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DEVELOPMENT OF GREEN/SUSTAINABLE CONCRETE INFILL WALLS

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ABSTRACT

The rapid growth in infrastructural development is leading to rapid environmental interruptions. Steel, cement, synthetic polymers and metal alloys used for construction activities are energy intensive, cause environmental pollution during their entire life cycle. Sustainable development could be termed as the reduction in the usage of renewable resources like soil, groundwater and biomass and etc., in a manner that does not eliminate their renewable usefulness for future generation. Also the naturally available bamboo has great potential to replace the steel reinforcement which is not fully explored. The bamboo can also reduce the wood usage so that it can reduce the deforestation. The use of Plastic waste and bamboo fibres are also used to produce composites system for the construction industry. The present study investigates the utilization of bamboo as an infill / structural element and plastic wastes for infill for the infilled wall-panels. The wall panels with bamboo and plastic waste were cast and tested. The panels are found to be more suitable for cast in-situ or precast wall panels for low cost with higher strength.

Keywords : Steel, Bamboo, Plastic waste, Prefabricate, Sustainable,Precast,Cast insitu.

1. INTRODUCTION

India, one of the most populous countries of the world is house to many sections of people who are below average in case of poverty. Shortage of housing facilities among them due to alarming rate of unaffordability has become a matter of concern in today's Indian scenario. As a matter of fact an attempt has been made to introduce low cost houses which are durable, safe and affordable.Bamboo – one of the oldest construction materials has been considered to have a high tensile strength and is being used as main structural component- reinforcement for these low cost houses. Bamboo, bearing the scientific name as *BASMBUSA TULDA, BANBUSA BALCONA* etc. is fastest growing woody plant belonging to grass family. Some of these species grow so fast that we can even see them growing. They are capable of growing 60cm or more in a day and can grow up to 30m or more. They can be grown in any climatic condition and soil type which is major factor for considering it. However the growth rate depends on the local climatic condition and soil type. It is considered to be matured after three years of its plantation and it is always advisable to go for matured bamboo for construction purpose. Bamboo is normally considered as organic and to mitigate this problem treatment is given to the bamboo samples to make the free from pest and insect attacks. One of the most important factors to be considered is that it shows its efficiency in climates having at least a little amount of humidity.

2. MATERIAL PROPERTIES

2.1GENERAL

Physical and mechanical properties of bamboo are evaluated for split and round bamboo as per IS 6874:2008 and IS 1842:1976. The properties are purely based on the requirements of reinforcement in concrete.

2.2 PHYSICAL PROPERTIES OF BAMBOO

The physical property of bamboo varies for each specimen. Moisture content and specific gravity test is carried out.

2.2.1 MOISTURE CONTENT TEST

A small piece of about 2.5 cm length shall be taken from the splint and it is weighed correct to 0.01 g and then dried in an oven at a temperature of 103 ± 2°C as per IS 6874:2008 and IS 1842:1976. The mass shall be recorded at regular intervals till the two consecutive weighing may not vary by more than 0.002g. The final mass shall be taken as oven-dry mass. The loss in mass expressed as a percentage of oven dry mass shall be taken as the moisture content of specimen. This shall be calculated correct to one place of decimal, by formula given below:

Moisture content, $\mathbf{M} = \frac{W' - W}{W} \times 100$

Where,

M =Moisture content, percent;

W' = Mass of sample in g; and

W =Oven dry mass of the sample in g.

2.2.2 SPECIFIC GRAVITY TEST

Specific gravity shall be generally determined for a hollow and strip bamboo sample. A hollow sample bamboo specimen which has node as both ends were chosen from each sample and a strip of size 150 X 20 mm in size shall be cut from the sound portion of specimen. The specimens shall be weighed correct to 0.01 g and its volume shall be measured with the help of measuring jar by a water displacement method as shown in fig 2.1

Fig 2.1 Specific Gravity Test Set Up for Hollow and Strip Bamboo

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The specific gravity shall be calculated by the formula given below

Specific gravity at test = $\frac{W}{V}$ **g /cc**

Where,

W = mass of sample in g;

V = volume of the sample in mm

2.3 MECHANICAL PROPERTIES OF BAMBOO

The mechanical properties are very important for using any material in construction and design. Mechanical properties of round bamboo were determined by conducting the compression test and water absorption test and Mechanical properties of split bamboo were determined by conducting the test such as tensile and compression. Test procedures are discussed below.

