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Comparative Study on Computation of Theoretical Moment Capacity of Ferrocement Panels

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Abstract: The scope of the project is to study the flexural behavior of ferrocement panels with various numbers of mesh layers and thickness. The first cracking moment is determined by flexure formula and the nominal moment capacity is determined by strain compatibility method and design aids by ACI 549.The theoretical moment capacity of ferrocement panels specified in the codal provisions of ACI is reliable if identical mesh layers are present. There must be a minimum of two mesh layers for calculating the moment capacity using prediction equation given in the design aids. Therefore, the ferrocement section is considered as a cracked section for calculating the first cracking moment. This method has no constraints in the number of mesh layers used. Both strain compatibility method and prediction equation gives same theoretical moment capacity
Keywords: ACI 549, Ferrocement, Flexure, Ultimate moment Capacity

I. INTRODUCTION

A great number of civil infrastructures around the world are in a condition of serious fall today due to carbonation, chloride attack, etc. In addition, many civil structures are no longer measured as safe due to increase load specifications given in the design codes or due to overloading or due to poor quality. So as to sustain well-organized serviceability, grown-up structures must be repaired or strengthened in order that they meet the same necessities demanded by the structures built today and in future. Ferrocement have gained respect in terms of its superior performance and adaptability over the years. Ferrocement is a form of reinforced concrete using closely spaced multiple layers of mesh in mortar. It is a very hard-wearing, cost effective and flexible material.

Ferrocement is a highly versatile construction material and possess high performance characteristic, especially in cracking, strength, ductility, and impact resistance. As its reinforcement is uniformly distributed in the longitudinal and transverse directions and closely spaced through the thickness of the section. Since ferrocement bends itself to precasting and hence, precast ferrocement elements can be prepared to meet the strength and serviceability conditions. There is an ample scope for mass production and standardization together with the economy in construction.

II. LITERATURE REVIEW

Randhir J. Phalke, Darshan G. Gaidhankar [1] investigated the effect of using different no of wire mesh layers on the flexural strength of flat ferrocement panels and to compare the effect of varying the no of wire mesh layers and use of steel fibers on the ultimate strength and ductility of ferrocement slab panels. Steel fibers of corrugated type with aspect ratio (l/d=57) were used. From the study the following were observed that, increasing the number of layers of wire mesh from 2 to 4 layers significantly increases the ductility and capability to absorb energy of the panels and Presence of steel fibers also increases the flexural strength of panels as compared to those without fibers and incorporation of steel fibers long with increment in number of layers leads to 58% increase in load carrying capacity and 33% decrease in deflection

C.Manikandan, S.Dharmar, S.Nagan [2] conducted an experimental investigation on ferrocement folded panel with geopolymer mortar and polypropylene fiber for various mix proportions and fiber ratio. The ferrocement Panels with folded shape of size 1000mm x 400 mm x30mm are casted with one layers of hexagonal chicken mesh with dia 1.29mm and thickness of 12mm are placed at mid depth of the panels with skeletal steel of 6mm dia. From this investigation, the researched concluded that Folded panels without fibers are deflected suddenly without any caution as compared to panels with fibers and the time taken from first crack to ultimate failure is too low for panel without fiber as compared to with fibers. It indicates more ductility of fibers folded panels. Flexural strength of folded panels with fiber is more as compared to panel without fibers.

HarunTanyildizi, YavuzYonar [3] studied mechanical properties of geopolymer concrete containing polyvinyl alcohol fiber exposed to high temperature. Polyvinyl alcohol fiber was used in 0%, 1%, and 2% by mass of the fly ash. The all mix was produced by curing these samples at 60, 80, and 100 C and the samples were exposed to high temperatures at 20 C, 400 C, 600 C and 800 C. For the alkaline activator, a combination of potassium hydroxide with potassium silicate solution was used. From the study the following observations were made that as the fiber ratio increased, compressive strength and flexural strength of the geopolymer concrete increased as well. As the temperatures increased, compressive strength and flexural strength of most samples decreased. However, the compressive strength of concrete that was cured at 60 C, and exposed to 400 C increased 29% with respect to the control sample (CR). Samples that were cured at 60 C demonstrated the best results in compressive strength and flexural strength among the samples that were cured at 60 C, 80 C, and 100C.

