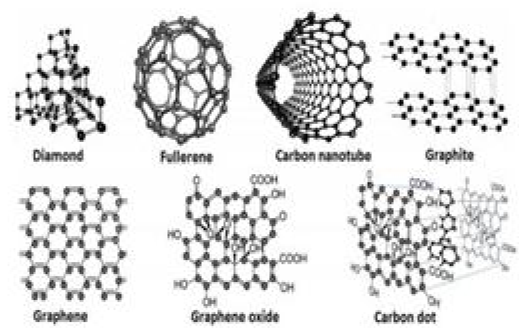

Figure 1.1 Forms of carbon

PROPERTIES OF GRAPHENE

*Mechanical Properties:*Due to the strength of its 0.142 Nm-long carbon bonds, graphene is the strongest material ever discovered, with an ultimate tensile strength of 130 Gpa compared to 400 Gpa for A36 Structural Steel. It is also very light at 0.77milligrams per square meter. Graphene sheets had spring constants in the region of 1-5 N/m and a Young's modulus of 0.5 TPa. Again, these are based on theoretical prospects using graphene that is unflawed containing no imperfections whatsoever and currently very expensive and difficult to artificially reproduce, though production techniques are steadily improving, ultimately reducing costs and complexity.

Optical Properties: Graphene's ability to absorb a rather large 2.3% of white light is also a unique and interesting property, especially considering that it is only 1 atom thick. This is due to its aforementioned electronic properties; the electrons acting like massless charge carriers with very high mobility.

Electronic Properties: One of the most useful properties of graphene is that it is a zero-overlap semimetal (with both holes and electrons as charge carriers) with very high electrical conductivity. Carbon atoms have a total of 6 electrons; 2 in the inner shell and 4 in the outer shell.

*Thermal Properties:*The measured thermal conductivity of graphene is in the range 3000 - 5000 W/mK at room temperature, an exceptional figure compared with the thermal conductivity of pyro lytic graphite of approximately 2000 W·m−1·K−1 at room temperature. ... Theoretically**,** graphene could absorb an unlimited amount of heat.

*Biological properties:*Graphene has been in the forefront of research since the past few years. Development of new methods of graphene synthesis has made this material easily available in the market. Along with graphene, its derivatives such as GO have gained much more interest in their application

ADVANTAGES OF GRAPHENE

1. It is a superb conductor of both heat and electricity.
2. It is the thinnest material known and with that also the strongest.
3. It consists of a single layer of carbon atoms and is both pliable and transparent.
4. It is used in the production of high speed Electronicdevices responsible
5. Transistors that operate at higher frequency as compared to others.
6. It has led to the production of lower costs of display screens in mobile devices by replacing indium electrodes in Organic Light emitting diodes
7. Used in the production of lithium-ion batteries that recharge faster.
8. These batteries use graphene on the anode surface.
9. Storing Hydrogen for fuel cell powered cars.

DISADVANTAGES OF GRAPHENE

1. Being a great conductor of electricity, although it doesn't have a Band gap (can't be switched off). Scientists are working on rectifying this.
2. The main disadvantage of graphene as a catalyst is its susceptibility.
3. To oxidative environments.
4. Research has proven that graphene exhibits some toxicqualities.Scientists discovered that graphene featur es jagged edges.

APPLICATION IN CONSTRUCTION

The composite could be used directly on building sites, enabling the construction of strong and durable buildings using less concrete and reducing greenhouse gas emissions. Using graphene meant the researchers were able to roughly halve the amount of materials used to make concrete.

GRAPHENE – REINFORCED CONCRETE

Researchers from the University of Exeter have created a new concrete production technique that reinforces the material with graphene. The researchers describe how the composite material which they've taken to calling GraphCrete – is at least two times as strong and four times more water resistance than conventional concrete, and could make future construction more sustainable and environmentally friendly. Graphene**-** reinforced concrete reduces the amount of materials required to make concrete by about 50 percent resulting in a significant reduction of 446 kilograms per tone of the carbon emissions. Moreover, it involves less maintenance, so it allows for construction in areas that are hard to reach. Spider drinks graphene, spins web that can hold the weight of a human. Even with defects, graphene is strongest material in the world

