# EXPERIMENTAL STUDIES ON PROPERTIES OF PAPERCRETE BOARDS

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***Abstract - Paper as a recyclable product is economically recycled only when the operational cost is minimum. On the other hand to optimize the cost of construction, engineers have always been on the lookout for efficient and lightweight materials which require minimum labor to install and maintain. In order to recycle mixed paper waste, this study analyses the viability of its use in the production of panel boards. This study is to develop panel boards with papercrete which can be used for internal partitions. The internal partition panel thus produced inherits the properties of papercrete. For this study mechanical parameters, such as water absorption, compression and flexural strength are evaluated. Papercrete as a green building material and has potential for this study.***

***Keywords – Papercrete; Fly Ash; Panel board; Compression strength; Flexural strength;***

## I. INTRODUCTION

More than 450 million tons of paper is produced worldwide per annum and it is expected that the demand for paper will reach 500 million tons per annum by the end of 2020 [5] (Ali *et al.* 2013). The environmental impact of pollution caused by discarding paper and paper products is also quite significant. In recent years, paper and paperboard constituted the largest portion of the United States (US) municipal solid waste generation (U.S. EPA 2010; 2011; 2013; 2014). In 2006, for example, paper and paperboard accounted for 33.9% (85.29 million tons) of the US municipal solid waste generated. Of this waste generated, 12.36 million tons of newspaper and 6.32 million tons of office-type paper were generated (U.S. EPA 2007). Most waste paper ends up in landfill sites while some are incinerated. Thus, they pollute the air, water and land. Waste paper recycling has not been able to match waste paper generation. One unique recycle opportunity is using waste paper as a construction material. The construction industry has been identified as one of the largest consumer of non-renewable resources.

Consequently, using waste paper for construction not only has the potential of waste paper recycling keeping pace with its generation but it will also reduce the demand on global natural resources.

Since the large demand has been placed on building material industry especially in the last decade owing to the increasing population which causes a chronic shortage of building materials. The civil engineers have been challenged to convert the industrial wastes to useful building and construction materials. This experimental study which investigates the potential use of waste paper for producing a low-cost and light weight composite element as a building material. These alternative element were made with papercrete. As the structures of tomorrow become taller and more complex, the materials of construction will be required to meet more demanding standards of performance than those in force today [6] (Fuller 2006).

India's present housing shortage is estimated to be as high as 31 million according to census and out of these shortages 24 million units are in rural areas and 7 million units in urban areas. Such a large housing construction activities require a huge amount of money. Out of this total cost of housing construction, building materials contribute to about 70% of cost in developing countries like India. The increase in the popularity of using environmental friendly, low-cost and light weight construction materials in building industry has brought about the need to investigate how this can be achieved by

benefiting the environment as well as maintaining the material.
In the construction industry, building technology is heading towards an entirely new area because of the usage of industrial wastes in various forms of building material production. For instance, the use of waste rubber, glass powder, industrial waste fibres, wood sawdust wastes and limestone powder wastes in building material production has received diligent attention over the past few years. This is quite understandable because it is slowly but increasingly being recognized that the economic progress in construction depends more on an intelligent use of materials and constant improvement of available materials.

## II. OBJECTIVE OF THE PROJECT

To utilize the waste materials like paper, fly ash etc., in the process of manufacturing new type of eco-friendly papercrete boards. To experimentally investigate the properties of papercrete boards.

## III. REVIEW OF LITERATURE

**Sirajul Muneer. M et al, (2016) [1]** studied by replacing natural resources by industrial waste for sustainable construction and for economic reasons. The industrial waste are difficult to dispose and the disposal of these materials are costly. Hence, these industrial wastes were used in construction materials. This project reports on experimental investigation of wall panels and slab panels constructed by Ferro-cement techniques using industrial waste like copper slag, fly ash and gypsum. Phosphogypsum and sludge were used as partial replacement for cement. Specific gravity is higher for copper slag compared to sand. As the content of copper slag increases density of cement mortar increases. Water absorption of copper slag is less compared to sand. Hence, the water requirement for mixing is less than the conventional cement mortar. The overall results demonstrated good performance of ferrocement panels which can be true construction merits in both developed and developing countries. Therefore, further research work can make it much better.