Darshangaid shankar, Mrudula kulkarni, Vinodvagadurgi [4] studied effect of different types of fibers on the flexural strength of ferrocement panels.They have studiedthe flexural behaviour of ferrocement slab panels with under flexural loading in which woven wire square mesh is used as a tensile reinforcement and three different types of fibers are used Hooked fibers , Flat crimped fibers and corrugated fibers are used as a different types of fibers Effects of different types of fibers and effect of panel thickness on flexural strength of ferrocement are investigated. Ferrocement Panels of size 550mm x 200 mm x20mm, 750mm x 200 mm x30mm, 950mm x 200 mm x40mm are casted for without and with 3 different fibers and 2 layers of woven square mesh 1.05mm dia and 13 mm side openings. From the study it was observed that Flexural strength of ferrocement panel increased with inclusion of fibers.First crack and ultimate loads are increased with inclusion of fibers.Panel with corrugated fibers provides high compressive strength of 65 Mpa and panel with Hooked fibers , Flat crimped fibers provided high flexural strength as compared to panels without and with corrugated fibers.

Mohammed Haloob Al-Majidi, Andreas Lampropoulos Andrew B. Cundy [5] Studied the properties of Steel fiber reinforced geopolymer concrete (SFRGC), containing various types of commercial Silica Fume and varying Ground Granulated Blast Furnace Slag (GGBS) content cured under ambient (room) temperature are examined types of SF used were densified, un densified and slurry silica fume and GGBS content increasing from 10% to 40% . 2% volume fraction of straight steel fibers with a length of 13 mm and 0.16 mm diameter was used as the fiber reinforcement. For the alkaline activator, a combination of potassium hydroxide with potassium silicate solution was used. They concluded that increasing the slag content in the FA and slag based geopolymer mortar decreases the workability and accelerates the setting times (initial and final). The compressive strength of plain geopolymer mortar and SFRGC was increased as the slag content was increased. Post cracking behaviour and energy absorption capacity was considerably improved by increasing the slag content.

Aameer bhutta, Mohammed farooq, nemkumar banthia [6] investigated performance characteristics of micro fiber reinforced geopolymer mortars for repair. For the study, HSS, waste steel wool, PVA, PP, Polyester, Carbon are the fibers used. 0.5% and 1% of volume fractions are used. Three different types of curing are studies such as ambient,4h and 24h heat curing. Workability is measured with shaking table method as per ASTM c1437, compressive strength as per ASTM 109 and flexural strength as per ASTM C1609. From the study, Mortars containing HSS and PVA fibers exhibit higher flexural strength than others. Performance of PP fibers in terms of deflection is inferior to HSS and PVA fibers but better than PET and CSW. PVA is the best among the polymer fibers

Aameer bhutta, Mohammed farooq, nemkumarbanthia [7] studied tensile performance of eco-friendly ductile geopolymer composites incorporating different fibers. The performance of EDGC incorporating 1%,2%,3% volume fractions of different fibers such as PVA,PP, HSS. CSW is investigated and effects of fiber type, fiber volume fraction, and alkaline solution are investigated. The following conclusions were made that higher volume fractions (2% and 3%) reduced the workability. PVA fibers have higher compressive strength than unreinforced composites and PP fibers have lesser compressive strength. HSS and PVA fibers perform best among all the fibers.

III. OBJECTIVES

The main objectives of this study are to compare the theoretical nominal moment capacity of ferrocement panels by strain compatibility method and ACI 549 prediction equation. The main parameter in this study is that effect of number of mesh layers and thickness of panel in moment capacity of ferrocement panels.

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IV. METHODOLOGY

A. Volume Fraction of Reinforcement

The volume fraction of reinforcement is the ratio of volume of reinforcement to the volume of composite

$$V_r = \frac{V_{reinforcement}}{V_{Composite}}$$

In the above definition, the volume of reinforcement includes skeletal steel. But, if the skeletal is placed in the Centre of a ferrocement member, and if bending is considered, then, its influence may be ignored. On the other hand, the skeletal steel should be considered in evaluating the resistance of tensile members when the same square or rectangular wire mesh is used throughout the depth of a ferrocement element. Then the volume fraction of reinforcement can be calculated from

$$V_f = \frac{N\pi {d_b}^2}{4h}\left(\frac{1}{D_l} + \frac{1}{D_t}\right)$$

Where

N – Number of layers of mesh reinforcement

d_b– Diameter of mesh wire

h - Thickness of ferrocement

D_l – Center to center spacing of wires aligned longitudinally in reinforcing mesh

