# Application of Graphene in Cement Based Composites – A Review

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**Abstract-** Sustainability in construction is the need of the hour, which can be achieved on a large scale by producing high-strength, high-durability cement-based products and utilising the recycled materials. One way is to incorporate nano-materials into the cement-based materials as reinforcements and additives. This not only improves the strength and functional properties but also prevents natural mining of raw materials. A decade ago, the studies were started and have yielded promising results to the present day. Nowadays, the most attractive nano material is graphene, which holds a potential market requirement of more than 9 billion USD in the year 2012 as it yields positive results in replacing silicon in electronics. Every direction in this world and space in the near future is going to have a product with graphene composite. This review sheds light on the possible utilization of the best properties of graphene for the up gradation of cement and cement-based composites, especially concrete.

**Index Terms**—Sustainability, Construction, Cement-based Composites, Graphene, Concrete, Compressive strength, Tensile strength

## 1 INTRODUCTION

Graphene – A wonder allotrope of Carbon with its best properties like the lightest known with the highest tensile strength, Young's modulus, strong electrical, optical, and reinforcing properties, is a 2D (two dimensional) material, strengthened due to C-C $SP_2$ bonds in hexagonal lattice single atomic thick carbon sheet. Synthesizing pure graphene is quite challenging whereas Graphene oxide(GO) and reduced graphene oxide (rGO) are valuable graphene derivatives and can be produced scalable. GO and rGO have different chemical and structural properties due to the differences in their chemical compositions. The most prominent differences are observed in the electrical conductivity, hydrophilic nature, mechanical strength, and dispersibility in solvents, which are the most essential in incorporating graphene into cement products.

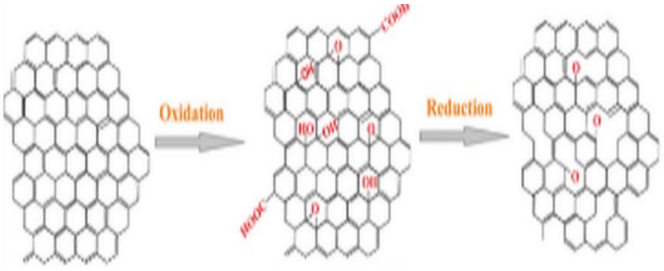


**Figure 1:** Illustration showing Chemical Structure of Graphene, Graphene Oxide(GO) and Reduced Graphene Oxide (rGO).

## 2 LITERATURE REVIEW

Valles Romero Jose Antonio et al 2016, [5] this paper describes research progress within the field of nanomaterials, which represents an important opportunity for developing compounds into nanoscale materials. The effect of introducing nanoparticles is reported at low doses for improved resistance in the concrete, better hydration, and improved microstructure and mechanical properties of the concrete, such as graphene oxide. increasing the substance of graphene oxide to a maximum of 2%, with a maximum increase of 57% at 28 days, after which decreases with advance increases in the content of graphene oxide.

BaominWang et al 2016, [6] For this study, suspensions of PNB were incorporated into the cement matrix to study the effect of PNB on the mechanical behaviour of the cement paste by weight of PNB split up by weight of cement. The compressive strength of the ordinary cement sample is increased by 7.5% to 63.3 MPa by adding 0.05%MP. However, when the age of the samples reached 28 days, the growth rates of flexural strength and compressive strength were 16.8% and 1.3%, respectively. The GNP-cement composite exhibited better mechanical properties when using surface-modified PNBs. 15% to 24% with 0.05% by weight of GNP. During this time, the compressive strength of the GNP-cement composite increase by up to 3% to 8%.

K.R.Mohammad Shareef, et al 2017, [7] this study investigates the feasibility of implementing graphene in the concrete matrix to improve its compressive and tensile or flexural strength. Although cement has great properties and high performance, its inherent brittleness is a weakness that requires

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further research for improvement. These specimens were tested at 28 days, 56 days, and 90 days of curing. The compressive strength of the concrete increased to 7% for the control sample of 1% GO at 28 days. The compressive strength of the concrete increased to 9.18% for a GO content of 1% and increased to 15.33% for a GO content of 2% compared to the control sample. to 90 days.The concrete split tensile strength increased to 17.41% for the 1% GO control sample at 28 days. The concrete split tensile strength increased from the control sample at 56 days. 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.