2.3.1 COMPRESSION TEST

The Hollow bamboo culms of 152mm length are cut for compressive test. Three different types of specimens are selected for the test as shown in fig 2.2. The first type of specimens contains central node; second type contains end node and third type without nodes. The dimensions of samples are measured using Vernier calliper and samples were placed in compressive testing machine of capacity 3000KN as shown in fig 2.2

Fig 2.2 Types of hollow bamboo specimens for Compression test.

The load is applied parallel to fibres of bamboo in gradual increments until the sample fail at the rate of loading 200 N/Sec and of 50 N/sec and the failure pattern is shown in the fig.3.4.Node to Node the specimen comes under long column whose Slenderness ratios are more than 12.From the ultimate load, compressive strength is determined.

As per IS 6874:2008 and IS 1842:1976 test is carried for the specimen of the length of 8 cm as shown in fig 2.3. The thickness of the specimen shall be the thickness of the splint. The dimensions shall be measured correct to 0.01 cm. The specimen shall be free from any defect like split, crack, crookedness, node, etc. For a split bamboo the specimen shall be practically rectangular in cross section with a width which shall be equal to twice the thickness.

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Fig 2.3 Failure Pattern of hollow bamboo

Lateral supports shall be provided to the specimen when needed. The load shall be applied in a uniform rate of motion of moving head equal to 0.6 mm per minute till maximum load is reached and a failure is indicated. Maximum load and the nature of failure shall be recorded. Maximum compressive strength shall be calculated by the formula given below:

Maximum compressive stress of split bamboo (N/mm^2) = $\frac{P}{lXh}$

Maximum compressive stress of round bamboo (N/mm^2) = $\frac{P}{A}$

Where,
P = Maximum crushing load in N,
l = Width of the specimen in mm,
h = Thickness of the specimen in mm, and
A = Area of hollow bamboo in mm^2.

2.3.2 WATER ABSORPTION TEST

For determining the water absorption capacity of the bamboo test is carried out for six samples of uncoated different specimens of bamboo like bamboo with single node, two nodes, without node and with different size and dimension. Dry weights of samples were noted and placed in water. The weights were recorded after a day; the samples were removed from water and wiped the surface with a cloth. The percentage of water absorption in 24 hours for 6 samples is calculated using the following formula.

Water absorption, **W = (M' - M) X 100**

Where,
W = Moisture content, percent;
M' = Mass of sample in wet state in g; and
M = Mass of the sample in dry state in g.

2.3.3 TENSILE TEST

Specimens for tensile strength test shall be with one node in the centre. The general direction of the fibres shall be parallel to the longitudinal axis of the test specimen. The length of the specimen shall be 600 mm and the width shall be 20 mm, so that the test specimen is more or less flat. The thickness of the specimen shall be that of the wall thickness or less, depending on the diameter of the culm. All the dimensions shall be measured to an accuracy of 0.1 mm, it shall be permitted to use test pieces with laminated ends for better grip. The grips shall press the test specimen perpendicular to the fibres and in radial direction to l prevent longitudinal twisting of the test piece. The load shall be applied continuously in a longitudinal axis and the movable head of the testing machine shall travel at a constant rate of 0.01 mm/s. The maximum load shall be recorded.

The maximum tensile strength σ_{ult}, (N/mm^2) = $\frac{P}{A}$

Where,
P = Maximum load, in N; and
A = Area of cross-section of test specimen, in mm^2.

3. TRIAL MIX

3.1CONCRETE NOMINAL MIX DESIGN FOR M_{20}

Grade mix designation : M_{20}
Type of cement :OPC 53 grade
Maximum size of aggregate : 12mm
Minimum cement content : 300 kg/m^3
Maximum water cement ratio : 0.60
Specific gravity of cement : 3.15
Specific gravity of coarse aggregate : 2.68
Specific gravity of fine aggregate : 2.66
Specific gravity of quarry dust : 2.5
Exposure : Mild

The nominal mix design for M_{20} is tabulated below in table 3.1. In this mix, 1 part of cementious material is split as 0.75 part of cement and 0.25 part of fly ash; 1.5 parts of sand; 1.5 parts of quarry dust and 1.5 parts of coarse aggregate (10-12 mm) is used.

