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An Experimental Investigation on Mechanical properties of Concrete with Graphene oxide

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ABSTRACT: Cement-based concrete is a widely used material for a great variety of constructions. Although, cement has great properties and high performance, its intrinsic brittleness is a weakness that requires further investigation for improvement. Graphene demonstrates a number of excellent properties, such as high flexibility, 1TPaYoungsModulus, 130 GPa tensile strength, high electrical and thermal conductivity. This study investigated the feasibility of implementing graphene into the concrete matrix for improving its compressive and tensile or flexural strength. The aim of this research is to study the performance of graphene cement concrete, and also compare the compressive and split tensile strengths of M25 concrete by replacing cement with 1% and 2% graphene oxide. To study compressive strength and split tensile strength the specimens were tested at 28days, 56days and 90 days of curing.XRD test was conducted to know the crystalline behaviour of the concrete specimens with amount of energy compared with nominal concrete.

KEYWORDS: Graphene Oxide (GO), compressive strength, split tensile strength, XRD analysis etc.,

I. INTRODUCTION

Cement-based concrete is the most commonly used material in civil infrastructure. Although cementitious materials have shown great properties, they are brittle materials with very low tensile strength and reduced strain capacity. The research aims to address the weaknesses of cement in different ways. Scientific research is conducted in different directions. The most prevalent research method gives emphasis on a bottom-up approach of the problem with a multi scale evaluation from atomic level to nanoscale, then microscale and finally mesoscale level.

According to Sobolev and Gutierrez (2005) nanotechnology can change the world and specifically for cement-based materials, focusing on their structure at the nanoscale will possibly give us more information on how we could improve its characteristics .As a result, concrete could become stronger with increased durability, increased strain capacity and other innovative properties. Later on, Sobolev and Shah (2008) suggested that with the development of nano-technology new generation of cementitious materials could be produced in the future.

Recent research has indicated that using nanomaterials (carbon nanotubes, graphene, titanium oxide, nanosilica and nanoalumina) can significantly improve cementitious materials. However, the high cost and the time-consuming procedure of production are very important factors that need great consideration. Such research for graphene has shown that there is strong connection between the structure and the performance of graphene-cement nanocomposites (GCNCs). The functionalized graphene-nanoplatelets had improved interfacial strength, which in turn improves their mechanical properties.

The main purpose of this thesis is to investigate the feasibility of functionalized graphene for compatibility with cement hydrates and reinforcement steel. The main objectives of this thesis are: 1) Literature study of cement concrete bonds with nano-materials such as graphene and their properties.2) Investigation of the compatibility by testing compressive and tensile strength of hardened concrete specimens mixed with graphene oxide.

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In this research the concrete specimens with 2%Graphene Oxide (GO) replaced with cement had increased in its tensile strength and also that there was good bonding between the GO surfaces and the cement matrix. X-ray diffraction (XRD) data also showed that the mortar with GO had increased calcium silicate hydrates (C-S-H) gels in comparison with normal cement concrete. As far as it concerns this master thesis, a feasibility study was conducted in order to investigate the compatibility of the functionalized graphene with the cement concrete hydrates.

II. RELATED WORK

The material properties are investigated as per Indian codal specifications. The materials are tested and compared with the standard values. The materials utilized as a part of the present study are cement, sand, coarse aggregate and Graphene oxide. Every one of these materials is tried in the research centre to set up their physical and mechanical properties according to the determination of Indian Standards. Mix Design was evaluated using the outline rules of IS 10262-2009 and Is 456 - 2000. Physical and mechanical characteristics were carried for trial mix of M25 at first phase, casting of natural aggregates cubes and cylinders for the mix M25.

Different ingredients used in this work are: 1. Portland Cement 2. Fine aggregate 3. Coarse aggregate 4. Graphene oxide 5.Water. Ordinary Portland cement (OPC) of 53grade has been used and the locally available river sand conforming to zone-II of IS 383-1970has been used as fine aggregate, Locally available crushed blue granite stones conforming to graded aggregate of nominal size 20 mm as per IS: 383 – 1970has been used. Water is needed for the hydration of cement and to provide workability during mixing and for placing. There is not much limitation for water except that the water must not severely contaminate. In this study, normal tap water was used.

