Properties of partially replaced cement by RHA in bamboo reinforced concrete beams

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Abstract

In order to have some productive possibility of using bamboo as a reinforcement in beams, various specimen of bamboo was subjected to series of tensile testing to predict their material property.

Bamboo sticks of length 500 mm were cut into half with cutter and were wrapped with G.I wire in order to prevent their crushing in UTM. During tensile testing, it was found that one or more of the following were modes of failure:

1. Grip failure 2. Failure at node 3. Failure due to splitting

Concrete beams each of size 100mm x 100mm x 500mm were subjected to third point bending tests. Various percentages of bamboo reinforcement were 0%, 2.4%, 3.2% and 4.5% whereas RHA content being 0%, 10%, 15% and 20%. Loads and their respective deflections for various combinations of bamboo reinforcement and RHA (Rice Husk Ash) content were recorded after placing test beams under testing machine. It was indicated by test results that having balanced reinforcement, OPC-RHA (85%-15%) showed the maximum load carrying capacity and bamboo reinforcement improved the load carrying capacity as compared under reinforced and over reinforced concrete beams.

Keywords: - RHA (Rice Husk Ash), Bamboo, GI (Galvanised Iron) wire

Methodology: -

The experimental program of this research is designed for two kinds of tests:

- Tensile testing of locally available bamboo specimen.
- Flexure tests of beams.

1. Obtaining the design mix for concrete and bamboo. Later, replacing the OPC with RHA at 10%, 15% and 20%.
2. Bamboo specimens were made water proof by coating two layers of polyurethane.
3. Determine ultimate tensile strength of bamboo specimens and obtain stress-strain curves.
4. Casting and curing were carried out in temperature-controlled curing tanks (Temperature maintained at 29℃)
5. Analyse the load deflection curves of beams having different percentages of bamboo reinforcement at 28, 56 and 90 days curing.

Materials

. All the tests were carried out in the laboratory according to the relevant codes of practice. The materials used were having the following characteristics:

Cement

Table-1: Physical Properties of Cement

Characteristic Properties	Observed Value	Codal Provisions
Fineness (%)	2	10% (Maximum)
Standard consistency (%)	34	……
IST (minutes)	65	>30
FST (minutes)	370	<600
Sp.Gr.	3.15	……
Soundness (mm)	2	<10.0
Comp.strength (MPa)		
3-days	18.42	23 (Minimum)
7-days	25.60	33 (Minimum)
28-days	44.65	43 (Minimum)

Fine Aggregate

River sand has been used. The sieve test result is shown in Table-1.2. The Specific gravity of fine aggregates came out to be 2.65 and with a fineness modulus of 2.75.

Table-2: Sieve Analysis of Fine Aggregates (1000 gm Sample)

Size of Sieve	Retained Mass (kg)	Retained %	% Passing	Retained (Cumulative)
4.75	0.012	1.3	98.8	1.3
2.36	0.105	10.5	88.3	11.7
1.18	0.221	22.1	66.2	33.8
600	0.183	18.3	47.9	52.1
300	0.273	27.3	20.6	79.4
180	0.180	18	2.6	97.4

Pan	0.020	2.6	-	275.6

Fineness modulus = ∑C/100 = 275.6/100 = 2.75 (Zone II)

Specific gravity of sand = 2.65

Coarse Aggregate

Two different types of aggregates were used one with maximum size of aggregates as 20 mm and other with 12.5 mm in the ratio of 50:50. The sieve analysis result is given in Table-3.3.

Table-3: Sieve Analysis of Coarse Aggregates (20 mm and 12.5 mm)

Sieve Size	Mass Retained (kg)	% Retained	Cumulative Retained (%)
80			
40			
20	.344	3.44	3.44
10	9.360	93.6	97.04
4.75	.136	1.36	98.4
Pan	.160	1.6	198.88

F.M = (∑C+500)/ 100 = 6.99

Specific gravity of C.A. = 2.69

Water Absorption = 21g

Rice Husk Ash

The specific gravity of RHA was found to be 1.96.

Bamboo Specimen

Bamboo specimens obtained are of three different conditions:

Table-4: Size of bamboo specimen used in beams

Specimens	Size	Condition
Specimen 1	12×10mm	Under Reinforced Section
Specimen 2	13×12mm	Balanced Section
Specimen 3	15×15mm	Over Reinforced Section

RESULTS AND THEIR DISCUSSION

The results of the investigation have been reported and discussed into following parts:

- Comparing Ultimate tensile strength of bamboo specimens with or without G.I. wire at Grip Area.
- Obtaining Stress-Strain relationships of different bamboo specimens.
- Workability of concrete mixes.
- Determining the Flexural Strength at first crack load and peak load of different Bamboo Reinforced concrete beams.

Tensile Test

The first set of tensile tests was conducted on bamboo specimens The tensile strength values of different bamboo specimens and their failure pattern are tabulated in Table- 4.1 and 4.2.Stress-Strain curves developed for different bamboo specimens is shown in Fig. 4.1

Table-5: Results of tension test for bamboo specimens having normal surface at Grip Area

Specimen No.	Average Area (mm^2)	Load at Failure(KN)	Failure Stress (MPa)	Type of Failure	Condition
1	114	22.4	196.49	Splitting	Without node
2	100	22.62	226.2	Splitting	Without node
3	114	15.84	138.95	Splitting	Without node

4	180	26.94	149.67	Splitting and failure at node	With node at centre
5	200	31.98	159.9	Splitting and failure at node	With node at centre
6	176	27.62	156.93	Splitting and failure at node	With node at centre
7	176	16.8	95.45	Failure at node	With node at edge

Table-6: Ultimate Tensile Strength of Bamboo

Sample	Load (KN)	Area (mm^2)	Length (mm)	Deflection (mm)	Stress (N/mm^2)	Strain (mm/mm)
1	31.98	200	310	36.9	159.9	0.119
2	27.62	176	320	35.2	156.93	0.11
3	27.72	210	315	38	132	0.12
4	16.8	176	190	47	95.45	0.247
5	27.20	194	300	34	140.20	0.113

Average tensile stress is taken as 136.896MPa.

The failure of bamboo specimens was observed mainly at nodes because of widely spacing of fibers at the node points. The G.I. wire wrapped at the ends resulted in failure of the samples due to piercing of the bamboo when lateral load was applied during the gripping. From the data shown in Table-4.1 and 4.2, it can be observed that the pattern of failure in most cases is splitting type failure: it may be splitting and failure at node or splitting and failure at grip.

