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Performance Assessment of Concrete Incorporating Recycled Coarse Aggregates and Graphene Oxide

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Abstract:The recycled coarse aggregate (RCA) can be utilized in concrete, which leads to produce a sustainable development in construction industry. On the utilization of recycled coarse aggregate minimize the amount of construction waste deposition towards environment. Also contemporary knowledge is agreed chance to progress the recycling material usage. The current research work has to access the effect of recycled aggregate concrete (RAC) containing 30% quantities of RCA with different quantities of reduced graphene oxide and to find the optimal percentage of reduced graphene oxide for RAC. The concrete mixtures formed by replacing the natural coarse aggregates(NCA) with 30% RCA and cement having0%, 0.3%, 0.6% and 0.9% of reduced graphene oxide. The mechanical properties present in the study include compressive strength and split tensile strength each evaluate after 28 days of curing all concrete mixes will be investigated .It provides a vibrant understanding on in what way it can be applied to progress the usage of 30% RCA with reduced graphene oxide content in concrete.

1 Introduction

Because of reliability in terms of strength, durability and economic aspect compared to other construction materials, the rate of production and use of concrete in the construction sector has been increasing in the recent past. On average approximately one percent of concrete was produced per person worldwide each year. Concrete is manufactured by using a huge amount of natural materials such as natural coarse aggregates, etc [1]. It is found that an average amount of 40 billion tons of a natural aggregate has been used annually around the world. The massive consumption rate of natural aggregates contributes to the limited use of these resources, which in many countries around the globe leads to a lack of natural aggregates [2]. Furthermore, natural aggregate production and processing contribute significantly to the emission of dust, noise and greenhouse gases, with a serious negative environmental effect [4]. Therefore, it is necessary for today's society to establish an alternative source of aggregates. In fact, almost all countries worldwide generate significant amounts of building and demolition (C&D) waste each year from the construction industries. The total production of C&D waste worldwide exceeds three billion tons a year. China, India and the USA, which generate approximately two billion tons of waste, contribute greatly to this waste generation. Natural forces, such as earthquakes, cyclones etc., create an enormous volume of solid waste, as large buildings are destroyed.

Consequently, recycling and reusing such waste has been described as a sustainable aggregate for the manufacture of recycled concrete as a fruitful way of mitigating the depletion of natural resources, waste management and environmental problems. RCA (recycled coarse aggregates) are produced from other discarded materials by removing demolished concrete pieces and shoring them to a suitable grading for engineering applications. RCA is an ancient, natural coarse aggregate (NCA) and two-phase material. The recycled aggregate cement (RAC) is generated in a different quantity by substituting natural aggregates for RCA. Compared to virgin aggregates, the main reason for the restricted use of RCA lies in its lower properties [6]. Several inquiries have established the lower characteristics of RCA. It is found that, due to vacuum and micro cracks on the old mortar attached to its surface, the RCA is characterized by high water absorption, low density, weak grading, etc [8]. Several experiments have been carried out to show that concrete RCA systems for structural applications can be used. Several factors like RCA, w / c ratio, strength and source age of concrete, adherence mortar and RCA humidity content have a major impact on the characteristics of RAC [5]. The properties of parent concrete such as the NCA size and the form of crushing measures impact the properties of RCA. Generally speaking, the RCA produced from the high strength and large size parent concrete NCA is of higher quality and therefore produces better RAC efficiency [7,10]. From several prior investigations, the assets of the RAC were not affected when the RCA replacement rate was below 30 percent [3,9]. Nonetheless, substantial deterioration of concrete products was observed at the higher replacement level of RCA. The compression strength (CS), bending strength (FS), elasticity module and tensile dividers have been decreased compared to conventional cement [11,12]. RAC water absorption was also improved over 50% when RCA was included in concrete. However, the durability properties of the RCA were significantly lowered by injecting RCA into concrete at higher level of substitution, such as acid resistance, carbonation, sulphate attack, chloride ion penetration, freezing and thawing [13]. While RAC showed great properties, the materials are also semi-weak with higher tensile strength and lower strain cap [14].
The research will fix RAC's weaknesses in different ways. Since nanotechnology will change the world and particularly cement-based materials, focusing on their nanoscale structure would hopefully give us more information about how we can develop their qualities [15,16]. Nevertheless, the high cost and repetitive generation approach are important considerations requiring exceptional contemplation [17]. Graphene experiments have shown that the structure and the application of graphene-concrete nano-composites. The worked reduced graphene oxide will increase interfacial efficiency, which increases their mechanical characteristics. In this investigation there was an increasing degree of rigidity in the solid examples of reduced graphene oxide (rGO) substituted by concrete with a percentage weight of cement and a good grip between rGO surrounds and cement frames. In fact when analysed with ordinary cement concrete, the rGO mortar had dispersed calcium silicate hydrate (C-S-H) gels between cement and aggregate [19]. The aim of the study is to investigate the effect of reduced graphene oxide in ordinary cement paste to enhance compressive and tensile properties of recycled coarse aggregate concrete.

