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AN EXPERIMENTAL STUDY ON THE REPAIR AND RETROFITTING OF BEAMS AND COLUMNS USING FERROCEMENT JACKETS AND FIBROUS FERROCEMENT JACKETS.

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ABSTRACT :

The experimental study on the repair and retrofitting of beams and columns using ferrocement jackets and fibrous ferrocement jackets investigates the effectiveness of these methods in enhancing the strength of reinforced concrete structures. Ferrocement, a composite material consisting of layers of wire mesh and cement mortar, is used to encase structural elements, providing additional load-bearing capacity and resistance to cracking. In this study, both conventional ferrocement jackets and fibrous ferrocement jackets, which incorporate fibers to improve the material's tensile strength, are applied to beams and columns. The research focuses on comparing the performance of these retrofitting techniques in terms of load capacity, and resistance to various forms of deterioration. The results demonstrate that the use of ferrocement jackets, particularly the fibrous version, significantly improves the structural performance of beams and columns, offering a cost-effective and efficient solution for the repair and retrofitting of reinforced concrete structures. The study also explores the impact of different fiber types and the thickness of the ferrocement jackets on the overall effectiveness of the retrofitting process.

1.Introduction:

Retrofitting essentially denotes the strengthening and enhancement of the performance of weak structural elements in a structure or structure as an entity. It is not the same as repair or rehabilitation. Repair is simply a partial restoration of strength degradation; it is purely a cosmetic improvement. Rehabilitation is a functional improvement wherein the aim is to regain the original strength of the structure, after its degradation and damage.

Retrofitting of RCC structural members is carried out to regain the strength of deteriorated structural concrete elements and to avoid further distress in concrete. The strength deficiency of the concrete structural members can be the result of poor workmanship, design errors, and deterioration due to the aggression of harmful agents. Common problems include, structural cracks, damage to structural members, excessive loading, errors in design or construction, modification of structural system, seismic damage, corrosion due to penetration- honey combs etc. The strengthening of damaged and deteriorated concrete structures has become a challenge and a necessity. It is far more economic than constructing new structures, but it also involves complications. The structural element, that is, reinforced concrete columns, performs the vital function of transferring the loads of the structure. The main deficiencies in concrete columns include low energy absorption capacity and no lateral confinement. These could be improved by constructing additional external confinement around columns. There are various techniques which are used for retrofitting structural members. Such techniques include section enlargement, external plate bonding, external post-tensioning, grouting, fiber reinforced polymer composites, and jacketing.

The specific proper retrofitting technique based on the degree of the damage and required capacity to be regained is specified and put in action. Retrofitting an existing building is making certain building systems more resilient in the future increase in loads by upgrading. Retrofitting is a better economic consideration, and immediate shelter to problems compared to building replacement. Upon choosing which retrofit to undertake, upgrading for accessibility, safety, and security should also be decided at the same time. Big renovations and retrofits concerning existing buildings on sustainability practices will reduce the operating costs along with environmental impacts while increasing its adaptability, durability and resiliency.

Jacketing is a type of retrofitting technique used for strengthening buildings and structural elements. Types of jacketing include: steel jacketing, reinforced concrete, fiber reinforced polymer composite, jackets with high tension materials such as carbon fiber, glass fiber etc., ferrocement jacketing.

2.Objectives of the study:

Retrofitting in construction refers to the process of modifying or upgrading existing buildings or structures to improve their performance, safety, and sustainability. This can involve adding new components, systems, or technologies to the existing structure, or modifying existing elements to meet new requirements.

Retrofitting can increase property value by improving the building's appearance, functionality, and sustainability. Upgraded systems and materials reduce maintenance costs and extend the building's lifespan. Retrofitting can reduce waste, conserve resources, and promote sustainability.

The main objective of this experimental investigation is to study the behavior of beams and columns retrofitted with ferrocement jacketing and fibrous ferrocement jacketing and then comparing both the methods of retrofitting.

3.Materials and methodology:

3.1. Cement:

OPC 43 cement shall comply with IS:8112-1989 and the designed strength of 28 days shall be minimum 43 MPa. The JK super cement has a specific gravity of 3.12 and is used in the experimentation.

3.2. Sand

Sand is one of the most used fine aggregates in construction. Fine aggregate is that material which passes through the sieve of 4.75 mm and helps to fill the voids between coarse aggregates in a concrete mix. For this experiment river sand is utilized. Specific gravity of fine aggregate is found to be 2.7.

3.3. Coarse aggregates

Coarse aggregates are an inherent component of concrete. The coarse aggregate should be sieved and retained and retained on 4.75mm.

3.4. Fly Ash

Fly ash is the fine ash powder produced and collected at coal-fired power plants. Fly ash used in this study is collected from Raichur Thermal Power Plant, Shakti nagar.