3.2 BATCHING AND MIXING OF MATERIALS

The measurement of materials for making concrete is known as batching. Here, we have adopted weigh-batching method which results in accuracy, flexibility and simplicity. Batched materials are stacked near the concrete mixer machine as shown in fig 3.6. Different types of weight batchers are available; the particular type to be used depends upon the nature of the job. When weight batching is adopted, the measurement of water must be done accurately.

Concrete is mixed either by hand or machine. Here, a concrete mixer device is used that homogeneously combines cement, aggregate such as sand or gravel, and water to form concrete

MATERIALS	WEIGHT(kg)	PERCENTAGE (%)
ORDINARY PORTLAND CEMENT	35.73	0.75
FLY ASH	11.91	0.25
SAND	71.33	1.5
DUST	71.5	1.5
COARSE AGGREGATE (10-12mm)	71.5	1.5
SP (Ceraplast400)	834 ml	1.75% of cementious material
WATER	28.1 litres	w/c : 0.59

Table 3.1 Nominal Mix Details

3.3 CASTING OF COMPANION CONCRETE SPECIMENS

Metal moulds were arranged and oil was applied for easy demoulding of specimens. After thorough mixing, the concrete was transferred to the cubical moulds. Concrete was placed in three layers and each layer was compacted. The casting of cylinders and prisms followed the same pattern as that of cube casting. There are totally four sets of 3 cubes were casted and each set of cubes were tested after a period of 7 days, 14 days, 21 days and 28 days curing. In case of cylinders, totally two sets of 3 cylinders were casted and each set of cylinders were tested after a period of 7 days and 28 days curing. For prisms, totally two sets of 3 prisms are casted and each set of prisms were tested after a period of 7 days and 28 days curing. The casting of a set of cubes, prisms and cylinders.

3.4 CURING OF SPECIMENS

Curing means to cover the concrete so it stays moist. By keeping concrete moist the bond between the paste and the aggregates gets stronger so as to promote hardening of concrete. Concrete doesn't harden properly, if it is left to dry out and leads to early age drying shrinkage. To help reduce water loss, immediately after demoulding of specimens they were placed in curing tank containing potable water for proper curing until testing for a period of 7days and 28 days.

3.5TESTING OF SPECIMENS

The testing of specimen was done using highly automated and equipped CTM which can apply upto 3000kN for testing of specimens as shown in figure 3.3. The computer configured with it provides load displacement graph from which the load at failure can be easily obtained for further strength calculations. Cubes and cylinders were placed one after the other properly in the compression testing machine in such a way that load will be applied uniformly over them. Loading was given at the rate of 2.5kN/s for cubes under compression and load at failure was noted for calculating the cube

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compressive strength.

Fig 3.3 Cube Compression Test

Loading was given at the rate of 1kN/s for split tensile test of cylinders. The load at failure was noted from load displacement graph for calculating the cylinder split tensile strength .The split tensile strength test set up and failure pattern are shown in figure 3.4

Fig 3.4 Split Tensile Test Set Up and Failure Pattern of cylinder

Fig 3.5 Flexural Strength Test Set Up and Failure Pattern of Prism

4.0 CASTING OF WALL PANEL SPECIMENS

4.1 INTRODUCTION

Totally three wall panels were casted having the dimension 1.04 x 1.04 x 0.15m for two panels and one of dimension 1.10 x 1.10 x 0.15 m. Each panel has been named SAB-1, SAB-2 and SAB-3 respectively. Casting of wall panel is discussed in this session below.