**Clauidu aciu et al, (2014) [2]** have reported a study on the recycling of paper waste, which is frequently found in almost all activities. In order to obtain an ecological plastering mortar, paper materials were used in four mortar recipes, as well as the methods of preparation were presented. Paper can be recycled only 6-10 times because with each recycling the length of the cellulose fiber was reduced. One ton of recycled paper is equivalent to saving 17 trees. This was adopted for newspaper and copy paper.

This four mix proportions were tested for density, compression, bending, water absorption, and adhesion behavior. Optimal proportion of the mortar recipe was around 40%. The developed technology ensures the manufacture of a new ecological plastering mortar with minimal embodied energy and with good thermal insulation properties. Comparing to normal mortar the density was between 842-1147 kg and $m^3$.Then it is a very good fire resistance and sound absorption material.

**Randhir J. Phalke et al, (2014) [3]** have reported the effect of using different numbers of wire mesh layers on the flexural strength of flat ferrocement panels and to compare the effect by varying the number of wire mesh layers and use of steel fibers on the ultimate strength and ductility of ferrocement slab panels. The number of layers used are two, three and four. Slab panels of size (550 x 200) with thickness 25 mm are reinforced with welded square mesh with varying no of layers of mesh. Panels were casted with mortar of mix proportion (1:1.75) and water cement ratio (0.38) including super plasticizer (Perma PC-202) with dosage of 1% of total weight of cement. Some panels were casted with steel fibers (0.5%) of total volume of composite and aspect ratio (l/d) =57. Panels were tested under two point loading system in UTM machine after curing period of 28 days.

Based on experimental test results the following conclusions were made. The flexural loads at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement panel. Increasing the number of layers of wire mesh from 2 to 4 layers significantly increases the ductility and capability to absorb energy of the panels. Presence of steel fibers also increases the flexural strength of panels as compared to those without fibers.

**Masood et al, (2003) [4]** investigated the performance of ferrocement panels in different environments. The study investigated the performance of ferrocement panels under normal, moderate, and hostile environments. The conditions were created using portable saline water for mixing and curing. Fly ash, a waste material, was also used as partial replacement of cement. The ferrocement slab panels cast with varying number of woven and hexagonal mesh layers were tested under flexure. Compressive and tensile strength of control specimens and load-carrying capacity of the panels under flexure with and without fly ash were investigated. Result showed that addition of fly ash in different environments affects the flexural strength of both woven and hexagonal wire fabric panels.

## IV. EXPERIMENTAL INVESTIGATION

### A. Materials Used

**1) Cement:** Ordinary Portland Cement (OPC) of 53 Grade (Ramco cement) from a single lot was used throughout the course of the investigation. It was fresh and without any lumps. The specific gravity of cement obtained is tested to be 3.14.

**2) Micro Silica:** Micro silica is a by-product of the manufacture of silicon and ferrosilicon alloys from high purity quartz and coal in a submerged-arc electric furnace. This is amorphous and therefore it is highly reactive which is in the form of extremely fine spherical particle. The fineness of the micro silica particles (about 40 times than Portland cement) enables them to fit in between the cement particles and especially in the voids at the surface of the aggregate and fill all the space available. This is called interface zone, whose properties influence the structural properties of concrete.

**3) Fine aggregate:** The fine aggregate used here is natural river sand conforming to zone-II of IS: 10262-2009. The specific gravity and fineness modulus are 2.7 and 2.47 respectively.

**4) Water Proofing Admixtures:** In this study, paper is the major ingredient in papercrete mix and it has high water absorption. Hence to minimize the water absorption, water proofing admixtures were used as one of additives in papercrete mix. Generally the water proofing admixtures consists of two approaches, namely internal and external. In this study, CERA concrete tonic 350 is used as water proofing admixture.

**5) Paper pulp:** Paper pulp is the main ingredient of papercrete and so its properties depend on paper's microstructure. Paper pulp is then squeezed to remove excess water. Paper is an anisotropic material and the quality and strength of its fibers differs depending on several factors including its source.

TABLE 1. PROPERTIES OF DRY PAPER

| Properties | Values |
|---|---|
| Weight | 42 GSM |
| Thickness | 0.06 mm |

**6) Geo grid:** Geogrids are geosynthetic material made from polymers such as polypropylene, polyethylene or polyester and are used widely in Civil Engineering applications to provide tensile reinforcement of soil. They are in the form of open grids so that soil can strike through the apertures and the materials dually interlock together to give composite behaviour. They are used in the construction of retaining walls, steep slopes, roadway bases and foundations. In this study it is used to provide confinement to the specimens casted.

