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FLEXURAL BEHAVIOUR OF POZZOLANIC (PEA NUT SHELL ASH) FIBRE REINFORCED FERROCEMENT

*Dr.K. Lakshmi Pathi, **Dr. V. Bhaskar Desai

** Head of the Department in Civil Engineering, GMR, Polytechnic, Srisailam, A.P. Cell: 094404 88894,*
*** Professor, Dept. of Civil Engineering, J.N.T.U.A. College of Engineering, Anantapur, A.P.*

Abstract: Now a days due to increase of population more infrastructure has to provide to meet the needs of the public. For this many civil engineering constructions throughout the globe is occur and the usage of OPC is very large and so the raw material for OPC becoming scarce. Because of this reason in the present days the usage of Pozzollanic cement has gained momentum. This paper presents a brief study on the flexural behaviour of fibre reinforced ferrocement elements with partial replacement of cement by pozzollanic material like pea nut shell ash. Nearly 360 specimens were cast and tested with the variables such as different percentages of replacement of cement by pozzolanic material addition such as pea nut shell ash addition, different percentages of steel fibre, number of wire mesh layers and different span to depth ratios (a/d) etc,. From the results it is observed that with the increase in percentage of fibres and PNSA the compressive strength of mortar, first crack load, ultimate load in flexure, flexural stress at first crack load, flexural stress at ultimate load and energy absorption increase up to certain extent and afterwards get decreased. Also the above strength parameters are found to increase with number of wire mesh layers. More so the above strengths are found to decrease with the increase in a/d ratio except the flexural stresses at first crack load and ultimate load. Besides the paper presents the behaviour of load – deflection variation and crack pattern for number of variables studied. Finally an analytical model has been proposed for Mcr and Mu with the inclusion of the most of the variables used in the present investigation.

Key words: PNSA, Span to Depth Ratio (a/d), Number of Mesh Layers (N), Volume Percentage of Fibres (Vf).

1. Introduction

Although few researchers have studied the behaviour of fiber reinforced ferrocement in flexure, much concentration has not been paid on the flexural study of fiber reinforced ferrocement with replacing cement by natural pozzolanic material like pea nut shell ash. It is new invention to introduce the Pea nut shell ash in ferrocement. In the light of the above in the present investigation an attempt has been made to study the flexural behaviour of pozzolanic (peanut shell ash) fiber reinforced ferrocement elements with the addition of natural agricultural waste such as pea nut shell ash which is otherwise posing serious disposal problem. Ferro cement is not a special type of cement, it is a composite material made up of cement mortar, wire mesh and/or skeletal steel reinforcement. When fibres with some aspect ratio are added to this Ferro cement, fibre-reinforced Ferro cement is obtained. When pozzolanic material like pea nut shell ash is added to this, pozzolanic fibre reinforced ferrocement is obtained. Ferrocement constructions in building industry began almost 60 years back. In late nineties, Chien Hung Lin & Shyh ming Perng[1] studied the flexural behaviour of concrete beams with welded wire fabric as shear reinforcement. Also in late nineties, Behaviour of Ferro cement beams under shear was studied by M.A.Al-Kubaisy and P.T. Nedwell[2]. S.K.Kaushik[3] et.al (+) conducted experimental investigations on Ferro cement plates using super plasticized fly ash mortar. M.Mazloom, A.A.Ramezanianpour and J.J.Brooks[4] studied the effect of silicafume on mechanical properties of high strength concrete. Sheela.S and Ganesan.N[5], studied on the Flexural Behaviour of Polymer Modified Ferrocement Structural Elements. Sheela.S and Ganesan.N[6], conducted study on the behaviour of Polymer Modified Channel Shaped Ferrocement Elements

2 . MATERIALS & EXPERIMENTAL PROGRAMME

2.1 . Materials

In this investigation ordinary Portland of 43 Grade cement, Pea nut shell ash, Crimpled Steel Fibres and Natural River Sand were used.

2.2 Experimental Programme

In this investigation 360 specimens of size 860x200x30mm were cast with varying volume percentages of crimpled steel fibres (flat 30mm length) .i.e. 0, 0.5, 1.0,1.5 and 2.0 ,with increasing number of chicken mesh layers 1,3 and 5,and with varying percentages of replacement of cement by pozollanic material (pea nut shell ash) .i.e.0,5,10,15 and 20. Constant water cement ratio of 0.5 was adopted. A constant vibration of 10 seconds was applied for all castings.

