Flexural Behavior of Ferrocement panel and investigation of Pavement as Ultra-Thin Overlay

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Abstract

The goal of this research paper is to investigate the flexural behavior of ferrocement panel, and the study of using this ferrocement panel as an ultra-thin overlay in the rigid pavement. Rigid pavements have sufficient flexural strength to transmit the wheel load stresses to a wider area .As a result of the large stress distribution on the pavement over the layers, it is subjected to a crack and that can be minimized with the use of a geo-grid. The ferrocement panel is a thin structure which has a high flexural strength and ductile in nature. The size of the panel is 700*300*20mm with mix ratio of cement and fine aggregate as 1:2. For the investigation on pavement study, this panel is designed according to Portland cement association (PCA) and referred with IRC-SP-76.This specimen is tested under 2point load in flexural testing machine .Experimental ferrocement panel result is compared with the conventional panel. The test result shows that the ferrocement panel is good in flexural, and that increase in number of wire mesh layers also increase in flexural strength and thus act as an overlay on the pavement. Thus the main aim of this project is to prevent the reflecting crack on the rigid pavement. The model of ferrocement panel is done by using abaqus unified finite element software.

Key words-*Flexural, ferrocement, rigid pavement, ultra-thin overlay, finite element analysis.*

I. INTRODUCTION

Improving mortar strength using available local materials is an effective way of overcoming the problem of low strength and failure in building construction. Lightweight pre-fabricated sandwich structural elements in building construction is a growing trend in construction all over the world due to its high strength-to-weight ratio, reduced weight, and good thermal insulation characteristics. Ferrocement is regarded as highly versatile construction material possessing unique properties of strength and serviceability. Its advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability cannot be matched by any other thin construction material. Its acceptance is hindered due to its small thickness and labour intensive method of production. In order to cope with the problem of thickness, one of the options currently suggested is to develop ferrocement sandwich elements. A rigid pavement is constructed from cement concrete or reinforced concrete slabs. Grouted concrete roads are in the category of semi-rigid pavements. The design of rigid pavement is based on providing a structural cement concrete slab of sufficient strength to resists the loads from traffic. Thin cement concrete overlays have been successively used for extending the life of existing pavements. These overlays can accommodate a variety of needs, such as extending performance lives by as much as 15 to 20 years, meeting rapid construction requirements, and conforming to any specific traffic management constraints. Thin cement concrete overlays are classified according to the type of existing pavement and the design composite action. When the overlay is bonded to the existing pavement in order to behave as a monolithic structure, the overlay is referred as “bonded”. If the overlay is separated from the underlying pavement (by placing a separator layer) or designed assuming some degree of slippage at the interface with the existing pavement, then the overlay is considered as “unbounded”. Cement concrete overlays placed on existing composite (i.e. Ferrocement overlay of a cement concrete pavement) pavements are sometimes called as “white topping”.

Flexural capacity being one of the most advantageous properties of Ferro cement, which improves the post cracking behavior of the slab and makes it applicable on earthquake zone. Steel mesh proves to be best n flexural. Thus depending on the design load, the number of mesh layer to be provided shall be increased. When Ferro cement is applied to the tension zone of the slab, it reduces the self-weight of the structure to above 30% [3]. The use of UTCRCP is intended as an alternative rehabilitation option by providing a thin 50 mm layer of high strength, flexible, concrete constructed as a durable cover on top of existing distressed pavements. This offered good control over the mixing process and significantly reduced the possibility for incorrectly measuring off mix proportions during the actual concrete mixing process. The concrete mixing took place in a mobile on-site mixing unit resulting in optimum workability of the mix during placing and compacting.Labour is extensively used for the construction of UTCRCP [4] Westergaard's empirical method is not the only method to calculate rigid pavement stresses and stresses Can be as effectively calculated by Finite Element Method. Finite Element Stresses when used in the design of rigid pavements as suggested can provide an optimum and economical design in practice because of the procedure of FEM to discretize each element under consideration and calculate stresses at each node. Estimation of the behavior of the rigid pavement critical points under the applied load can be more accurately described by Finite Element Method stresses. The lower value of the Finite Element Stresses as compared to the Westergaard's stresses ensures that the design of the pavement and its further manipulations by trial and error method can be easily done with constraints of design look-up minimized. The lifetime of the pavement can be considerably increased by the application of Finite Element Method Analysis and the fatigue and distress can be accurately ascertained. According to the analysis done by us it is found that the rigid pavement model exhibits minimum value of the stresses when the sub-grade layer is treated with 10 % sawdust as a stabilizer [8].

Thus from the inference ,the rigid pavement can also be analyzed using FEA and the main goal of this study is to prevent the reflecting crack of the pavement and also increasing the life period of period with using the Geo-synthetic grid as a core material.

II. CONSTITUENTS OF FERROCEMENT

The constituents of ferrocement include the hydraulic cement mortar which should be designed according to the standard mix design procedures for mortar and concrete which include cement, water, sand and wire mesh.

