Ferrocement – A Review

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Abstract

Ferrocement has been proved as a reliable, cheap strengthening component for reinforced concrete structure in construction industry. Ferrocement element can be used as a plate or walling units or as a fire resisting unit. Though there has been many experiments done on the strength (basically Flexural, compressive) by taking different section of ferrocement plates as well as beams, this paper has given an importance on the shear behavior of ferrocement elements. Since there is no codal provisions has been made for calculating the shear strength of ferrocement elements, this paper has been emphasized to form different empirical formula to calculate the shear strength of ferrocement element. The shear strength of ferrocement element varies due to different layer of mesh used and the shear span(a) to depth(d) ratio(a/d). It is observed that stress intensity as well as cracking shear strength of plate depends upon volumetric fraction (Vf) of wires.

1.Introduction

Ferrocement is a composite construction material where closely spaced wire mesh is embedded with mortar. *The ACI committee 549*[1] has defined ferrocement a "*thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced small diameter wire mesh". *The mix is generally of cement and sand mortar, where the wire mesh having wide openings which makes adequate bonding of mixture. This steel wire mesh is responsible for ferrocement structure having very high tensile and flexibility strength which is not found in ordinary concrete structures. Ferrocement is also ideally used as an alternative strengthening component for rehabilitation of R.C element.The ultimate tensile resistance of ferrocement is only due to the reinforcement in the direction of loading and the compressive strength is equal to that of a unreinforced mortar. But in the case of flexure and shear, the analysis and design of ferrocement is complex thus the principle as for the R.C.C is taken into consideration.There are very few reports available on the calculation of the shear strength of ferrocement element.

2. Literature Review

Till today there is no codal provisions being made for the calculating the shear strength of the ferrocement element empirically. Thus the codal empirical fomula for R.C.C has been extended for the ferrocement element. In various studies the experimental values has been compared with the empirically solved results obtained from *ACI* and *BS* code procedures for reinforced concrete.

This paper includes some of the empirical solutoin and their comparative experimental solution for determining the shear strength of ferrocement element. Different paper solution has taken into consideration to compare the semi empirical solution.

3. Factors Affecting Shear Strength Of Ferrocement Element

From the different experimental studies on ferrocement it has been found that the strength of ferrocement element in shear affects due to the shear span *(a)* to depth *(d)* ratio *(a/d)* and volumatric fraction (V_f) of mesh reinforcement.

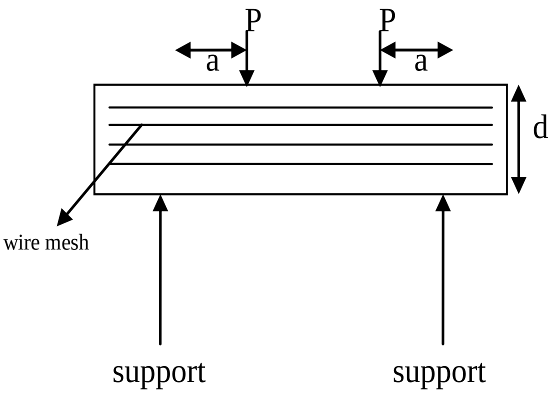

Fig 1:- Set up that showing the factors affecting strength of ferrocement element

4. Different proposed Empirical Solution for calculating the shear capacity Of Ferrocement element

4.1. Method 1 - Calculation of cracking shear strength of ferrocement plates [2]

According to the reference no.2 the increase in the volume fraction (V_f) of the wire mesh layer subsequently increase in the shear carrying capacity of the ferrocement plate. It is observed that stress intensity as well as cracking shear strength of plates depends upon volume fraction[2]. The experiment has been carried out by taking a section of [490×230×20 mm] and the test result is being verified by using the FEM *(Ansys)* [4].

From the above experiment it has been found that Hexagonal mesh improves the shear capacity than that of Diamond and Square mesh because higher straight length[5]. From these results it has been found that strength depends upon volume fraction*(Vf)*. The volumetric function all type of mesh can be calculated by using formula.

For square mesh:-

$$V_f = (N/4)(\Pi dw^2/h)[(1/Dl)+(1/D_t)]$$

Where N=No. of mesh layer, $\pi = 3.14$,
dw= Diameter of wire mesh
Dl= distance center to center between longitudinal wires
Dt =distance center to center between transverse wires
h= thickness of ferrocement plate

Now the cracking shear strength of the can be calculated analytically [3]. The following equation has been derived to predict the shear capacity of ferrocement plate.