D_t- Center to center spacing of wires aligned transversely in reinforcing mesh

Using the above equations volume fraction of reinforcement wasdetermined for welded mesh

For other types of meshes,

$$V_f = \frac{NW_t}{h\gamma t}$$

Where,

W_t – Unit weight of reinforcing mesh

γ_t – Density of reinforcing material

B. Specific Surface of Reinforcement

The specific surface of reinforcement is the total surface area of reinforcement divided by the volume of composite that is, the surface area of bonded reinforcement per unit volume of composite.

$$Sr = \frac{\epsilon}{bh}$$

Where

ϵ - Total surface area of bonded reinforcement per unit length

The relation between specific surface of reinforcement and volume fraction of reinforcement when square grid wire meshes are used is

$$Sr = 4Vf/d_b$$

Where,

d_b – diameter of the wire

C. Effective Area of Reinforcement

The area of reinforcement is an important input data in the design offerrocement. The area of reinforcement is associated in both the longitudinal andtransverse directions. Hence, the effective area of reinforcement resisting tensionand associated with a typical mesh layer 'i' of a ferrocement section, subjected tobending and is given by Equation

$$A = \sum_{i=1}^{n} Asi$$

$$Asi = \eta . V_f . A_c$$

Where,

Asi –effective area of reinforcement for mesh layer i
η – Global efficiency factor of reinforcement in the loading direction
Vf – Volume fraction of reinforcement for mesh layer i
Ac – Gross cross sectional area of mortar section

D. Modular ratio of reinforcement

It is the ratio of modulus of elasticity of reinforcement to the modulus of elasticity of mortar matrix

$$n = {E_r}/{E_m}$$

Where,

E_r –Modulus of elasticity of reinforcement

E_m - Modulus of elasticity of mortar matrix

E. Yielding of all Tensile Reinforcement

Based on computerised analysis of ferrocement sections, following anapproach similar to that of reinforced concrete columns, Naaman (2000) observedthat all layers of reinforcement were often at tensile yield, except, perhaps the firstone or two layers from top, which were either in or close to the compression zone.This is because, generally, the depth of the compression stress blocks at ultimate issmall (often less than 0.15h) and at most one layer of mesh. So a new method wasdeveloped with the assumptions that (i) the existence of the layers of reinforcementin the compression zone be ignored and ii) all other layers of reinforcement are intension and yield, at nominal bending resistance. Based on the above, followingequations leading to obtain the nominal bending moment has been derived andgiven by Naaman (2000) as Equation

Force Equilibrium

$$0.85f_c ba = A_n.\sigma_r.y_i \text{ ; i=j to N}$$

From the above equation the location of neutral axis a can be determined

The following equation represents the Moment equilibrium equation.

$$M_n = \sum_{i=1}^{n} A.\sigma ryi\left(di - \frac{h}{2}\right)$$

F. Plastic Moment

A ferrocement section reinforced with multiple layers of reinforcementshows a ductile behavior, it can be assumed to behave as a perfectly plastic material,with different properties in compression and tension. In compression zone, it isassumed that the stress block is rectangular and in the tensile zone, all layers ofmesh reinforcement are assumed to be in the plastic range.