SELF- CLEANING CONCRETE

Introducing graphene into concrete could have the potential to increase the material's strength in the long term. However, in the short term it is more likely that graphene will be used to improve the appearance and environmental performance of concrete. "Research is being carried out into concrete that is self- cleaning or could benefits the environment". Graphene –injected concrete could make darkened and stained facades a thing of the past, as the nanomaterial's impermeable characteristics would prevent surfaces from collecting dirt. Concrete that contains graphene would not only clean itself, but also have the benefits of cleaning the air around it, creating a catalytic environment that breaks down larger harmful molecules into harmless compounds to reducepollution.

STRUCTURE OF GRAPHENE

It is the one**-** atom thick planar sheet of carbon atoms (graphite), which makes it the thinnest material ever discovered. 2**-** Dimensional crystalline allotrope of carbon, c-c bond length is 0.142 nm, graphene sheets interplanar spacing is of0.335 nm. It is almost completely transparent, yet so dense that not even helium can pass through it.

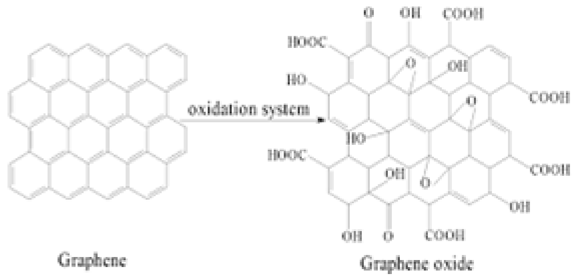

Figure 1.2 Forms of carbon

SCOPE OF THE STUDY

The scope of the project is work focuses on the prediction of the strength parameters, compressive strength, splitting tensile strength and flexural strength of concrete containing different amount of graphene oxide and to identify the correct proportion of high strength mix with the help of Graphene oxide.

OBJECTIVE OF THE STUDY

1. To Study the Behaviour of Strength Properties M30 Conventional Concrete and Graphene Oxide Concrete.
2. To Compare the Results of Strength properties for Conventional and Graphene Oxide Concrete

II. LITERATURE REVIEW

*Minzhen Cal (2012)*investigated, graphene produced by physical and chemical exfoliation of bulk graphite. They produce the bulk production of graphene oxide and graphene via exfoliation, focusing on the exfoliation techniques and yields. Successful exfoliation techniques that they categorize into three major classes: mechanical exfoliation, thermal exfoliation, and other methods (Electrochemical exfoliation, Supercritical fluid exfoliation).

*M.Devasena (2015)*Investigated on "Strength Properties of Graphene Oxide Concrete", in this they aimed to find out the optimum quantity of graphene oxide required to achieve maximum compressive, tensile and flexural strength of concrete. Graphene oxide was added to the concrete in three mix proportions. Graphene oxide content were varied by 0.05%, 0.1%, and 0.2% of cement content. The compressive strength increases in the range of 10.2% to 19.9% than the normal mortar respectively. Use of an optimal percentage (1.5wt %) of GO Nano platelets caused a 48% increase in the tensile strength of the cement mortar specimens. Virginia Wiktor conducted laboratory tests to show that only 0.05% of GO is needed to improve flexural strength of an OPC matrix from between 41% to 59% and compressive strength from between 15% to 33%.

S Nandhini (2016)Investigated on "Graphene oxide Composites with Fly Ash Concrete", one of the most interesting nanomaterial's which still require detailed investigation is graphene and graphene oxide. The study presented in this paper aims at assessing how 0.03 to 0.11 wt. % of graphene oxide incorporated into the cement can affect the physical–mechanical properties of the cement composite in fly ash concrete. The flexural behavior of graphene oxide fly ash concrete in structural member (beam) is investigated with the optimal percentage (0.03%), at the age of 28 days, the compressive strength increases by46.3%, the tensile strength increases by 21.3%. Flexural strength of beam is studied by applying two points loading.