Cracking shear strength (ϑcr):-

$$\vartheta_{cr} = (0.27 + Vf^{0.65})\times(F_{cu}\times(d/a))^{0.65}$$

Where,
Vf= volume fraction of mesh depending upon size of opening
f_{cu} = *Mortar compressive strength*
a = shear span
d = Overall depth of plate.

4.2. Method 2-Empirical formula For Calculating The Shear Capacity Of Ferrocement elements[6]

In this section[6] a rectangular section of size [600×150×25 mm] has been tested experimentally and the value is being compared with the empirical formula based on Australian code (AS 3600-1994) and American code (ACI Committee 318-95). It has been proved from this section that the number of increase in mesh improves the shear capacity of the member. Another result shows that beyond (a/d)=3,the flexural behavior is predominant and design of the member based on flexure is enough but (a/d)<3 the shear behavior is predominant.

The member is being put under a two point load testing machine and load was applied by means of proving ring. Different shear span to depth ratio as well as the number of layers of mesh has taken into consideration.

Different properties of member having same sizes has put under the same testing procedure and the ultimate shear force (Vu) and the cracking shear load is measured. Then the test result was compared with the empirical formula suggested for R.C.C in Australian code (AS 3600-1994) and American code (ACI Committee 318-95).After comparison it has been observed that the formula for R.C.C can be extended for ferrocement. Thus a separate formula is being generated for predicting the shear capacity of ferrocement element. Shear resistance of ferrocement member is mainly depends upon mortar and longitudinal reinforcement.

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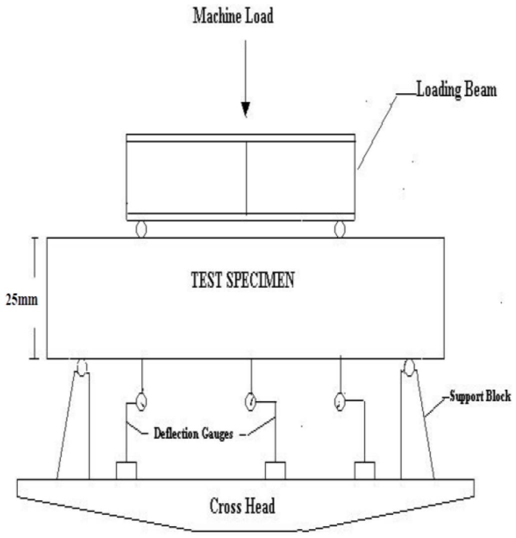

Figure 2. Experimental Setup

i) Thus Shear resistance due to mortar can be expressed as –

$$\frac{Vu}{bd} = k\frac{\sqrt{Fcu}}{\frac{a}{d}} \longrightarrow (1)$$

Where Vu=Shear capacity

F_{cu}=Compressive strength of mortar

K=constant, which can be calculated from the graph drawn between shear capacity vs. F_{cu}/(a/h).

ii) Shear resistance of ferrocement member can be expressed as the sum of shear resistance due to mortar and the wire mesh. Thus the expression derieved from the experimental data is due to the shear to be contributed by mesh only is-

$$\frac{Vu - Vm}{bd} = y \times Vf \times \frac{Fy}{\frac{a}{d}} \longrightarrow (2)$$

Where, V_m=ultimate shear load of mortar element

V_f = volumetric fraction

F_y =yield strength of the wire mesh

b = width of plate

y=constant which can be found from the graph plotted [(V_u-V_m)/bd] vs. [$(V_f \times F_y)$/(a/d)].

Thus from the combination of (1) & (2) will give the shear resistance of ferrocement element. Finally the empirical equation can be written as:-

$$\frac{Vu}{bd} = \frac{\sqrt{Fcu}}{\frac{a}{d}}\left\{k + y\frac{Vf \times Fy}{\sqrt{Fcu}}\right\} \longrightarrow (3)$$