III. METHODOLOGY

The main object of concrete mix design is to select the optimum proportions of the various ingredients of concrete which will yield fresh concrete of desirable properties like workability and hardened concrete possessing specific characteristic compressive strength and durability. Mix Design was evaluated using the outline rules of IS 10262-2009 and IS 456 – 2000. Mixing of ingredients is done in pan mixer of capacity 50L. The cementitious materials are thoroughly blended and then the aggregate is added and mixed followed by gradual addition of water and mixing. Wet mixing is done until a mixture of uniform colour and consistency are achieved which is then ready for casting. Before casting the specimens, workability of the mixes was found by slump cone test.

At least 3 cubes of sizes 150*150*150mm are used and the average strength is taken into consideration and cylinders of sizes 150 *300mm are used. Compressive strength of a material is defined as the value of uni axial compressive stress reached when the material fails completely. In this investigation, the cube specimens of size 150 mm x 150 mm x 150 mm of all the multi blended mix concretes are tested in accordance with IS: 516 – 1969. The testing was done on an automatic compression testing machine of 200 KN capacities. Split Tensile strength of material is defined as it is the standard test, to determine the tensile strength of concrete in an indirect way. This test could be performed in accordance with IS: 5816-1970. . A standard test cylinder of concrete specimen (300 mm X 150mm diameter) is placed horizontally between the loading surfaces of Compression Testing Machine. The compression load is applied diametrically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter.

In this research the cement was replaced with 0%, 1%, 2% Graphene Oxide by weight of cement. The casted cubes and cylinders of M25 grade concretes are cured, and tested for its compressive strength and split tensile strength at 28 days, 56days and 90 days.
MIX-1 refers to the 100%cement +0%GO,MIX-2 refers to the 99%cement +1%GO, MIX-23refers to the 98%cement +2%GO.

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IV. EXPERIMENTAL RESULTS

One set of normal concrete and one set of grapheme oxide mixed concrete were casted for M25 grade. The purpose was to compare compressive strength and split tensile strength between reference mix and the different mixes with graphene oxide.

The following below table shows the results regarding to compressive strength

Table 1: compressive strength of concrete in Mpa at 28, 56,90days testing

S.NO	MIX DESIGNATION FOR M25	28DAYS	56DAYS	90DAYS
1	MIX-1 (100%CEMENT+0%GRAPHENE OXIDE)	30.15	37.5	48.13
2	MIX-2 (99%CEMENT+1%GRAPHENE OXIDE)	32.44	41.033	52.55
3	MIX-2 (98%CEMENT+2%GRAPHENE OXIDE)	35.39	43.7	55.51

