EXPERIMENTAL STUDY ON THE BEHAVIOUR OF GYPSUM PLASTER BOARD INCORPORATED WITH WASTE PLASTIC

[1]Muruganantham R, [2]Chockalingam T, [3]Jacksingh Dharma B, [4]Thanga Guru K

[1]Assistant Professor, Department of Civil Engineering, Ramco Institute of Technology, Rajapalayam
[2]Assistant Professor (Senior Grade), Department of Civil Engineering, Ramco Institute of Technology, Rajapalayam
[3,4] Final Year Student, Department of Civil Engineering, Ramco Institute of Technology, Rajapalayam
*murugasanjeev@gmail.com

ABSTRACT

Plastering is a construction technique using a mixture of cement, fine aggregate (River sand or M-sand) to create a smooth, protective finish on walls and ceilings. It conceals imperfections, enhances aesthetics, and improves insulation. But Cement production is a major source of carbon dioxide (CO_2) emissions. River sand mining can alter and destroy natural habitats in and around riverbeds. Quarrying for raw materials to produce M-sand can disrupt local ecosystems and habitats, potentially affecting wildlife and plant species in the area. Instead of traditional cement plastering, Also The generation of waste plastic is increasing day by day. It has numerous negative effects on the environment. 9.46 million tons of plastic garbage are produced in India each year. The fact that about 40% of this waste is not collected has an impact on the environment. Hence the Eco plaster gypsum board making with waste plastic, used for reducing environmental impact and contributing to sustainable construction practices. These Board typically incorporate eco-friendly materials such as waste plastic pet bottles, waste cement bag and production practices to minimize their carbon footprint and contribute to a greener construction industry. The study's objective is to look at the gypsum plaster board's mechanical characteristics, including its water resistance, flexural strength, and compressive strength. In this study, small fragments of used pet bottle plastic are shred and heated to depolymerize them. Ethylene glycol and Nano-Magnesium Oxide are added in the proper amounts for the chemical reaction. The board is then made by mixing melted waste plastic with gypsum. By adding of molten waste plastic it improves the water proofing capacity of gypsum board by 30%, The study aims to address the fragility of plaster in the design of decorative pieces with large dimensions that may cause issues for users. Specifically, the plaster will be reinforced with a ratio of 1 and 2% for plastic fiber and 5 and 10% for liquefied plastic, based on the volume of reference specimens that were studied. Test samples were created for the experiment and put through the Flexure and Total Water Absorption tests. The purpose of this study is to lessen the quantity of waste plastics that are disposed of in landfills and to examine the water-resistant qualities of gypsum plaster board combined with used plastic bottles. The PET (Polyethylene Terephthalate) bottles, once collected, undergo a chemical process where they are transformed into a liquid form. This process utilizes Ethylene glycol and Nano-Magnesium Oxide as catalysts, with a specific ratio of 4:1 EG to PET molar ratio. The aim is to evaluate their suitability as a viable alternative to address moisture issues in buildings. Consequently, the material being examined presents a promising replacement for gypsum currently available in the market, particularly in areas of buildings susceptible to water exposure. Moreover, it contributes to reducing environmental impact.

Keywords: Gypsum Board, Waste Plastic, Polymerization, flexure test, water absorption test.

1 Introduction

The global construction industry faces dual challenges: meeting the growing demand for building materials while addressing pressing environmental concerns. Gypsum plasterboard, a widely used construction material, accounts for approximately 5-8% of construction waste in developed countries [1]. Simultaneously, plastic waste management has emerged as one of the most significant environmental challenges of our time, with only 9% of all plastic waste ever produced being recycled [2]. The integration of waste plastic into construction materials presents a promising solution to both these challenges. Recent years have witnessed increased research interest in incorporating various types of waste materials into building components, driven by both environmental consciousness and the search for improved material properties. Gypsum plasterboard, given its widespread use and relatively simple manufacturing process, offers an excellent opportunity for such innovation.Previous studies have demonstrated the potential of incorporating different waste materials into gypsum-based products. For instance, Zhang et al. (2019) [3] successfully integrated recycled rubber particles into gypsum composites.

This study aims to investigate the physical and mechanical properties of gypsum plasterboard incorporating different percentages of waste plastic as a partial replacement for conventional materials. The research focuses on understanding the impact of waste plastic incorporation on key performance parameters, including compressive strength, flexural strength, thermal conductivity, and water absorption characteristics.

By examining these properties through systematic experimental analysis, this study contributes to the growing body of knowledge on sustainable construction materials and provides valuable insights for the practical application of waste plastic in gypsum plasterboard manufacturing. The findings have significant implications for both waste management strategies and the development of eco-friendly building materials. The integration of waste plastic into gypsum plasterboard presents unique challenges and opportunities in terms of material behavior and manufacturing processes. Traditional gypsum plasterboard, comprising primarily calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) and paper facing, exhibits well-documented properties including fire resistance, acoustic insulation, and dimensional stability. The incorporation of waste plastic materials necessitates a comprehensive understanding of how these fundamental properties may be altered or enhanced.