Valles Romero Jose Antonio (2016) "Optimizing content graphene oxide in high strength concrete". This paper describes research advances in the field of nanomaterial's, which represents a valuable opportunity for developingcompounds Nano scale materials, such as graphene oxide, the effect of the incorporation of nanomaterial's disclosed in low doses for increased resistance in the concrete, better hydration and improve the microstructure and mechanical properties of the concrete. Increasing the content of graphene oxide, to a maximum of 2%, with a maximum increase of 57% at 28 days, after which decreases with further increases in the content of graphene oxide.

P. Sudheer, (2017), "Comparative Study on Performance of Concrete Enhanced With Graphene Compound", This experimental work is completely based on Nano technology and came up with the idea of introducing nanoparticles in the raw materials used for construction. This study investigates the properties of graphene and its applicability in construction i.e. in cement based mortar and concrete. Graphene is available in different forms like 0D, 1D and 2D. Graphene has created interest as it is believed to improve the strength of concrete allowing the possibility of controlling properties of concrete. In this work graphene is used as a reinforcing additive in cement based mortar and concrete. Graphene compound is prepared by using conventional graphite and concentrated hydrogen peroxide due to the unavailability of graphene. As a part of investigation, specific gravity and particle size distribution of graphene is studied in the laboratory. Different combination of mixes tried by replacing various proportions of cement with graphene such as 1%, 2%, 3%, 4%, and 5% and mortar cubes are casted. Their compressive strengths are compared with compressive strength of conventional mortar cubes. A slight increase in compressive strength is observed using graphene when compared to conventional mortar cubes. Concrete cubes made with graphene compound showed improvement even up to 25% when compared to conventional concrete cube strength for a proportional replacement by 5% with cement

Dimitar Dimov, (2018)"Ultrahigh Performance Nano engineered Graphene– Concrete Composites for Multifunctional Applications", The high-shear liquid phase exfoliation method used to manufacture water-based graphene dispersions is suitable for combining graphene with concrete because of the potential for high throughput of the industrial scale equivalent equipment, i.e., in excess of 100 Lh−1. Thus, we have incorporated Graphene into concrete by mixing the water-based graphene dispersions with ordinary Portland cement (OPC), fine dry sand, and 10 mm coarse aggregate. These include an increase of up to 146% in the compressive and 79.5% in the flexural strength. A surprising decrease in water permeability by nearly 400% compared to normal concrete makes this novel composite material ideally suitable for constructions in areas subject to flooding.

III. MATERIAL PROPERTIES

CEMENT

A cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together. Cement mixed with fine aggregate produces mortar for masonry, or with sand and gravel, produces concrete. Ordinary Pozzolana Cement confirming to IS: 12269 was used. It should be free from lumps. The physical properties of cement are shown in Table 3.1.

Table 3.1 Physical properties of cement

Characteristics	Value
Specific gravity	2.9
Consistency	32%
Initial setting time	35 minutes
Final setting time	600 minutes

FINE AGGREGATE (M - SAND)

Fine aggregate is an important and essential ingredient of concrete. The M sand product from plant is of a consistent high quality and has good equi dimensional shape. The crusher sand used for the experimental programmed was locally procured and conformed to grading zone II. The fine aggregates were tested per Indian Standard Specifications IS: 383-2016

Table 3.2 Physical properties of Fine Aggregate

Characteristics	Value
Type	Crushed (M - Sand)
Maximum size	4.75mm
Specific gravity	2.61

COARSE AGGREGATE

Coarse aggregate are produced by disintegration of rocks and by crushing rocks. These are available in different sizes. Coarse aggregate are usually those particles which are restrained on IS 4.75mm sieve. Coarse aggregate used in this study were 20 mm nominal size and tested as per Indian standard specification IS: 383 – 2016

Table 3.3 Physical properties of Coarse Aggregate

Characteristics	Value
Type	Crushed
Maximum size	20 mm
Specific gravity	2.74

GRAPHENE OXIDE

Graphene oxide (GO) is a unique material that can be viewed as a single monomolecular layer of graphite with various oxygen-containing functionalities such as epoxide, carbonyl, carboxyl, and hydroxyl groups.