4.2 SPECIFICATIONS

The thickness adopted for each panel is 150 mm. The reinforcement provided consists of 6mm dia bars of yield strength 250 N/mm^2. The 1x1 weld mesh is used for both top and bottom surface and five numbers of stiffeners at diagonals are used. A clear cover of 20 mm and beam of 65x110 mm were provided on all four sides and it is filled with concrete and remaining portion is filled with filler materials. Detailed explanation is tabulated in table

Name	Details	Size	Date Of Casting	Remarks
SBA-1	Bamboo as infill	110x110x15cm	23/01/2014	Two layer of chicken mesh
SBA-2	Bamboo as diagonal member and plastics waste as infill	104x104x15cm	05/02/2014	1x1 weld mesh
SBA-3	Bamboo as reinforcement and diagonal member and plastics waste as infill	104x104x15cm	18/2/2014	1x1 weld mesh

Table 4.1 Specification of Panel

4.3 SURFACE PREPARATION AND CONCRETING

In this stage method of preparing the infill unit of three cases are explained. For SBA-1 and SBA-2, abeam of section 0.085 x 0.12m is fabricated with 4 nos. of main rods and stirrups both using 6mmϕ MS bars to cover all round the outer edge of the mold and in case of SBA-3 round bamboo is used as reinforcement instead of steel cage as shown in figure 3.13. The open ends of bamboo are sealed with plastic covers or thermacol in order to avoid entry of concrete into the culms. Mesh (chicken mesh for SBA-1 and 1x1 weld mesh for SBA-2&3) was cut to the size of the reinforcement cage (i.e.; 1 x 1m) and it is tied to it at the bottom face using binding wires. Weld mesh is brushed using wire brush and coated with red oxide for preventing corrosion.

In case of SBA-1, hollow bamboo is cut into pieces of different length and the cut ends are sealed as shown above. Now, these bamboo pieces are filled inside the space within the reinforcement cage as boundary in random manner and it is packed tight using chicken mesh on the top which results into an infill unit as shown in fig 4.1.

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Fig 4.1 Bamboo As Infill SBA-1

For SBA-2, bamboo is used as diagonal struts and hence it is cut into four pieces of dimension 0.59 m. Then provisions for connecting the bamboo struts to the cage was made by nailing it over either sides of its both ends. The diagonal bamboo struts are held in their position and it is tied to the cage using binding wires of sufficient length to wind around the bamboo. Waste plastic bags are collected and packed tight into the free space left within the diagonal struts and the top layer is closed by tying the weld mesh to the reinforcements using binding wire.

Fig 4.2 Bamboo as Diagonal Struts and Waste Plastic Bags as Infill SBA-2

For SBA-3, the only change is bamboo was used as beam all around the outer edge of wall panel and as diagonal struts. In order to maintain the depth of beam section bamboo were placed one above the other by proper trimming of nodes. The bamboo placed above was cut into half and fixed using nail and binding wire and the open bamboo top was filled with waste plastic covers. The process of making SBA-3 infill unit is shown in fig 4.3

Fig 4.3 Bamboo as Reinforcement and Diagonal Struts with Plastic Waste as Infill SBA-3

The infill wall panels are cast within the formwork on a suitable level surface at the casting site. Mould of required size is made ready for casting infill wall panel. The mould is fixed over clean plastic sheet by using Plaster of Paris and then oil is applied on all sides of the mould as shown in figure 3.18. Initially 10 mm thick wooden cover blocks are placed in random positions as shown in figure 3.18 and concrete is laid and it is levelled to about 10mm thickness and the cover blocks are removed.Then the infill unit will be placed over the concrete layer and shake well for better compaction.Concrete is now laid at all four sides of wall panel into the beam portion, side cover and into the stiffeners. Now dead weights are placed over top of the weld mesh in order to avoid bending of weld mesh and top layer is covered with concrete. Once the concrete sets, the dead weights can be removed and finishing can be done.

Fig 4.4 Concreting of Infill Wall Panel

4.4 CURING OF INFILL WALL PANEL

The infill wall panel can be demoulded after 24 hours. Then the panel is cured for 28 days using gunny bags as shown in fig 4.5.After curing the panels were transported to the laboratory with minimum handling stresses.