Fig 1: Number of days versus compressive strength for different mixes of GO

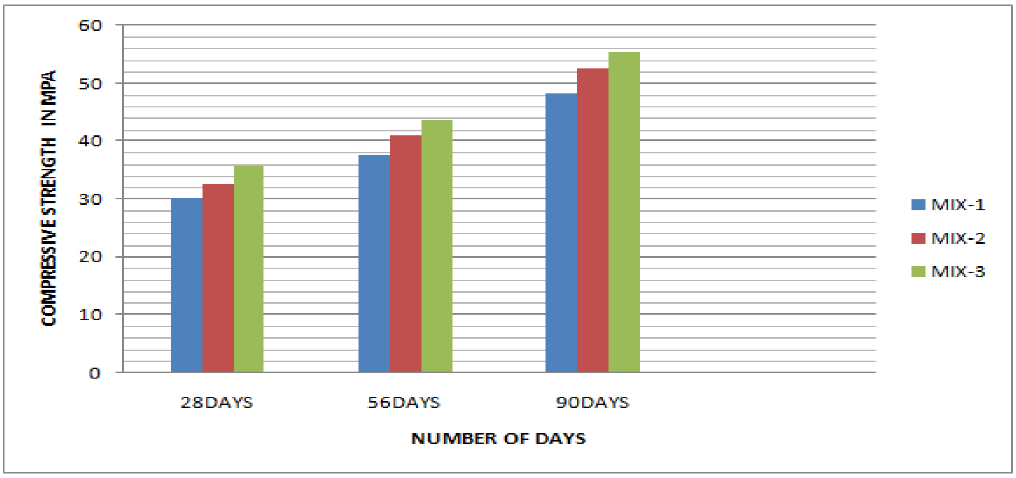

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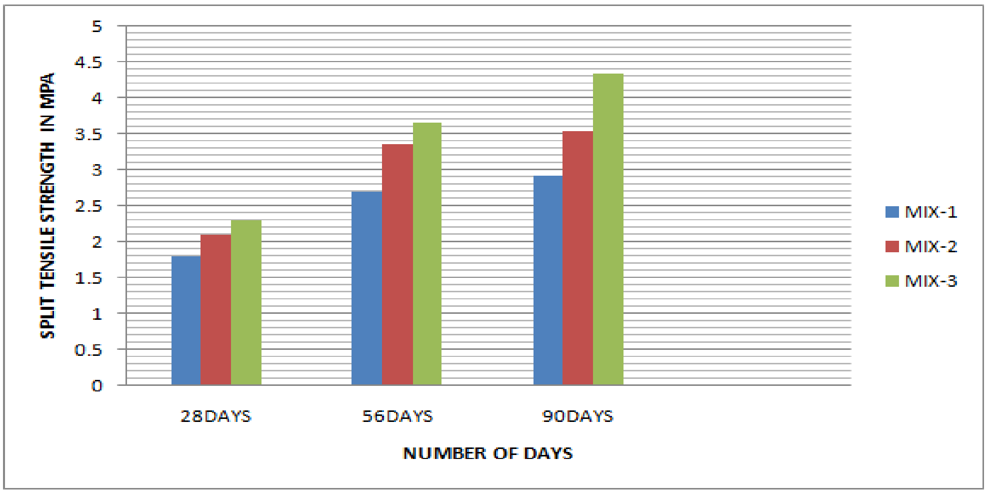
Table 2: split tensile strength of concrete in Mpa at 28, 56,90days testing

S.NO	MIX DESIGNATION FOR M25	28DAYS	56DAYS	90DAYS
1	MIX-1 (100%CEMENT+0%GRAPHENE OXIDE)	1.78	2.70	2.91
2	MIX-2 (100%CEMENT+1%GRAPHENE OXIDE)	2.09	3.36	3.53
3	MIX-2 (100%CEMENT+2%GRAPHENE OXIDE)	2.28	3.66	4.33

Fig 2: Number of days versus compressive strength for different mixes of GO



X-RAY DIFFRACTION TEST

X-ray diffraction test was conducted on the concrete samples which were collected after crushing the compression tested specimens. The Crushed specimens were broken in to small species and were tested for X-ray diffraction test.XRD test is conducted to study the crystalline structure of the concrete specimens.

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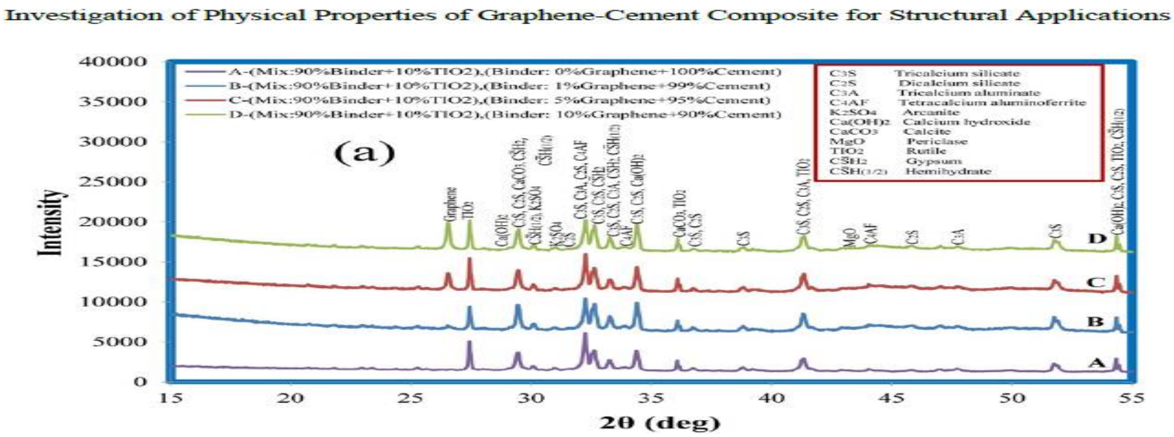
REFERENCE XRD GRAPH OF GRAPHENE-CEMENT COMPOSITE