I. Class – C flyash
II. Specific gravity 2.3

3.5. Welded mesh

Weld mesh is the term applied to the type of barrier fencing that is made in square, rectangular or rhombus mesh from steel wire, welded at each intersection.

i. Opening Size: 1” ×1”
ii. Shape: Square
iii. Material: Mild steel

3.6. Chicken mesh

Poultry netting is another term for chicken wire. It is actually a type of wire mesh used in keeping birds such as chickens inside a pen or coop. It is made from thin, bendable, and galvanized steel wire having hexagon-shaped openings.

i. Material: Aluminum wire
ii. Mesh size: 1 inch (2.5 cm) mesh

3.7. **Steel Fibers**

Steel fibres used in the experimentation are procured from Udyambhag, Belagavi and is corrugated.

i. Type of Fiber: Deformed steel fibers
ii. Length: 40mm

3.8. Methodology:

After casting the beams and columns, they are wrapped with ferrocement jacketing and fibrous ferrocement jacketing as the case may be. For this welded mash chicken mesh are cut to the required size and they are wound around the beam and column. The cement mortar of proportion 1:4 was applied on the mesh layers and then it is finished smooth. For fibrous ferrocement jacketing steel fibres were added into cement mortar and then applied on mesh layers. The specimens are cured for 28days.

4.Experimental results :

This section deals with the experimental results on the behavior of concrete beams and columns wrapped with ferrocement and fibrous ferrocement jacketing.

4.1. Workability test results:

Table 1 gives the workability test result through slump, compaction factor and VB degree for the concrete produced by replacing the cement by flyash in different percentages. The workability results are graphically indicated in fig 1, fig 2 and fig 3.

Table 1. Workability test results

% replacement of cement by flyash	Slump (mm)	Compaction factor	V.B degree (sec)
0%	75	0.85	12
5%	78	0.86	9
10%	80	0.88	8
15%	87	0.89	7
20%	82	0.82	8
25%	80	0.80	10
30%	72	0.71	12

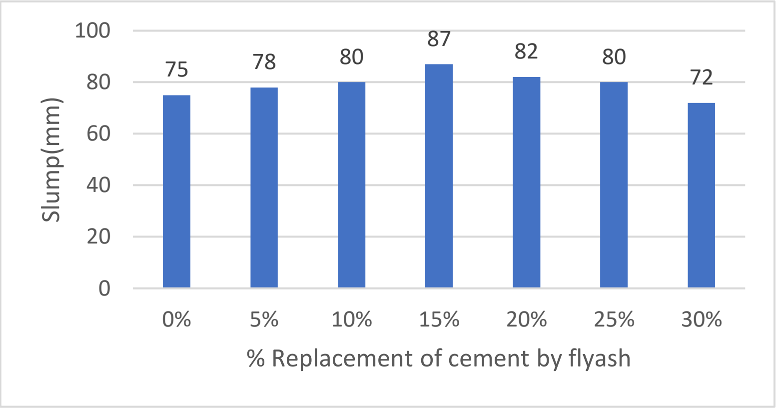

Fig 1 Variation of slump

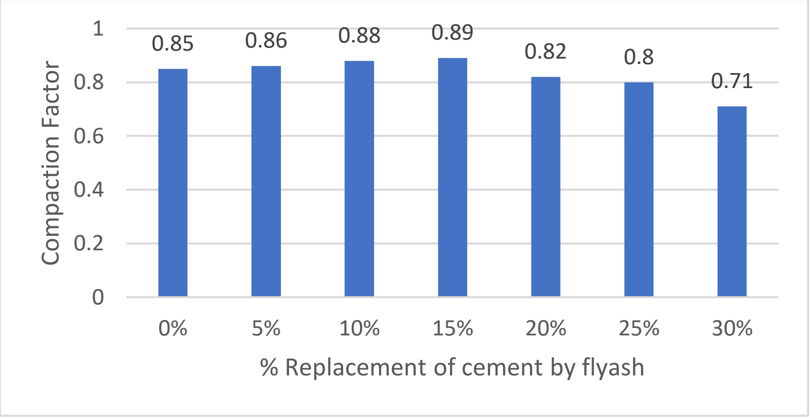

Fig 2 Variation of compaction factor

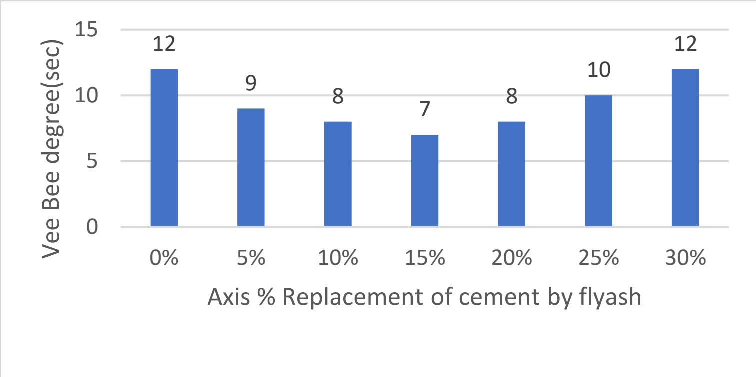

Fig 3 Variation of Vee Bee degree

4.2 Compressive strength test result of columns

Table 2 gives the failure load and compressive strength of columns without jacketing. Also, it gives the percentage increase or decrease of compressive strength with respect to reference mix. The result is graphically presented in fig.4.

Table 3 gives the failure load and compressive strength of columns with ferrocement jacketing. Also, it gives the percentage increase or decrease of compressive strength with respect to reference mix. The result is graphically presented in fig.5.

Table 4 gives the failure load and compressive strength of columns with fibrous ferrocement jacketing. Also, it gives the percentage increase or decrease of compressive strength with respect to reference mix. The result is graphically presented in fig.6.

