2025 Volume: 01 Issue: 04 www.ijrpa.com Research Article

International Journal Research Publication Analysis

Page: 42-52

ANALYTICAL STUDY OF THE FLEXURAL BEHAVIOUR OF A PROFILE LIGHT-WEIGHT REINFORCED COMPOSITE PLATE ELEMNT

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Article Received: 23 June 2025

Article Revised: 13 July 2025

Published on: 03 August 2025

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ABSTRACT

The project centers on the cross examination of both the flexural strength and deflection of a high profile light-weight reinforced composite plate material. Manual mixing operation was done on several materials and all polystyrene concrete ingredients were batched by weight, after which total of seventy-two cubes were produce. The size of each was 150mm x 150mm x 150mm and six mix ratios of water-cement ratio: cement: sand: polystyrene beads with different ranges for compressive strength test were prepared. 16 slabs of size 1200mm x 558mm x 125mm were cast for flexural strength of slab. Twelve out of the total slabs, were produced from profile sheet- polystyrene fibre reinforced composite with mix ratio 0.45:1:3:3 and 6 different fibre content in the mixture, 2 were produced from conventional composite having normal concrete ingredients (coarse aggregates, fine aggregates, cement and water) with 10mm rebar, profile sheet and mix ratio of 0.45:1:2:4. The remaining 2 slabs were made from plain polystyrene fibre reinforced slab with mix ratio of 0.45:1:3:3 and 0.31% Agro fibre content in the mixture, without profile sheet. The 28th day average compressive strength for the six mix ratios used were 4.81MPa, 5.3MPa, 6.2MPa, 6.4MPa 4.33MPa, and3.08MPa respectively. **The average flexural strength** of profile sheet-polystyrene fibre reinforced composite slab for different fibre content in the mixture were 2.1MPa, 2.45MPa, 3.3MPa, 3.9MPa, 3.4MPa, and 2.85MPa respectively. It was noticed that small percentage slab

component has maximum deflection while the minimum deflection took place in the slab with 0.31% agro fibre content in the mixture. The flexural strength of profile sheet-polystyrene fibre reinforced composite slab was within limit for light structural slab.

KEYWORDS: flexural strength, slab, profile sheet, polystyrene beads, compressive strength, static modulus of elasticity and deflection, , Polystyrene fibre concrete.

INTRODUCTION

Environmental pollution is one of the major challenges facing humanity in the 21st century. Industrialization, urbanization and developmental projects are the major cause of environmental pollution which is associated to anthropogenic activities have increased with the last century globally (Qiu, 2010; Izah et al., 2018;). Dumpsite is a widespread land meant or designed for deposition of waste and unwanted materials from household, institutions, industries or the environment and is generally open or covered with soil layer with or without liner at the bottom. Dump/landfill is a major source of contamination of groundwater (Wilfred et al.2022). Open dumpsite is common in developing countries (Mentore Vaccari et al. 2018). Open dumping system of waste disposal is the most common method of waste disposal in Nigeria.

A structure is an assembly of elements that transfer stresses (loads) from one element to another without much or excessive differential deformation of any of its elements. In building, structural elements include slabs, beams, columns and foundations. A slab is a planar structural element that is flat and has two dimensions. Its thickness is very minimal in relation to its other two dimensions. (Ibearugbulam, Ezeh, and Ettu, 2014). It acts basically as a flexural member; its primary function is to carry lateral loads, fixed and transient loads to beams and columns (Mosley, Bungey, and Hulse, 1999). Slab can be produced using different construction materials like wood (timber), steel, and composite members like concrete, steel-composite etc. The EN 1994-1-1:2004 defines “composite slab as a slab in which profile steel sheets are used as permanent shuttering initially and subsequently combined structurally with the hardened concrete to act as tensile reinforcement in the finished floor. In this flooring/slab system, steel decking that are usually cold formed with different types of embossments are commonly used. This steel deck performs as a formwork during concrete casting in the service stage. For continuous composite slab, reinforcement steel is required at the support to resist the negative bending moment (Marimuthu, Seetharaman, Jayachandran, Chellappan, and Dutta, 2007). The design of concrete slab can