Previous studies investigating polymer-modified gypsum composites have shown varying results depending on the type, size, and percentage of plastic incorporation. While some researchers have reported improvements in water resistance and impact strength, others have noted potential challenges regarding fire performance and bonding between the plastic and gypsum matrix. These contradictory findings highlight the need for systematic investigation into optimal plastic waste incorporation methods and their effects on board performance.The selection of appropriate waste plastic types for incorporation is crucial, as different polymers exhibit varying physical and chemical properties that can significantly impact the final product. This study specifically focuses on polyethylene terephthalate (PET) and high-density polyethylene (HDPE) waste, given their abundance in the waste stream and relatively consistent material properties. The processing of these materials, including size reduction and surface treatment methods, plays a vital role in achieving desired composite properties.

2 Materials and Methods

Experimental Procedure

Preparation of PET: Gypsum composite involved series of steps as follows

(i) Green synthesis of MgO nanoparticles

MgO is used as a catalyst in converting PET into a paste or powder for further processing. It is prepared by a green synthesis method. $MgSO_4$ is dissolved in water.

(ii) Preparation and chemical recycling of PET powder

Waste PET bottles were collected from a local landfilling site. They are shredded into 10mm x 10mm. Approximately 100g of PET shreds and 116 ml of ethylene glycol (EG) were combined. As a catalyst, 0.05% of nano magnesium oxide was combined. For three hours, the mixture was boiled in a Leibig condenser until it was almost at the ethylene glycol boiling point. The shredded plastic was slowly converted into a liquid, then into paste form and finally dried into powder form in an hot air oven. Plastic fibres cut from the cement bags were also used in the investigation instead of liquid PET for comparison. Fig No.1 shows the process of manufacturing of liquified plastic waste for water proofing.

Fig. 1: shredding of plastic waste

Fig. 2: Polymerization process

Fig. 3: Molten plastic

Fig. 4: Plastic Fibre

Preparation of liquefied waste plastic for water proofing

(iii) Preparation of modified gypsum board using PET and plastic fibres

The liquid form of PET and plastic fibres were mixed with gypsum plaster. The components were mixed to homogeneity, moulded and dried into a board. The components and board parameters were listed in table 1. In addition to the modified gypsum-PET composite plaster board, normal gypsum board and PET paste coated gypsum boards were also prepared for a comparative study.

Table 1: Components and dimensions of the gypsum composite plaster board

S.No.	Components	Dimensions/measures
1	Length of the board	60mm

2	Breadth of the board	60mm
3	Thickness of the board	15mm
4	Volume of the board	$54000mm^3$
5	quantity of gypsum	4.59kg
6	quantity of fibre	0.054kg
7	quantity of water	2300ml
8	percentage of plastic added	14%

(iv) Characterization of gypsum composite plaster board

(a) Sieve analysis

The sample was precisely weighed to 1000g, and the sieves were meticulously cleaned to ensure no particle blocks were present. The sieves were then arranged in a shaker according to their size ranges, ranging from 4.75 mm for the largest to 0.075 mm for the smallest. Over a period of ten minutes, the materials underwent sieving using the designated set of IS Sieves. Following the completion of the sieving procedure, the aggregates collected on each sieve were weighed individually. The cumulative weight of material passing through each sieve was calculated as a percentage of the initial sample weight. This process was repeated for two additional samples. The quantity of fine aggregates present in the gypsum mixture was determined through sieve analysis. Furthermore, the fineness modulus of the aggregate was calculated using the prescribed formula.

$$Fineness\ modulus\ of\ aggregate = \frac{(Cumulative\ \%\ retained)}{100}$$

The details of the sieve analysis are listed in the table 1.

Table 1: Sieve Analysis for Fine Aggregate of Gypsum Mixture

Sieve Size	Weight retained (g)	Cumulative % retained	%passing
4.75mm			100
2.36mm	1.5	0	98.5
1.18mm	35.5	1.5	63
0.71mm	26	37	37
0.425mm	30	63	0
0.212mm	4	93	3
0.125mm	2	97	1
0.75mm	0.1	99	0.9
EmptyPan		99.1	
Total		489.6	

The fineness modulus of the given fine aggregate is 4.896. As per IS code (IS 383 -2016 fine aggregate modulus.