III. SCOOPE AND OBJECTIVE

The main objective of the Project is,

- To study the behavior of ferrocement panel under flexural loading.
- To design a panel according to Portland Cement Association (PCA) method.
- To behave a ferrocement panel as ultra-thin overlay (topping) on the rigid pavement.
- To prevent the reflecting crack on the pavement.

IV. EXPERIMENTAL WORK

The experimental program includes the design of ferrocement panel according to PCA, testing of ferrocement panel for initial load obtained and finally analysis is done by using finite element software.

A. Material used

Cement-Portland Pozzalana Cement (PPC) (Fly Ash Based) conforming to IS 1489 (Part 1)-1991is used.

Table 1 – Physical Properties on cement

PROPERTIES	OBSERVED VALUE
Specific gravity	3.148
Fineness	3.33%
Initial setting time	3hr 15min
Final setting time	6hr 20min

Fine Aggregate-M –Sand is chosen. It conforms to IS 383 1970 falls under Zone II.

Table 2 – Physical Properties on Fine aggregate

PROPERTIES	OBSERVED VALUE
Specific gravity	2.642
Zone	Zone II
Fineness modulus	2.84
Bulk Density	1324.04 kg/m^3
Water Absorption	1.52%

Water-Portable tap water available in the laboratory with pH value of 7.0 and confirming to the requirements of IS456-2000 is used.

Natural fiber-The natural fiber used in this project is Coir fiber and Bagasse Fiber.

Mesh -The wire mesh used was mild steel galvanized welded wire mesh of 1.00mm diameter and 13.0mm square grid size/square mesh(SM) as per ACI 549-IR-7.

Table 3- Details of specimen to be casted

NO	NAME OF THE SPECIMEN	NO OF PANEL/ BEAM
1	Panel with plain mortar (PM)	3
2	Ferrocement panel (FP-1)	3
3	Ferrocement panel (FP-2layer)	3

B. Preparation Of Composite

Mortar was prepared by calculating the exact amount of cement, sand and water. The wooden mould was casted to a size of a panel of 700*300*20 mm.

Fig 1- Panel

At bottom a layer of mortar was applied to a thickness of 3-5mm followed by a layer of welded mesh and again followed by layer of mortar. The procedure continues for placing the layers of mesh. The mesh sizes were cut down according to the size of the panel leaving a cover of 3mm on both side of mesh. This procedure is continued placing the layers of mesh one by one.

Fig 2 - Casting of ferrocement panel

C. Curing

After casting of panels they were removed from mould after a period of 24hours.After removal the panels and the lipped beam were cured in normal water tank for a period of 28days.

D. Design of panel

A variety of cement based products can be used in pavement applications including soil-cement; roller compact concrete, cast-in place slabs, pervious concrete, and whitetopping.They all contain the three same basic components of Portland cement, soils/aggregates, and water. While concrete pavements are best known as their riding surface for interstate highways, concrete is also a durable, economical and sustainable solution for rural roadways, residential and city streets,inter-sections,airstrips,intermodalfacilities,militarybases,pa rkinglots and much more. Design of the panel is done according to Portland Cement Association (PCA).

PCA Design Method

a) Two failure modes considered:

– Fatigue failure due to slab flexure

– Erosion failure due to foundation compression

b) Edge loads produce the worst stresses (Fatigue based on tensile stress due to edge loads).
c) Corner loads produce the worst deflections.

Design Parameters

1. Concrete modulus of rupture (MR)

2. Modulus of subgrade reaction (k)

3. Design traffic volume

4. Axle load spectrum

Modulus of Subgrade reaction

The modulus of subgrade reaction is taken according to the soil of untreated or treated subbases.

Design Traffic Volume

V = 365 (ADT) (T) (D) (L) (G) (Y)

Where,

ADT- Average Daily Traffic (2-way)

T – % of trucks

D- Direction distribution factor

L – Lane Distribution Factor

G – Traffic Growth Multiplier

Y – Design life

Growth Factor (according to PCA)

$$G = (1+r)^{Y/2}$$

Axle load spectrum

The axle load depends on the single or tandem with respect to the frequency.

V. TESTING

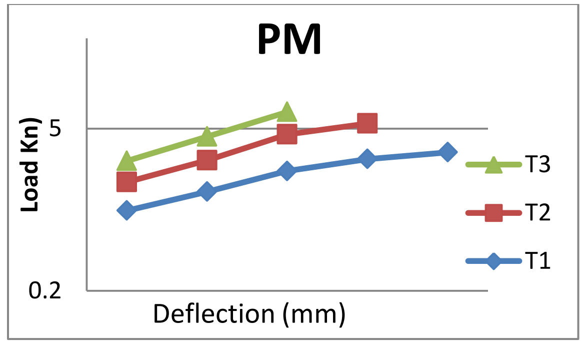
The Panels were removed from the curing tank. Panels were tested for flexural test under two-point in a universal testing machine. The panels were placed on support leaving a space of 50mm from both sides. Dial gauge was placed below the panel to record the deflection in mm at each stage of loading.

