PERFORMANCE EVALUATION OF FERRO CEMENT SANDWICH WALL PANELS WITH DIFFERENT INFILLS

P. Balaji[1], Dr. S. Arul Selvan[2]

[1]M.E. Structural Engineering Student, Department of Civil Engineering, Coimbatore Institute of Technology College, Coimbatore, Tamilnadu, India.
[2]Associate Professor, Department of Civil Engineering, Coimbatore Institute of Technology College, Coimbatore, Tamilnadu, India.

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Abstract - *The main objective of this investigation is to study the structural behavior of Ferro cement wall panels when subjected to axial compressive load. Ferro cement wall panels with different infill materials of size 1m x 1m x 0.2m were cast and tested under axial load. Experimental studies and research must determine the results in terms of ultimate load carrying capacity, compressive strength, and load vs deflection monotonic graph analysis, cyclic load graph analysis and stiffness degradation graph analysis. These results were compared as different infill materials such as red soil and m-sand are being used. The response of the Ferro cement wall panels subjected to axial compressive loading and from above results whichever infills such as red soil and m-sand wall panels are satisfactory and optimum, then it can be used as a wall panel in construction sector. It is hoped the overview on this subject matter could be used as guidance for future research on developing a lightweight sandwich panel system in low to medium rise building construction.*

Key Words: **Ferrocement Sandwich Panels, Red Soil And M-Sand Infills, Ultimate Load, Stiffness, Ductility, Stiffness, Light Weight.**

1. INTRODUCTION

The concept of industrialization of the construction technology has emerged as well accepted and preferred option in the field of building construction now days, to reduce in-situ construction up to maximum extent. This could be achieved by employing several strategies including the application of newly developed cement-based composites for structural applications. Cement based composites perform better than conventional plain concrete. Ferro cement is such a material that is slim and slender but at the same time strong and elegant which provides a potential solution to roofing problems. In countries in continuous growth and low resources economic, where the demand of house of low cost is very high, the Ferro cement has been used like an effective alternative that, on the one hand, offers durable houses and of good quality, and, on the other hand, it offers a constructive system with base in not described intensive manpower. Prefabrication saves engineering time on the construction site in civil engineering projects. Prefabricated elements and systems offer bridge designers and contractors significant advantages in terms of construction time, safety, environmental impact, constructability, and cost. The use of prefabricated Ferro cement components for construction could possibly reduce the cost of construction and time for completion.

1.1. Ferrocement sandwich wall panels:

Ferro cement is a thin, lightweight composite material which has layers of steel meshes as the tensile reinforcement encased by cement mortar. These panels possess high strength-weight ratio and extreme bending ability. The steel meshes used for these panels differ, based on the design load of the slab and multiple layers of meshes may also be used to increase the tensile resistance of the slab. The concept of sandwich slabs using Ferro cement panels with the development of high workability and high-performance slag-cement based mortar mix to cast encasement for the different infill materials is given the closely-spaced and uniformly-distributed steel mesh reinforcement in Ferro cement, transforms the brittle nature of the cement concrete into a superior ductile composite. This proves the highly versatile nature of Ferro cement panel possessing unique properties of strength and serviceability. However, due to the small thickness and labor-intensive production method of the panel, they are not accepted worldwide, which gave rise to the concept of Sandwich panels with Ferro cement, which uses the tensile strength of the high-performance panel as face sheet with lightweight, thick, low strength core. This also possesses good thermal insulation properties.

1.2. Importance for ferrocement sandwich panels

- The present modular coordination system usually focusses on the use of cement or concrete blocks for the infill or to certain extent as load bearing walls which are heavy.
- Ferro cement structural elements are widespread as lightweight, high performance composite material which can replace its counterpart conventional materials.
- Moreover, the psychological factor coined with buildings constructed with such thin sections would be unsafe to live, is also another factor.
- Thus, sandwich composite construction system, presents one of the potential solution, where, Ferro cement is applied as face sheets/encasement and different infill materials is adopted as core.

- The structural sandwich elements should be as per the standard size leading towards the industrialization of building system, to reduce the in-situ construction which is associated with social and economy problems.

2. MATERIALS

Ferro cement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small diameter wire mesh; the mesh may be made of metallic or other suitable materials.

