Sustainability, Agri, Food and Environmental Research, (ISSN: 0719-3726), 11(X), 2023:
http://dx.doi.org/ 10.7770/safer-V12N1-art2758

Numerical analysis of cement panels reinforced with galvanized iron or polypropylene meshes.

Análisis numérico de paneles de cemento reforzados con mallas de hierro galvanizado o polipropileno.

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ABSTRACT

This paper deals with the numerical analysis of panels reinforced with galvanized iron (GI) or polypropylene (PP) meshes. It has been a common practice to use galvanized iron meshes as reinforcement in panels and is popularly called as ferrocement panels. Elevated humidity level and presence of salts can lead to corrosion of these galvanized iron meshes, leading to reduced service life. A rust-freepolypropylene mesh can be used as an alternate to the steel mesh. This paper presents numerical analysis in ANSYS Workbench based on an experimental study published in the literature" Comparative study of ferrocement panels reinforced with galvanized iron and polypropylene meshes". A total of 16 rectangular panels tested in flexure was analyzed. Out of 16 panels, 8 were reinforced with GI mesh and 8 with PP mesh. The specimens were simply supported on two short edges and subjected to four-point bending. The parameters investigated include thickness of panels, volume fraction and the material of the mesh. All the GI mesh panels showed better strength than the corresponding PP mesh reinforcedcement panels. However, PP mesh panels exhibited better ductility as compared to GI mesh panels. An increase of 54% is noticed in 40mm thick panels reinforced with GI mesh, when compared to 20mm thick panels. Similarly, an increase of 83% is noticed in 40mm thick panels reinforced with PP mesh, when compared to 20mm thick panels. The results of numerical analysis were found to be comparable with the corresponding experimental results.

Keywords: Flexure, Polypropylene mesh, Galvanized Iron mesh.

RESUMEN

Este artículo trata del análisis numérico de paneles reforzados con mallas de hierro galvanizado (GI) o polipropileno (PP). Ha sido una práctica común el uso de mallas de hierro galvanizado como refuerzo en los paneles y se denomina popularmente como paneles de ferrocemento. El nivel de humedad elevado y la presencia de sales pueden provocar la corrosión de estas mallas de hierro galvanizado, lo que reduce la vida útil. Se puede utilizar una malla de polipropileno libre de óxido como alternativa a la malla de acero. Este artículo presenta un análisis numérico en ANSYS Work-bench basado en un estudio experimental publicado en la literatura "Estudio comparativo de paneles de ferrocemento reforzados con mallas de hierro galvanizado y polipropileno". Se analizó un total de 16 paneles rectangulares probados en fl exión. De los 16 paneles, 8 fueron reforzados con malla GI y 8 con malla PP. Las muestras simplemente se apoyaron en dos bordes cortos y se sometieron a flexión de cuatro puntos. Los parámetros investigados incluyen el espesor de los paneles, la fracción de volumen y el material de la malla. Todos los paneles de malla GI mostraron mejor resistencia que los correspondientes paneles de cemento reforzado con malla de PP. Sin embargo, los paneles de malla de PP exhibieron una mejor ductilidad en comparación con los paneles de malla GI. Se observa un aumento del 54% en los paneles de 40 mm de espesor reforzados con malla GI, en comparación con los paneles de 20 mm de espesor. Asimismo, se observa un aumento del 83% en paneles de 40 mm de espesor reforzados con malla de PP, en comparación con los paneles de 20 mm de espesor. Se encontró que los resultados del análisis numérico eran comparables con los resultados experimentales correspondientes.
Palabras clave: Flexión, Malla de polipropileno, Malla de hierro galvanizado.

INTRODUCTION

Ferrocement panels are prepared using cement mortar with thin steel wire meshes embedded in it. The reinforcement is generally in the form of two dimensional meshes or fibers, making ferrocement a homogenous material. The reinforcement can be metallic or non-metallic in nature [1]. The major advantage of using ferrocement is its light weight and high modulus of rupture compared to concrete. Ferrocement panels are commonly reinforced with galvanized iron meshes. Elevated humidity level and presence of salts can lead to the corrosion of galvanized iron meshes, which eventually reduces its service life. As the diameter of wires is very small, corrosion may lead to complete disintegration of the wire cross-section creating a potential plane of failure. Therefore, arustfreealternate material, such as polypropylene meshes can be used as a replacement for galvanized iron meshes to increase the service life of the structure.