Table 5 gives the failure load and compressive strength of columns without jacketing, jacketing by using ferrocement and jacketing by using fibrous ferrocement. Fig.7 gives the graphical representation of the comparative results.

Table 2: Compressive strength test result and columns without jacketing

Percentage replacement of cement by flyash	Failure load (kN)	Compressive strength (MPa)	Avg compressive strength (MPa)	% increase or decrease of comp. strength w.r.t ref mix
0% (Ref.mix)	495	22	22.01	0%
	498	22.13		
	493	21.91		
5%	520	23.11	23.25	5.63
	523.3	23.26		
	526	23.37		
10%	568	25.25	25.46	15.67
	572.2	25.43		
	578	25.69		
15%	591.5	26.29	26.44	20.13
	595.3	26.45		
	598	26.58		
20%	474	21.06	21.3	3.33
	480.8	21.33		
	484	21.51		
25%	470	20.89	21.04	4.61
	474.8	21.1		
	476	21.15		
30%	393	17.46	17.46	-26.06
	397.2	17.65		
	389	17.29		

Table 3: Compressive strength test results of columns with ferrocement jacketing.

Percentage replacement of cement by flyash	Failure load (kN)	Compressive strength (MPa)	Avg compressive strength (MPa)	% increase or decrease of comp. strength w.r.t ref mix
0% (Ref.mix)	512	22.75	22.97	0
	515.7	22.92		
	523	23.24		
5%	659	29.28	29.5	28.43
	664.7	29.54		
	668	29.68		
10%	708	31.46	31.67	37.88
	712.8	31.68		
	717	31.87		
15%	723	32.13	32.15	39.97
	719.6	31.98		
	728	32.35		
20%	625	27.78	28.27	23.07
	639.7	28.43		
	644	28.62		
25%	611	27.15	27.39	19.24
	615.7	27.36		
	623	27.68		
30%	554	24.62	24.79	7.92
	557.4	24.77		
	562	24.98		

Table 4: Compressive strength test results of columns with fibrous ferrocement jacketing

Percentage replacement of cement by flyash	Failure load (kN)	Compressive strength (MPa)	Avg compressive strength (MPa)	% increase or decrease of comp. strength w.r.t ref mix
0% (Ref.mix)	662	29.42	29.31	0
	657.7	29.23		
	659	29.28		
5%	683	30.35	30.47	3.96
	680	30.22		
	694	30.85		
10%	728	32.35	32.53	10.99
	736.1	32.71		
	732	32.53		
15%	759	33.73	33.62	14.70
	750	33.33		
	761	33.82		
20%	639	28.4	28.52	-2.77
	644.2	28.63		
	642	28.53		
25%	611	27.15	27.48	-6.66
	620	27.56		
	624	27.73		
30%	554	24.17	24.92	-17.62
	566.9	25.19		
	572	25.42		