2 Materials

2.1 Cement

Ordinary portland cement was used in this project. The cement quantity is obtained for testing, and deposited in a state of the laboratory environment. 0.3%, 0.6%, 0.9% reduced Graphene oxide will add with weight of the cement.

2.2 Aggregate

2.2.1 Natural coarse aggregate

Throughout the research experiments, natural aggregate was used according to Indian standard code in concrete mixes with a maximum size of 20 mm.

2.2.2 Recycled coarse aggregate

RCA is obtained from the management of the remaining, unwanted concretes and the concrete that will be destroyed. RCA's proportional size has been used in 20 mm.

Figure 1. Recycled Coarse Aggregate

2.2.3 Fine aggregate

Fine aggregate used in mixtures of concrete made of M sand with an average particle size of 5 mm according to Indian standard code book.

Table 1. Characteristics of aggregate

Characteristics	Fine Aggregate M sand	Natural Coarse Aggregate	Recycled Coarse Aggregate
Specific gravity	2.68	2.65	2.48
Bulk density	1.64	1664	1356
Water absorption	0.5	1.1	5.1

2.3 Reduced graphene oxide

Graphene oxide is a type of graphene that contains oxygen functional groups and has interesting

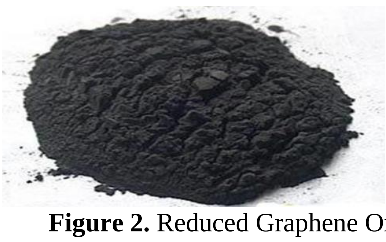

Figure 2. Reduced Graphene Oxide

properties that may vary from graphene. Such oxidized functional groups are extracted by reducing graphene oxide in order to obtain a graphene sheet. This substance of graphene is called reduced oxide of graphene, sometimes abbreviated to rGO. Graphite oxide, a material made of many layers of graphene oxide, can also be derived from rGO after a process of graphene oxide reduction and then rGO.

Table 2. Parameters of reduced graphene oxide

Parameters	Approximate values
Product Purity	99%
Lateral Dimension	5-9 micrometer
Bulk Density	0.135g/cc
Thickness	0.9-2nm
Surface area	>125m2/g
Number of layers	3-6

Table 3. Chemical composition of reduced graphene oxide

Element	Percentage of Composition
Carbon	>90%
Nitrogen	<5%
Oxygen	<5%

3 Mixture method

A certain volume of reduced graphite oxide powder was dispersed into the water mixture and the polycarboxylate ether (PCE) super plasticizer to prepare rGO solution. The resulting aqueous reduced graphene oxide suspension at a concentration of 0.5 g/L was sonicated. Three mixes where prepared based on the differentiation of reduced graphene oxide % of 0.3, 0.6, 0.9.

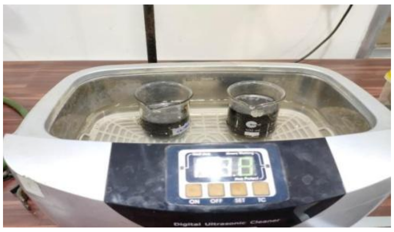

Figure 3. rGo inSonication

Figure 4. rGo mixture

4 Mix proportion

The mixing proportion of the concrete shall be maintained in 1:1.8:2.8. 30 per cent of the recycled coarse aggregate has been replaced by natural aggregates according to Indian standard code book. To determine GO's microstructural effect on RCA concrete, GO was blended into RCA concrete based on various proportions, respectively. 0 percent, 0.3 percent, 0.6 percent, 0.9 percent by weight of cement. Cement water (w / c) was selected as 0.45 due to high water absorption in RCA. Mixture was made in mixture machine. A mixture of recycled coarse aggregate, fine aggregate, cement and mixture of water with reduced graphene oxide was poured into mixture machine and rotated for 5 min. Then concrete was poured in specimen mould, after 24 hours specimen has to demould and the specimen let to water curing for 7, 14, 28 days.