Workability

W/B ratio of 0.38 was kept throughout. Super plasticizer Glenium SKY 777 was used to maintain the required slump. Dosage of super plasticizer was varied from 0.3% to 0.6% by weight of binder depending up on the type of mix.

Table-7: Workability of concrete mixes

Mix no.	Description	Super plasticizer (%) by weight of binder	Slump (mm)
1	100%OPC	0.30	120
2	90%OPC+10%RHA	0.40	118
3	85%OPC+ 15%RHA	0.50	117
4	80%OPC+20%RHA	0.60	115

Flexural Test

Flexural Strength results for bamboo reinforced concrete mixes with bamboo reinforcement and Rice Husk Ash (RHA) contents at 28 days curing period are shown in Table-4.5 and Fig. 4.2, 4.3 and 4.4.The maximum increase in flexural strength, taken as the average of the specimens of the particular batch varied from 36% to 184% for 3.2% bamboo reinforcement i.e. balanced reinforced section, 70% to 72% for 2.4% bamboo reinforcement i.e. under reinforced section and 82% to 88% for 4.5% bamboo reinforcement i.e. over reinforced section. But a decrease of 2% to 7% had also been occurred in the flexural strength on an increase of Rice Husk Ash percentage to 20% with 2.4% and 4.5% bamboo reinforcement. The maximum increase of 184% was obtained for balanced reinforced concrete beam.

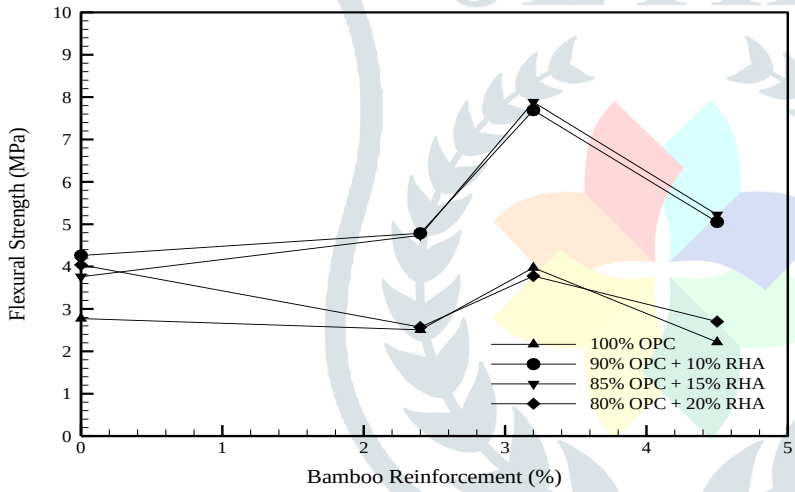
Concrete beams at 28 days curing period with different percentages of bamboo reinforcement and different percentages of Rice Husk ash are listed in Table-4.6. The load at first crack and the centre point deflection at first crack load of the test specimens in the batches with different percentages of RHA and Bamboo Reinforcement at 28 days curing period are listed in Table-4.7. The results show that there is an increase in first crack load, taken as average of all specimens in a particular batch of the order of -31.65% to 56.97%, -2.61% to 112.81% and -4.39% to -32.93% for mixes having 2.4%, 3.2% and 4.5% bamboo reinforcement respectively. The first crack load in flexure of 43.21%, 44.15% and 112.81% with respect to the amount of bamboo reinforcement and RHA content is for the mix having balanced reinforcement. A decrease of first crack load strength also takes place in case of under reinforced beams.

Table-8: Flexural Strength Results at 28 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Flexural Strength (MPa)	Increase/Decrease (%)
V10	0	0	2.774	0.00
V11	0	240	2.533	-8.688
V12	0	320	3.973	43.222
V13	0	450	2.217	-20.079
V20	10	0	4.262	53.641
V21	10	240	4.787	72.567
V22	10	320	7.691	177.25
V23	10	450	5.053	82.156

V30	15	0	3.761	35.580
V31	15	240	4.739	70.836
V32	15	320	7.885	184.246
V33	15	450	5.222	88.248
V40	20	0	4.04	45.638
V41	20	240	2.571	-7.318
V42	20	320	3.777	36.157
V43	20	450	2.702	-2.596

Fig.4.2 and Fig.4.3 shows that as the percentage of reinforcement values are increasing, the flexural strength first increases and then decreases. The flexural Strength is found to be maximum for the mixes having 3.2% bamboo as reinforcement. It is also observed that the maximum value for the flexural strength is found for the mix with 85% OPC+ 15% RHA having 3.2% bamboo reinforcement.



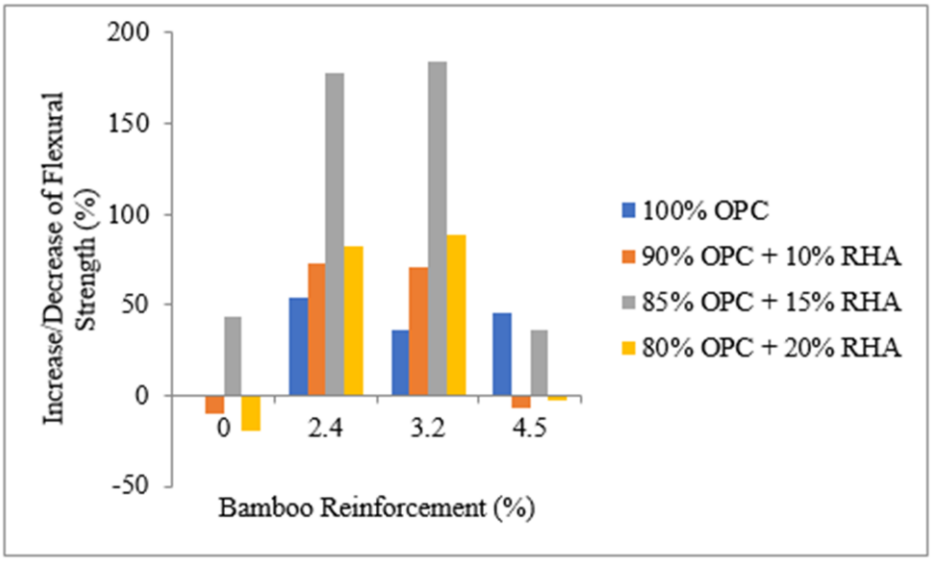


Fig. 1 Flexural Strength of Bamboo Reinforced Concrete vs Volume fraction of bamboo at 28 days curing