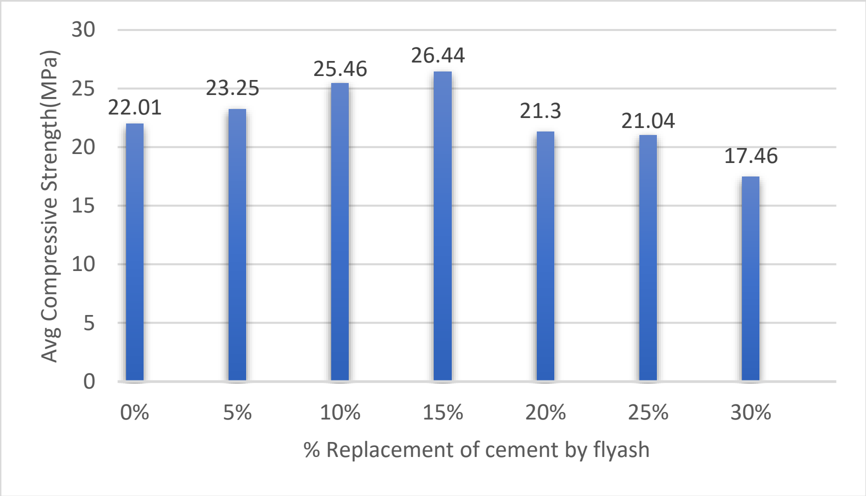

Fig 4: Variation of compressive strength of columns without jacketing

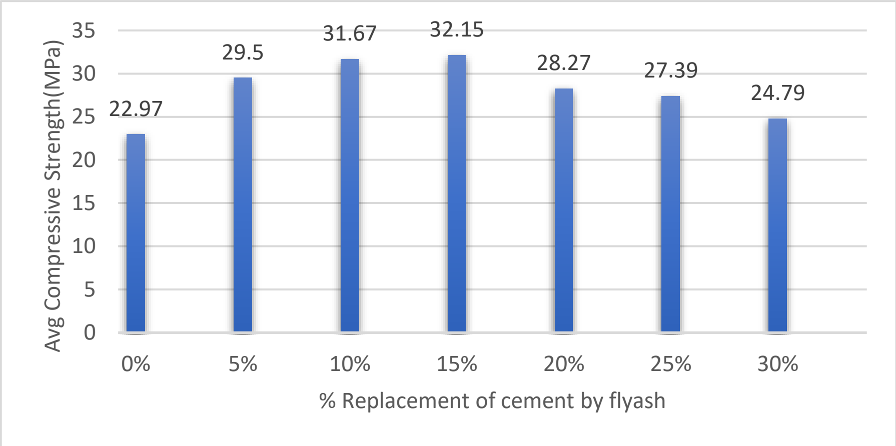

Fig 5: Variation of compressive strength of columns with ferrocement jacketing

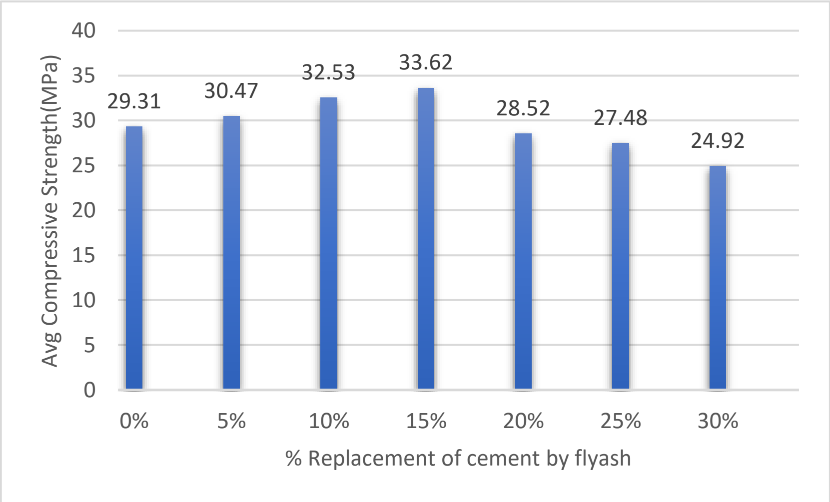

Fig 6: Variation of compressive strength of columns with fibrous ferrocement jacketing

Table 5: Comparative overall results of compressive strength of columns with and without jacketing

Percentage replacement of cement by flyash	Compressive strength of columns without jacketing (MPa)	Compressive strength of columns with ferrocement jacketing (MPa)	Compressive strength of columns with fibrous ferrocement jacketing (MPa)
0%	22.01	22.97	29.31

5%	23.25	29.5	30.47
10%	25.46	31.67	32.53
15%	26.44	32.15	33.62
20%	21.3	28.27	28.52
25%	21.04	27.39	27.48
30%	17.46	24.79	24.92

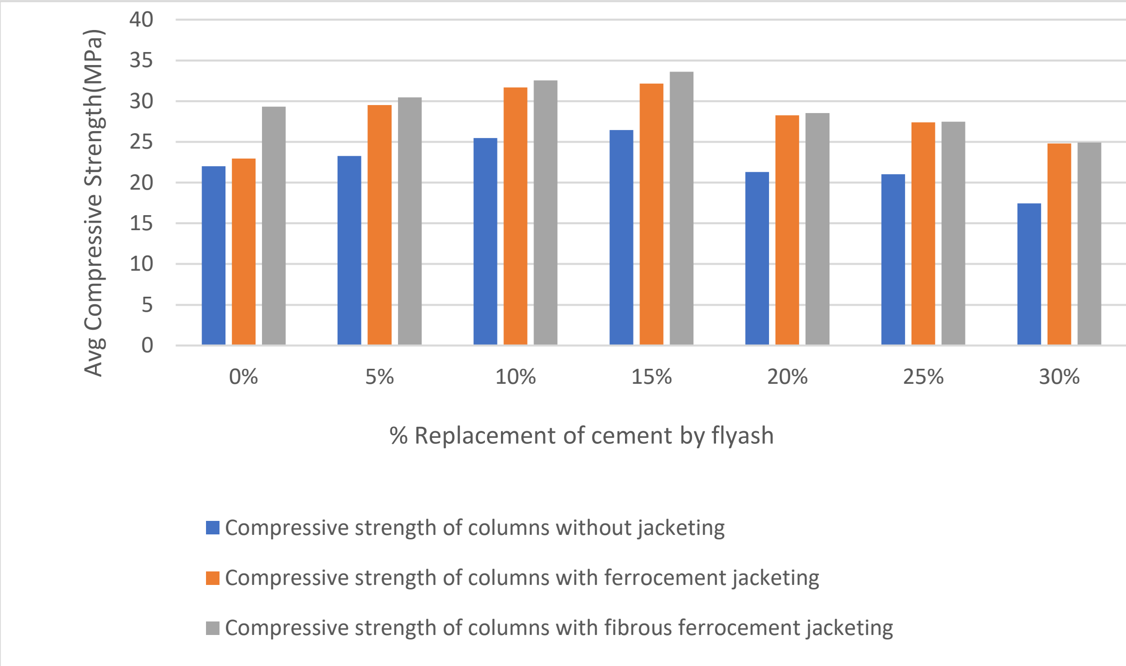

Fig .7 Variation of compressive strength columns with and without jacketing

4.3 Flexural strength test result of beams

Table 6 gives the failure load and flexural strength of beams without jacketing. Also, it gives the percentage increase or decrease of flexural strength with respect to reference mix. The result is graphically presented in fig.8.