be seen in BS 8110 parts 1, 2 and 3. The actual problem associated with concrete slab is self-weight. To solve the problem of self-weight for concrete slab, a lot of lightweight materials have been used as replacement to components of concrete. Industrial and agricultural wastes are among the lightweight materials that have been shown to be appropriate. which includes sawdust, palm kernel shell, fly ash, coconut shells, and pre-expanded polystyrene beads, among others which are produced from milling stations, industries and so on (Ganiron, 2014).

Statement of Problem

Over the years, composite slabs, commonly used in the building industry, has posed challenges of excessive self-weight. This study investigates the potentials of profile sheet-polystyrene fibre reinforced composite slabs for construction in order to get reduced weight in composite slabs whilst still maintaining a good strength and meeting deflection and shrinkage criteria as well as obtaining a cost-effective composite slab.

Objectives of Study

The main objective of this study is to determine the structural characteristics of profile sheet-polystyrene fibre reinforced composite slab. The specific objectives are firstly to determine the workability and the setting time of polystyrene concrete, secondly to determine the compressive strength of polystyrene concrete furthermore to determine the flexural strength of profile sheet-polystyrene fibre reinforced composite slabs, conventional composite slabs and plain polystyrene concrete fibre slab and finally to determine the deflection of profile sheet-polystyrene fibre reinforced composite slabs.

Justification of Study

The notable significance of this project is that it will provide the structural characteristics of profile sheet-polystyrene fibre reinforced composite slab. Profile sheet-polystyrene fibre reinforced composite slab as a lightweight slab will help to reduce the load on structures as the slab will reduce the load transferred to both beams and columns. Another very notable significance of this project is that it will also encourage waste recycling of polystyrene and agro fibre, which is a very interesting area as far as global waste recycling is concerned. Research have been carried out on the use of many lightweight components like sawdust, palm kernel shell but the use of polystyrene and agro fibre needs to be investigated. Hence, this is the basis for the present research work.

Scope of Study

The scope of this study is limited to determination of structural characteristics of profile sheet-polystyrene fibre reinforced composite slab. Compressive strength, static modulus of elasticity, flexural strength, and deflection are among the structural properties that were determined. The time of final setting of polystyrene concrete was determined.

MATERIALS

The materials used for this work were Portland limestone cement, Polystyrene beads, Profile sheet, fine aggregate (natural sand), coarse aggregate (crushed granite), Agro fibre, Water, 10mm reinforcement bars, binding wire.

i. Firstly the cement Dangote 3X Portland Limestone cement which conforms to NIS 44-1, part1 was obtained from a dealer in Owerri and used for all the work.
ii. To carry out this work, polystyrene bead was obtained from the Jik saw PLC at Industrial Cluster, Owerri North, Imo State, Nigeria. The diameter ranged from 3.1mm to 1.12mm.
iii. The aggregates used in this research work were coarse aggregate and fine aggregate. The coarse and fine aggregates used for this work were purchased from tipper stand at Owerri, Imo State Nigeria, it was sun-dried for seven days inside the laboratory before usage. The aggregates used were free from deleterious matters. The maximum diameter of natural sand used as fine aggregate was 5mm while that of coarse aggregate used was crushed granite of 19mm. The compacted bulk density of the coarse aggregate is 1615kg/m^3 and the non-compacted bulk density is 1400kg/m^3.
iv. Water from a well on the Federal University of Technology campus in Owerri, Imo State, was used for this study. The water meets BS EN 1008: (2002) standards and is potable. It is also suitable for curing and mixing concrete, as it satisfies drinking standards.
v. The profile sheet used for this research work were obtained from Owerri timber Market and the t hickness is 1mm conforming to (2005, Eurocode 3). They were cut to 1200mm x 558mm x 75mm and used to produce slab of 1200mm x 558mm x 125mm.
vi. The agro fibre used in this project is from raffia palm tree and was bought from Afor Ogbe market in Ezinihitte Mbaise. The fibres were cleaned. The fibres were further dried in natural sunlight to remove moisture content and long uniform fibres were obtained.
vii. The reinforcement bars were purchased from a dealer in Owerri Timber market. The rebars were as specified in BS 4449:1997 and 10mm size reinforcement bars was used for the control slab.