Fig 3: Reference XRD graph of graphene-cement composite



XRD patterns of 0%, 1%, 2% GO –concrete composites at 28days

Fig 4: XRD patterns of 0%GO –concrete composites at 28days

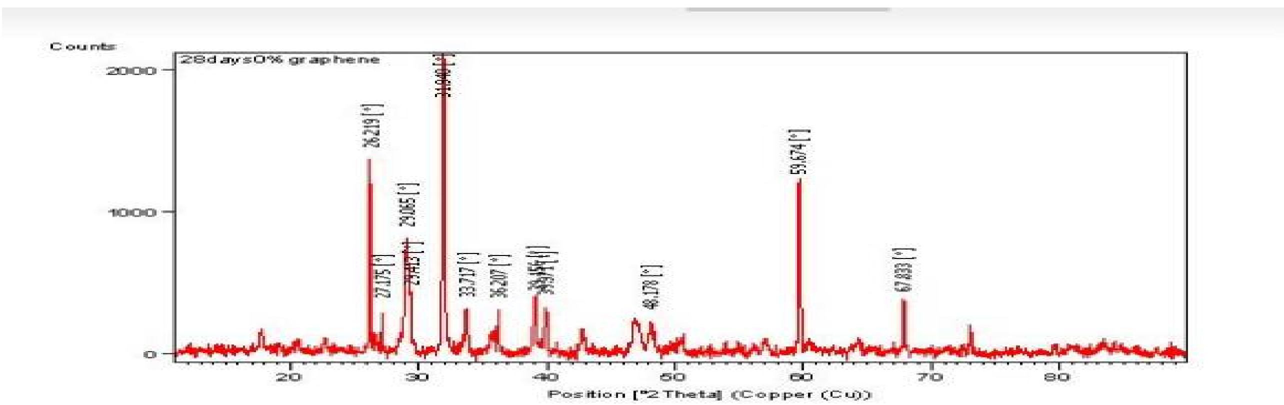


Fig 5: XRD patterns of 1%GO –concrete composites at 28days

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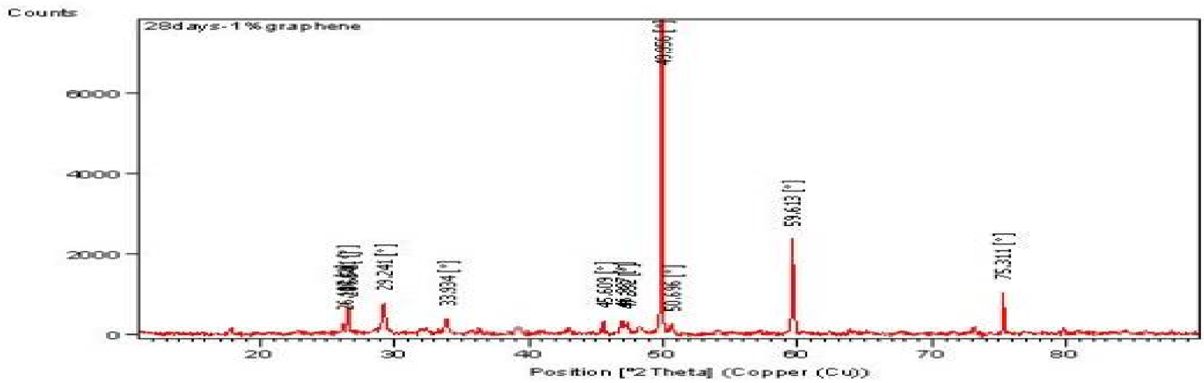
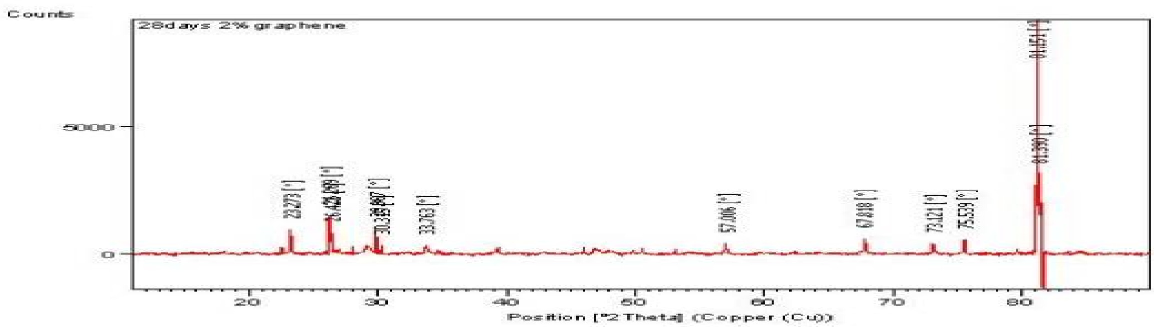