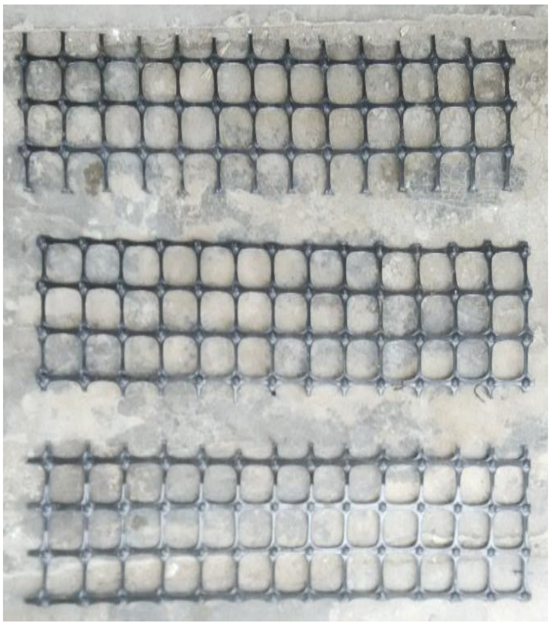


**Fig 1: Geo grid**

## V. EXPERIMENTAL WORK

The experimental program includes preparing and testing of papercrete boards under two-point loading, compression test and water absorption test.

### A. MIX PROPORTION OF PAPERCRETE BOARDS

Paper is the major constituent of the mix proportions. From literature support, papers with cement, fly-ash (replacing 10% of cement), micro silica (replacing 5% of sand) and sand with and without geo-grid mesh are used as ingredients of the mix with various proportions.

TABLE II. MIX PROPORTIONS OF PAPERCRETE

| S. No | Mix Designation | Mix Proportion C: S: P.P (%) |
|---|---|---|
| **1** | **M 11** | **40 : 30 : 30** |
| 2 | M 12 | 35 : 30 : 35 |
| 3 | M 13 | 30 : 30 : 40 |
| **4** | **M 21** | **35 : 35 : 30** |
| 5 | M 22 | 30 : 35 : 35 |
| 6 | M 23 | 25 : 35 : 40 |
| **7** | **M 31** | **30 : 40 : 30** |
| 8 | M 32 | 25 : 40 : 35 |
| 9 | M 33 | 20 : 40 : 40 |

From these materials, 9 mix proportions were used and studied in terms of compressive strength, flexural strength and percentage of water absorption.

**B. PREPARATION OF PANELS:**

A total of 9 cubes of size (70 x 70) of above proportion were casted. Compressive strength obtained to be best proportion evaluating the flexural test and compression test specimen will be prepared. Mortar was prepared by calculating the exact amount of cement, sand, papercrete and water. At first the cement and sand were mixed dry with additionally added in paper pulp, fly ash and silica fume. In admixture of CERA water proofing and water will be mixed in consider ratio. The wood mould prepared were properly oiled before casting .At bottom a layer of mortar was applied of thickness 20 mm followed by layer of geo grid and again followed by layer of mortar. The mesh pieces were cut down according to the size of panel leaving a cover of 3 mm on both side of mesh. After casting of panels they were removed from mould after a period of 24 hours. After removal the panels were dried in direct sunlight in open surface for a period of 28 days. The panels were removed from the drying after a period of 28 days. White wash was applied to the panels to get clear indication of the cracks due to loads.

**Fig 2: Paper pulp preparation**

**Fig 3: Papercrete mix**

**Fig 4: Mould oiled before casting of thickness 20 mm**

**Fig 5: Placing of layers in mortar**

### C. TESTING OF SPECIMENS:

**1) *Compressive Strength Test:*** The compressive strength test was carried out as per IS 516 -1968 (Methods of Tests for Strength of Concrete) on 750mm x 450mm x 60mm of panel board specimens to find the strength of the developed mortar mix. Compressive strength of board was found at the age of 28 days. Totally 6 mix proportion of specimens were tested. Compression Testing Machine of capacity 1000kN was used for the test. The panel board specimen was placed between upper and lower platens such a way that finished surface form the side of the specimen and exactly placed on the central axis. The load was applied gradually at UDL loading. Test was continued and the failure load was noted.