viii. The binding wires were purchased from Owerri Timber market in Imo State and the Grade are as specified in BS 4449: 1997.

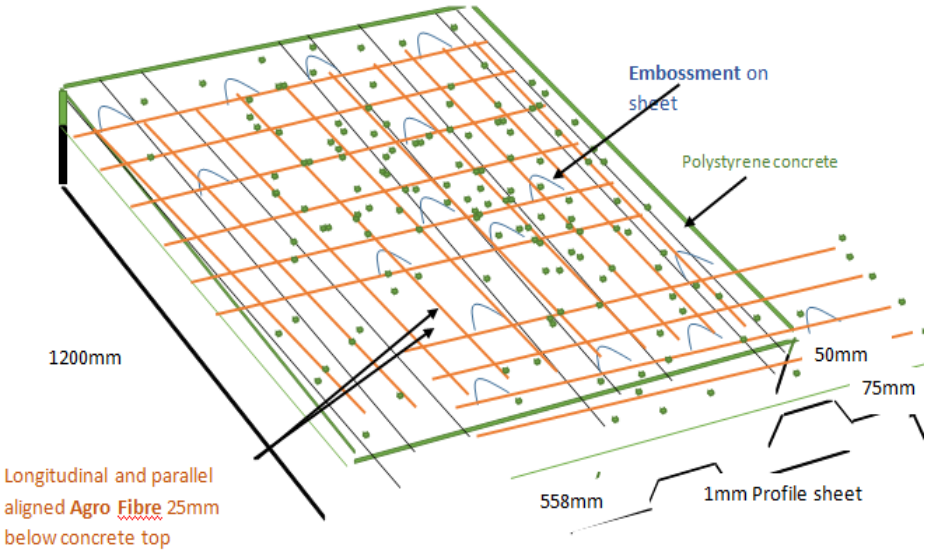
Methodology

4.5 Determination of Flexural Strength of profile sheet- polystyrene concrete fibre Composite Slabs.

Flexural strength tests were carried out to determine the Flexural strength of the Profile Sheet-Polystyrene concrete fibre composite slab, the test was carried out in accordance with BS EN 12390-5:2000.

The Profile Sheet-Polystyrene concrete fibre composite slab measured 1200 x 558 x 125 mm and reinforced with agro fibre for crack control were produced using manual mixing method and proper vibration to obtain good compaction of the composite. Figure 3.1 shows the components of the composite slab. The mix ratio used was 1:3:3. The mix ratios stand for cement, sand and polystyrene beads respectively. Water cement ratio for all the mixes was 0.45. There were six different % content of Agro fibre in concrete(see Table D1, page 123, Appendix D).

The profile sheets were cold rolled and were cut into size 1200mm x 558mm x 75mm. To make sure that there was proper bond between polystyrene concrete and the profile sheet, embossments were used at intervals of 300mm to create friction between the concrete and the profile sheet. The fresh polystyrene-concrete were filled into the profile sheet and 50mm above the top with temporary wooden support by the sides. Longitudinal and parallel (see Table D1) aligned Agro Fibre were placed 25mm below concrete top to form a mesh which was used as crack control. After the compaction has been completed, the surface was leveled. A total of twelve (12) slabs were produced. Two (2) slabs each from the six different Agro fibre content in the mixture.