4.1 Test method

To determine the compressive strength of recycled coarse aggregate cube specimen size should be in 150x150x150mm are used. Top surface should be smooth and even. Load should be applied gradually in compressive strength machine till the specimen get failed. To determine the split tensile strength of recycled coarse aggregate cylinder specimen size should be in 300mm in height and 150mm in diameter. Test should be carried out at interval of 7 days, 14 days and 28 days.

5 Results and discussion

5.1 Compressive strength

The result has been obtained from compressive strength test. Recycled coarse aggregate with reduced graphene oxide has higher compressive strength when compare with recycled coarse aggregate without reduced graphene oxide. Where reduced graphene oxide increase the improvement in the C-S-H gel could be one of the reason for increasing strength. So RAC with rGo has higher strength when compare with ordinary Portland cement and RAC without rGo. The optimum percentage of recycled coarse aggregate with reduced graphene for compressive strength is at 0.6%.

Figure 5. Compressive Test

Table 4. Compressive strength of cubes with incorporating of 30 % RCA concrete with different percentage of rGO at different ages.

% of rGo with RCA concrete mix	Compressive strength in N/mm^2		
	7 days	14 days	28 days
0%	16	20	25
0.3%	20	24	28
0.6%	25	30	34
0.9%	22	26	31

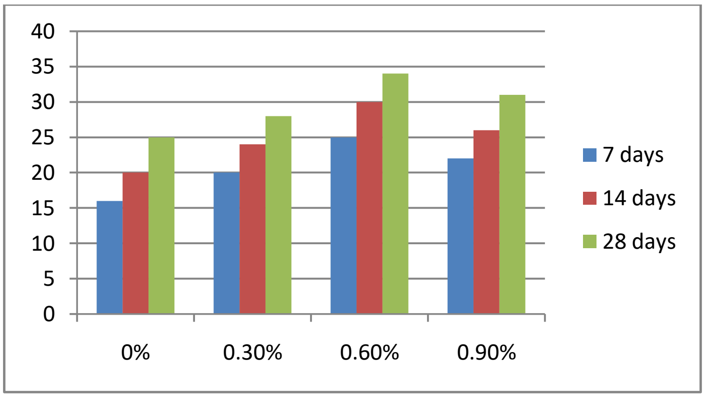

Figure 6 Comparing the compressive strength of cubes with of 30 % RCA concrete with different percentage of rGO.

5.2 Split tensile strength

Figure 7. Split tensile strength

The result has been obtained from split tensile strength test. Recycled coarse aggregate with reduced graphene oxide has higher tensile strength when compare with recycled coarse aggregate without reduced graphene oxide. Where reduced graphene oxide is good at tensile strength and increased tensile strength of specimen could be one of the reason for increasing strength. So RAC with rGo has higher strength when compare with ordinary Portland cement and RAC without rGo. The optimum percentage of recycled coarse aggregate with reduced graphene for compressive strength is at 0.6%.

Table 5. Split tensile strength of cylinder with incorporating of 30 % RCA concrete with different percentage of rGO at different ages.