Fig 4.5 Curing of Infill Wall Panel

4.5 TESTING OF WALL PANEL

The casted wall panels are tested by applying an axial compression to investigate the adequacy of the infill system. The load is applied using an enerpac jack by application of pressure through piston. The load cell with load meter is kept between slab and enerpac which gives the reading of load in Tonnes as shown in fig 4.6

Fig 4.6 Axial Compression Test Setup with Load Cell

The test specimen is prepared with white wash in order to have a pleasant appearance as well as to read the crack easily. The grid lines are drawn on the vertical surfaces with grids of size 5x5cm. This grid line helps in easy tracking of crack pattern during testing and transpiring into graph sheet.The details about the position of Strain Gauge and Dial Gauge are given below,

S_1 : Strain gauge at front middle top
S_2 : Strain gauge at front middle centre
S_3 : Strain gauge at front middle bottom
S_4 : Strain gauge at side middle
B_1 : Strain gauge at back left centre
B_2 : Strain gauge at back right centre

D_1 : Dial gauge at back middle centre
D_2 : Dial gauge at front left centre
D_3 : Dial gauge at back top centre

Fig 4.7 Position Of Strain Gauge And Dial Gauge For Wall Panel SBA-1

Spirit level is used for checking the level of the loading area. The three dial gauges are positioned as specified above and the strain gauges and dial gauges are connected to the Data Logger through cables. The readings of strain and deflection produced due to loading are obtained from Data Logger for every 0.5Tonne increment of load. The first crack was found to appear near the top. The crack widened and the panel caused failure gradually. There was no sudden failure. The other two wall panels i.e., SBA-2 and SBA-3 are tested.

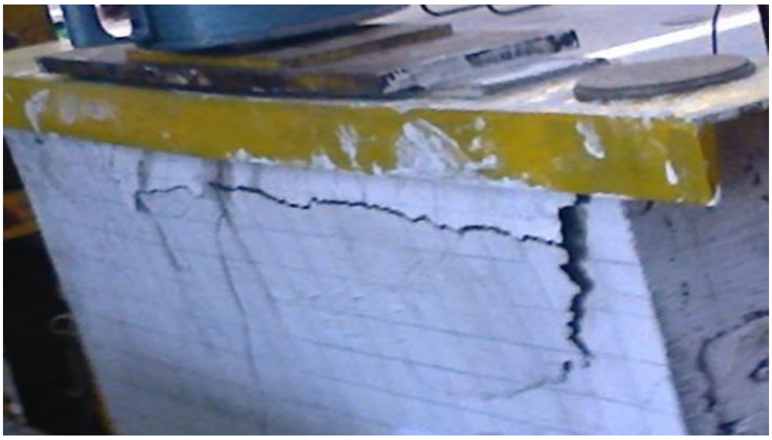

Fig 4.8 Failure Pattern of SBA-1

5.0 RESULTS AND DISCUSSION

5.1 AXIAL COMPRESSION STRENGTH OF INFILL WALL PANEL

Graphs were plotted between load and strain produced.