Table 3.4 Physical properties of Graphene Oxide

Characteristics	Value
Purity	99%
Thickness	2 – 5nm
Surface area	380 m^2/g
Number of layers	2 – 4
Ingredients	Distilled water
Concentration	0.5%
Physical state	Liquid
Color	Black
Odor	Odorless

IV. MIX DESIGN

GENERAL

Mix design is the process of selecting suitable ingredient if concrete and determines their relative proportions with the object of certain minimum strength as economically as possible. Design procedure was formulated for concrete which was relevant to Indian standard (IS 10262-2009).

1) STIPULATIONS FOR PROPORTIONING

Gradedesignation -M30
Type of cement - OPC 53 Grade
Maximum nominal size of aggregate - 20 mm
Minimum cement content - 380 kg/m3
Maximum water-cement ratio - 0.50 for reinforced concrete
Workability - 75 mm (Slump)
Exposure condition - Mild (for RCC)
Method of concrete placing - Manual
Degree of supervision - Good
Type of aggregate - Crushed angular
Maximum cement content - 454 kg/m3
Chemical admixture type - Graphene

2) TEST DATA FOR MATERIALS

Cement used - OPC 53 Grade
Specific gravity - 3.14
Chemical admixture - Graphene
Specific gravity of FA - 2.61
Specific gravity of CA - 2.74
Water absorptionof FA - 2.2%
Water absorptionof CA - 0.5%
Free surface moisture - Nil
Sieve analysis of FA - Confirming to Table 7 of IS 383:2016
Sieve analysisof CA - Confirming to Zone II Table 9 of IS 383:2016
Assumed standard deviation
Grade of Concrete - M30
Standard Deviation as per IS – 5.0 N/mm²

3) TARGET STRENGTH FOR MIX

4) PROPORTIONING:

f´ck = fck +1.65s
= 30 + (1.65 X 5.0)
= 38.25 N/mm²

WATER CEMENT RATIO

Maximumwatercontent = 186 litres
[IS 10262: 2009]
(For 25 to 50 mm slumprange)
Estimated water content = 186 + [3/100 x 186]
= 191 litres
(For 75 mm slumprange)

CEMENT CONTENT

Water cement ratio =0.45
Cement content = 191/0.45
= 424.5Kg/m³
424.5 > 300 Kg/m³.
Hence ok.

PROPORTION OF VOLUME OF COARSE & FINE AGGREGATE CONTENT

Volume of coarse aggregate corresponding to 20mm size aggregate zone II for w/c ratio 0.50 = 0.62.
In present case w/c ratio is 0.45
(At the rate of -/+0.01 for every ± 0.05 change in w/c ratio)
Corrected proportion of volume of coarse aggregate for the w/c ratio of 0.45 = 0.63
Volume of coarse aggregate = 0.63
Volume of fineaggregate = 1 – 0.63 =0.37

MIX CALCULATION

Volumeof concrete = 1m³
Volumeof cement = 0.134 m^3
Volumeof water = 0.191 m^3
Volumeof all aggregate =[a - (b+c)]
= [1 – (0.131+0.191)]
= 0.675 m^3
Mass ofcoarseaggregate = d x volume of CA x Specific Gravity of CA x 1000
=0.675 x 0.63 x 2.74x1000
= 1165Kg
Mass offine aggregate= d x volume of FA x Specific Gravity of FA x 1000
= 0.675 x 0.37 x 2.61x1000
= 652Kg

MIX PROPORTION

Table 4.1 Mix proportions of concrete

SI No	Mix	Cracking load at failure (kN)			Avg load (kN)	Comp strength (N/mm²)
1	C C	560	507	539	535.33	23.79
2	G O 1 %	567	543	529	546.33	24.28
3	G O 2%	521	569	534	541.33	24.05
4	G O 3 %	572	543	557	557.33	24.77

V. TEST RESULTS BASED ON STRENGTH

COMPRESSIVE STRENGTH TEST

Compressive strength is the capacity of a material to withstand axially directed pushing forces. When the limit of compressive strength is reached, brittle materials are crushed. The compressive strength is used to determine the hardness of cubical and cylindrical specimens of concrete. The compressive strength of concrete was carried out as per IS 516:1959. After the curing period was over, the cubes were tested in the compression testing machine (CTM) of capacity 300 tonne, at the rate of 140 kg/cm²/minute. The ultimate load at which the cube failed were taken. The test were carried out on three specimens and average compressive strength were recorded

