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STRENGTHENING OF GLASS FIBER REINFORCED GYPSUM PANELS USING RECYCLED AGGREGATE CONCRETE

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ABSTRACT

Housing sector is one of the largest consumer in India. This reveals the demand for affordable housing thereby introducing Glass Fiber Reinforced Gypsum (GFRG) panels, an energy saving in housing sector. GFRG panel is an energy efficient green building material with huge potential for use as a load bearing and non-load bearing wall panels. It is a large load bearing panel with modular cavities suitable for both external and internal walls. Light weighted GFRG panels have high compressive strength, shearing strength, flexural strength and ductility in addition to having a high level resistance to fire, heat, termites, rot and corrosion. They are resistant to earthquakes, cyclones and fire. Concrete is used at the corner joints of GFRG panels for making it a single structure. For 3 storeys or more concrete is used as filler material in the cavities. But the usage of concrete increases the cost of construction thus making the structure uneconomical.

This project aims to make the construction using GFRG panels more economical and sustainable along with increasing its compressive strength. Here recycled aggregate concrete is used instead of normal concrete as filler material in the cavities of GFRG panels. The natural aggregates is replaced with 60% of recycled aggregates. The project also analyses the economy of construction using GFRG panels by comparing it with the cost of construction of conventional method (using brick).

KEYWORDS: GFRG, Strengthening, Economy, Recycled aggregate concrete

1. INTRODUCTION

Glass Fiber Reinforced Gypsum (GFRG) walls are large gypsum panels which are prefabricated. They have hollow cores which reduces the use of materials. It is developed in Australia in the early 1990's and then adopted by other countries, including China and India. GFRG is used in residential, commercial, and industrial buildings. These walls are used both architecturally and structurally as walls and slabs, with this the columns and beams are avoided. They have wide application, even without mature structural design codes, largely because of their environmental friendliness. Up to two storeys filler materials are not required but for buildings with 3 to 5 storeysfiller materials are required and above 6 storeys reinforced filler materials are required.

This paper presents about strengthening the structural behavior of GFRG panel with a more sustainable and economically feasible filler material rather than normal concrete. Aggregates are already diminishing day by day and the environmental threat posed by the increase in concrete waste from demolition urges the requirement of an alternative filler material. Recycled aggregate concrete makes a perfect alternative by producing an economical filler material also making the construction sustainable. As there is only a small percentage decrease in strength while using recycled aggregate when compared to normal concrete as filler material makes it a good substitute filler material.

The scope of the paper can be summarized as:

- M20 grade recycled aggregate concrete is used as filler material.
- Recycled aggregate concrete with 60% recycled coarse aggregate and 40% normal coarse aggregate is used.
- Compressive strength of GFRG panel with and without filler material is tested.

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Impact Factor: 5.164
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- Cube size of GFRG panel for testing is 250mm*120mm*300mm.
- Cost analysis of 2000 ft² house is done with conventional and GFRG building method.
- Cost analysis of 3m x 3m room using GFRG panel with NAC and RAC as infills.