% of rGo with RCA concrete mix	Tensile strength in N/mm^2		
	7 days	14 days	28 days
0%	2.12	2.35	2.93
0.3%	2.39	2.78	3.45
0.6%	2.91	3.53	4.02
0.9%	2.67	3.14	3.89

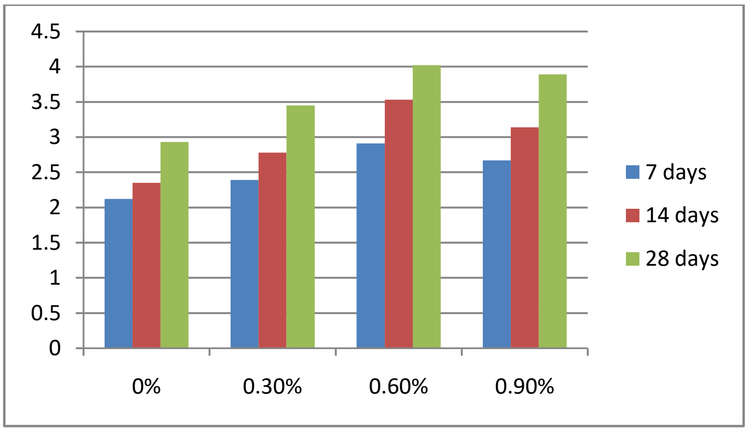

Figure 8 Comparing the split tensile strength of cubes with 30 % RCA concrete with different percentage of rGO.

5.3 Load deflection behaviour

All the beams were tested under two point loading condition. The Monotonic load was applied by using hydraulic jack and to record the load precisely, proving ring was used. The beam was gradually loaded by increasing the load level at an increment of 5kN. The beams were loaded up to failure and the values of load at first crack and at ultimate failure state were noted. As the load level was increased, the observed deflection was increased slightly in each increment of load. But the beam where analysed only by ANSYS software.The value of flexural strength is found to increase for the 0.6 percentage of reduced graphene oxide concrete than compared to ordinary Portland cement concrete. The ultimate load carrying capacity of 0.6% of reduced graphene concrete is 85kN and the load carrying capacity of OPC concrete is 65kN. Hence, the 0.6% of reduced graphene oxide with recycled coarse aggregate concrete comprises higher load carrying capacity than the OPC concrete. The maximum load deflection of beam carried out is 5.05mm.

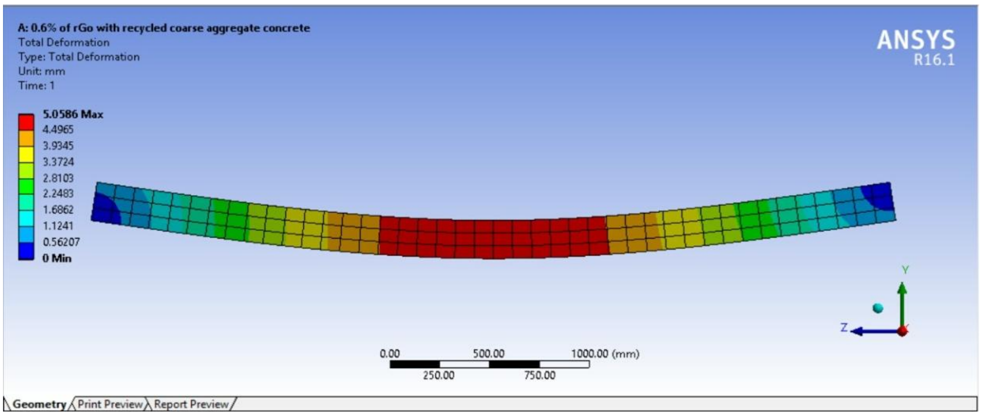

Figure 9. Total deformation of beam

6 Conclusion

In this research the mechanical properties of recycled concrete aggregate with reduced graphene oxide were studied of compressive strength and tensile strength.

The results indicate an increase in strength of compressive and tensile strength of recycled aggregate concrete with addition of reduced graphene oxide with an optimum percentage of 0.6 reduced graphene oxide with cement. Such changes may mainly be due to better interaction in the ITZ between the RA and cement matrix.

Because of the cohesive action of hydration products coupled with go filling effect, interfaces between the RCA and the cement matrix have been enhanced. The strengthened ITZ could increase the performance of RCA cement composites, which could be of important ecological and economic benefits to the construction industry.

With increasing of rGo in mortar the number of different pores decreased by transportation of charges between solid and fluid phases was hindered by the addition of rGo in the C-S-H gel in pores.

Results indicate that by adding rGo in recycled coarse aggregate haws better environmental performance than natural aggregate, which may be additional, and has equivalent mechanical strength. Speed up C&D waste recycling and then foster the sustainable building sector development.

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