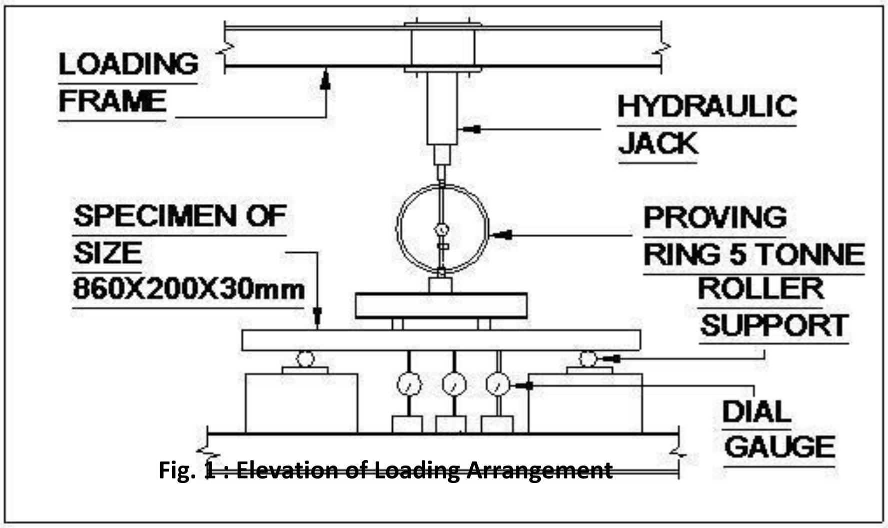

Fig. 1 : Elevation of Loading Arrangement

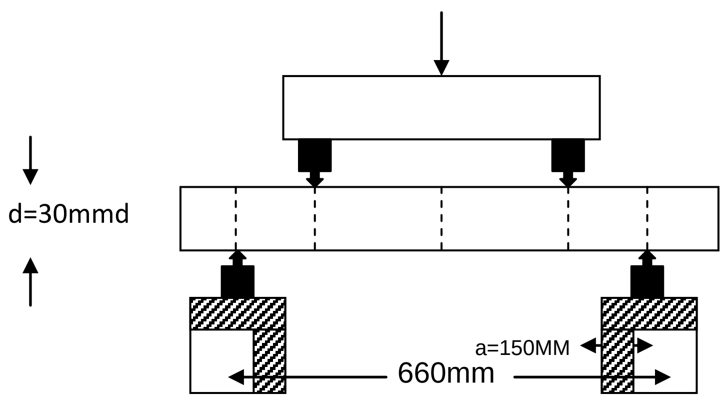

Fig. 2 : Loading Pattern for a/d=5

3 . TESTING

The specimens were tested under two point loading as shown in fig.1 through a pre calibrated 5 tonnes proving ring .Three dial gauges were used as shown in fig.1 to measure deflections. During testing all specimens were tested with three span to depth ratios 5, 8 and11. A span to depth ratio (a/d) is defined as the ratio of distance between the loading point and support point of the specimen to the depth of the specimen. More details of a sample loading are shown in fig 2. The specimens were tested up to failure.

4 . DISCUSSION OF CRACK PATTERN

For almost all the specimens it was commonly observed that the crack initiation was mostly at the bottom. As the load was increased further already formed cracks got widened and progressed towards the top edge of the specimen.

Also immaterial of a/d ratio, all most all the specimens with one layer of wire mesh and with 0% of fibres failed suddenly due to poor ductility without any clear warning. As the number of wire mesh layers was increased the ductility got increased and specimens failed by showing sufficient warning. However with the addition of fibres the ductility was additionally increased and the decrease in the crack width was noticed.

Regarding the failure of specimens for lower a/d ratios, the cracks were found to form in the zone between the load point and mid point of the specimen .For higher values of a/d ratios the cracks were formed with in the vicinity of midpoint.

Regarding the effect of Pozzolanic material content, it was observed with naked eye that for higher percentage of pozzolonic addition, cracks were found to be widened when compared with those specimens with lower percentage of pozzolonic material addition.

5. DISCUSSION OF TEST RESULTS

Here the experimental results were analyzed and discussed. The variation of ultimate load in flexure of ferrocement specimens with the partial replacement of cement by pea nut shell ash for constant percentage of fibres, constant number of mesh layers and for different a/d ratios is presented in fig-3. From this it may be observed that, with the increase in pea nut shell ash content the ultimate load in flexure increases slowly and marginally up to an optimum content (around 5%) and afterwards decreases. Similar behaviour was also observed with respect to first crack load .