2.1. Constituents of Ferro Cement:

Ferro cement is defined as being made of cement-based mortar mix and steel wire mesh reinforcement. However, a broader definition of Ferro cement includes the use of skeletal steel in addition to the mesh system.

2.2. Mortar Mix:

The hydraulic cement mortar mix consists of Portland pozzolana cement, fine aggregate (m-sand), 10mm coarse aggregate, water as per the requirement. The materials should satisfy standards like those used for quality reinforced concrete construction.

2.3. Formation Steel:

8mm HYSD steel bars used in Ferro cement is in form of a grid of steel rods, strands of 8mm diameter. Skeletal reinforcement is needed to form the shape of the structure to be built; around mesh layers are attached.

2.4. Steel Wire Chicken Mesh Reinforcement:

Steel wire chicken mesh meshes are considered as primary reinforcement. This include square woven or welded meshes, chicken (hexagonal/aviary) wire mesh, expanded metal mesh, etc. Galvanized Chicken wire mesh with a hexagonal opening of size 12mm and wire thickness of 1.2 mm was used in this study.

2.5. Cement:

The cement shall comply an equivalent standard; the cement shall be fresh, of uniform Consistency, and free of lumps and foreign matter. It shall be stored under dry conditions for as short duration as possible. Portland pozzolana cement of grade 53 is used.

2.6. Fine Aggregate:

Aggregate used in Ferro cement shall be normal weight fine aggregate (m-sand). It shall comply with an equivalent standard. It shall be clean, inert, free of organic matter and deleterious substances, and relatively free of silt and clay.

2.7. Water:

The mixing water shall be fresh, clean, and potable.

2.8. Coarse Aggregate:

Aggregate used in Ferro cement shall be in the sieve size of 10mm retained in the sieve. It shall comply with an equivalent standard. It shall be clean, inert, free of organic matter and deleterious substances.

2.9. Infill Materials:

Manufactured sand (M-sand) and red soil are used as infill materials in the wall panels.

3. CASTING OF THE FERRO CEMENT WALL PANELS

3.1. Formation of Skeletal Steel:

Fig-1: Skeletal Steel Bars

To make formation of bars, 8mm diameter HYSD bars were bent and tied with required size and shape with the consideration of clear cover 50mm and 300mm spacing is provided between the bars and wall spacing is provided as 100mm.

3.2. Wounding of Steel Wire Chicken Mesh:

Fig-2: Wounding of Steel Wire Chicken Mesh

Two layers of steel chicken wire mesh were tightly wounded over the steel bars and tied, and tension is maintained all over the bars.

3.3 Casting of Specimens:

Two specimens were casted as box like structures to fill the infills.

Fig-3: Box Like Structure

Fig-4: The Infill Materials Such as Red Soil in Wall Panel-P1, M-Sand in Wall Panel –P2.

All the infills were filled and compacted in their wall panels respectively.

- The wall panels were filled and compacted with their respective infills and the top side of the wall panels were closed with concrete and allowed to set for 24 hours.
- The wall panels were casted, and curing process were started. Jute bags were covered over the specimen as it has the capacity to retain the moisture for long period.

4. TESTING OF THE WALL PANELS

4.1. Testing Procedure of Wall Panels:

- The wall panels are subjected to uniformly distributed loading throughout the section and the wall panels are placed over the platform of simply supported supports.
- Since it is subjected to UDL, the steel plate is placed over the wall panel so then the load acts uniformly throughout the section.
- Proving ring is placed above the steel plate to determine the load which is given by the hydraulic jack
- Dial gauges D1, D2& D3 were pointed on the h/3 distance of the ferrocement wall panel. Dial gauge D1 is pointed on the bottom of the wall panel. Dial gauge D2 is pointed on the front face of the wall panel and Dial gauge D3 is pointed on the side face of the wall
- The steel pellets were fixed in the grid with 150mm spacing and were marked as S1, S2, S3 &S4. And the strain is measured by the strain gauge.
- The whole setup is levelled with the help of the spirit level and the experiment were made ready to start the test.
- Using the hydraulic jack load is applied on the steel plate which is placed over the steel plate and the cyclic loading with the interval of 5KN is followed throughout the process.
- The dial readings and the strain readings of their respective loads were noted periodically, and the wall panels such as soil infill wall panel and m-sand infill wall panel bear the ultimate load of 55KN and 80KN respectively.
- The crack pattern formed in the wall panels were marked and mentioned in their respective wall panels.