Table-9: Maximum Flexural Loads and Corresponding Deflections at 28 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Peak Load (KN)	Deflection (mm)
V10	0	0	6.165	0.201
V11	0	240	5.629	5.406
V12	0	320	8.829	0.300
V13	0	450	4.927	0.705
V20	10	0	9.474	0.300
V21	10	240	10.634	1.100
V22	10	320	17.092	1.301
V23	10	450	11.228	1.302
V30	15	0	8.357	0.301
V31	15	240	10.531	1.602
V32	15	320	17.523	1.602
V33	15	450	11.604	1.401
V40	20	0	8.984	0.300
V41	20	240	5.713	0.700
V42	20	320	8.393	2.707
V43	20	450	6.004	1.005

Table 10. First Crack Flexural Loads and Corresponding Deflections at 28 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Load at first crack (KN)	Deflection (mm)
V10	0	0	6.165	0.201
V11	0	240	4.214	0.298
V12	0	320	8.829	0.300
V13	0	450	4.927	0.705
V20	10	0	9.470	0.300
V21	10	240	9.677	0.500
V22	10	320	8.887	0.300
V23	10	450	5.894	0.400
V30	15	0	8.357	0.300
V31	15	240	8.244	0.700
V32	15	320	13.120	0.900
V33	15	450	4.135	0.200
V40	20	0	8.984	0.300

V41	20	240	4.267	0.200
V42	20	320	6.004	1.005
V43	20	450	5.693	0.601

The L-D curves for bamboo reinforced concrete beams containing 100% OPC in the mix for different percentages of bamboo reinforcement are shown in Figs. 4.5(a) to 4.5(d). The corresponding curves and their comparison for bamboo reinforced concrete beams containing 10% RHA at 28 days curing period are indicated in Figs. 4.6(a) to 4.6(d). Further the load and their comparison for bamboo reinforced concrete beams containing 15% RHA and 20% RHA at 28 days curing period are indicated in Figs. 4.7(a) to 4.7(d) and Figs. 4.8(a) to 4.8(d) respectively. Whereas the Figs. 4.5(e), 4.6(e), 4.7(e) and 4.8(e) present the load-deflection curve for all the bamboo reinforcement percentages i.e. 2.4%, 3.2% and 4.5% tested for each RHA content i.e. 0% RHA, 10% RHA, 15% RHA and 20% RHA respectively. The flexural test results from the present investigation show that the mix having 85% OPC + 15% RHA have greater influence over the peak load and the mix having 80% OPC + 20% RHA have least influence over the peak load. From Figs. 4.5(e) to 4.8(e), it is clear that in all cases immediately after the first crack there is sharp decline in the load carrying capacity and then gradually it becomes nearly constant. Moreover the load carrying capacity is maximum in case of balanced reinforced sections and among all balanced reinforced sections, it is maximum in case of 85% OPC + 15% RHA.

Beams prior to appearance of the first crack exhibited very short range of deflections

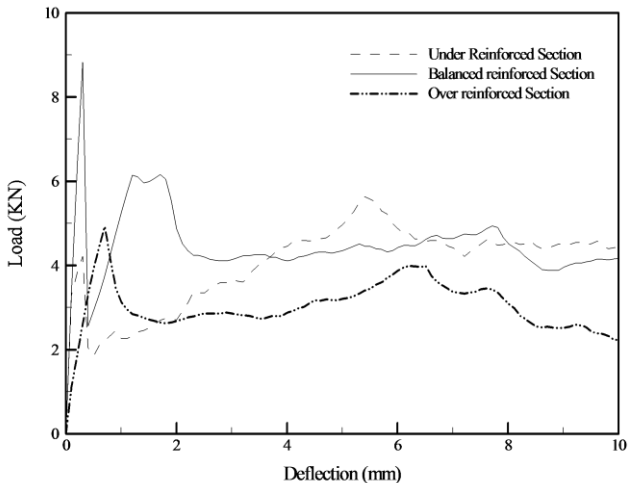


Fig. 2 L-D curve for plain concrete beam having 90% OPC + 10% RHA at 28 days curing period

Fig. 4.5(c) L-D curve for balanced reinforced concrete beam having 100% OPC at 28 days curing period

Fig. 4.5(e) Comparison of Load-Deflection curves for Under Reinforced, Balanced Reinforced and Over Reinforced Beams having

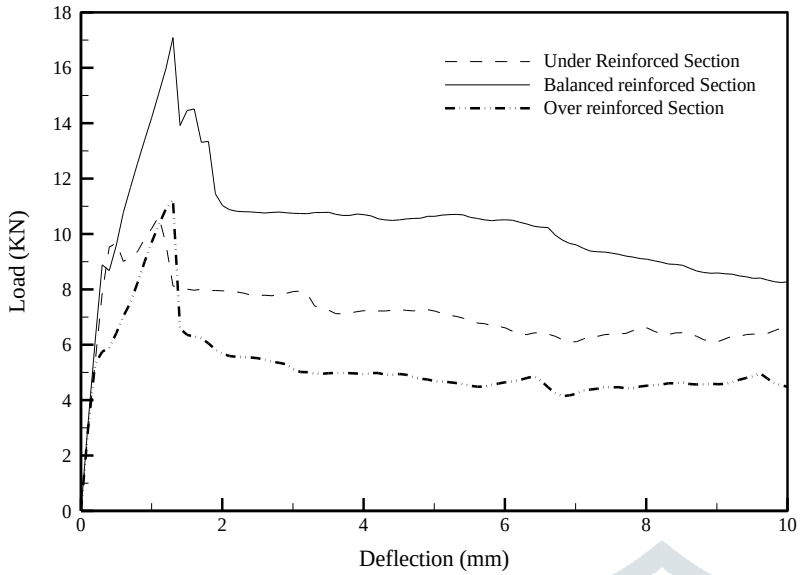


Fig. 3.Comparison of Load-Deflection curves for Under Reinforced, Balanced Reinforced and Over Reinforced Concrete Beams having 90% OPC + 10% RHA at 28 days curing period

Fig. 4.7(a) Load-Deflection curve for plain concrete beam having 85% OPC + 15% RHA at 28 days curing period