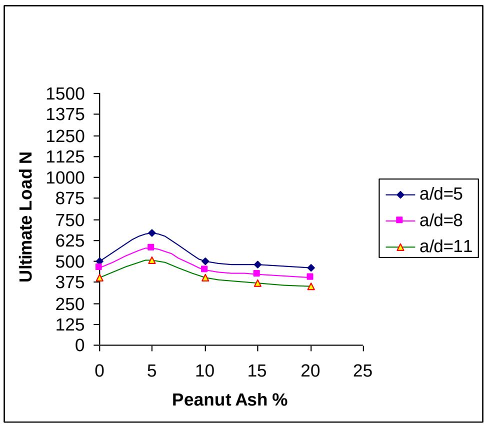

Fig-3 : Variation Of Ultimate load Vs Peanut Shell Ash % for N=3,Vf=0.5

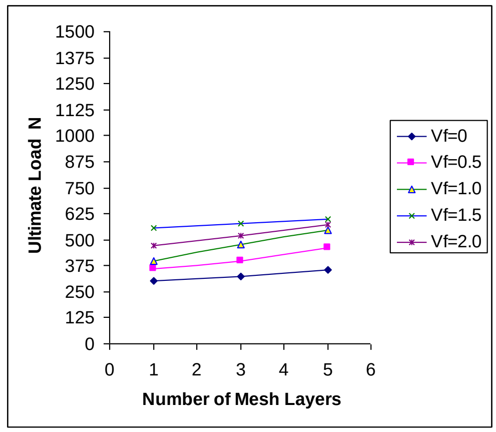

Fig 4: Variation of Ultimate load Vs Number Of Mesh Layers for a/d=8, PNSA=20%

Secondly the variation of ultimate load in flexure with number of wire mesh layers for a given percentage of fibre content for constant % of pea nut shell ash and constant a/d ratios are shown in figs-4. From these figures it is seen that with the increase in number of wire mesh layers and fibre content the ultimate load in flexure is found to increase.

Thirdly the variation of ultimate load in flexure with the percentage of fibres for constant number of mesh layers constant % of pea nut shell and constant a/d ratio is presented in fig-5. From this figure it may be observed that as the percentage of fibres is increased the ultimate load in flexure is increased up to optimum content and there after it gets decreased.

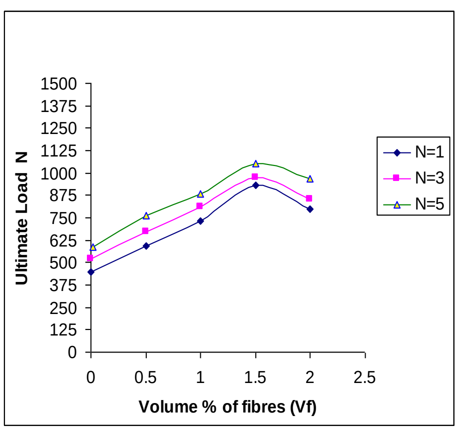

Fig 5: Variation of Ultimate load Vs Volume % of fibres (Vf) for a/d=5,PNA=5%

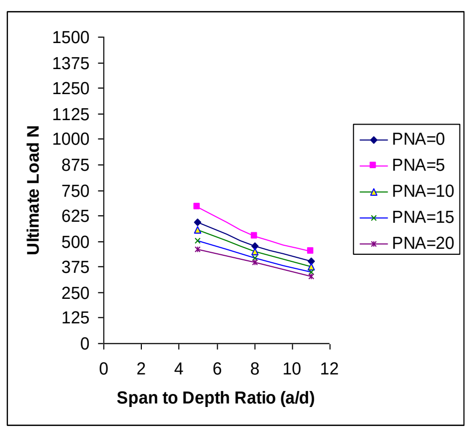

Fig 6 : Variation of Ultimate load Vs Span to Depth Ratio (a/d) for Vf=1.0,N=5

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Fourthly the variation of ultimate load in flexure with the a/d ratios for constant number of wire mesh layers for a given percentage of fibre content for constant % of pea nut shell ash are shown in figs-6. From these figures it is seen that with the increase a/d ratio the ultimate load in flexure is found to decrease.

The variation of flexural stresses with the number of variables is observed to be more or less same as that with the first crack and ultimate loads. However their variation gets increased with the increase in a/d ratio.

In this investigation load deflection variations (P. δ diagrams) for number of variables were also studied. The sample load deflection variations are presented in figs 7 and 8. From the load-deflection variations studied in this investigation it is seen that with the increase in pea nut shell ash content up to more or less optimum content, the curves were observed to become steeper and steeper and afterwards the curves were showing reverse trend.