4.2. Testing Setup for Wall Panels:

Fig-5: Test Setup for Ferro-Cement Red Soil Infill Wall Panel

Fig-6: Test Setup for Ferro-Cement M-Sand Infill Wall Panel.

4.3. Crack Patterns of Wall Panels:

4.3.1. Crack Observations for soil infill wall:

- At 40KN initial crack (diagonal shear crack) from bottom to top at the right side of the front face of the wall panel.
- At 45KN second crack at left side wall till h/3 distance and shear crack at the left bottom of the wall panel.
- At 50KN third crack, the extension of second crack at left side (bottom to top).
- At 55KN diagonal shear crack at the left side face of the wall.

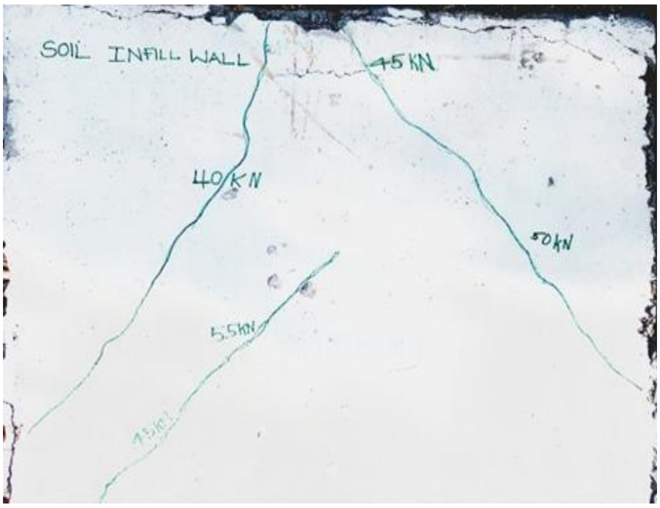

Fig-7: Crack Pattern of Red Soil Infill Wall Panel

4.3.2. Crack Observations For M-Sand Infill Wall Panels:

- At 30KN first crack (diagonal shear crack) starting from right support towards middle of h/3.
- At 50KN extension of 30KN (diagonal shear crack) from bottom to top.
- At 55KN further extension of 30KN (shear crack).
- At 60KN back face crack at support from bottom to top.
- At 70KN front face crack at support to centre from bottom to top.
- At 80KN extension of shear crack happened at 70KN.

Fig-8: Crack Pattern of M-Sand Infill Wall Panel

5. RESULTS AND DISCUSSIONS

5.1. Cyclic Loading of Wall Panels:

- The wall panels have been subjected to in experimental investigation (cyclic loading) with the interval of 5KN
- The red soil infill wall panel attained its ultimate loading capacity in the (11^{th} cycle) with the maximum load of 55KN.
- The m-sand infill wall panel attained its ultimate loading capacity in the (16^{th} cycle) with the maximum load of 80KN.