Various researchers have studied ferrocement to investigate its flexural, axial and punching strength properties. Kulkarni et al. [4] did flexural test on 48 ferrocement panels of size 500 x 200 mm having different thicknesses. It was seen that the ultimate load and first crack depend on the thickness and the number of reinforcing mesh layers in ferrocement panels. Another study was carried out by Chandrudu and Desai [5] in which ferrocement panels of size 970 x 300 x 35 mm were tested under four point bending to investigate the effect of fly ash on the flexural strength of ferrocement under acidic environment. The variables included were mortar quality, number of reinforcing mesh layers, curing environment and exposure period. It was summarized that 10% addition of fly ash was the optimum dosage. And it was noticed that an increase in concentration of hydrochloric acid decreased the flexural strength of ferrocement panels. Ibrahim [6] studied 27 ferrocement panels each of size 490 x 490 mm for finding the punching shear capacity. He summarized that the ultimate capacity of panels increased by increasing the reinforcement ratio and slab thickness. Sakthivel and Jagannathan [7] investigated the effect of polyvinyl chloride (PVC) coated galvanized iron mesh on the flexural capacity of ferrocement panels. The panel size was 700 x 200 x 15 mm. Variables comprises number of reinforcing mesh layers and the configuration of wire mesh. The study briefed that the PVC coated wire mesh panels exhibit 10% less strength than uncoated GI mesh panels. The Finite Element Method (FEM) projects a calculation method to solve complex differential equations. In this paper, experimental results on ferrocement panels are validated by FE elements software. In the finite element software, experimental objects are divided into finite elements. In the next step, these elements are assigned with certain conditions, such as material parameters, support conditions and loads to obtain stress, displacement and strain distributions of the experiment. Conclusions about the failure, as well as the stress and crack development in a component can be obtained from evaluation and more detailed analysis.

MATERIAL AND METHODS

The experimental work includes the comparison of flexural responses of GI and PP reinforced ferrocement panels. Experimental results were taken from literature ”Comparative study of ferrocement panels reinforced with galvanized iron and polypropylene meshes” by A M Ubaid et.al. In the experimental work a total of 16 panels were tested, each of size 1000x450mm with thicknesses of 20 mm, 30 mm and 40 mm incorporating 2, 3 and 4 layers of GI and PP meshes with square opening. Each specimen was given an ID based on its thickness, type of mesh and number of mesh layers. For example, 20P-2 means 20 mm thick panel reinforced with 2 layers of PP mesh. Similarly, 40GI-3 means

40mm thick panel with 3 layers of GI mesh. The PP wire had a tensile strength of 24 MPa and 2.7mm^2 as cross-sectional area. The opening size of PP mesh was 14 mm in both directions. The GI wires had tensile strength of 350 MPa and 0.70mm^2 as cross-sectional area. Specimens were tested using a 1000 kN capacity universal testing machine in displacement control mode at a rate of 2 mm/min. [8].

a) Panel with Galvanized Iron Mesh b) Panel with Polypropylene Mesh

Fig 1: Panels during casting process

FE ANALYSIS USING ANSYS ANSYS WORKBENCH combines finite element theory with real world practice. ANSYS is one of the software in finite element analysis (FEA) used to solve complex engineering problems. The behavior of concrete and reinforced concrete structures can be analyzed under various loads. The behavior of deformation or displacement of the body can be observed.

DESCRIPTION OF FEA MODEL: Element solid 186 is used to represent cement mortar. SOLID 186 is a higher order 3D solid element that exhibits quadratic displacement behavior. The element is defined by 20 nodes. The element can exhibit plasticity, hyper elasticity, creep, stress stiffening, large deflection and large strain capabilities [9, 10]

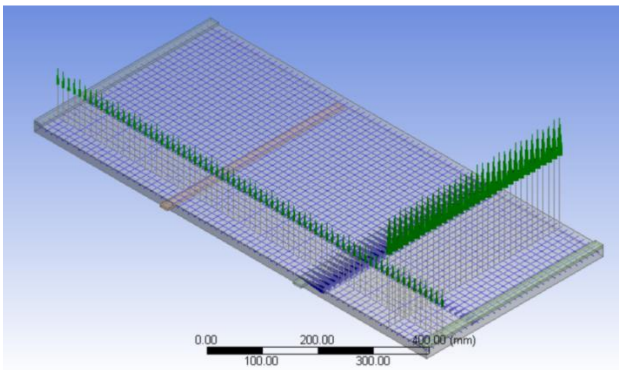

Fig 2: FE model of slab with meshes

LINK 180 is used to represent polypropylene mesh and galvanized iron mesh. The element is a uniaxial tension- compression element with three degrees of freedom at each node. These include translations in x,y and z directions. It is considered as a pin jointed structure; no bending of element is considered. Plasticity, creep, rotation, large deflection and large strain capabilities are included. The slab modelled using these elements are shown in figure 1. There are three material properties used in the analysis. The elastic properties of the materials such as mortar, polypropylene mesh and galvanized iron mesh are given in Table 1. The material is assumed to be homogeneous and isotropic. The stress strain curve of each material is given in figure 3 to figure 5.