Table 7 gives the failure load and flexural strength of beams with ferrocement jacketing. Also, it gives the percentage increase or decrease of flexural strength with respect to reference mix. The result is graphically presented in fig.9.

Table 8 gives the failure load and flexural strength of beams with fibrous ferrocement jacketing. Also, it gives the percentage increase or decrease of flexural strength with respect to reference mix. The result is graphically presented in fig 10.

Table 9 gives the failure load and flexural strength of beams without jacketing, jacketing by using ferrocement and jacketing by using fibrous ferrocement. Fig 11 gives the graphical representation of the comparative results.

Table 6: Flexural strength test result of beams without jacketing

Percentage replacement of cement by flyash	Failure load (kN)	Flexural strength (MPa)	Avg flexural strength (MPa)	% increase or decrease of flexural strength w.r.t ref mix
0% (Ref.mix)	32.3	6.67	6.67	0
	31	6.43		
	33.4	6.92		
5%	34.9	7.23	7.14	7.05
	35	7.26		
	33.5	6.95		
10%	42.5	8.81	8.84	32.53
	41.9	8.69		
	43.6	9.04		
15%	43.5	9.02	9.06	35.83
	43.9	9.1		

	43.8	9.08		
20%	40.8	8.46	8.48	27.14
	42.1	8.73		
	39.8	8.25		
25%	36.8	7.63	7.65	14.69
	37.1	7.69		
	36.8	7.63		
30%	29.1	6.03	5.85	-14.02
	28.1	5.82		
	27.6	5.72		

Table 7: Flexural strength test results of beams with ferrocement jacketing

Percentage replacement of cement by flyash	Failure load (kN)	Flexural strength (MPa)	Avg flexural strength (MPa)	% increase or decrease of flexural strength w.r.t ref mix
0% (Ref.mix)	55.2	11.45	11.25	0
	54.5	11.3		
	53.1	11.01		
5%	56.8	11.78	11.75	4.44
	57.2	11.86		
	56.1	11.63		
10%	64.2	13.32	13.35	18.67
	64.8	13.44		
	64.1	13.3		
15%	70.6	14.64	14.42	28.18
	68.9	14.29		
	69.1	14.33		
20%	55.6	11.53	11.24	-0.09
	53.9	11.18		
	53.1	11.01		
25%	50.6	10.49	10.67	-5.44
	51.7	10.72		
	52.1	10.8		
30%	44.2	9.16	9.15	-22.95
	44.6	9.25		
	43.7	9.06		

Table 8: Flexural strength test results of beams with fibrous ferrocement jacketing

Percentage replacement of cement by flyash	Failure load (kN)	Flexural strength (MPa)	Avg flexural strength (MPa)	% increase or decrease of flexural strength w.r.t ref mix
0% (Ref.mix)	58.2	12.07	12.06	0
	57.5	11.92		
	58.8	12.19		
5%	60.2	12.48	12.4	2.82
	59.4	12.32		
	59.8	12.4		
10%	69.9	14.5	14.55	20.65
	70.9	14.7		
	69.8	14.47		
15%	70.9	14.7	15.24	26.37
	76	15.76		
	73.6	15.26		
20%	59	12.23	12.2	1.16
	58.7	12.17		
	58.9	12.21		
25%	51.8	10.74	10.78	-11.87
	51.9	10.76		
	52.3	10.84		
30%	49	10.16	10.4	-15.96
	51	10.58		
	50.5	10.47		