VI. RESULTS AND ANALYSIS

A. TEST RESULTS

Table 4 – Panel with 20mm thick

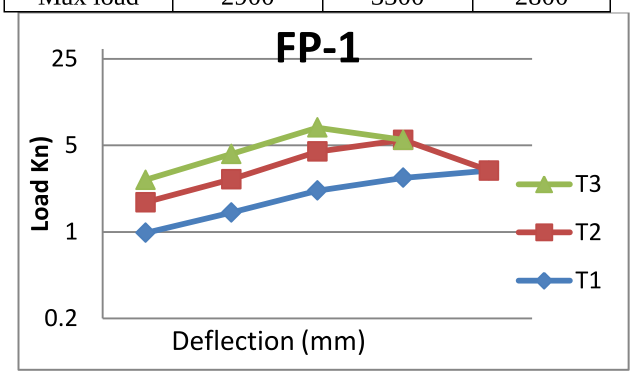
Load (N)	Deflection (mm)		
	T1	T2	T3
500	0.98	0.75	0.9
1000	1.43	1.23	1.6
1500	2.15	2.3	2.5
2000	2.73	2.8	-
2500	3.12	-	-
1ST Crack	1.43	1.23	1.6
Max Load	2300	1800	1700



Graph 1- Load vs Deflection (Plain mortar)

Table 5 – Ferrocement panel (FP-1)

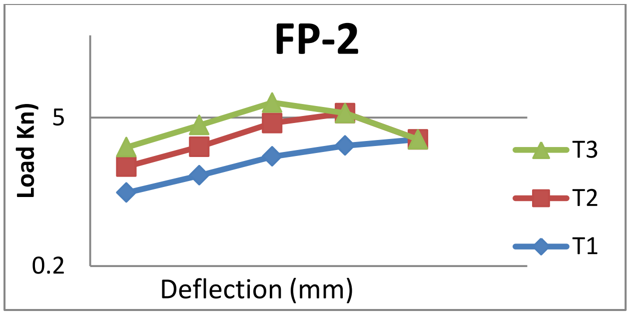
Load (N)	Deflection (mm)		
	T1	T2	T3
500	0.82	075.	0.9
1000	1.5	1.3	1.5
1500	2.15	2.23	2.1
2000	2.98	3.01	2.7
2500	3.4	3.4	3.2
2800	3.90	4.1	-
1ST Crack	2.15	3.01	2.1
Max load	2900	3300	2800



Graph 2- Load vs Deflection (FP-1))

Table 6 – Ferrocement panel (FP-2) with two layer of mesh

Load (N)	Deflection (mm)		
	T1	T2	T3
500	0.62	078	0.68
1000	1.75	1.8	2.1
1500	2.53	2.45	2.8
2000	2.98	3.1	3.4
2500	3.4	3.9	4.1
3000	4.2	4.7	4.65
3500	-	5.3	-
1ST Crack	2.98	3.1	2.8
Max load	3400	3800	2800



Graph 3- Load vs Deflection (FP-2)

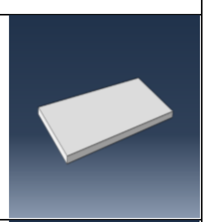
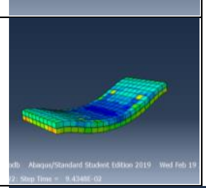
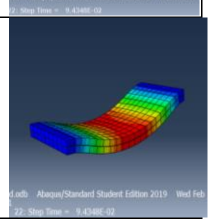
Table 7 – Flexural strength of Ferrocement panel

Panel	Cracking Load(N)	Ultimate Load(N)	Flexural strength **(σcr)** at cracking load (N/mm^2)	Flexural strength **(σult) at** Ultimate load (N/mm^2)
PM	1000	2300	1.4	3.22
FP-1	2000	3300	2.8	4.62
FP-2	2000	3800	2.8	5.33

B. ANALYSIS

Analysis- Abaqus Unified FEA which is a finite element based software and a powerful tool to investigate the behavior of the proposed ferrocement panels, was applied in this study. The ferrocement mortar was modeled with concrete characteristics using elastic modulus of 210GPa and Poisson's ratio of 0.3.

Table 8- Analysis of ferrocement panel

SI.NO	PANEL CONFIGURATION	ANALYSIS RESULT
1	Model of the ferrocement panel in Abaqus -FEA	
2	Stress variation on the ferrocement panel	
3	Deflection on the ferrocement panel	

VII. CONCLUSION

Based on the experimental test results, the flexural loads at first crack and ultimate loads depends on number of reinforcing mesh layers used in the ferrocement panel. Thus increasing the number of wire mesh layers significantly increases the ductility of the panel. In this study, samples were designed and constructed with various material (eg.meshes and mortar) and the models of the panels were implemented using Abaqus Unified FEA.Thus from the analyses results, the models can be used to obtain optimal span of panel which can be used in different application (such as roof or slab) and also the results are nearly similar to experimental values. By this application ,the ferrocement panel can be considered as a ultra -thin overlay on the pavement structures which minimize the crack and can with stand the stress distribution below the base since pavements are normally good in flexural.

VIII. REFERENCE

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