Fig 6: XRD patterns of 2%GO –concrete composites at 28days



XRD patterns of 0%, 1%, 2% GO –concrete composites at 56days

Fig 7: XRD patterns of 0%GO –concrete composites at 56days

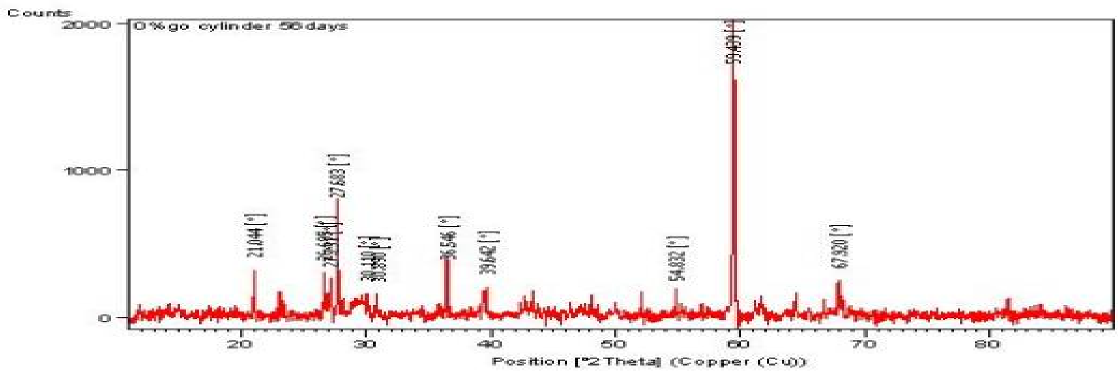


Fig 8: XRD patterns of 1%GO –concrete composites at 56days

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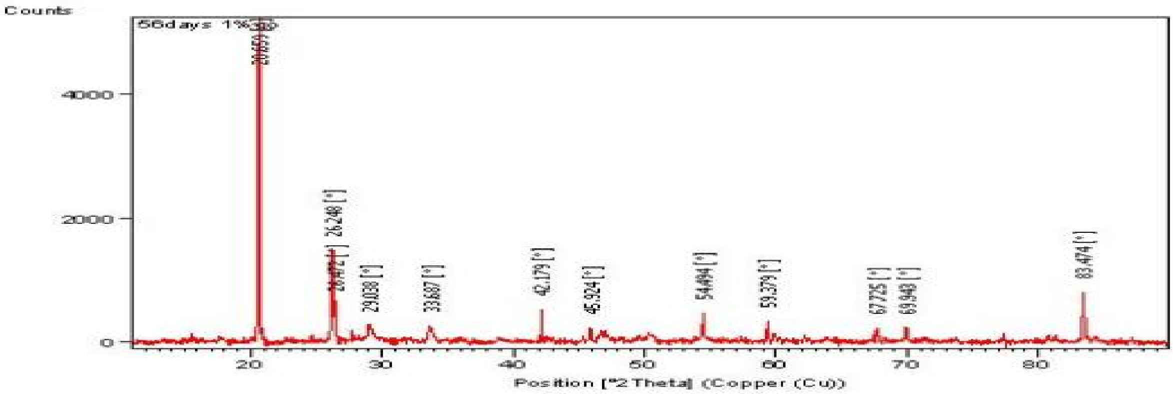
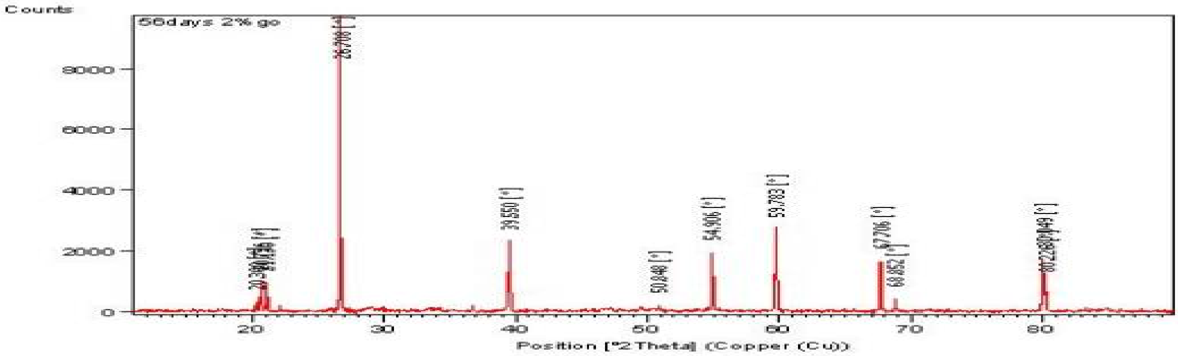