Materials used and Casting of Gypsum Board

Length of the board =60mm, Breadth of the board = 60mm

Thickness of the board =15mm, Volume of the board = 54000mm^3

Quantity of gypsum = 4.59kg, Quantity of fibre = 0.054kg

Quantity of water =2300ml, Percentage of plastic added =14%

Fig.5: Preparing pet powder from waste plastic

Fig. 6: Procession of plastic

Fig. 7: Gypsum Plaster Board

Fig. 8: Mold used for the plaster board

3 Results and Discussion

3.1 Mechanical Properties

A compression testing apparatus with a 200-ton capacity was utilized to assess the compressive strength of cast mortar cube samples and gypsum mortar, depicted in Figure 9. Before commencing the procedure, thorough cleaning of the machine's bearing surface was undertaken to eliminate any dirt or contaminants. The specimens were subjected to a consistent load until they collapsed, with pressure closely monitored throughout. These tests pushed the specimens to endure the highest recorded load. The results from the crushing strength tests conducted on the specimens after 28 days are presented in figures 10 and 11.

Fig. 9: Test set up for compressive strength

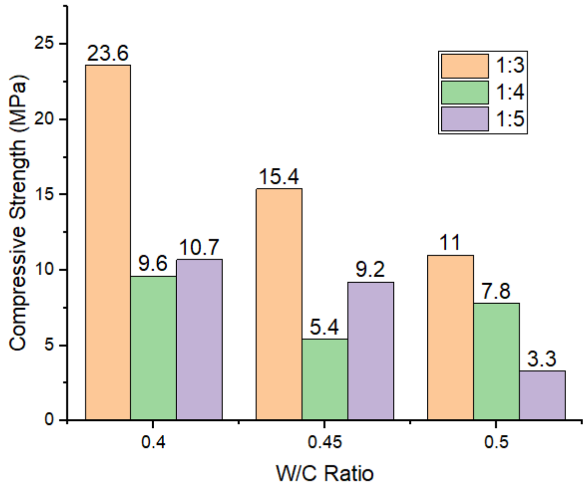

Fig. 10: Compressive Strength for Mortar Cube

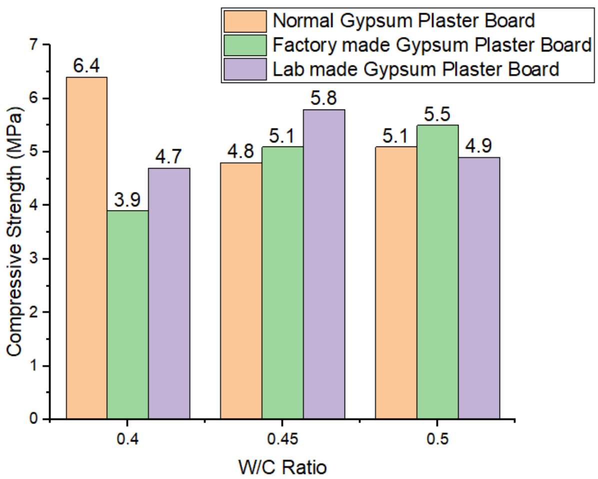

Fig. 11: Compressive Strength for Gypsum mortar

3.2 Flexural Strength for Gypsum board

The diameter of the loading and securing rollers should fall within the range of 25 to 40 mm. To determine the distance between the two supporting rollers, measured from center to center, the entire length of the specimen minus 50 mm should be considered. The loading roller needs to be positioned in a manner that applies force between the supporting rollers along the vertical center line, starting from the top of the specimen. Additionally, there should be at least 10 mm of space on all sides beyond the measurements of the specimens.

F = 3PL/2BD2. Equation 3.1,

F represents the flexural strength in N/mm².

P stands for the maximum applied load in newtons.

L denotes the measured span length in millimeters between the central lines of the rollers.

B represents the width in millimeters.

D represents the thickness of the specimen in millimeters.

It's observed that the flexural strength is greater for the 0.45 water-cement (W/C) ratio compared to other mix components. Control mixes with a 0.5 W/C ratio exhibit similar characteristics. Consequently, it can be inferred that the addition of gypsum board has no impact on bending strength at any stage of development.