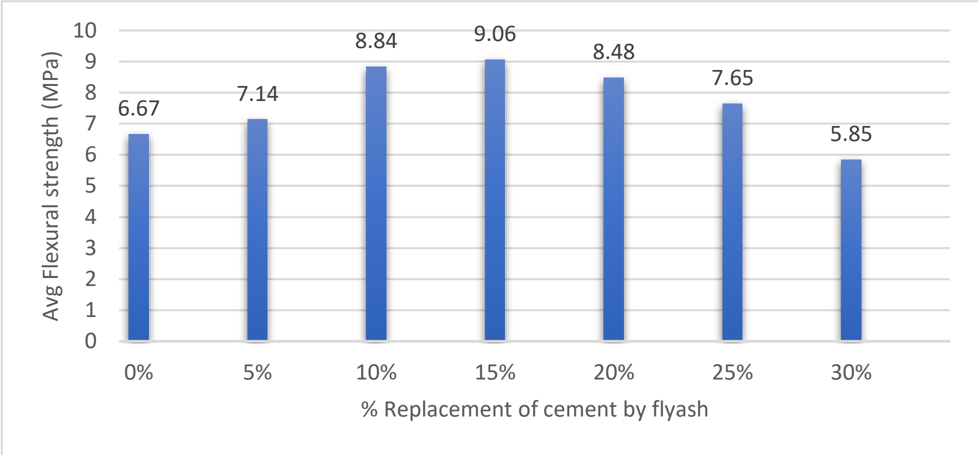

Fig 8: Variation of flexural strength of beams without jacketing

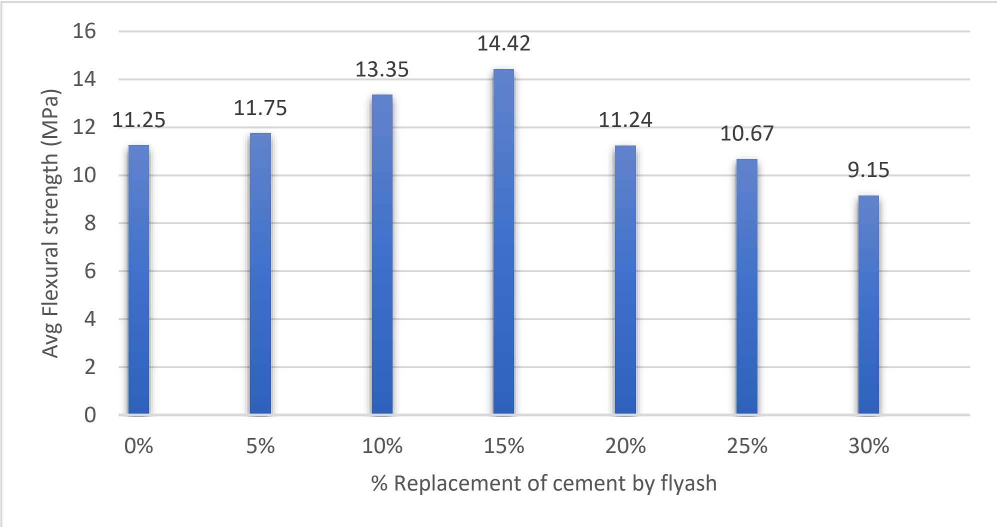

Fig 9: Variation of flexural strength of beams with ferrocement jacketing

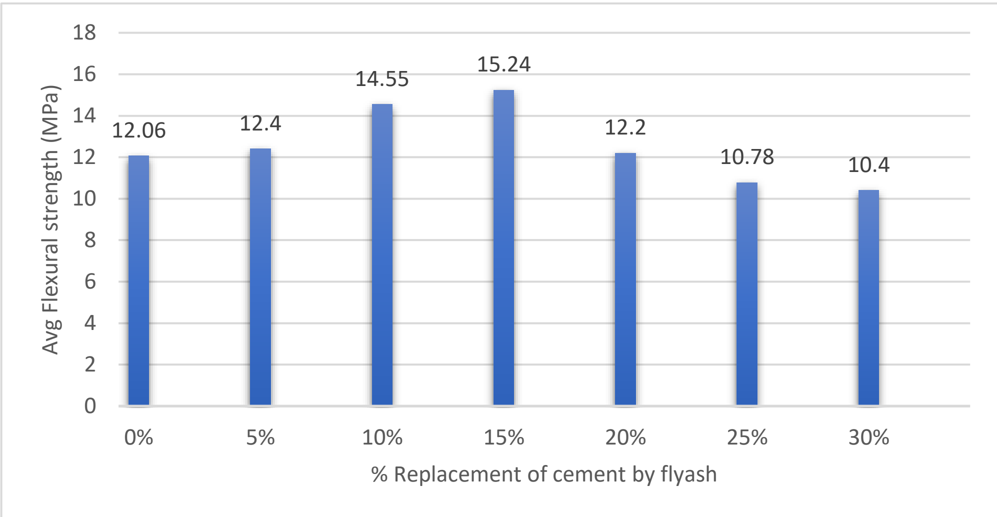

Fig 10: Variation of flexural strength of beams with fibrous ferrocement jacketing

Table 9: Comparative overall results of flexural strength of beams with and without jacketing

Percentage replacement of cement by flyash	Flexural strength of beams without jacketing (MPa)	Flexural strength of beams with ferrocement jacketing (MPa)	Flexural strength of beams with fibrous ferrocement jacketing (MPa)
0%	6.67	11.25	12.06
5%	7.14	11.75	12.40
10%	8.84	13.35	14.55
15%	9.06	14.42	15.24
20%	8.48	11.24	12.20
25%	7.65	10.67	10.78
30%	5.85	9.15	10.40