Fig 9: XRD patterns of 2%GO –concrete composites at 56days



XRD patterns of 0%, 1%, 2% GO –concrete composites at 90days

Fig 10: XRD patterns of 0%GO –concrete composites at 90days

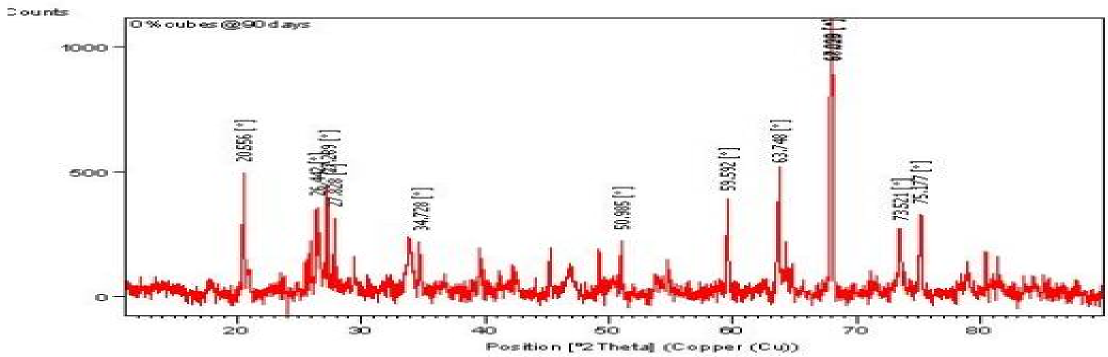


Fig 11: XRD patterns of 1%GO –concrete composites at 90days

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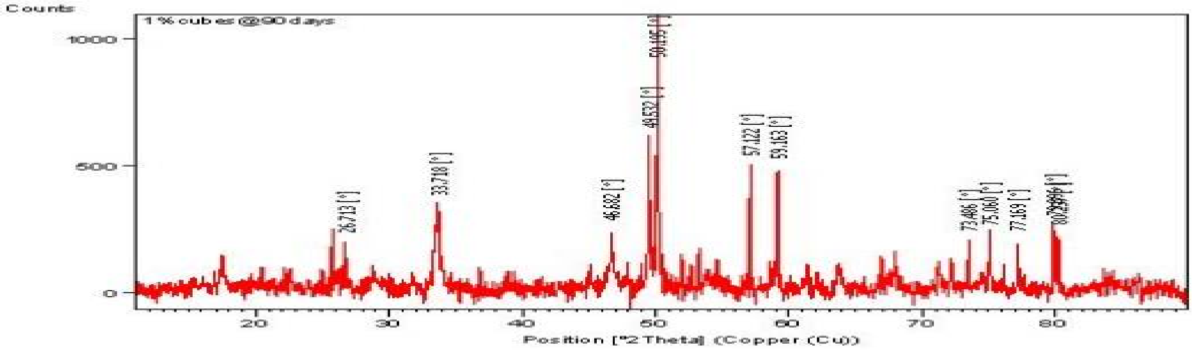