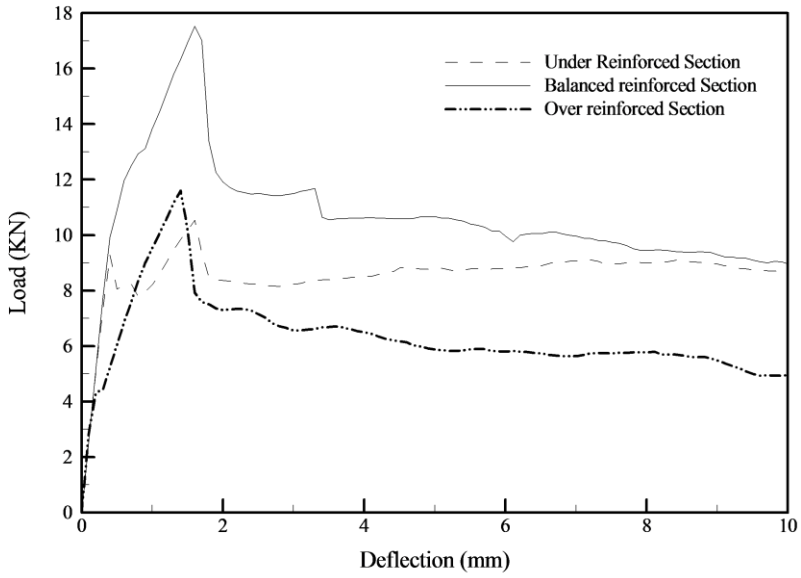


Fig. 4 Comparison of Load-Deflection curves for Under Reinforced, Balanced Reinforced and Over Reinforced Concrete Beams having 85% OPC + 15% RHA at 28 days curing period

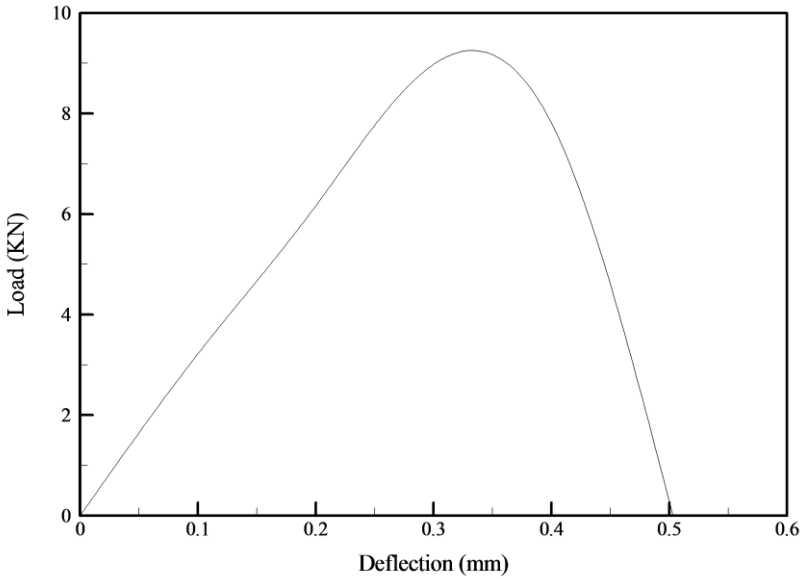


Fig. 5 Load-Deflection curve for plain concrete beam having 80% OPC + 20% RHA at 28 days curing period

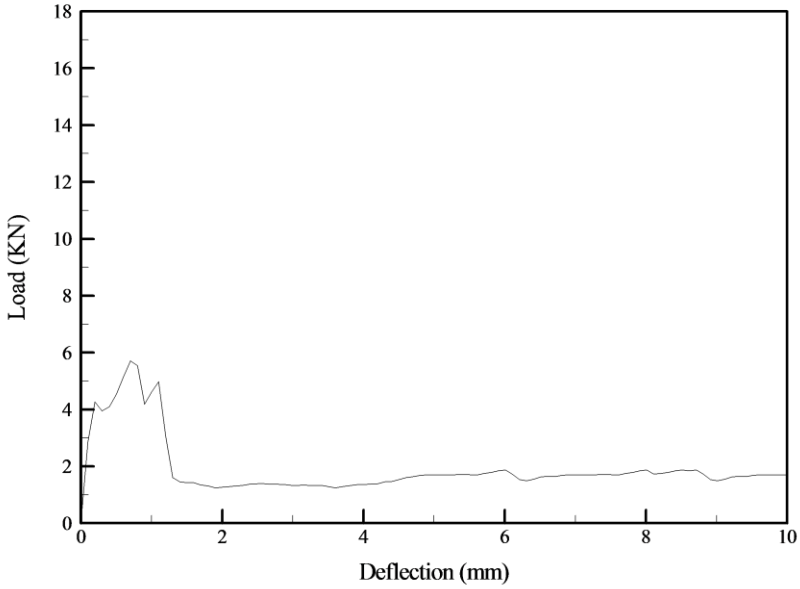


Fig. 6 Load-Deflection curve for under reinforced concrete beam having 80% OPC + 20% RHA at 28 days curing period

Flexural Strength results for bamboo reinforced concrete mixes with of bamboo reinforcement and RHA contents at 56 days curing period are shown in Table-4.8 and Fig. 4.9, 4.10 and 4.11.The average of the specimens of the particular batch varied from 52% to 129% for 3.2% bamboo reinforcement i.e. balanced reinforced section, 53% to 101% for 2.4% bamboo reinforcement i.e. under reinforced section and 51% to 109% for 4.5% bamboo reinforcement i.e. over reinforced section. But a decrease of 13% had also been occurred in the flexural strength on an increase of Rice Husk Ash percentage to 20% with 2.4% bamboo reinforcement. The maximum increase of 129% was obtained for balanced reinforced concrete beam with 15% of RHA.

The peak loads for concrete beams at 56 days curing period with different percentages of bamboo reinforcement and different percentages of Rice Husk ash are listed in Table-4.9. The load at first crack and the centre point deflection at first crack load of the test specimens in the batches with different percentages of RHA and Bamboo Reinforcement at 56 days curing period are listed in Table-4.10. The results show that there is an increase in first crack load, taken as average of all specimens in a particular batch of the order of -44.31% to 97.35%, 54.73% to 129.44% and -50.38% to 40.71% for mixes having 2.4%, 3.2% and 4.5% bamboo reinforcement respectively. The maximum increase in first crack load in flexure of 66.80%, 80.08%, 129.44% and 54.73% with respect to the amount of bamboo reinforcement and RHA content is for the mix having balanced reinforcement. A decrease of first crack load strength also takes place in case of under reinforced beams.