Figure 5.1 Compression test on cube

Table 5.1Compressive strength of cube at 7th day

SI No	Mix	Cracking load at failure (kN)			Avg load (kN)	Comp strength (N/mm²)
1	C C	560	507	539	535.33	23.79
2	G O 1 %	567	543	529	546.33	24.28
3	G O 2%	521	569	534	541.33	24.05
4	G O 3 %	572	543	557	557.33	24.77

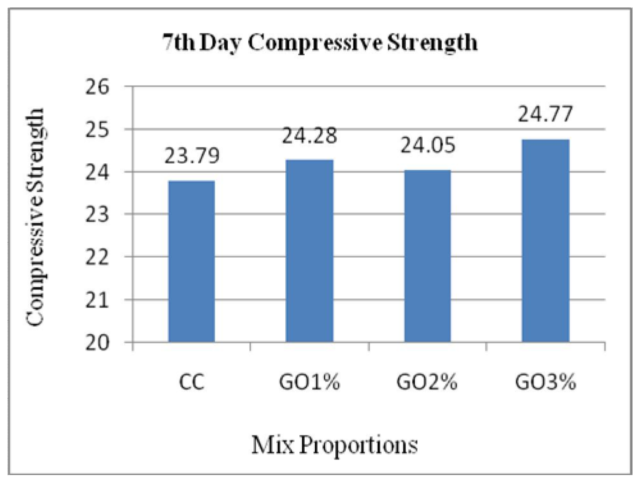

Figure 5.2Compressive strength of cube at 7th day

There is an increase in strength, 4.1% in Graphene Oxide 3% when compared to the conventional concrete at 7th Day

Table 5.2Compressive strength of cube at 28th day

SI. No	Mix	Cracking load at failure (kN)			Avg load (kN)	Comp strength (N/mm^2)
1	C C	660	653	674	662.33	29.43
2	G O 1 %	678	695	688	687.00	30.53
3	G O 2%	716	729	703	716.00	31.82
4	G O 3 %	739	763	748	750.05	33.34

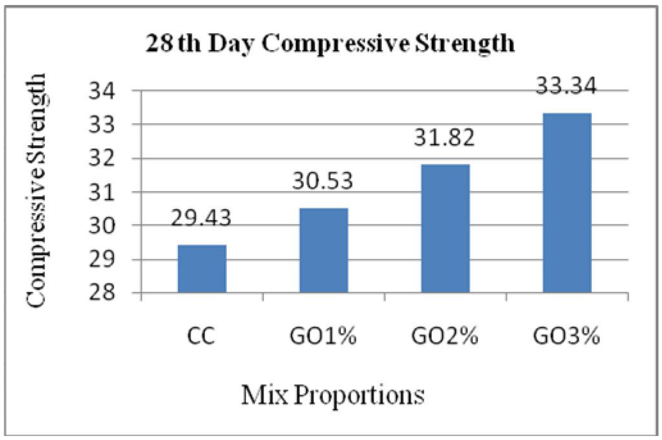

Figure 5.3Compressive strength of cube at 28th day

There is an increase in strength, 13.28 in Graphene Oxide 3% when compared to conventional concrete at 28th Days

SPLIT TENSILE TEST

A method of determining the tensile strength of concrete using a cylinder which splits across the vertical diameter. It is an indirect method of testing tensile strength of concrete. In direct tensile strength test it is impossible to apply true axial load. There will be always some eccentricity present, another problem is that stresses induced due to grips. Due to grips there is a tendency for specimen to break at its end. The load shall be applied without shock and increase continuously at a nominal rate within the range 1.2 N/mm²/min to 2.4 N/mm²/min. Record the maximum applied load indicated by the test machine atfailure

Figure 5.4 Split Tensile test on Cylinder

Table 5.3Split Tensile strength of Cylinder at 7th day

SI. No	Mix	Cracking load at failure (kN)			Avg load (kN)	Tensile strength (N/mm^2)
1	C C	233	215	229	225.67	3.19
2	G O 1 %	246	239	241	242.00	3.42
3	G O 2%	251	237	246	244.67	3.46
4	G O 3 %	264	257	269	264.33	3.73