Fig 12: XRD patterns of 2%GO –concrete composites at 90days

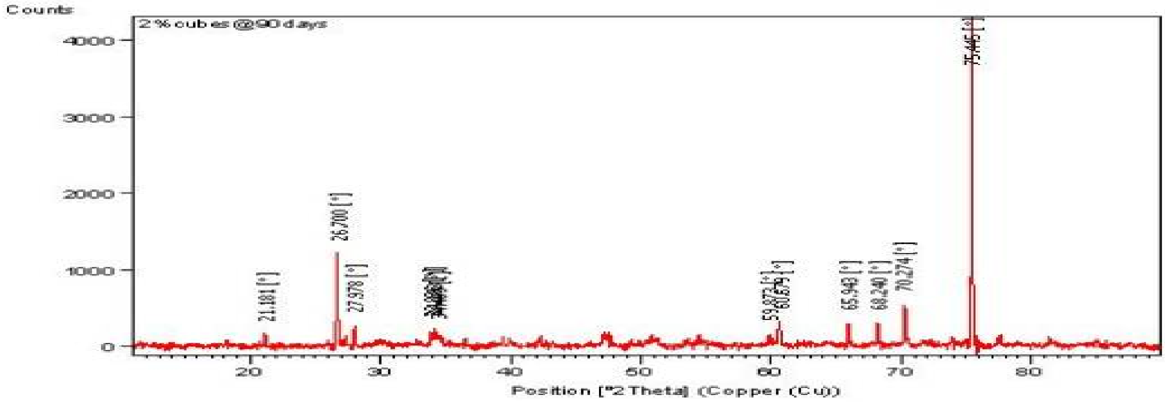
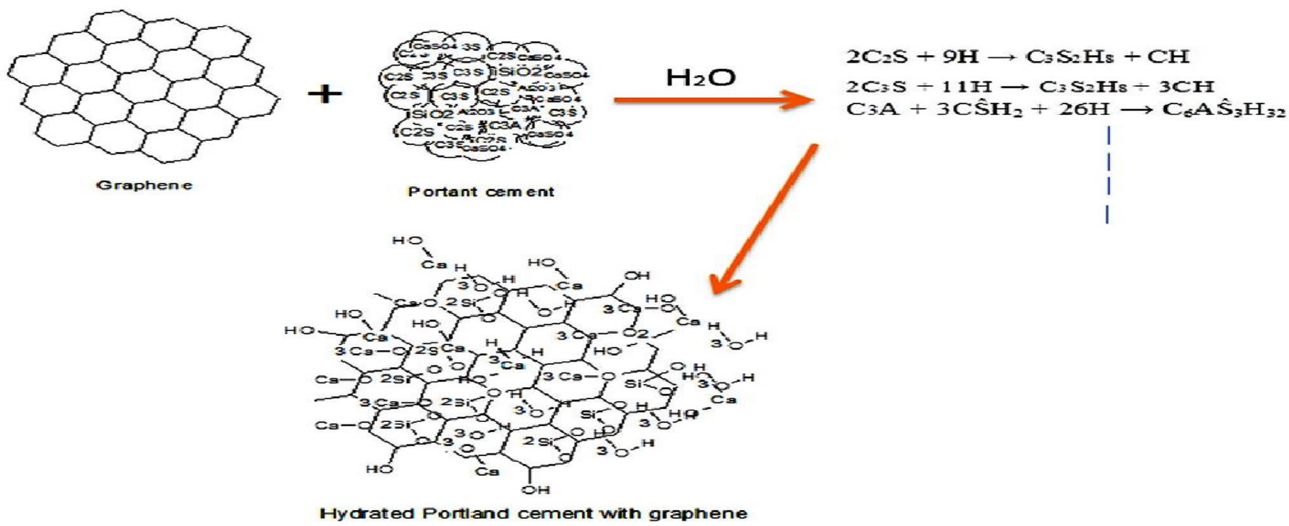


Fig 13: Schematic diagram of reaction between graphene and cement composite



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V. CONCLUSION

1. Incorporation of Graphene Nanoparticles in concrete showed interested modifications in mechanical and micro structural properties.
2. Nanoparticles graphene oxide improves the mechanical properties of the concrete, both compression and flexural strength, concrete samples were tested with Graphene Oxide (GO) in percentage of 1% to 2% by weight to obtain high strength; it is carried out for M25 grade of concrete.
3. The compressive strength of concrete increased to 7% for 1%GO content and it increased up to 17% for 2%GO content when compared with control sample at 28days.
4. The compressive strength of concrete increased to 10.44% for 1%GO content and it increased up to 17.63% for 2%GO content when compared with control sample at 56days.
5. The compressive strength of concrete increased to 9.18% for 1%GO content and it increased up to 15.33% for 2%GO content when compared with control sample at 90days.
6. The split tensile strength of concrete increased to 17.41% for 1%GO content and it increased up to 28% for 2%GO content when compared with control sample at 28days.
7. The split tensile strength of concrete increased to 24.49% for 1%GO content and it increased up to 35.55% for 2%GO content when compared with control sample at 56days.
8. The split tensile strength of concrete increased to 21.30% for 1%GO content and it increased up to 48% for 2%GO content when compared with control sample at 90days.
9. From the XRD Test it is concluded that the incorporation GO in concrete resulted in a good crystalline structure and high intensity compounds were formed when compared with control sample.

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