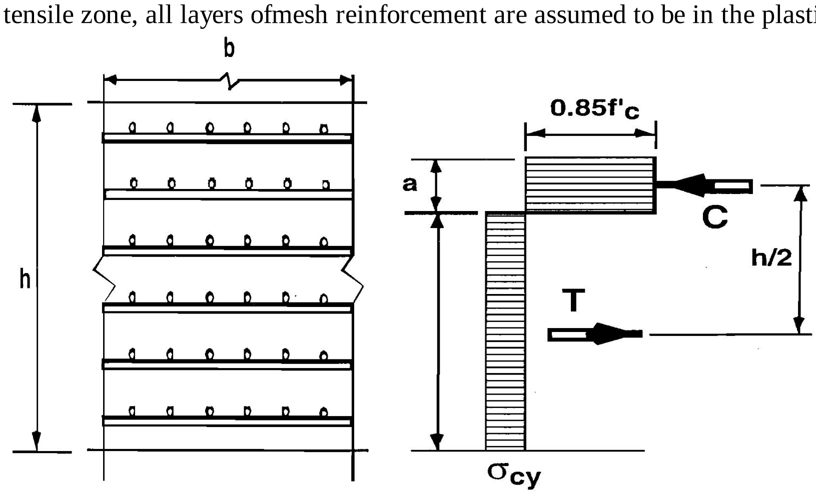


Fig 1.3 Stresses in section for computing plastic moment

Referring to Figure 1.3 the following equations can be written

Tension; T = σ_{cy}.b.(h-a)
Compression; C = 0.85 f'cba
In the above-simplified plastic (moment) analysis, the depth of the rectangular stress block (a) is assumed to be at the plastic NA. It is observed that plastic analysis, carried out with slight differences from the above procedure have yielded results in good agreement with experimental observations with several investigations.

G. Design Chart for Prediction of Equation

Based on extensive computerized parametric evaluation of various ferrocernent rectangular sections with different layers and different types of meshes Naaman and How rich (1986) developed a non-dimensionlized regression equation and a corresponding design chart, which was subsequently adopted in the ACI Guide for Ferrocement Design, Construction and Repair. Non-dimensionalized variables indicated in the design chart. X, Y are valid in all systems of units and defined by following chart

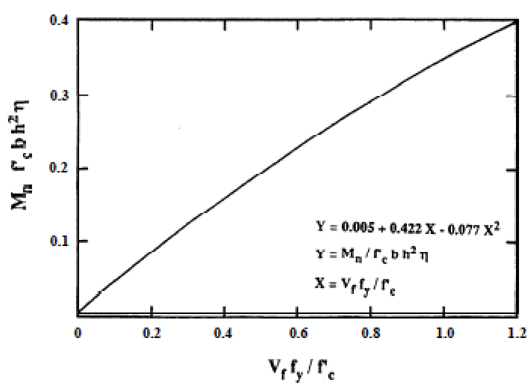


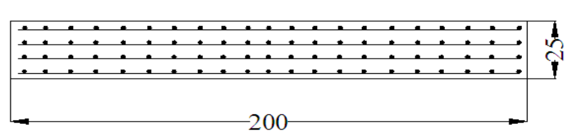
Fig 1.4 Chart for strength design of ferrocement in bending (Ref:ACI 549.1R-93,Fig 4.2)

From the above chart, the predicated nominal moment capacity is given by following expression

$$\frac{Mn}{fc.b.h.h.\eta} = \mathbf{0.005 + 0.422\ (V_f.f_y/f_c') + 0.0722 + 0.422\ (V_f.f_y/f_c')^2}$$

V. RESULTS AND DISCUSSION

The theoretical values of moment for a ferrocement panel of size 550mm x200mm with varying thickness of 25mm,40mm and 50mm were calculated with following specifications
Cement mortar 1:1.75
Water cement ratio 0.38
Type of wire mesh Welded square mesh
Diameter of mesh 1.6 mm
Spacing of wires 20mm
Number of layers 2 to 4
Compressive strength 40.84 N/mm^2 (28 days cube compressive strength)



All dimensions are in mm
Fig 1.5 Ferrocement model with 4 layers of wire mesh

Table 1– Theoretical moment values

Sl.No	Thickness (mm)	No of mesh layers	Volume fraction of reinforcement (V_f)	Theoretical Cracking moment (N.mm)	Theoretical Nominal Moment (N.mm)		% Deviation
					Strain compatibility method	ACI 549 Prediction equation	
1	25	2	1.61	173075.65	228032.20	222147.06	2.6
2	25	3	2.42	270835.75	324871.56	321252.66	1.1
3	25	4	3.22	335827.26	418198.95	416091.35	0.5
4	30	2	1.61	243117.74	328208.95	319891.80	2.4
5	30	3	2.42	446082.26	499612.14	462603.79	1.4
6	30	4	3.22	463666.59	602766.57	599171.48	0.4
7	40	2	1.61	432209.32	583482.58	568696.56	2.25
8	40	3	2.42	793035.13	888199.35	822406.79	1.2
9	40	4	3.22	824296.169	107585.02	1065194.23	0.7

VI. CONCLUSIONS

From all the work, the following conclusions are made

A. Cracking moment is predicted by flexure formula and Nominal moment is calculated by strain compatibility method and ACI 549 prediction equation
B. Both cracking and nominal moment capacity are increased with the increase in number of mesh layers and increase in thickness of panel
C. Both Strain compatibility method and ACI 549 prediction equation give similar result on nominal bending moment but former method consumes more time because of more calculations as compared to later method
D. It has been concluded that ACI 549 method is the best method to predict the nominal moment capacity of Ferrocement panels.