**Fig 6: Compression testing on boards**

***2) Flexural Strength Test*:** The experimental program includes preparing and testing of papercrete panel boards under two-point loading. Specimen size (500 x 150 x 60mm) and then including single layers of geo grid meshes in panels. Panels were tested for flexure test under Universal testing machine. The panels were placed on support leaving a space of 50 mm from both ends. After testing to calculate the flexural strength of the panels were loaded under two point loading and load and deflections were noted down.

**Fig 7: Flexural testing on panels**

***3) Water absorption test:*** This test is carried out to determine the amount of water absorbed by the brick. When immersed in water for a period of 24 hours it should not, in any case, exceed 20% of weight of dry brick. This test is carried out for all the samples of papercrete bricks with and without CERA WP.

**4) *Nacl resistance test*:** Test specimens of size 22.5 x 9 x 8 cm were cast and kept under 28 days curing. Then the specimens were dried and weighed. For chemical resistance NaCl the solution was prepared and the specimens were immersed in it. The test was carried out for 28 and 60 days. The solution was prepared in the proportion of 1: 5. The pH concentration of the solution was maintained. After the completion of curing time period the specimens were taken out and the surface of the specimens were scraped and surface deposits were removed, washed and dried for 2 to 3 hours and weighed again. The percentage loss was determined by,

Percentage loss in mass = [(W2- W1)/ (W1)] x 100

**Fig 8: Nacl resistance test**

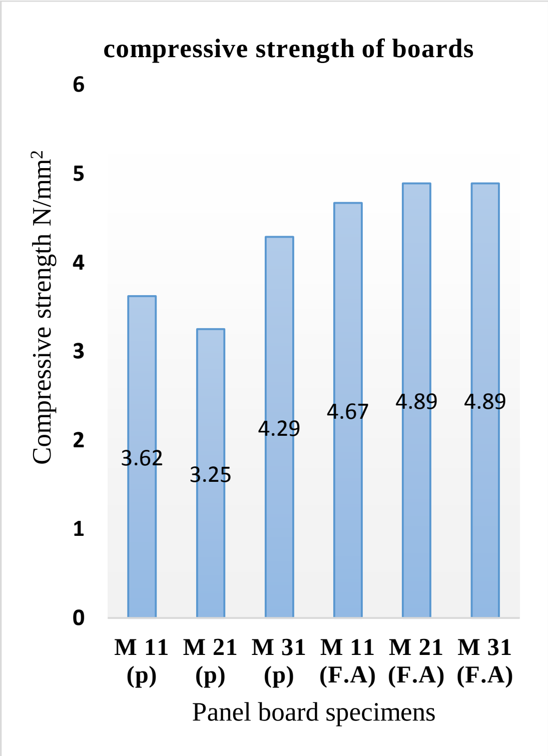
Preparation of solution, 5 % - hydrochloric acid, 100 litres of water 5 litres of NaCl

***5) Impact test:*** Specimens in the form of slabs of dimensions 750 x 450 x 60 mm were prepared using normal Portland cement, fine aggregate, paper pulp. The papercrete is mixed using a hand type mixer, placed in elastic forms. After 24 hours, the specimens de moulded. The specimens placed on the cylinder with the finished up and positioned. The weight of the steel ball is 1.756 kg and is dropped from a height of 110.8 cm. the steel ball is dropped repeatedly. The number of blows required for the first crack to form at top surface or bottom surface of the specimen is to be recorded and also for ultimate failure to be recorded. The time to hit the top surface of the specimen is also recorded. The first crack was based on visual observation. White washing the surface of the specimen facilitated the identification of this crack. Ultimate failure is defined in terms of the number of blows required to open cracks in the specimen.