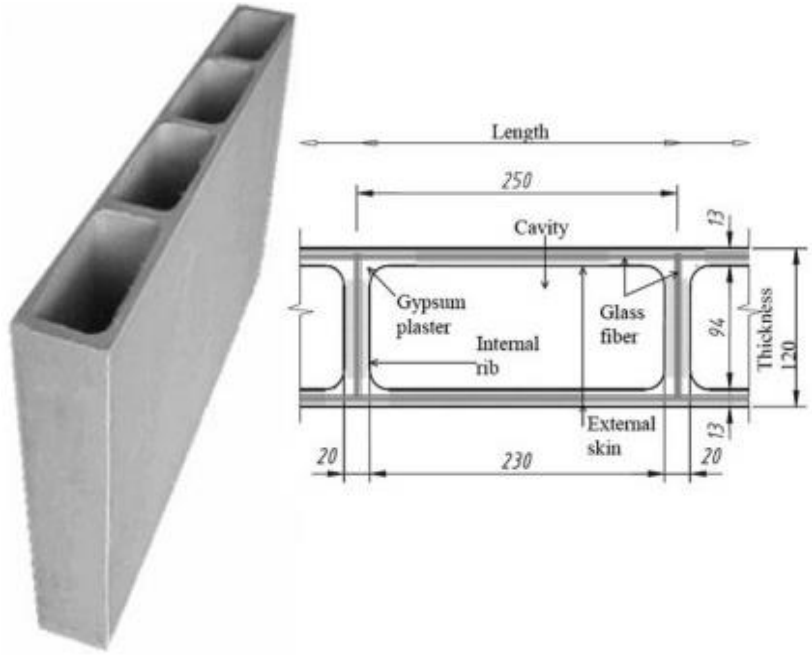

Figure-1. Dimensions of GFRG panel

2. PRELIMINARY TESTS

Tests done on gypsum plaster

Optimum moisture content test
Optimum moisture content of gypsum plaster is tested by collecting required amount of plaster after calcination process. The sample is placed in the apparatus called moisture balance MOC, and there is nothing left behind in the sampler pan of the apparatus. Final reading is obtained directly after 6-8 minutes.

Density test
Measuring cylinder of 100ml is taken and is weighed (w1) and then the measuring cylinder is filled with plaster which is collected from the outlet after calcination process and the final weight (w2) of gypsum plaster filled in measuring cylinder is taken. Density is found out from these values.

Cube test
Cube test is done with the cube of size 71mmx71mm. It is placed in universal compression testing machine and load is applied gradually till failure and final load is noted.

Tests done on GFRG block

Water absorption test
Test specimens taken from GFRG panel are of size 250mm x 300mmx120mm. The test specimens areweighted as such and then dried. The specimens are kept in the oven at 50°C for finding constant weight. The test specimens are immersed in water for 24 hours. The test specimens were taken out from water after 24 hours to

ISSN: 2277-9655
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CODEN: IJESS7

find the wet weight. The samples before weighing were wiped with dry cloth to remove surface water. With the increase in weight of panel, water absorption at 24 hours is obtained.

Axial Compression test

The test specimen of size 250mm x 300mm x 120mm is placed at the center of the platen in the compression testing machine. The specimen shall not be placed outside the perimeter of the platen of the test machine under no circumstances. Dental paste or quick setting plaster is used to cap the top and bottom faces of the specimen. Capping is done in a thin layer to ensure the firmness and to make uniform contact with the platen. The strength of the plaster shall not be lower than that of the test specimen at the time of testing. Then the compression load is gradually applied at a rate not greater than 10KN per minute until it reaches peak load and then drops at least 20% off the peak load. The maximum applied load (F) or peak load shown in the compression testing machine is noted.

Figure-2.Test on hollow GFRG block

Density test of panel

The density (weight per surface area) of a specimen is calculated by taking the measurements for each specimen immediately after the water content tests and before water absorption tests. H1 and H2 are the lengths of the two vertical sides respectively and B1 and B2 are the horizontal dimensions that is perpendicular to the vertical sides measured with a right-angle ruler with an accuracy of within 1mm. W is the weight of the specimen measured and dimensions H1, H2, B1 and B2 are shown in figure below.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

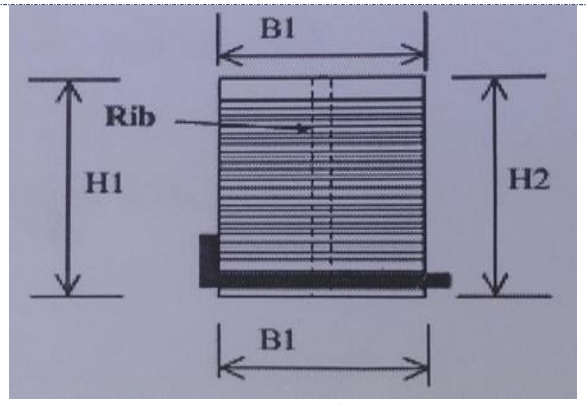

Figure-3.Dimensions for density test

Density ρ is obtained from the equation below.
Density = W/{[(H1+H2)/2]x[(B1+B2)/2]}

3. COST ANALYSIS

Cost analysis of conventional and GFRG panel building
The estimate for the construction of the building as per the plan area of 2000ft² considering the present market cost is done using conventional building method(using brick) and using GFRG panels. The cost analysis is essential in order to study the feasibility of the GFRG method during the project design stage to get successful investments.

Cost analysis of GFRG panel with NAC and RAC as in fills
The cost for construction of a room of size 3m x 3m is estimated for Natural Aggregate Concrete and Recycled Aggregate Concrete as infillings in the voids of GFRG panels and analysis is done to find the economy of the infillings.