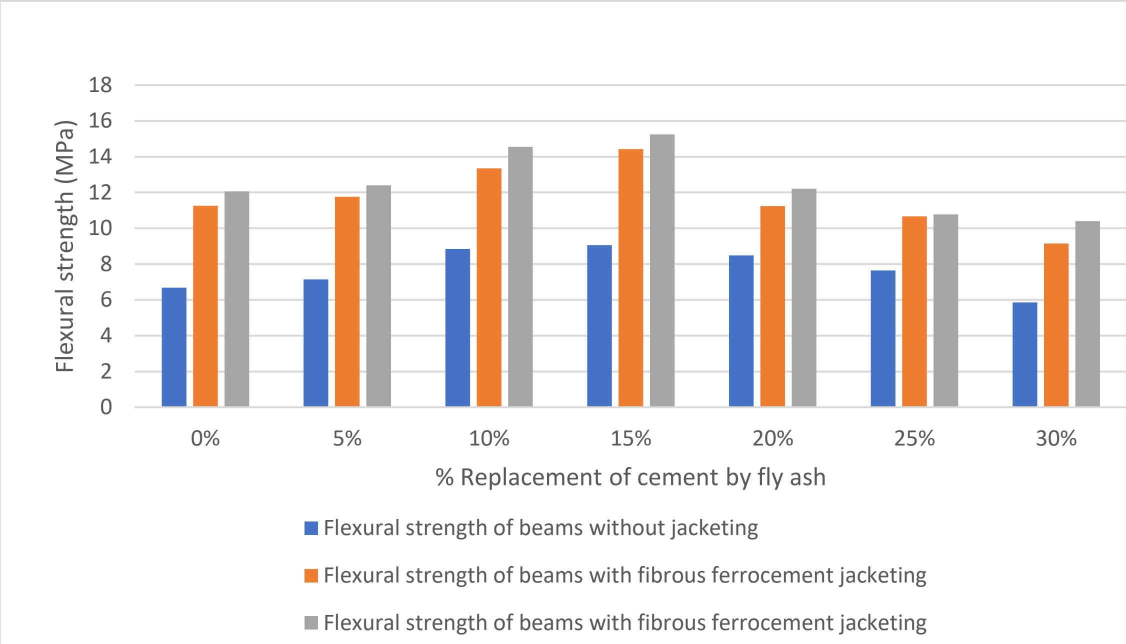

Fig. 11 Variation of flexural strength of beams with and without jacketing

5.Observations and discussions :

The following observations are made with respect to the study conducted on repair and retrofitting of beams and columns with ferrocement jacketing and fibrous ferrocement jacketing.

1. Table1 gives the workability test results it in terms of slump, compaction factor and V.B. degree. The variation of workability is shown graphically in fig no.1 ,2 and 3. It is observed that the workability of concrete in terms of slump, compaction factor and V.B. degree goes on increasing upto 15% replacement of cement by flyash. After 15% replacement level the workability shows a decreasing trend. Thus, higher workability for concrete is achieved when 15% cement is replaced by flyash.

This may be due to the fact that at 15% replacement level the flyash added will act as ball bearing and enhance the flow characteristics of concrete there by increasing the workability.

Thus, it can be concluded that the workability of concrete is high when 15% cement is replaced by flyash. There after the workability decreases.

2. The load carrying capacity and compressive strength of columns without jacketing is given in table 2. The variation of compressive strength is graphically represented in fig 4. It is observed that the load carrying capacity and the compressive strength of columns without jacketing go on increasing up to 15% replacement cement by flyash. After 15% replacement, the load carrying capacity and compressive strength go on decreasing. At 15% replacement level, it is found that the compressive strength of the column is 26.44MPa and % increase in compressive strength is 20.13%.

This may be due to the fact that when 15% cement is replaced by flyash, a higher pozzolanic reaction may occur which produces more C-S-H gel. Also, it may be due to the fact that at 15% replacement level all the pores of the concrete may be filled by the flyash particles making the concrete very dense. Thus, it may be concluded that for the column without jacketing, the higher load carrying capacity and compressive strength can be obtained when 15% cement is replaced by flyash and the corresponding compressive strength is 26.44MPa.

3. The load carrying capacity and compressive strength of columns with ferrocement jacketing is given in table 3. The variation of compressive strength is graphically represented in fig.5. It is observed that the load carrying capacity and the compressive strength of columns with ferrocement jacketing go

on increasing up to 15% replacement cement by flyash. After 15% replacement, the load carrying capacity and compressive strength go on decreasing. At 15% replacement level, it is found that the compressive strength of the column is 32.15MPa and % increase in of compressive strength is 39.97%.
This may be due to the fact that when 15% cement is replaced by flyash, a higher pozzolanic reaction may occur which produces more C-S-H gel. Also, it may be due to the fact that at 15% replacement level all the pores of the concrete may be filled by the flyash particles making the concrete very dense. Thus, it may be concluded that for the column with ferrocement jacketing, the higher load carrying capacity and compressive strength can be obtained when 15% cement is replaced by flyash and the corresponding compressive strength is 32.15MPa.

4. The load carrying capacity and compressive strength of columns with fibrous ferrocement jacketing is given in table 4. The variation of compressive strength is graphically represented in fig.6. It is observed that the load carrying capacity and the compressive strength of columns with fibrous ferrocement jacketing go on increasing up to 15% replacement cement by flyash. After 15% replacement, the load carrying capacity and compressive strength go on decreasing. At 15% replacement level, it is found that the compressive strength of the column is 33.62MPa and % increase in compressive strength is 14.70%.
This may be due to the fact that when 15% cement is replaced by flyash, a higher pozzolanic reaction may occur which produces more C-S-H gel. Also, it may be due to the fact that at 15% replacement level all the pores of the concrete may be filled by the flyash particles making the concrete very dense. Thus, it may be concluded that for the column with fibrous ferrocement jacketing, the higher load carrying capacity and compressive strength can be obtained when 15% cement is replaced by flyash and the corresponding compressive strength is 33.62MPa.

5. Table 5 gives a comparative result of columns with and without jacketing. Fig.7 gives graphical representation of variation of compressive strength of columns with and without jacketing. It is observed that the compressive strength of columns with fibrous ferrocement jacketing is higher as compared to that of ferrocement jacketing. Also, the compressive strength of columns with ferrocement jacketing is higher than that of without jacketing. Thus, it distinctly seen that ferrocement jacketing or fibrous ferrocement jacketing will yield higher compressive strength or higher load carrying capacity for the columns. This is true for all the % replacement of cement by flyash.
This is obviously due to the fact that ferrocement jacketing or fibrous ferrocement jacketing will confine the concrete there by increasing the load carrying capacity of the column.
Thus, it can be concluded that the performance of fibrous ferrocement jacketing is better than that of ferrocement jacketing and without jacketing.