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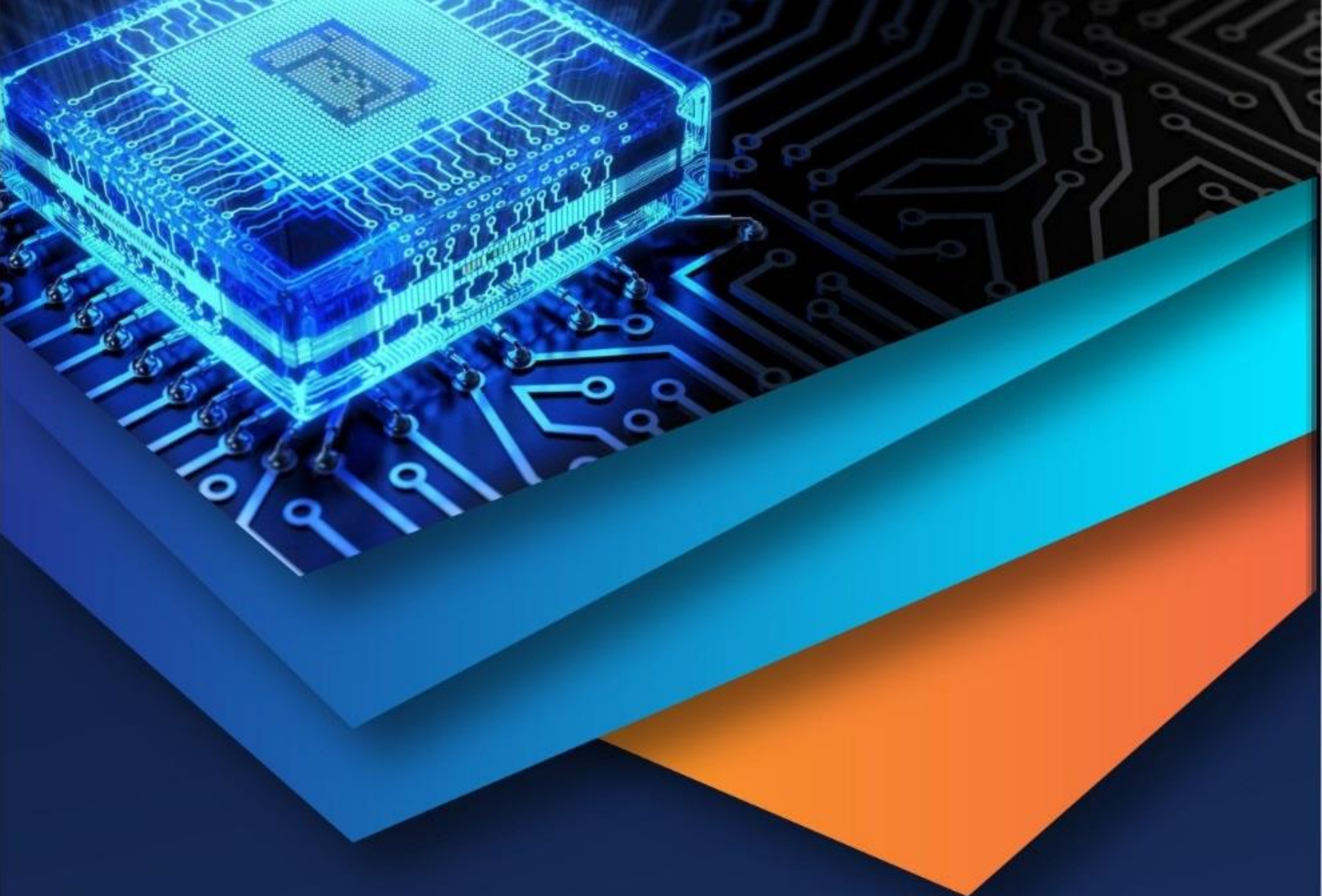

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