There is an increase in strength, 16 % in Graphene Oxide 3% when compared to the conventional concrete at 7th Day

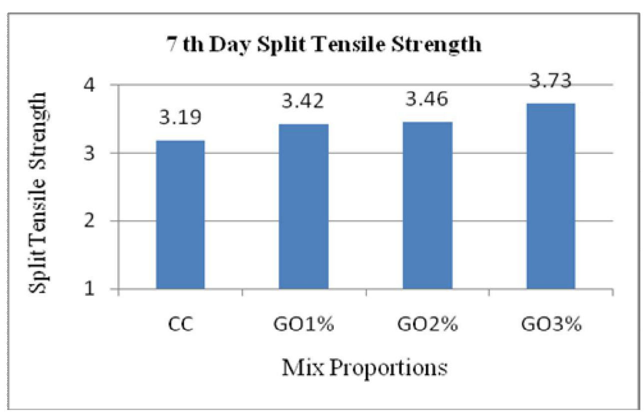

Figure 5.5 Split Tensile strength of Cylinder at 7th day

Table 5.4Split Tensile strength of Cylinder at 28th day

SI. No	Mix	Cracking load at failure (kN)			Avg load (kN)	Tensile strength (N/mm²)
1	C C	310	336	327	324.33	4.59
2	G O 1 %	317	332	339	329.33	4.65
3	G O 2%	327	341	362	343.67	4.86
4	G O 3 %	334	352	369	351.67	4.97

There is an increase in strength, 8.27 % in Graphene Oxide 3% when compared to the conventional concrete at 28th Days

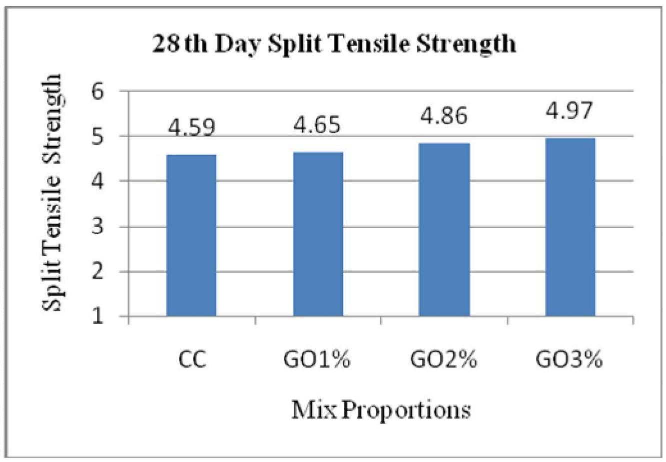

Figure 5.6 Split Tensile strength of Cylinder at 28th day

FLEXURAL TEST

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam to resist failure in bending. The flexural strength is expressed as modulus of rupture (MR), bending strength or fracture strength, a mechanical parameter for brittle material, it is defined as a material's ability to resist deformation under load. The load shall be applied without shock and increasing continuously at a rate such that the fiber stress increases at approximately 7 kg/cm²/min, that is, at a rate of loading of 180 kg/min for the 10cm specimens. The load shall be increased until the specimen fails and the maximum load applied to the specimen during the test shall be recorded. Flexural MR is about 10to 20 % of compressive strength depending on the type, size and volume of coarse aggregate used. The flexural strength represents the highest stress experienced within the material at its moment of rupture. In the central point loading, maximum fiber stress will come below the point of loading where the bending moment is maximum. In case of symmetrical two point loading, the critical crack may appear at any section, not strong enough to resist the stress within the middle third, where the bending momentis maximum. It can be expected that the two point loading will yield a lower value of modulus
of rupture than the enter pointloading

Figure 5.7 Flexural test on Prism

Table 5.5Flexural strength of Prism at 7th day

SI. No	Mix	Cracking load at failure (kN)			Avg load (kN)	Flex strength (N/mm²)
1	C C	12.34	11.76	12.69	12.26	6.13
2	G O 1 %	11.64	12.59	12.82	12.35	6.18
3	G O 2%	12.73	12.52	11.94	12.39	6.20
4	G O 3 %	13.26	12.84	13.64	13.25	6.62