Table-11. Flexural Strength Results at 56 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Flexural Strength (MPa)	Increase/Decrease (%)
V1	0	0	3.967	0.00
V11	0	240	6.084	53.36

V12	0	320	6.617	66.80
V13	0	450	6.287	58.48
V2	10	0	6.489	63.57
V21	10	240	8.001	101.69
V22	10	320	8.444	112.85
V23	10	450	6.959	75.42
V3	15	0	5.081	28.08
V31	15	240	6.748	70.10
V32	15	320	9.102	129.44
V33	15	450	8.301	109.25
V4	20	0	5.462	37.68
V41	20	240	3.436	-13.39
V42	20	320	6.138	54.72
V43	20	450	5.996	51.15

Fig.4.2 and Fig.4.3 shows that as the percentage of reinforcement values are increasing, the flexural strength first increases and then decreases. The flexural Strength is found to be maximum for the mixes having 3.2% bamboo as reinforcement iIt is also observed that the maximum value for the flexural strength is found for the mix with 85% OPC+ 15% RHA having 3.2% bamboo reinforcement.

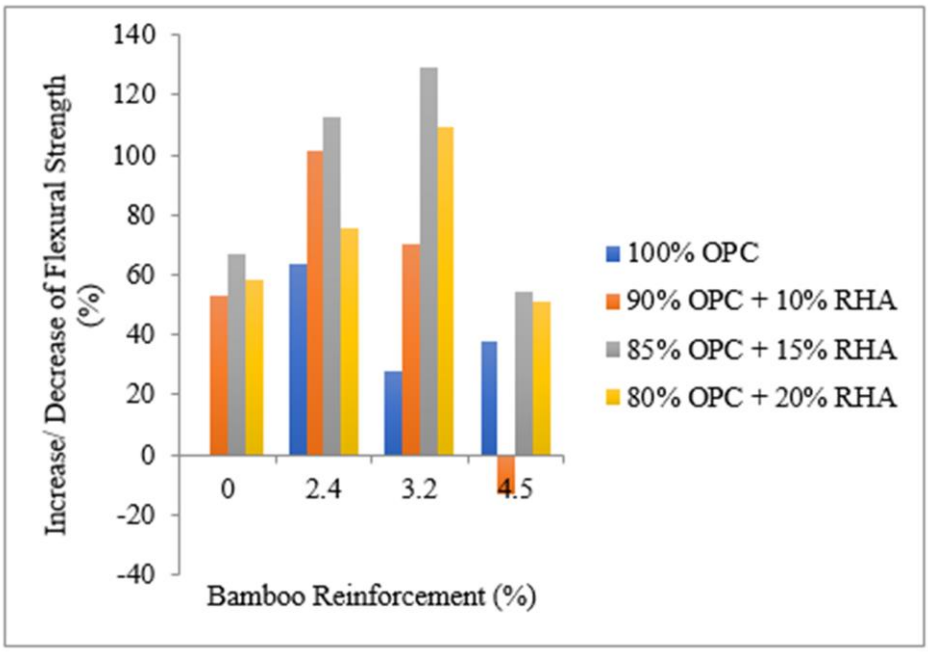


Fig. 7 Trends in flexural Strength of Bamboo Reinforced Concrete having different percentages of RHA with different Volume fraction of bamboo at 56 days curing

Table-12. Maximum Flexural Loads and Corresponding Deflections at 56 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Peak Load (KN)	Deflection (mm)
V10	0	0	8.8165	0.300
V11	0	240	13.520	0.603
V12	0	320	14.705	0.501
V13	0	450	13.971	8.612
V20	10	0	14.420	0.500
V21	10	240	17.778	2.404
V22	10	320	18.764	1.803
V23	10	450	15.465	1.703
V30	15	0	11.291	0.402
V31	15	240	14.997	1.401
V32	15	320	20.227	1.902
V33	15	450	18.446	1.902
V40	20	0	12.139	0.401
V41	20	240	7.635	0.901
V42	20	320	13.641	1.504
V43	20	450	13.324	1.703

Table-13. First Crack Flexural Loads and Corresponding Deflections at 56 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Load at first crack (KN)	Deflection (mm)
V10	0	0	8.816	0.300
V11	0	240	13.520	0.603
V12	0	320	14.705	0.501
V13	0	450	12.405	0.600
V20	10	0	14.420	0.500
V21	10	240	17.398	1.804
V22	10	320	15.876	1.001
V23	10	450	7.622	0.401
V30	15	0	11.291	0.402
V31	15	240	9.423	0.399
V32	15	320	20.227	1.902
V33	15	450	8.224	0.400
V40	20	0	12.139	0.401
V41	20	240	4.910	0.300
V42	20	320	13.641	1.504

V43	20	450	4.374	0.200

The curves for bamboo reinforced concrete beams containing 100% OPC in the mix for different percentages of bamboo reinforcement at 56 days curing period are shown in Figs. 4.12(a) to 4.12(d). The corresponding curves and their comparison for bamboo reinforced concrete beams containing 10% RHA at 56 days curing period are indicated in Figs. 4.13(a) to 4.13(d). Further the load deflection curves and their comparison for bamboo reinforced concrete beams containing 15% RHA and 20% RHA at 56 days curing period are indicated in Figs. 4.14(a) to 4.14(d) and Figs. 4.15(a) to 4.15(d) respectively. Whereas the Figs. 4.12(e), 4.13(e), 4.14(e) and 4.15(e) present the load-deflection curve for all the bamboo reinforcement percentages i.e. 2.4%, 3.2% and 4.5% tested for each RHA content i.e. 0% RHA, 10% RHA, 15% RHA and 20% RHA respectively. The flexural test results from the present investigation show that the mix having 85% OPC + 15% RHA have greater influence over the peak load and the mix having 80% OPC + 20% RHA have least influence over the peak load. From Figs. 4.12(e) to 4.15(e), it is clear that in all cases immediately after the first crack there is sharp decline in the load carrying capacity and then gradually it becomes nearly constant. Moreover the load carrying capacity is maximum in case of balanced reinforced sections and among all balanced reinforced sections, it is maximum in case of 85% OPC + 15% RHA.