Table 1: Material property parameters

Material	Parameter	Parameter value
Mortar (SOLID 186)	Density	2100 kg/m^3
	Youngs modulus	4000 MPa
	Poisson's Ratio	0.18
	Tensile ultimate strength	2 MPa
	Compressive ultimate strength	20MPa
Polypropylene mesh(LINK 180)	Density	855 kg/m^3
	Youngs modulus	6000 MPa
	Tensile ultimate strength	300 MPa
Galvanized iron mesh(LINK 180)	Density	7800
	Youngs modulus	140GPa
	Tensile ultimate strength	500 MPa

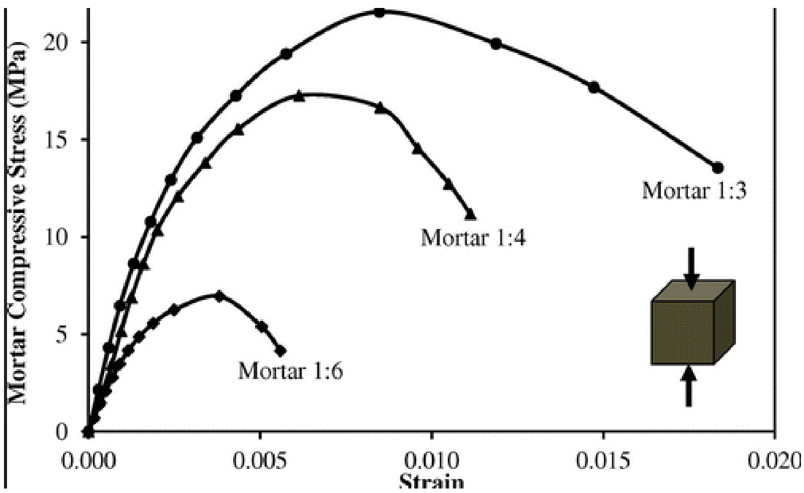

Fig 3: Stress strain curve of mortar with compressive strength of 20 MPa[11]

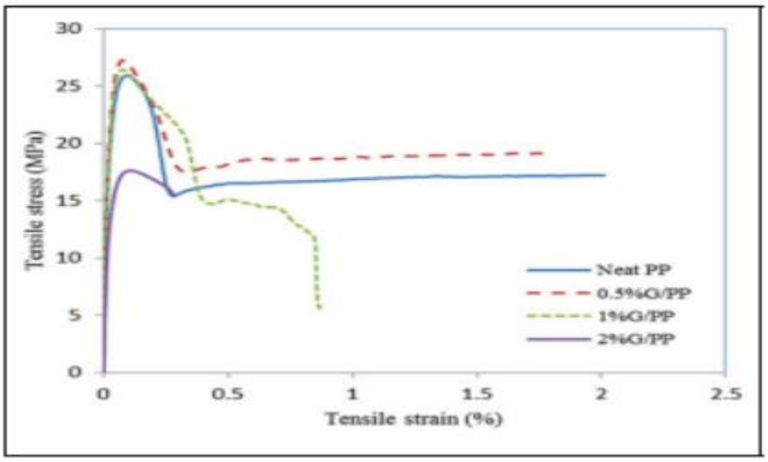

Fig 4: Stress strain curve of polypropylene mesh [12]

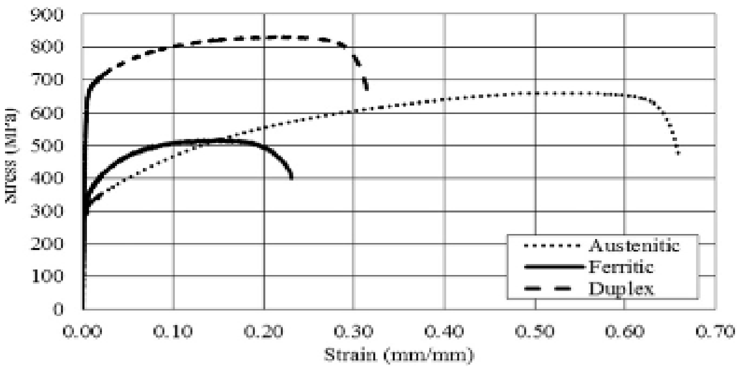

Fig 5: Stress strain curve of galvanized iron mesh [13]

Meshing of model is crucial. The shape of finite element decides the accuracy of calculation. Larger the mesh size of finite elements, less accurate the stresses and strains calculated in the model. In the present work the mesh size 25mm. Model after meshing is shown in Fig. 6.