There is an increase in strength, 7.99 % in Graphene Oxide 3% when compared to the conventional concrete at 7th Day

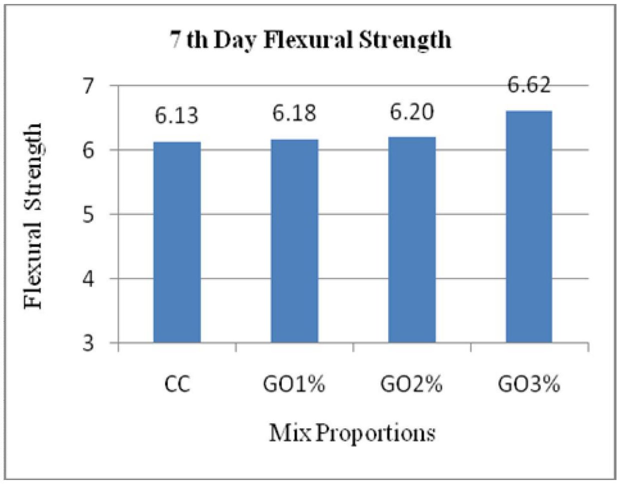

Figure 5.8 Flexural Strength on Prism at 7th Day

Table 5.6Flexural strength of Prism at 28th day

SI. No	Mix	Cracking load at failure (kN)			Avg load (kN)	Flex strength (N/mm²)
1	C C	13.19	12.74	13.49	13.14	6.57
2	G O 1 %	13.64	13.23	13.75	13.54	6.77
3	G O 2%	13.78	13.36	13.84	13.66	6.83
4	G O 3 %	13.81	13.51	13.92	13.74	6.87

There is an increase in strength, 4.5 % in Graphene Oxide 3% when compared to the conventional concrete at 28th Days

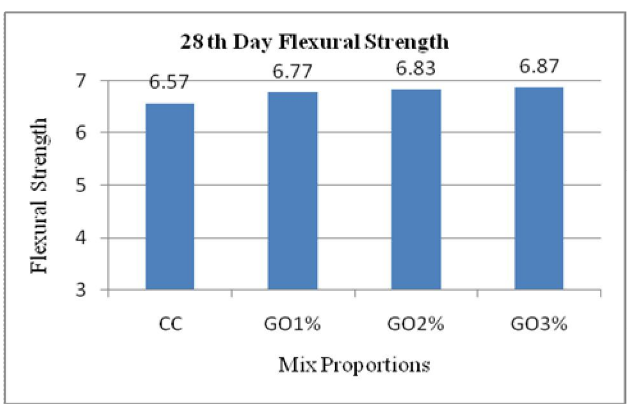

Figure 5.9 Flexural Strength on Prism at 28th Day

VI. CONCLUSION

From this thesis it is observed that the usage of Graphene as an admixture in the concrete greatly increases the strength of the concrete. It is important to know the specifications of the graphene to be used. Since, it defines the percentage of the graphene to be used. Based on the percentage of Graphene, strength of the concrete differs. For these specifications of graphene, to find the optimum percentage of graphene three trial mixes 1%, 2%, 3%, were done. The strength of the concrete increases to the maximum at 3% of graphene to the weight of water and also the strength of the concrete increases at 2% to the weight of cement which is nearer to strength of 3% graphene . So, the graphene percentage in this project is finalized as 2% and 3%. These two percentages and the conventional concrete are casted as cube, cylinder and prism to find out the compression, split tension and flexure strength respectively. The optimum percentage of graphene is found as 3% of graphene to the weight of the water.

These results are compared with the conventional concrete and found that the compressive strength of the concrete is increased by 13.28 % for 3 % whereas the Split tensile strength is increased by 8.27 % for 3% and the flexural strength is increased by 4.5 % for 3%. From these results it is observed that the compressive strength, tensile strength and flexural strength of the concrete has been increased greatly. So, the usage of graphene in construction industry will greatly help to decrease the size of the concrete section which reduces the amount of materials, including cement. As a result of this, the amount CO2 emission will be reduced. Since this concrete reduces the CO2 emission this is “Eco-friendly”

REFERENCES

[1] Minzhen Cai, Daniel Thorpe, Douglas H. Adamson and Hannes C. Schniepp, September 2012, “Methods of graphite exfoliation”, Journal of Materials Chemistry.