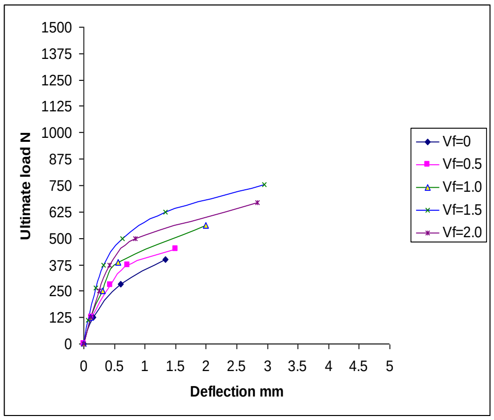

Fig 7.variation of ultimate load Vs deflection for N=1,a/d=8andPNA=5

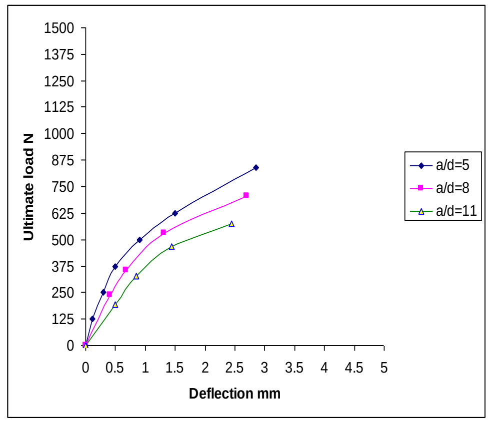

Fig 8.variation of ultimate load Vs deflection for N=5,PNA=5andVf=1.0

From the Fig.7, it is seen that with the increasing volume percentage of fibres the P- δ variation is increasing up to optimum content and there after the variation gets decreased. Besides from Fig.8 with the increase in a/d ratio, the curves are found to become flatter and flatter. From this it is also observed that with the increase in number of wire mesh layers, the P- δ variation also gets increased.

Finally energy absorpted by the ferro cement specimens have been calculated as the area under P- δ diagrams. Sample diagram is presented in Fig:9.

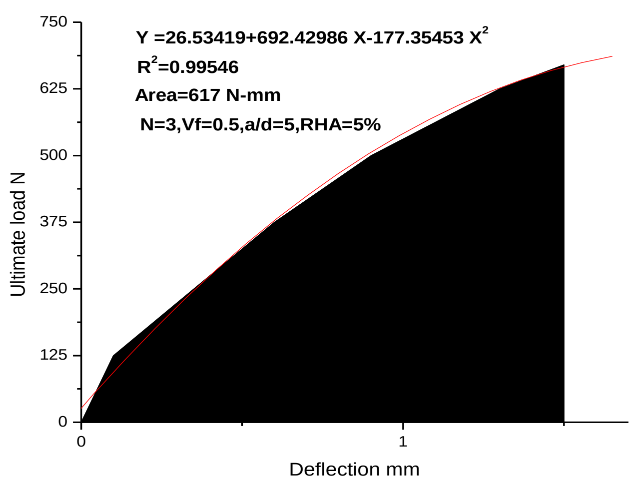

Fig 9: Area under the Ultimate Load Vs Deflection for N=3,V_f=0.5,a/d=5,PNA=5%
(Energy absorbed by the specimen)

Its behaviour and variation are observed to be same as the P- δ variation as discussed above. From the study it is also noticed that more number of wire mesh layers and fiber addition up to certain extent increase the ductility, load carrying capacity etc.

6. PROPOSED REGRESSION MODEL

Here an attempt has been made to formulate a regression model incorporating most of the variables studied in this experimental study.

In the present investigation the assumed dependent variables are $M_u/f_{cu}^{-}bd^2$ and $M_{cr}/f_{cu}^{-}bd^2$. Independent variables are 1) Ratio of area of contact of hexagonal chicken mesh wire layer to the unit plan area of wire mesh layer (a_r) 2) Volume percentage of fibres (V_f) and 3) Span to depth ratio (a/d).