P. Sudheer, S. Chandramouli, et al 2017, [8] this test work is totally based on nanotechnology and came up with the thought of introducing nanoparticles within the raw materials utilised for development. In this work, graphene is utilised as a reinforcing agent in cement-based mortar and concrete. Due to the inaccessibility of graphene, a graphene compound is by utilising conventional graphite and concentrated hydrogen peroxide. Their compressive strengths are compared with the compressive strengths of conventional mortar cubes. A slight increase in compressive strength is observed when utilising graphene when compared to conventional mortar cubes.

Dimitar Dimov, Iddo Amit 2018,[9] The high shear liquid phase exfoliation method used to prepare water-based graphene dispersions is suitable for the combination of graphene and concrete due to the high throughput potential of equivalent industrial scale equipment, i.e., greater than 100 L/h-1. These include a compressive strength increase of up to 146 percent and a flexural strength increase of up to 79.5 percent. The growth of stabilised graphene dispersions in water produces the exceptional range of functionality described in this investigation, a step forward in the growing area of nanotechnology concrete that may be easily implemented in the more cost-effective development of the construction industry.

Henrik Kjaernsmo et al 2018,[10] for this study the effects of water distributing and powdering graphene oxide nanoparticles on new cement ortar, mechanical and micro-structural strength after 3, 7, and 28 days of curing. These properties are studied by treating the cement mortar with 0.03 wt%, 0.05 wt%, and 0.2 wt% GO of the cement weight combined with 0.8 wt% polycarboxylate super-plasticizer. The result shows that the workability reduces as the substance of water distributed GO increases. The percentages of the discussed substance in 0.03 wt% and 0.05 wt% GO are nearly constant, but in 0.2 wt% water dispersed GO it increased from 3.2% to 4.9%.

## 3 Conclusion

The improvements made to the concrete by Graphene were reviewed and discussed. The key areas that attracted attention and improved confidence in using graphene in cement composites were:

1) Graphene performs better as GO rather than rGO.
2) Graphene in powder or amorphous form needs more energy to achieve a uniform distribution in the cement paste matrix.
3) Graphene dispersion/emulsion obtained by ultrasonication yields better results than powder form, which also enables the RMC plants to fix dosages easily.
4) Very low proportions of graphene by weight of cement, say 0.05% to 3%, are sufficient to achieve fantastic mechanical strength results.
5) The compressive strength improves by 15% to 40%, while the tensile strength improves by 50%.
6) Even the addition of fly-ash with OPC also behaves well in the presence of GO.

**Table 1**: Comparison of graphite addition methods and mechanical properties in cement-based composites.

| S. no | Author Name | Method of using grapheme oxide | Compressive strength | Tensile strength |
|---|---|---|---|---|
| 1 | Devasena et. al., (2015) | Graphene oxide added in OPC cement 0.05 % to 0.2% of cement weight | Up to 20% | Upto 48% |
| 2 | Kai Gong et. al., (2014) | Grapheme oxide approximately OPC cement added in 0.50% of cement weight | Upto 43% | Upto 50% |
| 3 | Nandhini et.al., (2016) | 0.03% to 0.11% + 20% flyash + 80% cement | Upto 43.3 % | Upto 21.3% |
| 4 | Valles Romero et.al., (2016) | Using nano material | Upto 39.5 | Upto 57% |
| 5 | Henrik Kjaernsmo et.al., (2018) | cement mortar with 0.03 %, 0.05 % & 0.2 % GO of the cement weight combined with 0.8 wt% of super-plasticizer. | Upto 30.2% | Upto 40.9% |
| 6 | K.R.Mohmmad Shareef et.al., (2017) | implementing graphene in the concrete matrix | Upto 17.41% | Upto 21.30% |
| 7 | Dimitar Dimov et.al.,(2018) | liquid phase exfoliation method | Upto 46% | Upto 79.5% |

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