[2] Wencheng Du, Xiaoqing Jiang and Lihua Zhub, July 2013, “Direct liquid- phase exfoliation of graphite to produce single and few layered pristine graphene”, Journal of Materials Chemistry.

[3] M. Devasena and J. Karthikeyan, February 2015, “Investigation on Strength Properties of Graphene Oxide Concrete”, International Journal of Engineering Science Invention Research & Development.

[4] Kai Gong, Zhu Pan, Asghar H. Korayem, Ling Qiu, Dan Li, Frank Collins, Chien Ming Wang and Wen Hui Duan, February 2015, “Reinforcing Effects of Graphene Oxide

on Portland Cement Paste", Journal of Materials in Civil Engineering.

[5] S Nandhini and I Padmanaban, June 2016, "Experimental Investigation on Graphene oxide Composites with Fly Ash Concrete", International Journal of Earth Sciences and Engineering.

[6] Valles Romero Jose Antonio, Cuaya-Simbro German and Morales Maldonado Emilio Raymundo, June 2016, "Optimizing content graphene oxide in high strength concrete.

[7] Tasnuba B. Jamal, Jerin Tasnim, Zunnun B. Pial and Rubaiya Rumman, November 2016, "A Review Paper on Graphene Modified Cement.Baomin Wang, Ruishuang Jiang and Zhenlin Wu, November 2016, "Investigation of the Mechanical Properties and Microstructure of Graphene Nanoplatelet-Cement Composite".

[8] K.R.Mohammad Shareef, Shalik Abdul Rawoof and K.Sowjanya, Dec 2017, "A Feasibility Study on Mechanical Properties of Concrete with Graphene Oxide", International Research Journal of Engineering and Technology.

[9] Liulei Lu and Dong Ouyang, July 2017 "Properties of Cement Mortar and Ultra-High Strength Concrete Incorporating Graphene Oxide Nanosheets".

[10] Sardar Kashif Ur Rehman, Zainah Ibrahim, Shazim Ali Memon, Muhammad Faisal Javed and Rao Arsalan Khushnood, July 2017, "A Sustainable Graphene Based Cement Composite".

[11] P.Sudheer, S. Chandramouli, K. Abhinay Kumar, 2017, "Comparative Study on Performance of Concrete Enhanced With Graphene Compound", International Journal of Current Engineering and Scientific Research (IJCESR).

[12] Qiaofeng Zheng, Baoguo Han, Xia Cui, Xun Yu and Jinping Ou, 2017, "Graphene-engineered cementitious composites: Small makes a big impact".

[13] Dimitar Dimov, Iddo Amit, Olivier Gorrie, Matthew D. Barnes, Nicola J. Townsend, Ana I. S. Neves, Freddie Withers, Saverio Russo, and Monica Felicia Craciun, 2018, "Ultrahigh Performance Nano engineered Graphene– Concrete Composites for Multifunctional Applications".

[14] Henrik Kjaernsmo, Samdar Kakay, Kjell T Fossa and John Gronli, 2018, "The Effect of Graphene Oxide on Cement Mortar

[15] IS 456 (2000): Plain and Reinforced Concrete – Practice

[16] IS 10262 (2009): Concrete Mix Proportioning – Guidelines.

[17] IS 383 (2016): Coarse and Fine Aggregate for Concrete - Specification.

[18] IS 2386 -1 (1963): Methods of Test for Aggregates for Concrete, Part 1: Particle Size andShape.

[19] IS 2386 -3 (1963): Methods of Test for Aggregates for Concrete, Part 3: Specific gravity, Density, Voids, Absorption andBulking.

[20] IS 2386 -4 (1963): Methods of Test for Aggregates for Concrete, Part 4: MechanicalProperties.

[21] IS 516 (1959): Methods of Tests for Strength ofConcrete