Applying multiple regression model analysis taking all the experimental values studied in this chapter into account, following regression equations are proposed for cracking moment (M_{cr}) and ultimate moment (M_u).

$$M_{cr}/f_{cu}^{-}bd^2 = -0.00011 + 0.000275\, a_r + 0.000358\, V_f + 0.000349\, a/d - 9.8\text{X}10^{-6}\, P_z$$

Regression coefficient:0.901, S.D=0.000447

$$M_u/f_{cu}^{-}bd^2 = 0.00025 + 0.000656\, a_r + 0.001169\, V_f + 0.000532\, a/d - 2.1\text{X}10^{-5}\, P_z$$

Regression coefficient:0.928, S.D=0.000664

Where

M_{cr} = Cracking moment or First crack moment,

M_u = Ultimate moment,

f_{cu}^{-} = Compressive strength of cement mortar cube for 28 days curing,

b = Breadth of the specimen,

d = Depth of the specimen,

a_r = Ratio of area of contact of hexagonal chicken mesh wire layer to the unit plan area of wire mesh layer,

V_f = Volume percentage of fibres,

a/d = Span to depth ratio,

S.D = Standard deviation.

From these equations generally it is possible to calculate M_{cr} and M_u values for known values of a_r, V_f and a/d and for the type of chicken mesh adopted in this investigation and for the type of crimpled steel fibres used in this investigation,

CONCLUSIONS

On the basis of limited experiments conducted in this investigation the following tentative conclusions seem to be valid.

1. The compressive strengths of mortar specimens increase with the addition of fibres up to some extent called optimum content (1.5%) and there after decrease.
2. Both the first crack and ultimate loads increase with the partial pozollanic material addition up to some extent called optimum content and after wards decrease. They increase with the increase in volume percentage of fibres, number of wire mesh layers and decrease with increasing a/d ratio
3. Both the first crack and ultimate loads in flexure increase with the addition of fibres up to some extent called optimum content (1.5%) and after wards decrease for a given number of mesh layers and for a given a/d ratio.

4. Both the first crack and ultimate loads in flexure increase with the increase in number of mesh layers, for a given a/d ratio and for a given volume percentage of fibres.
5. The first crack load and ultimate loads in flexure are found to increase with the decrease in a/d ratio for a given volume percentage of fibres and for a given number of wire mesh layers.
6. The flexural stress values at first crack load and ultimate load are found to increase with the addition of fiber up to some extent called optimum content (1.5%) and after wards decrease.
7. The flexural stress values at first crack load and ultimate load are found to increase with the increase of number of mesh layers and a/d ratio.
8. With the increasing volume percentage of fibres up to optimum content (1.5%) the energy absorption of specimen increases and there after gets decreased.
9. It may be observed that with the increasing number wire mesh layers the energy absorption of specimen gets increased.
10. It may be observed that with the increasing a/d ratio the energy absorption of specimen gets decreased..
11. From the P-δ diagrams it may be observed that with the increase in pea nut shell ash content up to more or less optimum content, the curves were observed to become steeper and steeper and afterwards the curves were showing reverse trend. It is also observed that with the increasing volume percentage of fibres and number of mesh layers the curves are found to become steeper and steeper. Also with the increase of a/d ratio the variation is found to become flatter and flatter.
12. Thus from the present investigation it has been observed that certain natural agricultural wastes which is posing serious disposal problem can be effectively used as pozzolanic material in ferrocement industry there by decreasing the content of costly binding material cement.
13. From load-deflection (P-δ) diagrams, in general it is observed that as the load increases deflection also increases. Up to first crack the P-δ diagrams are more or less straight and after wards the curvature gets changed. Beyond the first crack, the rate of increase of deflection is more compared to the un cracked range.
14. From the P-δ diagrams it may be observed that with the increasing volume percentage of fibres up to optimum content (1.5%) the P- δ variation is increasing and afterwards the variation gets declined for higher volume %ge of fibres beyond the above optimum content.
15. Besides from the P-δ diagrams it may be observed that with the increase in a/d ratio, the P- δ variation gets decreased.
16. More so from the P-δ diagrams it may be observed that with the increase in number of wire mesh layers the variation is maximum for the specimens with maximum number of wire mesh layers.
17. Finally analytical models have been proposed for M_{cr} and M_u incorporating most of the variables used in the present investigation .The regression coefficient for the analytical models is almost unity. Hence these models are supposed to predict the M_{cr} & M_u values for any given set of variables with in the frame work of present investigation with satisfactory accuracy.
18. Higher volume fraction of reinforcement in the form of chicken mesh provides more effective control of cracking and also improves the strength properties of the specimens.
19. Also introduction of fibers increases ductility, crack control and load carry capacity of the member of the ferrocement.
20. Thus the combination of chicken mesh and fibers improves load carrying capacity of the specimen in flexure and in addition improves the crack arresting mechanism

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