4.1 Typical example of the Polystyrene concrete fibre composite slab.

Determination of Deflection at Failure of profile sheet- polystyrene concrete fibre Composite Slabs

The deflection of polystyrene concrete fibre composite slab was measured using instrument as can be seen in Plate 4.2. The instrument used was constructed using the principle of incompressibility of water. The load from the slab was allowed to act on the T- flange pump that was filled with water and connected to burette that contained water to a particular level. When the slab fails, the changes in height of water in the burette and pump pipe were recorded and having known the areas of the T-flange pump and the burette the deflection was computed.

Plate 4.2: Deflection measurement using principle of incompressibility of water

RESULTS

5.1 Flexural Strength Test Results of Profile Sheet- Polystyrene concrete Fibre Composite Slab

The flexural strength test results of profile sheet-polystyrene concrete fibre composite slab were as shown in Table 5.1.

Table 5.1: 28th-day Flexural Strength Result for Profile Sheet-Polystyrene concrete fibre composite Slab.

Mix ratio	Test	Agro fibre content (%)	Sample number	Crushing Load in (KN)	Flexural Strength of the Slab in (MPa)	Average Flexural Strength in (MPa)
1:3:3	1st	0.21	A	19.4	2	2.1
1:3:3	1st	0.21	B	21.3	2.2	
1:3:3	2nd	0.24	A	24.2	2.5	2.45
1:3:3	2nd	0.24	B	23.3	2.4	
1:3:3	3rd	0.28	A	31	3.2	3.3
1:3:3	3rd	0.28	B	29.6	3.4	
1:3:3	4th	0.31	A	38.8	4	3.9
1:3:3	4th	0.31	B	36	3.8	
1:3:3	5th	0.35	A	34.9	3.6	3.4
1:3:3	5th	0.35	B	31	3.2	
1:3:3	6th	0.38	A	30	3.1	2.85
1:3:3	6th	0.38	B	25.2	2.6	

5.1.2 Deflection at Failure Results of Profile Sheet-Polystyrene Fibre Reinforced Composite Slab

Deflection at Failure results of polystyrene concrete fibre composite slab were as shown in Table 5.2.

Table 5.2: Deflection at Failure Result for Polystyrene concrete fibre composite Slab.

Mix ratio	Test	Agro fibre content (%)	Sample number	Crushing Load in (KN)	Flexural Strength of the Slab in (MPa)	Average Flexural Strength In (MPa)	Deflection in mm At failure
1:3:3	1st	0.21	A	19.4	2	2.1	25
1:3:3	1st	0.21	B	21.3	2.2		22
1:3:3	2nd	0.24	A	24.2	2.5	2.45	23
1:3:3	2nd	0.24	B	23.3	2.4		18
1:3:3	3rd	0.28	A	31	3.2	3.3	18
1:3:3	3rd	0.28	B	29.6	3.4		20
1:3:3	4th	0.31	A	38.8	4	3.9	15
1:3:3	4th	0.31	B	36	3.8		10
1:3:3	5th	0.35	A	34.9	3.6	3.4	24
1:3:3	5th	0.35	B	31	3.2		20
1:3:3	6th	0.38	A	30	3.1	2.85	22
1:3:3	6th	0.38	B	25.2	2.6		23

DISCUSSION

The results presented above have been discussed in this section.

6.1 Flexural strength Test

The average flexural strength of profile sheet-polystyrene fibre reinforced composite slab ranged from 2.1MPa to 3.9MPa. The average flexural strength of plain polystyrene concrete fibre slab was 1.25MPa. The flexural strength of conventional composite slab with 10mm rebar was 7MPa but the permissible stress in bending for concrete ranged from 2.5MPa to 16MPa.