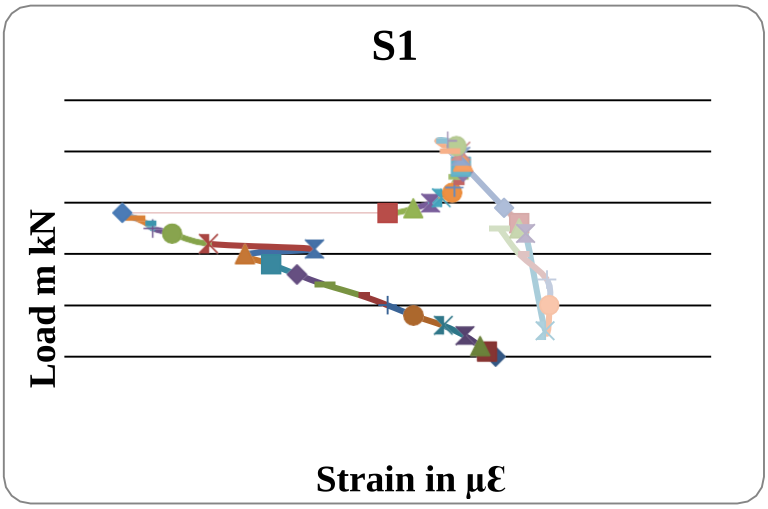

Fig 5.1 Graph Plotted Between Load Vs Strain From S1 –Strain Gauge

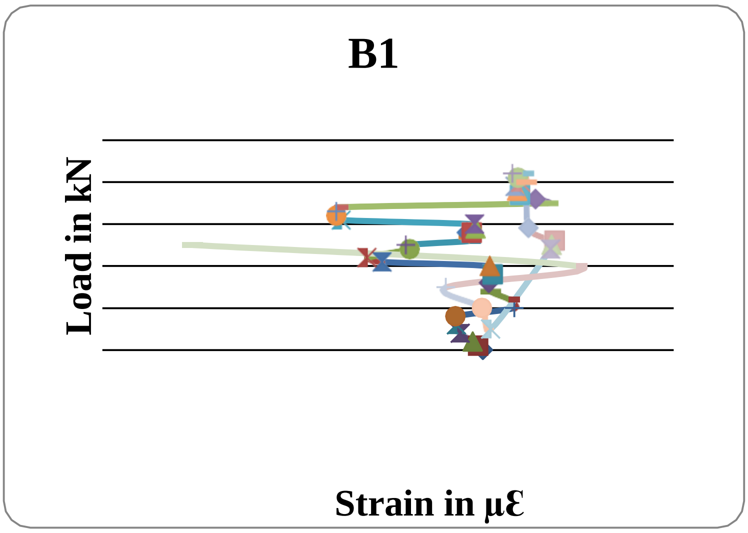

Fig 5.2 Graph Plotted Between Load Vs Strain from B1- Strain Gauge

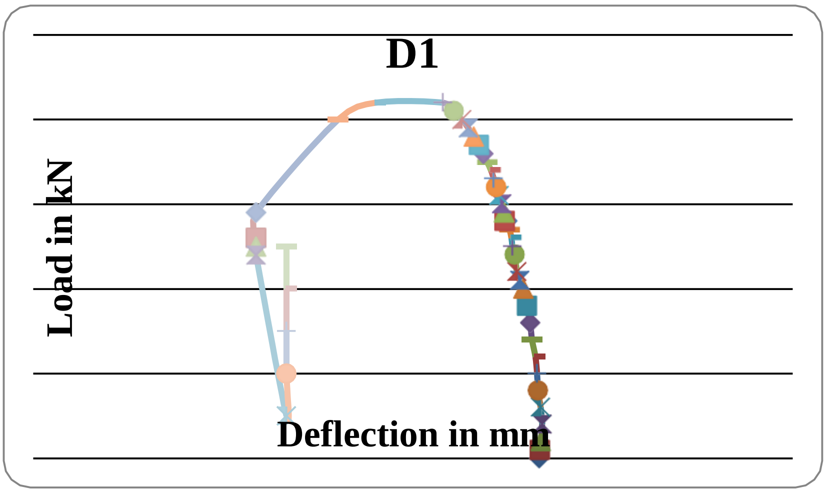

Fig 5.3 Graph Plotted Between Load Vs Deflection from D1-Dial Gauge

6.0 SUMMARY AND CONCLUSION

6.1 CONCLUSION

Testing of bamboo and its results are interpreted and the following conclusions were arrived.

1. Bamboo has the compressive strength of 65.47 N/mm^2 which is more than concrete.
2. The average percentage of water absorption was found to be 27.87% hence water proofing agent is recommended. But, the cover concrete has good water proofing properties and also the bamboo in the tested and broken infill specimens showed a dry nature of bamboo confirms resistance against water absorption. A 20 mm concrete cover is sufficient to avoid the water intrusion into bamboo.
3. The average specific gravity of bamboo is 0.78 g/cc which is very low compared to reinforced concrete and it is very much suitable for light weight composite infilled slabs.
4. The average tensile strength of the proposed bamboo is found to be about 108-125 N/mm^2 which indicates the suitability as reinforcement into the infill slabs.

From the results of compression test of wall panel SBA-1 the following conclusions are made.

1. The precast panels carried a load about 210 KN in compression. The average compressive stress of wall panel is about 1.29 N/mm^2. The safe bearing capacity is found to be 860 kN/m^2 whereas the safe bearing capacity of stock brick masonry is 50kN/m^2. Hence it is safer and capable of withstanding heavier load when compared to standard brick masonry. The results indicate the suitability of proposed infilled walls for the housing sector.
2. The first crack is at 15 Tonnes (0.90 N/mm^2) and the ultimate load is 21 tonnes (1.27 N/mm^2). The failure pattern is more gradual and no sudden collapse of slab is occurred in entire testing which indicates the superiority of proposed wall panel compared with brick infills.

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