6.The load carrying capacity and flexural strength of beams without jacketing is given in table 6. The variation of flexural strength is graphically represented in figure 8. It is observed that load carrying capacity and the flexural strength of beams without jacketing go on increasing up to 15% replacement of cement by flash. After 15% replacement the load carrying capacity and flexural strength goes on decreasing. At 15% replacement level, it is found that the flexural strength of the beams is 9.06 MPa and percentage increase of flexural strength is 35.83%.
This may be due to the fact that when 15% cement is replaced by flyash, a higher pozzolanic reaction may occur which produces more C-S-H gel. Also, it may be due to the fact that at 15% replacement level all the pores of concrete may be filled by flyash particles making the concrete very dense.
Thus, it may be concluded that for the beams without jacketing the higher load carrying capacity and flexural strength can be obtained when 15% cement is replaced by flyash and the corresponding flexural strength is 9.06 MPa.

7. The load carrying capacity and flexural strength of beams with ferrocement jacketing is given in table 7. The variation of flexural strength is graphically represented in figure 9. It is observed that load carrying capacity and the flexural strength of beams with ferrocement jacketing go on increasing up to 15% replacement of cement by flyash. After 15% replacement the load carrying capacity and flexural strength goes on decreasing. At 15% replacement level, it is found that the flexural strength of the beams is 14.42 MPa and percentage increase of flexural strength is 28.18%.
This may be due to the fact that when 15% cement is replaced by flyash, a higher pozzolanic reaction may occur which produces more C-S-H gel. Also, it may be due to the fact that at 15% replacement level all the pores of concrete may be filled by flyash particles making the concrete very dense.
Thus, it may be concluded that for the beams with ferrocement jacketing the higher load carrying capacity and flexural strength can be obtained when 15% cement is replaced by flyash and the corresponding flexural strength is 14.42 MPa.

8. The load carrying capacity and flexural strength beams with fibrous ferrocement jacketing is given in table 8. The variation of flexural strength is graphically represented in figure 10. It is observed that load carrying capacity and the flexural strength of beams with fibrous ferrocement jacketing go on increasing up to 15% replacement of cement by flyash. After 15% replacement the load carrying capacity and flexural strength goes on decreasing. At 15% replacement level, it is found that the flexural strength of the beams is 15.24 MPa and percentage increase of flexural strength is 26.37%.
This may be due to the fact that when 15% cement is replaced by flyash, a higher pozzolanic reaction may occur which produces more C-S-H gel. Also, it may be due to the fact that at 15% replacement level all the pores of concrete may be filled by flyash particles making the concrete very dense.
Thus, it may be concluded that for the beams with fibrous ferrocement jacketing is the higher load carrying capacity and flexural strength can be obtained when 15% cement is replaced by flyash and the corresponding flexural strength is 15.24 MPa

9. Table 9 give a comparative result of beams with and without jacketing. Figure 11 gives graphical representation of variation of flexural strength of beam with and without jacketing. It is observed that the flexural strength of beams with fibrous ferrocement jacketing is higher as compared to that of ferro cement jacketing. Also, the flexural strength of beam with ferrocement jacket is higher than that of without jacketing. Thus, it is distinctly seen that ferrocement jacketing or fibrous ferro cement jacketing will yield higher load carrying capacity and higher flexural strength. This is true for all the percentage replacement of cement by flyash.
This is obviously due to the fact that ferro cement jacketing or fibrous ferrocement jacketing will confine the concrete there by increasing the load carrying capacity of the beams.

Thus, it can be concluded that the performance of fibrous ferrocement jacketing is better than that of ferrocement jacketing or without jacketing.

6. Conclusions :

Following conclusion may be drawn based on the study conducted on the effect of ferrocement jacketing and fibrous ferrocement jacketing on columns and beams.

1. The workability of concrete is high when 15% cement is replaced by flyash. There after the workability decreases.
2. For the column without jacketing the higher load carrying capacity and compressive strength can be obtained when 15% cement is replaced by flyash and the corresponding compressive strength is 26.44MPa.
3. For the column with ferrocement jacketing the higher load carrying capacity and compressive strength can be obtained when 15% cement is replaced by flyash and the corresponding compressive strength is 32.15MPa.
4. For the column with fibrous ferrocement jacketing the higher load carrying capacity and compressive strength can be obtained when 15% cement is replaced by flyash and the corresponding compressive strength is 33.62MPa.
5. 5.The performance of fibrous ferrocement jacketing is better than that of ferrocement jacketing and without jacketing for columns.
6. For the beams without jacketing the higher load carrying capacity and flexural strength can be obtained when 15% cement is replaced by flyash and the corresponding flexural strength is 9.06 MPa.
7. For the beams with ferrocement jacketing the higher load carrying capacity and flexural strength can be obtained when 15% cement is replaced by flyash and the corresponding flexural strength is 14.42 MPa.
8. For the beams without jacketing the higher load carrying capacity and flexural strength can be obtained when 15% cement is replaced by flyash and the corresponding flexural strength is 15.24 MPa.
9. The performance of fibrous ferrocement jacketing is better than that of ferrocement jacketing or without jacketing for beams.

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