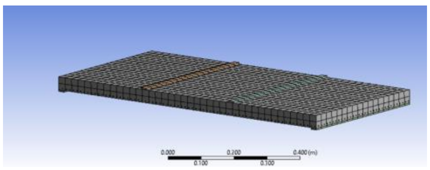

Fig 6: Meshed model of slab

VALIDATION OF TEST DATA

The load deflection responses of four point bending tests were extracted from software and compared. These load deflection curves are shown in Fig.7.

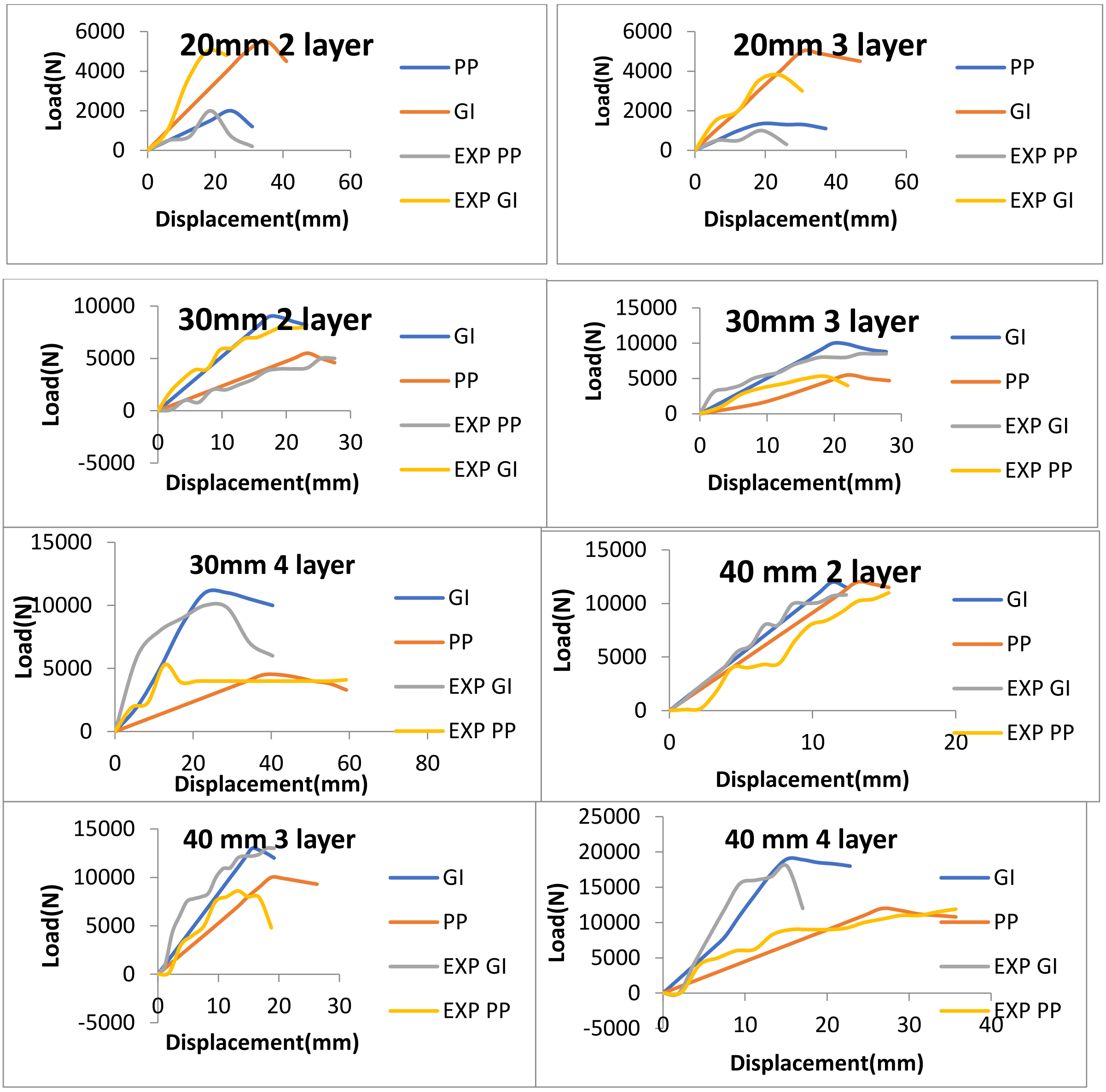

Fig 7: Load deformation responses from numerical analysis

RESULTS AND DISCUSSION

Thickness of panel, and the type and number of mesh layers play significant role in the structural deflection performance of the reinforced cement panels. Displacement at ultimate load increased with increase in the number of mesh layers for a particular thickness of panel. When compared to 20mm thick panels, 40 mm thick panels reinforced with GI meshes showed a decrease of 68% in deflection and 47% decrease in deflection for panels reinforced with polypropylene meshes. This reduction in deflection is due to the increased thickness of panels. No significant difference in behavior is seen in panels 20-GI-2 and 20-GI-3 similarly, in panels 20-PP-2 and 20-PP-3. This is because the middle layer in three-layer panels lies in the neutral axis and hence shows same behavior as that of panels reinforced with two layers. Similar behavior is seen in panels with higher thickness, such as 30mm and 40 mm panels. Ultimate load sustained by each specimen is tabulated and compared with experimental results in Table 2.

Table 2: Comparison of Ultimate load

Sl No.	Specimen ID	Ultimate load(kN)		Percentage Variation
		Experimental load P_e in kN [8]	Analytical load P_a in kN	
1	20-GI-2	5.15	5.50	6.79
2	20-PP-2	1.83	2.00	9.28
3	20-GI-3	4.72	4.99	5.72
4	20-PP-3	1.23	1.35	9.75
5	30-GI-2	8.04	8.80	9.45
6	30-PP-2	5.10	5.50	7.84
7	30-GI-3	9.12	9.99	9.53
8	30-PP-3	5.40	5.49	1.66
9	30-GI-4	10.35	11.00	6.28
10	30-PP-4	4.66	4.50	3.43
11	40-GI-2	11.12	11.99	7.82
12	40-PP-2	11.55	12.00	3.89
13	40-GI-3	13.06	13.00	0.45
14	40-PP-3	9.81	10.00	1.93
15	40-GI-4	18.67	19.00	1.76
16	40-PP-4	11.27	12.00	6.47