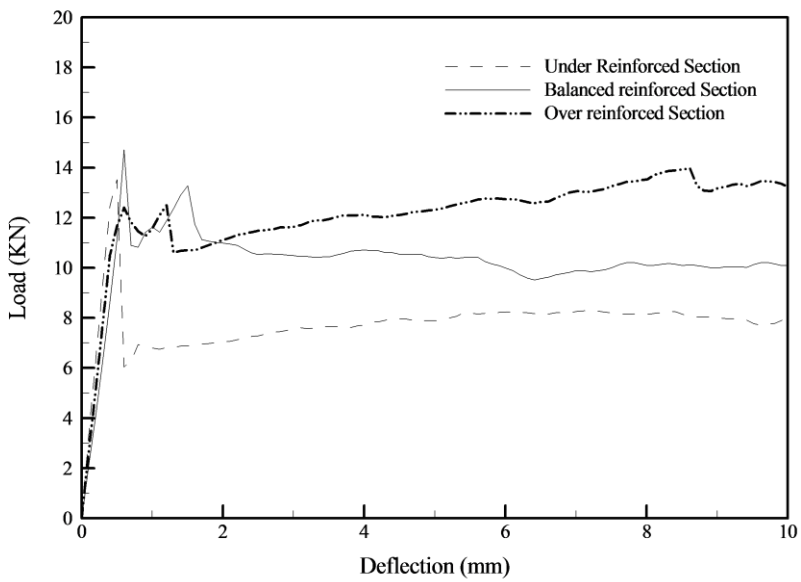


Fig. 8 Comparison of Load-Deflection curves for Under Reinforced, Balanced Reinforced and Over Reinforced Concrete Beams having 100% OPC at 56 days curing

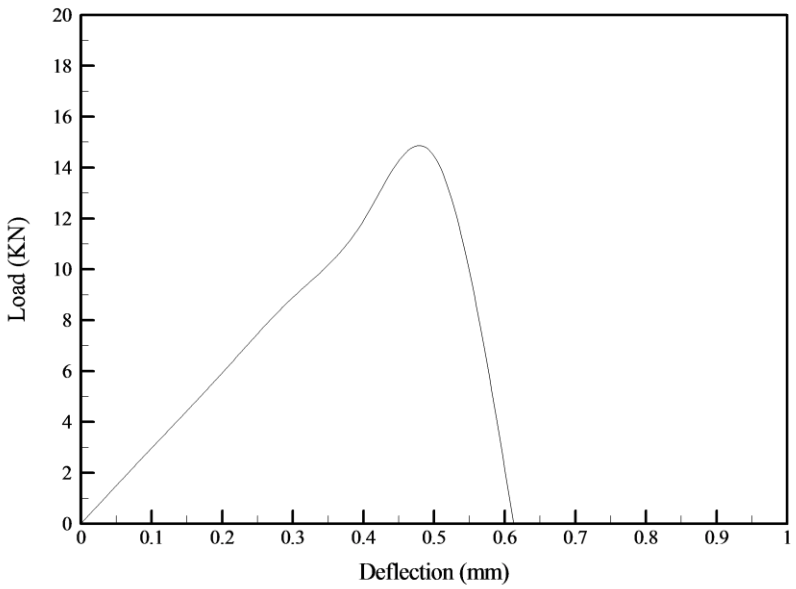


Fig. 9 Load-Deflection curve for plain concrete beam having 90% OPC+10%RHA at 56 days curing period

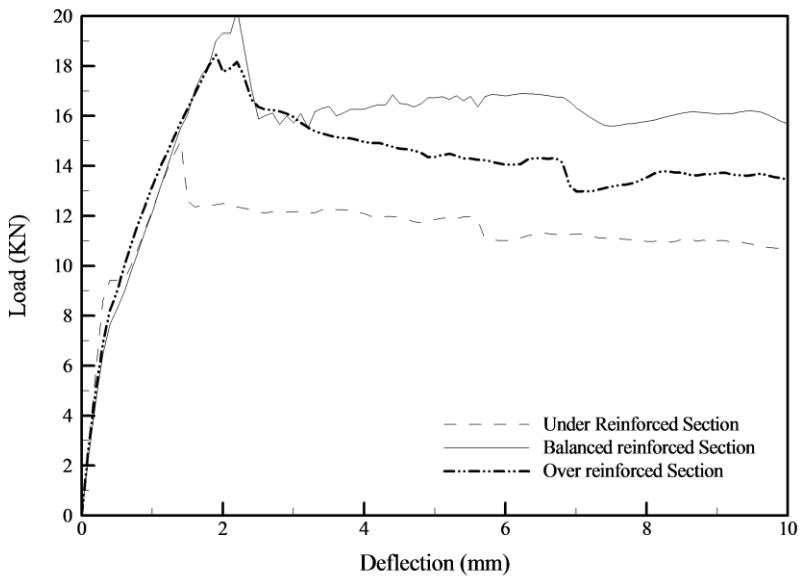


Fig. 10 Comparison of Load-Deflection curves for Under Reinforced, Balanced Reinforced and Over Reinforced Concrete Beams having 85% OPC + 15% RHA at 56 days curing period

Flexural Strength results for bamboo reinforced concrete mixes with bamboo reinforcement and Rice Husk Ash (RHA) contents at 90 days curing period are shown in Table-4.11 and Fig. 4.16, 4.17 and 4.18.The maximum increase in flexural strength, taken as the average of the specimens of the particular batch varied from 36.86% to 99.89% for 3.2% bamboo reinforcement i.e. balanced reinforced section, 17.48% to 45.11% for 2.4% bamboo reinforcement i.e. under reinforced section and 14.31% to 59.07% for 4.5% bamboo reinforcement i.e. over reinforced section. But a decrease of 14.90% had also been occurred in the flexural strength on an increase of Rice Husk Ash percentage to 20% with 2.4% bamboo reinforcement. The maximum increase of 99.89% was obtained for balanced reinforced concrete beam with 15% of RHA.

percentages of Rice Husk ash are listed in Table-4.12. The load at first crack and the centre point deflection at first crack load of the test specimens in the batches with different

percentages of RHA and Bamboo Reinforcement at 90 days curing period are listed in Table-4.13. The results show that there is an increase in first crack load, taken as average of all specimens in a particular batch of the order of -14.89% to 17.47%, -32.90% to 6.089% and -10.73% to 17.88% for mixes having 2.4%, 3.2% and 4.5% bamboo reinforcement respectively. A decrease of first crack load strength also takes place in case of under reinforced beams.