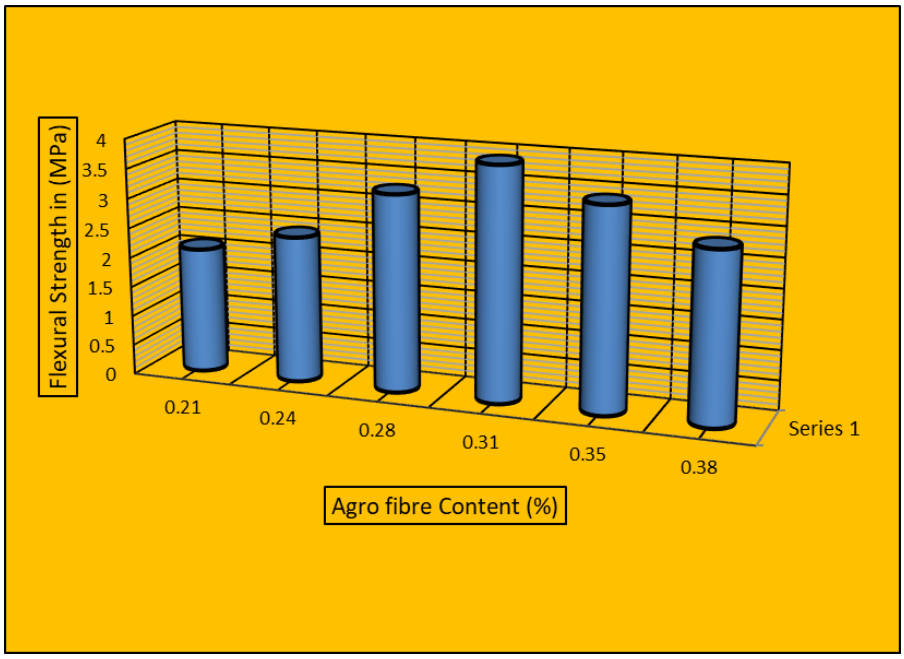


Figure 6.1: Flexural strength of Profile Sheet-Polystyrene Fibre Reinforced composite slab and Agro Fibre Content.

6.2 Deflection Test

The deflection at failure for profile sheet-polystyrene fibre reinforced composite are discussed below alongside with its flexural strength.

S/N	% Afro Fibre Content	Average Deflection (mm)	Average Flexural Strength (Mpa)
1	0.21	23.5	2.1
2	0.24	20.5	2.45
3	0.28	19	3.3
4	0.31	12.5	3.9
5	0.35	22	3.4
6	0.38	22.5	2.85

For convectional slab, the deflection at failure is

For 10mm rebar's, the average deflection is 11mm and the average flexural strength is 7Mpa. For plain polystyrene concrete fibre slab, the average deflection is 21mm and the average flexural strength is 1.25Mpa.

From the results, increase in Agro fibre resulted to an increase in flexural strength with corresponding decrease in deflection values till the 0.31%Agro fibre content, further increase of Agro fibre decrease the flexural strength with corresponding increase in deflection values.