The GI mesh reinforced panels perform better than the PP mesh panels in ultimate load. The GI mesh panels also showed stiffer behavior than the PP mesh panels as GI mesh is having higher elastic modulus when compared to PP mesh. An increase of 54% is noticed in 40mm thick panels reinforced with GI mesh, when compared to 20mm thick panels. Similarly, an increase of 83% is noticed in 40mm thick panels reinforced with PP mesh, when compared to 20mm thick panels. Thus, it is evident that, ultimate load carrying capacity of panels increases with thickness of panels. Variation in percentage increase in the above case is due to variation in type of reinforcement used. No significant difference can be noticed in the load carrying capacity of panels 20-GI-2 and 20-PP-2 similarly, for panels 20-PP-2 and 20-PP-3. This is because the middle layer in three-layer panels lies in the neutral axis and hence three-layer panels show the same behavior as that of two-layer panel. Similar trend is seen in panels with increased thickness such as in case of 30mm and 40mm panels. Variation in analytical results is within ten percentage in all cases. This is due to the unavailability of standard stress strain results to be inputted in ANSYS software.

As conclusion, total of 16 panels reinforced with GI mesh and PP mesh were modelled and analyzed in ANSYS. The objective of this investigation was to study the influence of type of reinforcement and number of layers of reinforced meshes. In all cases GI reinforced panels are superior in structural performance than PP reinforced panels. An increase of 54% is noticed in 40mm thick panels reinforced with GI mesh, when compared to 20mm thick panels. Similarly, an increase of 83% is noticed in 40mm thick panels reinforced with PP mesh, when compared to 20mm thick panels. Ultimate load carrying capacity increased with increase in thickness of panels and number of layers of reinforcement. However, PP mesh panels exhibited higher ductility than GI mesh panels.
In this study, the variation between the experimental and predicted load is found to be less than 10 percent. Hence, it can be concluded that the finite element modelling method used in this study is appropriate to model the reinforced cement panels. It is expected that the proposed modelling technique can be extended for the study of the effect of behavior of various other geometrical configurations of reinforced cement panels.

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Received: 03th November 2020; Accepted: 04th January 2022; First distribution: 04th November 2022.