Table-14 Flexural Strength Result at 90 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Flexural Strength (MPa)	Increase/Decrease (%)
V10	0	0	5.727	0
V11	0	240	6.728	17.475
V12	0	320	7.838	36.859
V13	0	450	6.751	17.883
V20	10	0	6.946	21.285
V21	10	240	8.311	45.109
V22	10	320	9.389	63.943
V23	10	450	7.003	22.275
V30	15	0	5.608	-2.074
V31	15	240	7.022	22.613
V32	15	320	11.448	99.890
V33	15	450	9.110	59.071
V40	20	0	6.457	12.737
V41	20	240	4.874	-14.898
V42	20	320	8.229	43.687
V43	20	450	6.547	14.308

Fig.4.2 and Fig.4.3 shows that as the percentage of reinforcement values are increasing, the flexural strength first increases and then decreases. The flexural Strength is found to be maximum for the mixes having 3.2% bamboo as reinforcement It is also observed that the maximum value for the flexural strength is found for the mix with 85% OPC+ 15% RHA having 3.2% bamboo reinforcement.

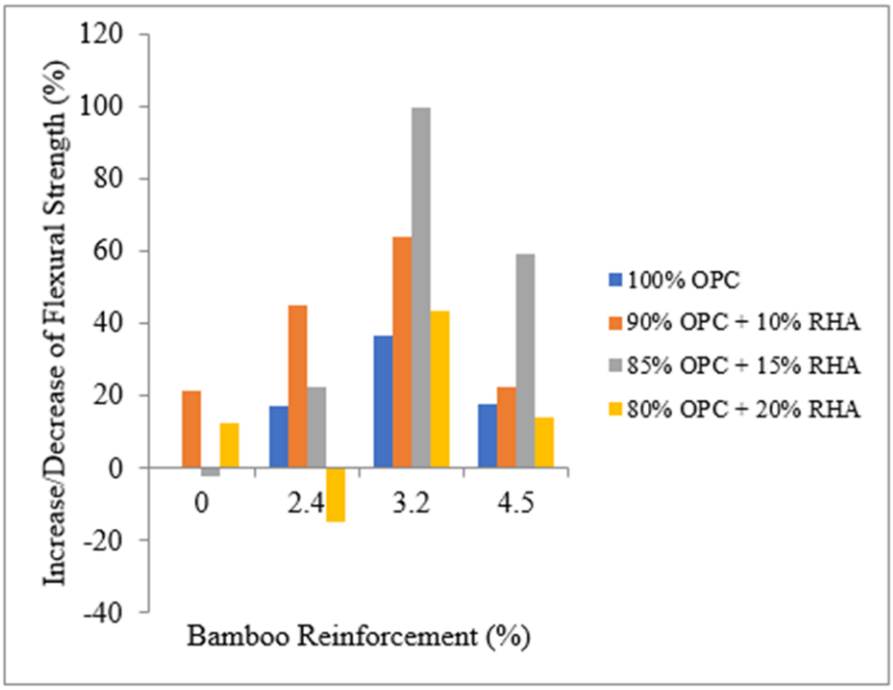


Fig. 11 Trends in flexural Strength of Bamboo Reinforced Concrete having different percentages of RHA with different Volume fraction of bamboo at 90 days curing

Table-15 Maximum Flexural Loads and Corresponding Deflections at 90 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Peak Load (KN)	Deflection (mm)
V10	0	0	12.727	0.400
V11	0	240	14.951	0.600
V12	0	320	17.418	5.907
V13	0	450	15.003	0.500

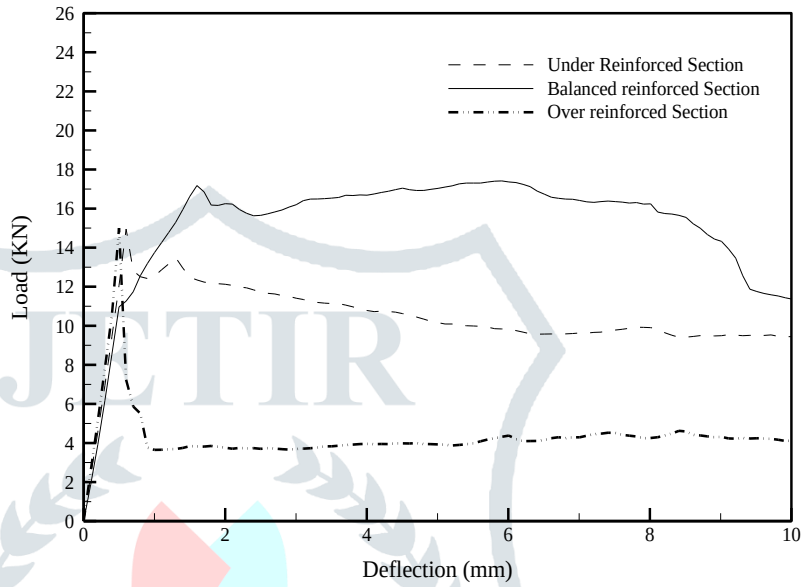
V20	10	0	15.436	0.529
V21	10	240	18.468	1.804
V22	10	320	20.865	1.803
V23	10	450	15.563	1.503
V30	15	0	12.463	0.410
V31	15	240	15.605	2.201
V32	15	320	25.440	2.102
V33	15	450	20.245	1.903
V40	20	0	14.348	0.510
V41	20	240	10.831	0.401
V42	20	320	18.287	1.302
V43	20	450	14.548	1.302

Table-16 First Crack Flexural Loads and Corresponding Deflections at 90 days curing period

Mix ID	Rice Husk Ash (%)	Bamboo Area (mm^2)	Load at first crack (KN)	Deflection (mm)
V10	0	0	12.727	0.400
V11	0	240	14.951	0.600
V12	0	320	8.540	0.400
V13	0	450	15.003	0.500
V20	10	0	15.436	0.529
V21	10	240	11.189	0.401
V22	10	320	13.044	0.601
V23	10	450	12.396	0.601
V30	15	0	12.463	0.410
V31	15	240	11.240	0.500
V32	15	320	13.502	0.500
V33	15	450	11.361	0.501
V40	20	0	14.348	0.510
V41	20	240	10.831	0.401
V42	20	320	11.628	0.401
V43	20	450	11.802	0.401