Fig. 12: Flexural Strength Testing Machine

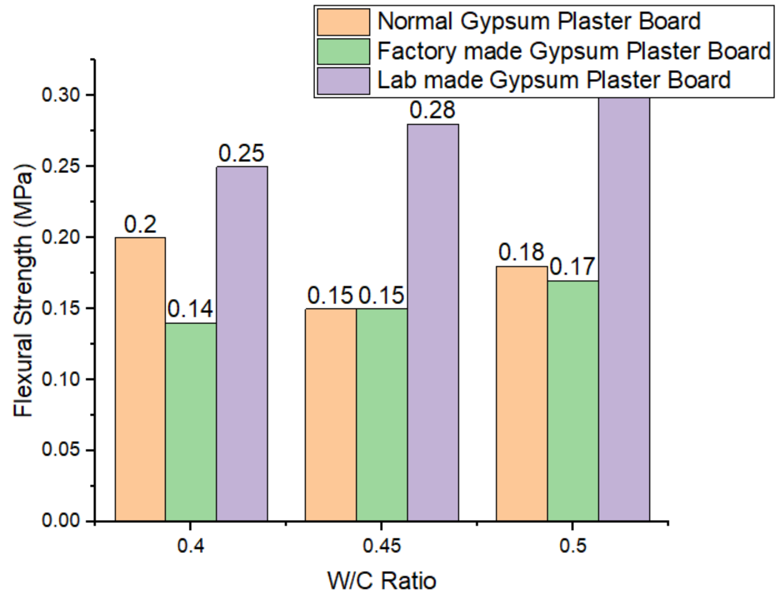

Fig. 13: Flexural strength test

3.3. Water absorption test

According to ASTM C140-11a standards, a water absorption test was conducted as follows: Specimens were submerged in water ranging from 15 to 26°C for a duration of 24 to 28 hours, ensuring their upper surfaces remained at least 6 inches (152 mm) below the water's surface. Each specimen was separated by a minimum of 18 inches. The immersed weight (Wi) of the specimens was measured while suspended in water and recorded. The process involved draining the mixture for 60 ± 5 seconds after introducing a 3/8-inch (9.5mm) wire mesh, followed by wiping away any visible water with a towel. The weight was then recorded as Ws, indicating saturated weight. After a minimum of 24 hours of drying at 100 to 115°C in an oven, the weight of the desiccated specimens was determined and documented as Wd, representing the oven-dry weight. Comparing the control mix with the gypsum board, minimal differences were observed. However, due to the inclusion of waste plastic in the gypsum board, the water absorption value of the 0.45 W/C ratio samples showed better results compared to those with 0.4 and 0.5 W/C ratios. Additionally, the gypsum board contained a coat of melted plastic waste.

Fig. 14: Water absorption test

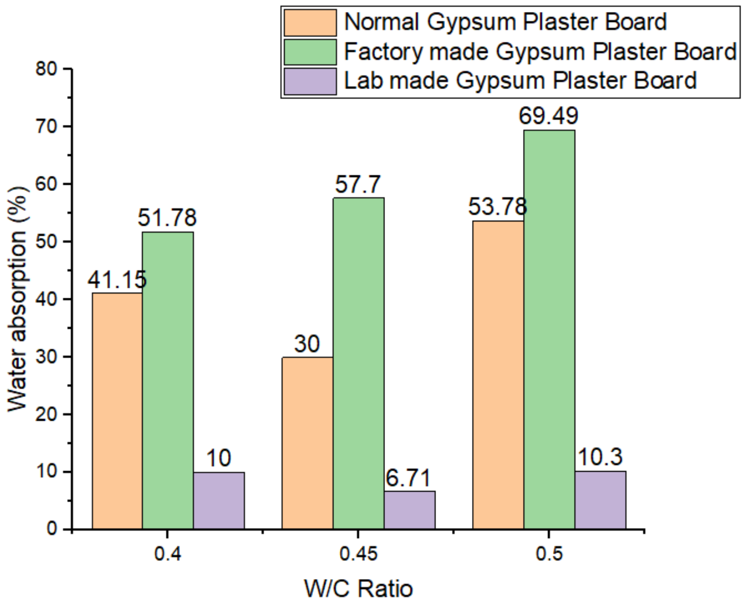

Fig. 15: Water absorption test

Conclusion

- The usage of waste plastic materials will reduce the amount of Ocean Polluting Materials, causing environmental impacts.Almost 30 to 40% water absorption can be reduced in Modified Gypsum Board.
- Modified Gypsum Plaster Board achieves maximum flexural strength whencompared with factory made and lab made Gypsum Plaster Board.
- Therefore the Modified Gypsum Plaster Board can be used in the moisture in-tented areas. The Modified Gypsum Plaster Board is cost effective and also it is safer to the Environment

Acknowledgement

The management and principal of Ramco Institute of Technology, Rajapalayam, Tamil Nadu, India, are acknowledged by the authors for providing the tools required to complete the research.

References

[1] Wang, J., Wu, H., Duan, H., Zillante, G., Zuo, J., & Yuan, H. (2018). Combining life cycle assessment and Building Information Modelling to account for carbon emission of building demolition waste: A case study. Journal of Cleaner Production, 172, 3154-3166. https://doi.org/10.1016/j.jclepro.2017.11.087

[2] Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science Advances, 3(7), e1700782. https://doi.org/10.1126/sciadv.1700782

[3] Zhang, W., Hama, Y., & Na, S. H. (2019). Drying shrinkage and microstructure characteristics of mortar incorporating ground granulated blast furnace slag and ground waste rubber tire. Construction and Building Materials, 203, 467-480. https://doi.org/10.1016/j.conbuildmat.2019.01.052