**Fig 9: Impact test of boards**

## V. GRAPHICAL REPRESENTATION

### A) Compressive strength:



### B) Flexural strength:

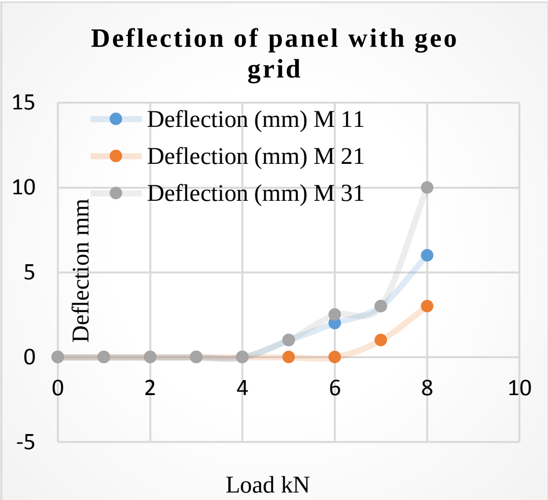



**Fig 10: Load vs deflection with geo grid panel**

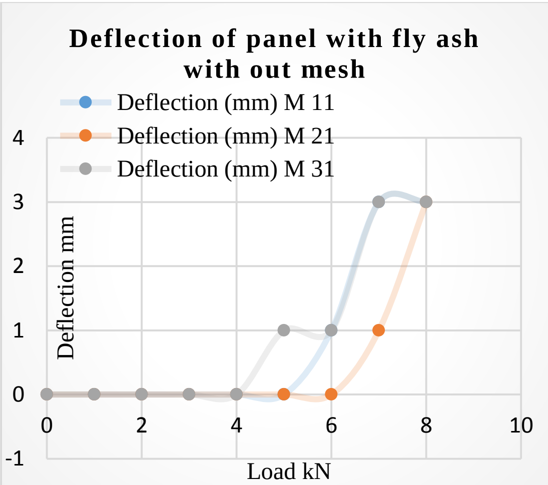



**Fig 11: Load vs deflection with fly ash panel**

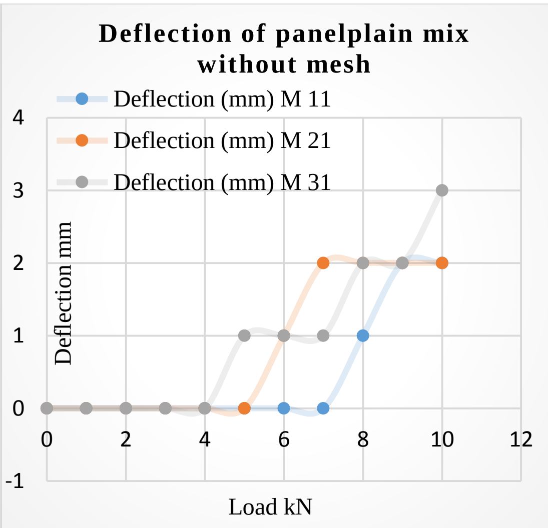



**Fig 12: Load vs deflection plain mix without mesh**

### C) Water absorption test:

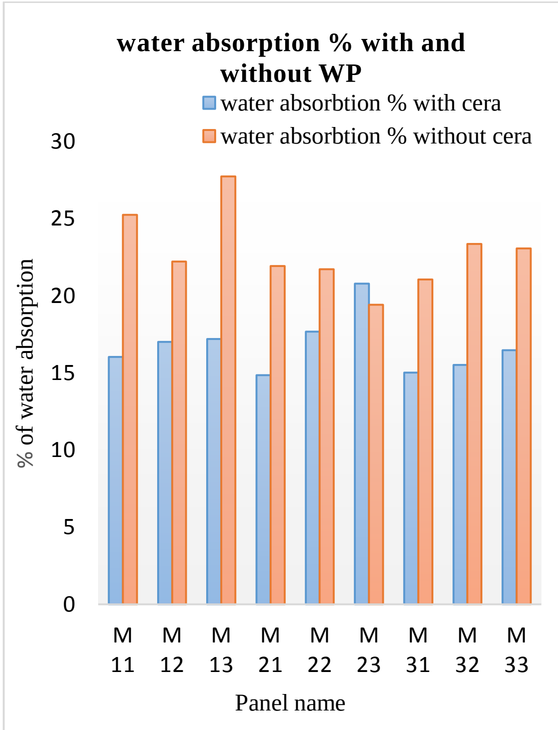



**Fig 13: Percentage of water absorption**

### D) Nacl test:

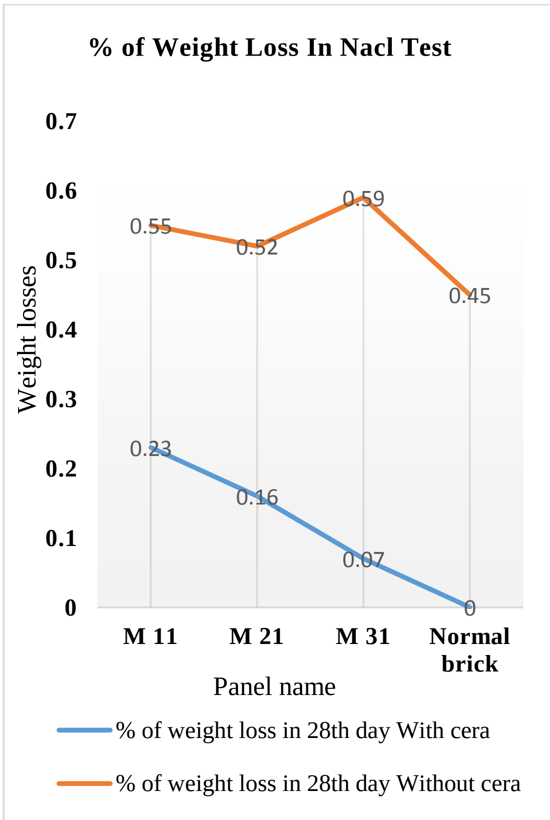



**Fig 14: % of Weight Loss in Nacl Test**

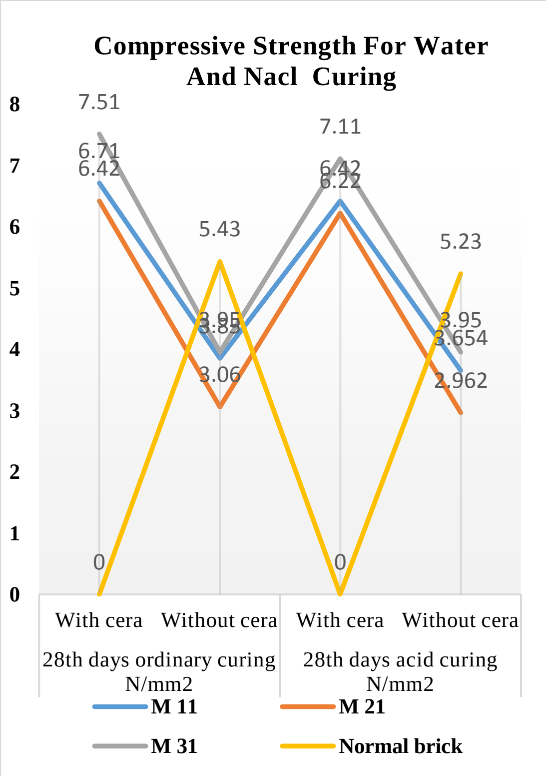