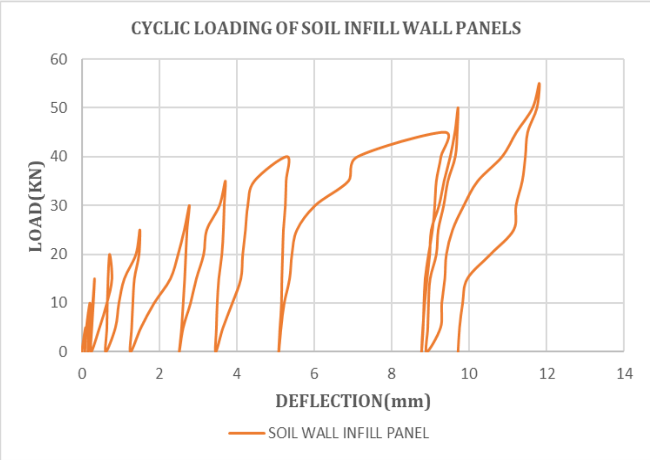

Chart-1: Cyclic Loading of Red Soil Infill Wall Panels

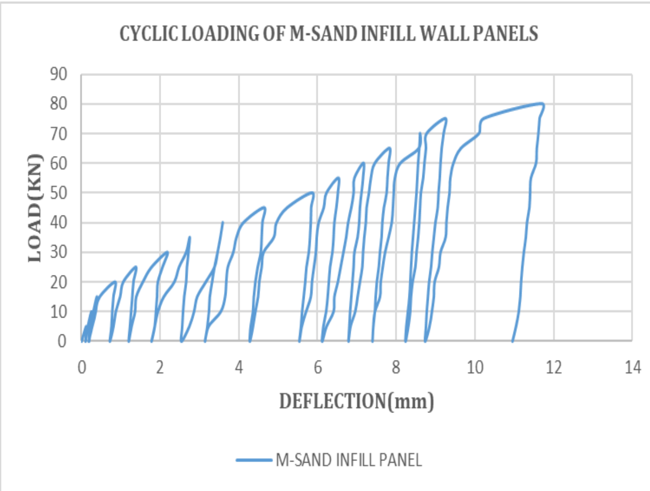

Chart-2: Cyclic Loading of M-Sand Wall infill Panels

5.2. Monotonic Deflection Curves:

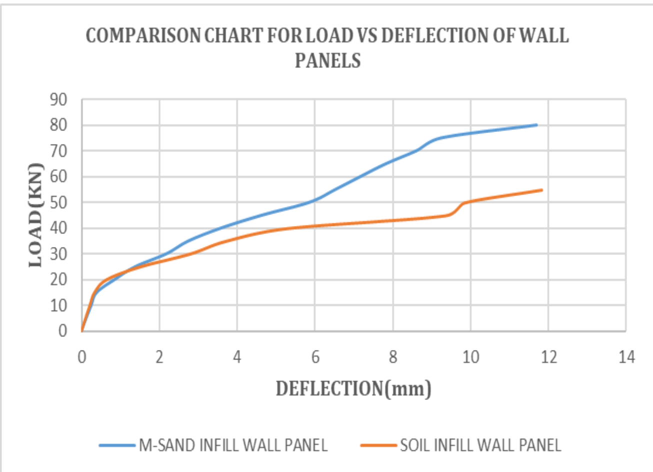

Chart-3: Comparison Chart for Load Vs Deflection of Wall Panels

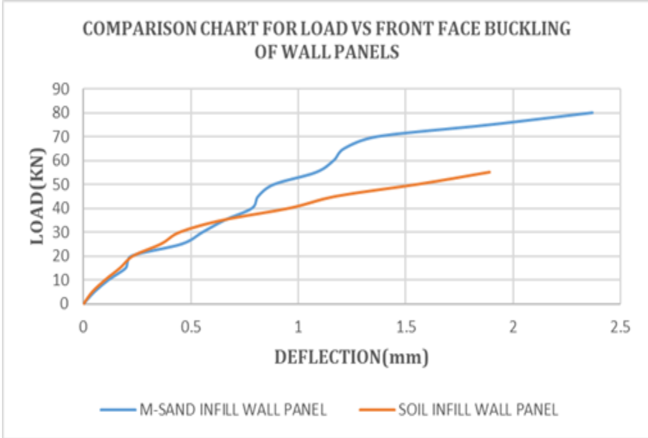

Chart-4: Comparison Chart for Load Vs Front Face Buckling of Wall Panels

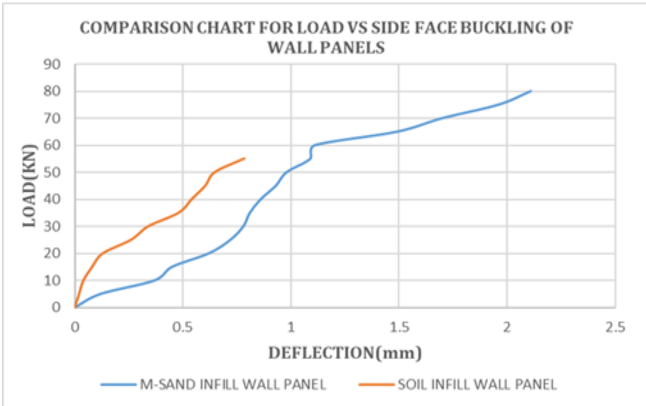

Chart-5: comparison chart for load vs side face buckling of wall panels

5.3. STIFFNESS DEGRADATION:

The stiffness of the member is obtained from the relationship, $K=P/\Delta$; where

K= stiffness of the member

P=load applied in the frame in KN

Δ=Deflection in mm

The stiffness of the wall panel for various load cycles were calculated and the variation of stiffness with respect to load cycles is shown in chart-5. The stiffness of the m-sand infill wall panels was found to decrease from third cycle 15KN/mm to seventh cycle 30KN/mm and for red soil infill wall panel the decrease was found to be from third cycle 15KN/mm to fourth cycle 20KN/mm.