The Concrete beams containing 100% OPC in the mix for different percentages of bamboo reinforcement at 90 days curing period are shown in Figs. 4.19(a) to 4.19(d). The corresponding curves and their comparison for bamboo reinforced concrete beams containing 10% RHA at 90 days curing period are indicated in Figs. 4.20(a) to 4.20(d). Further the their comparison for bamboo reinforced concrete beams containing 15% RHA and 20% RHA at 90 days curing period are indicated in Figs. 4.21(a) to 4.21(d) and Figs. 4.22(a) to 4.22(d) respectively. Whereas the Figs. 4.19(e),

4.20(e), 4.21(e) and 4.22(e) present the load-deflection curve for all the bamboo reinforcement percentages i.e. 2.4%, 3.2% and 4.5% tested for each RHA content i.e. 0% RHA, 10% RHA, 15% RHA and 20% RHA respectively. The flexural test results from the present investigation show that the mix having 85% OPC + 15% RHA have greater influence over the peak load and the mix having 80% OPC + 20% RHA have least influence over the peak load. From Figs. 4.19(e) to 4.22(e), it is clear that in all cases immediately after the first crack there is sharp decline in the load carrying capacity and then gradually it becomes nearly constant. Moreover the load carrying capacity is maximum in case of balanced reinforced sections and among all balanced reinforced sections, it is maximum in case of 85% OPC + 15% RHA.



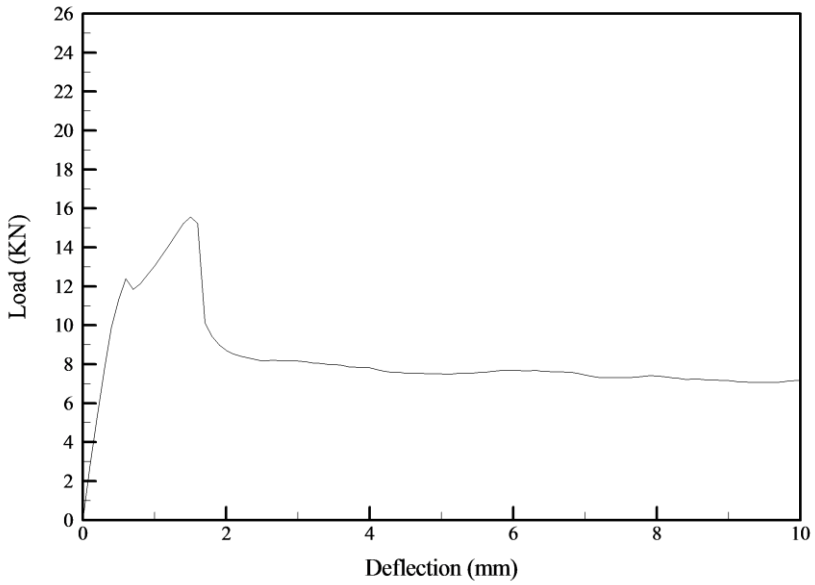


Fig. 12 L-D curve for over reinforced concrete beam having 90% OPC + 10% RHA at 90 days curing period

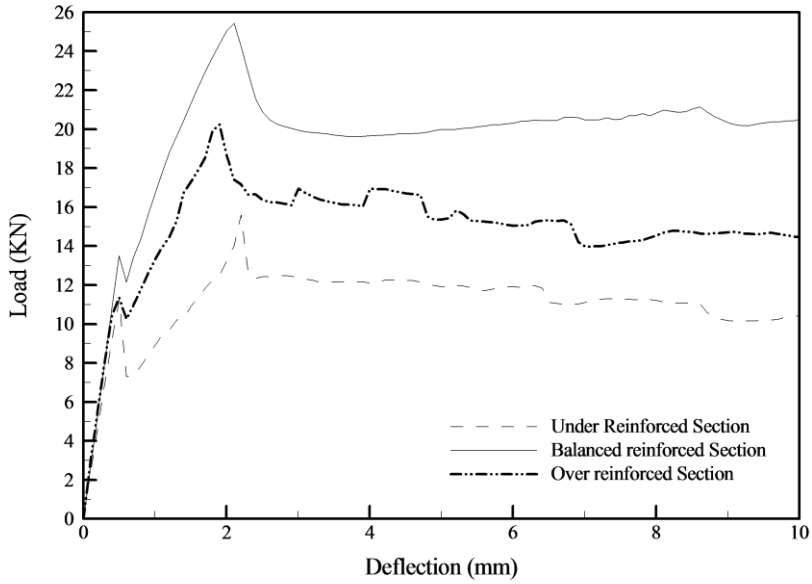


Fig. 13 Comparison of L-D curves

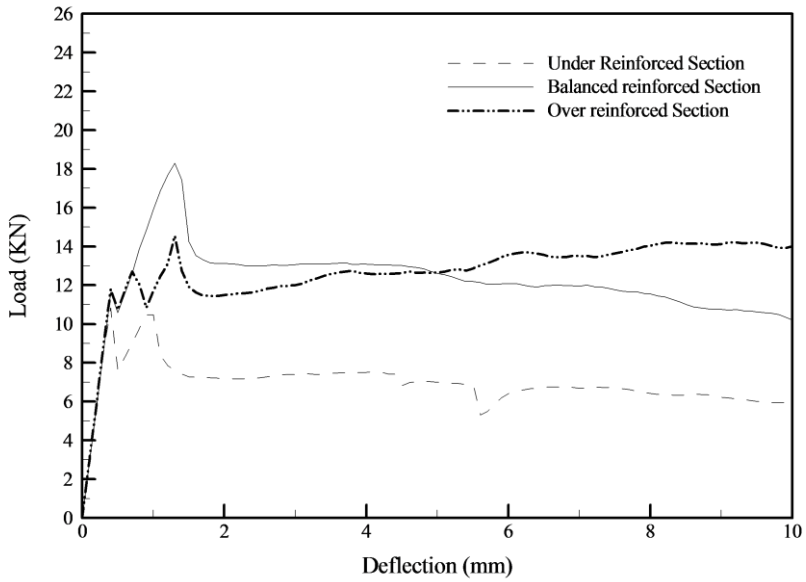


Fig. 14 Comparison of Load-Deflection curves for Under Reinforced, Balanced Reinforced and Over Reinforced Concrete Beams having 80% OPC + 20% RHA at 90 days curing period

Concluding Remarks

The results conclude that post cracking strength can be improved by bamboo reinforcement. The inclusion of bamboo reinforcement increases the post ductility cracking.

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