**Fig 15: Compressive Strength for Water and Nacl Curing**

**E) Impact test:**

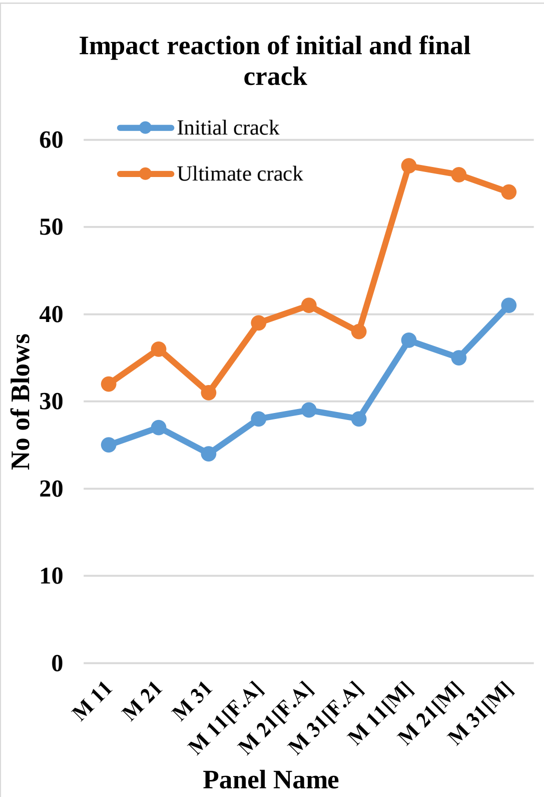



**Fig 16: Impact reaction of initial and final crack**

## VI. CONCLUSION

The experimental work shows low water absorption with CERA for M21 and good mechanical behavior at the same front. Hence this work gives positive hope of this mix proportion to be used for interior wall panels. It is needed to further study about the durability properties of these mixes. Further it becomes easy to produce these panels in large scale which will quench the thirst for search for new materials for interior panels.

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