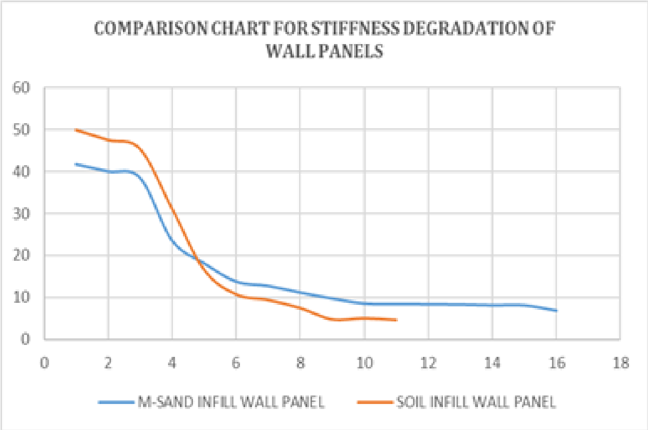

Chart-5: Comparison Chart for Stiffness Degradation of Wall Panels

5.4. DISCUSSIONS:

The both wall panels were tested for ultimate loads. These wall panels were compared in terms of graph analysis such as cyclic loading curves, monotonic deflection curves and front face and side face buckling curves and stiffness degradation of both m-sand and red soil infill wall panels.

- The initial crack of the m-sand at 30KN first crack (diagonal shear crack) starting from right support towards middle of h/3.
- The final crack of the m-sand infill wall panel is found to be at 80KN extension of shear crack happened at 70KN.
- The initial crack of the red soil infill wall panel is obtained at 40KN initial crack from top to bottom at the right side of the front face of the wall panel.
- The final crack is found to be at 55KN shear crack at the left side face of the wall.

6. CONCLUSIONS

- In this research article, effort has been made to study the suitability of prefabricated ferrocement sandwich wall panels with red soil and m-sand infill for the construction of low cost buildings. For the study, model specimens were casted and tested in a loading frame UTM with a capacity of 100T. It was also observed that, the usage chicken mesh as reinforcement in ferrocement, sufficiently confined the panel skins and effectively reduced the concrete spalling out of outer skin layer.
- Based on results obtained from the study, the following conclusions were arrived from the experimental investigation of wall panels for the better understanding
- The prefabricated ferrocement sandwich wall panels maybe used for the construction of low cost housing and it is also cheaper compared to RCC elements of similar size. With use of ferrocement elements the dead load can be reduced for a building.
- Ferrocement sandwich panels show good potential for use in several construction applications as reflected by their relatively high ultimate and serviceability loads, crack resistance control, high ductility, and remarkable energy absorption.
- The wall panels possess high ductile nature which is very important in highly earthquake prone zones.
- It is a good alternative for nominal brick construction. Brick walls tend to sudden failure during earthquakes
- But, these wall panels will be more ductile, so we can reduce collapse of the building during earthquakes.
- The chicken mesh sufficiently confined the panel skins and effectively reduced the concrete spalling out of outer skin layer. It is seeming to be a good alternate for welded mesh to reduce cost.
- Precast wall panel can be made in the factory and it can be transported to the site to fix.
- For precast panel, standard sized panel can be made and there should be groove on each panel to fix with the other.
- Thus, Ferro cement wall panels were introduced and can be used in construction for low income people to improve their quality of life due to its low cost and good structural performance.

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BIOGRAPHIES

	P. BALAJI[1], balajistructural7@gmail.com M.E. Structural Engineering Student, Department of Civil Engineering, Coimbatore Institute of Technology College, Coimbatore.
	Dr. S. ARUL SELVAN[2], arulselvan.civil.cit@gmail.com Associate Professor, Department of Civil Engineering, Coimbatore Institute of Technology College, Coimbatore.