4.3. Method-3-Empirical formula derived by Desayi[7] for Different Cases Of Shear Formula

According to reference no. 7 there may be formation of flexure-shear crack and web shear crack, and the failure due to flexure-shear and web-shear may occurred. Thus the analytical expressions has been derived to predict the shear force at cracking and failure. The equations has been developed by comparing the different experimental results. These empirical formula has been derived from the ACI and BS code procedures applicable for reinforced concrete and compared. Most of the empirical procedure currently available to predict the shear behavior of ferrocement element are probably less than satisfactory. As it has been found that there are two possible types of inclined cracks, namely flexure-shear and web-shear cracks and correspondingly two different modes of failure in ferrocement member[8,9]. In this study[7] two layouts of meshes have been proposed and they (1) distributed throughout the thickness and (2) lumped near the extreme fibers of the specimen. Small diameter of steel called skeletal steel are placed at the middle of the specimen. The proposed empirical solutions are derived as in [Ref no. 7] was compared with experimentally obtained data [Ref no. 8 & 9] and the best fit equation s are proposed for evaluating the different characteristics strength. These equations can be used for design purpose.

The following table-1 shows the best fit equations proposed for shear force at cracking and failure and ratio of the experimental and empirical solution. The above empirical solution has been proposed after the experimental results being compared with the procedure followed to calculate the shear strength by ACI:318[10] and BS:8110[11].Where 'd' has been taken as overall depth of ferrocement element instead of effective depth.

Table-1

Sl No.	Reinforcement	No. of Test data	Best fit Equation	Ratio of Calculated-experimental shear force
				Mean & CV(%)
1	Distributed meshes and lumped meshes	41 & 17	$Vcf = 0.214\frac{bd\sqrt{fcu}}{a/d}(0.712 + 64.64Pm)$	1.01 & 17.8
2	Bars and meshes at centre	35	$Vcf = 0.173\frac{bd\sqrt{fcu}}{a/d}\left(0.712 + 64.64(Pm + Pbt)\right)$	1.10 & 40.13
3	Distributed meshes and lumped meshes	4 & 1	$Vuf = 0.158\frac{bd\sqrt{fcu}}{a/d}(0.712 + 173.36Pm)$	0.95 & 22.7
4	Distributed and lumped meshes	39 & 13	$Vcw = 1.08\frac{bd\sqrt{fcu}}{\sqrt{(a/d)^2 + 1}}(0.234 + 40.11Pm\sin\theta)$	1.04 & 23.13
5	Bars and meshes at centre	31	$Vcw = 1.28\frac{bd\sqrt{fcu}}{\sqrt{(a/d)^2 + 1}}(0.234 + 40.11(Pm + \mathrm{Pbt})\sin\theta)$	1.02 & 29.51
6	Distributed and lumped meshes	7 & 1	$Vuw = 1.257\frac{bd\sqrt{fcu}}{((a/d)^2 + 1)} \times \left((0.249\sqrt{fcu}\right)\sqrt{(a/d)^2 + 1} + Pm \times fy)$	1.03 & 15.6

5. CONCLUSION

The conclusions that can be drawn from the above investigations are as follows :-

1. After experimental as well as empirical solution the shear strength of ferrocement depends upon the volumatric fraction ow wire mesh and the shear span to depth ratio.
2. The ductility and load carrying capacity of ferrocement element can be improved by applying different layer of wire mesh.
3. The number of mesh increases the shear load carrying capacity of the ferrocement element.
4. Shear behaviour of ferrocement element is equal to that of reinforced concrete element.
5. The equation used for calculating the shear strength of reinforced concrete thus can be implimented for the case of ferrocement member.
6. Based on the simple mechanism of R.C.C the proposed equation can be used to predict the shear force at cracking and failurefor different cases of ferrocement reinforcement.
7. The critical shear force is normally found to be governed by flexure-shear.
8. The given expression [10 & 11] can be used for calculating the shear strength of ferrocement element .
9. The partial safety factor can probably used for designing the ferrocement element against shear.

6. NOTATIONS USED

a = shear span
b= width of the section
d=overall depth of the section
P=Load applied
Vf= volumatric fraction of wire mesh
ϑcr=cracking shear strength
Vu=ultimate shear load
F_{cu}=compressive strength of mortar
Fy=yield strength of wire mesh
Vuf=Shear force at flexure-shear failure
Vcf=Shear force at flexure-shear crack
Vuw=Shear force at web-shear failure
Vcw=Shear force at web-shear crack
Pm=Volume fraction of wire mesh used in longitudinal direction
Pbt=Volume fraction of skeletal steel bars in longitudinal direction
Θ=Inclination of the crack with the longitudinal axis of the specimen,tan^-1(d/a)

7. References

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