4. SELECTED FILLER MATERIALS

Nominal mix M20
The nominal mix was prepared with M20 grade concrete since the decrease in cement content leads to a more economical mix. Comparison can be made amongst the other special types of filler materials when nominal M20 mix is used. The GFRG panel already have good structural strength and when M20 grade concrete mix is used it gives extra strength. More than strength, integrity is the priority which can be achieved by using M20 grade concrete. Therefore the experiment is more viable and economical by using M20 grade concrete as filler material. The nominal mix is worked out for Zone II fine aggregate. The coarse aggregates used were of 20mm to 25mm size.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Figure-4.Test on GFRG filled with NAC

Recycled aggregate concrete

In our society, protection of environment is very important and earning more priority. By reusing, recycling and reducing the use of raw materials would decrease the waste materials into the environment. Construction industry is emitting waste which is estimated as 12 million to 14.7 million tonnes per annum in India, of which 7 million to 8 million tonnes are concrete and brick waste. Some of the construction and demolition waste is recycled and reused and the remaining is landfilled. The use of recycled aggregates from construction and demolition wastes can be used as an alternative to natural aggregates. Therefore, the study about recycled aggregate concrete and it's characteristics like workability, strength, durability is needed for different applications in construction industry. Here normal aggregates were replaced with 60% recycled aggregates which were taken from compression tested cubes and demolition waste. These aggregates where thoroughly washed and grits, dirt etc. are removed. The coarse aggregates used were of size 20mm to 25mm.

Figure-5.GFRG block filled with RAC

5. RESULTS AND DISCUSSION

Various tests were conducted on the GFRG panels to determine its physical properties.

Table 1. Properties of gypsum plaster

Properties	*Value*
Optimum moisture content	5.5%
Density	0.96g/cm^3
Cube strength	5.1N/mm^2

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Table 2. Physical properties of GFRG panel

Properties	*Value*
Density (weight per surface area)	45kg/m^2
Water absorption	3.4%
Compressive Strength	1.3 N/mm^2

Table 3. Compressive strength of GFRG panel with filler material

Compressive strength	
GFRG block filled with NAC	16.22 N/mm^2
GFRG block filled with RAC	13.89 N/mm^2

Table 4. Result of estimation

Type of building	*Estimate in Rs.*
Conventional building	25 lakhs
GFRG building	20.1 lakhs

Table 5. Result of GFRG panel with NAC and RAC

GFRG infills	*Estimate in Rs.*
Normal aggregate concrete	66414
Recycled aggregate concrete	64882

6. CONCLUSION

Properties of Gypsum & GFRG Panel:

- GFRG Panels are light weight building material which can be used as walls and roof slab.
- Phosphogypsum, which is by-product of fertilizer industry can be effectively used in the production of panel.
- Compressive strength of hollow GFRG Panel was obtained as 1.3 N/mm^2.
- Water absorption value is obtained as 3.4%.
- Density of GFRG panel is obtained as 45kg/m^2.

Strengthening of Panel:

- From the results obtained from various tests conducted on GFRG panel, it is clear that the compressive strength gets increased with the inclusion of filler materials.
- Nominal- M20 mix gave maximum strength when used in panels.
- Recycled aggregate concrete filler also gave satisfactory strength in compression, and in-turn it leads to an economic method of construction.
- There is only a reduction in compression strength of 12-18% when replacing normal aggregate with recycled aggregate (60% replacement).
- Recycled aggregate being a waste product of demolished buildings can be effectively used as a replacement for filler material in GFRG Panel.

Cost estimation in construction using GFRG panel method and conventional method:

- Using GFRG panels construction cost will be less compared to construction with conventional material.
- For mass housing or flats, average savings will be around 30 to 40% in cost.
- When the construction cost includes labour cost then the cost is further reduced.
- For a 2000 ft^{2}building the time of construction in almost 3 months.

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Cost analysis of construction using GFRG panel with NAC and RAC as infills:

- Using GFRG panels with Recycled Aggregate Concrete as infills there is a reduction in cost about 2%-4% decrease in cost when compared to Normal Aggregate Concrete as infills for housing construction.
- For mass housing construction and flats there will be a reduction in cost of 8% - 14%
- There is only a small cost incurred for making the recycled aggregates to required sizes.

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