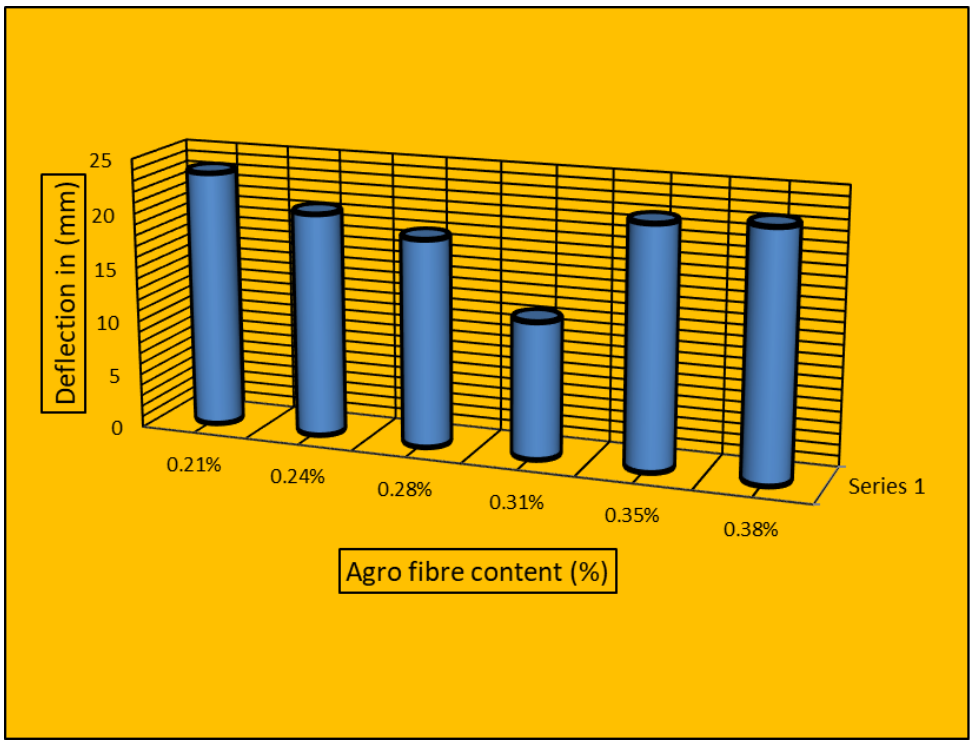


Figure 6.2: Deflection of Profile Sheet-Polystyrene fibre reinforced composite slab and Agro fibre content.

CONCLUSIONS AND RECOMMENDATIONS

The workability of the mix ratios and the setting time were all noted. Workability rises with increasing polystyrene bead content, and this concrete was considered medium workable by Shetty (2006). The concrete's typical final setting time ranged from 240 to 480 minutes. This means that the addition of polystyrene beads extended the setting time by more than 38%. The final setting time of 710 minutes was observed during the practical to establish the structural features.

The average compressive strength of polystyrene concrete composite ranged from 3.08MPa to 6.4MPa, which is far below the recommendations in ACI 213, (1987) which states that the minimum 28 days' strength value of light weight concrete should not be less than 17MPa for structural purposes. The value was below recommended value for normal structural concrete, but the value was within ordinary concrete value, which has its maximum as 10MPa.

The average deflection of profile sheet-polystyrene fibre reinforced composite slab ranged from 12.5mm to 23.5mm, which according to ACI 318, the minimum depth for deflection of reinforced concrete should be L/16, therefore, the deflection was within limit for structural slab. Although the permissible stress in bending for concrete ranged from 2.5 MPa to 16 MPa for slabs, the average flexural strength of profile sheet-polystyrene fiber reinforced composite slab ranged from 2.1 MPa to 3.9 MPa, and the flexural strength of convectional composite slab with 10 mm rebar gave 7 MPa. Consequently, the flexural strength was within limit for light structural slab.

Shrinkage in profile sheet-polystyrene fibres reinforced composite slab was adequate as the slabs showed no visible crack at 28^{th}-day. Raffia palm agro fibre served as a good crack control in composite slab. Based on this Further studies should be carried out on the fire resistance of profile sheet-polystyrene fibre reinforced composite slabs compared to traditional concrete also the relationship between deflection and flexural strength should be observed at different loading other than crushing load.

CONTRIBUTIONS TO KNOWLEDGE

This work has contributed to knowledge in the following ways:

This work has given information on flexural strength and deflection of profile sheet-polystyrene fibre reinforced composite slab with varying content of raffia palm agro fibre in profile sheet composite slab.

This work has given information on compressive strength and workability of profile sheet-polystyrene fibre reinforced composite slab with varying content of raffia palm agro fibre in profile sheet composite slab.

The work also will help as reference material for further study on polystyrene beads, fine aggregate, raffia agro fibre and composite concrete slab.

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