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Serviceability Limits in Asbestos Fibre RCC Beams

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ABSTRACT

In recent past very few methods have been proposed to improve the serviceability criteria (of crack and deflection). Most of the reinforced concrete structures do not fail but are rendered unserviceable and are declared unsafe. Beams form an important structural element in framed construction for the transfer of loads, so finding a method to increase the serviceability of flexural members without compromising its strength is a necessary need of hour.

The effect on the serviceability and strength of RCC beams due to addition of asbestos fibre of varying percentages is studied. Different percentages of asbestos fibre were incorporated in RCC beams. Asbestos fibre reinforced concrete (AFRC) beams with varying percentages of asbestos fibre (0.5%, 1%, 1.5% and 2%) were tested under two point loading condition to determine flexural strength. The flexural behaviour under incremental loading was observed and data of increase in elastic and ultimate strength, load deflection characteristics, load and crack width variation were recorded for each beam.

There was an increase in the serviceability and strength parameters of AFRC beams up to a certain optimum percentage of asbestos fibre and, thereafter the strength of the beam was harmed. The results indicated an increase in the strength of AFRC beams ranging from 33.33% to 42%, increase in stiffness ranging from 11% to 78%. Meanwhile, the crack width at ultimate load decreased by 55% - 90% and ductility (which is a measure of decrease in deflection) increased by 23% - 51% as compared to the control beams.

INTRODUCTION

Serviceability of concrete structures mainly depends on control over cracking, deflections and degree of vibrations. The design of concrete structures for serviceability is possibly the most difficult and least well understood aspect of the design. The non-linear behaviour of concrete that complicates serviceability calculations is due to cracking, tension stiffening, creep, and shrinkage.

The quest for serviceable reinforced concrete structures without compromising strength parameter of the structural member must be aimed at determining methods which could bridge the gap between limit state of serviceability and limit state of safety.

Fibre Reinforced Concrete can be defined as a composite material consisting of mixtures of cement mortar or cement concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Fibre reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented. Fibres include steel fibres, glass fibres, synthetic fibres and natural fibres. Within these different fibres the character of fibre reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation and densities.

Fibre-reinforcement is mainly used in shotcrete but can also be used in normal concrete. Fibre-reinforced normal concretes are mostly used for on-ground floors and pavements but can be considered for a wide range of construction parts (beams, piers, foundations etc.) either alone or with hand-tied rebars

Fibre reinforced concrete is the composite material containing fibres in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depend upon the efficient transfer of stress between matrix and the fibres.

The strength of the composite largely depends on the quantity of fibres used in it. An increase in the volume of fibres enhances, almost linearly, the tensile strength and toughness of the composite. Use of higher percentage of fibre is likely to cause segregation and harshness of concrete and mortar.

This factor is the focus of this study

It was observed that the fibres aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibres.

Incorporation of steel fibre decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fibre volume at which this situation is reached depends on the length and diameter of the fibre.

Another consequence of poor workability is non-uniform distribution of the fibres. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures/plasticizers.

Mixing of fibre reinforced concrete needs careful conditions to avoid balling of fibres, segregation and, in general, the difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fibre content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix.

It is important that the fibres are dispersed uniformly throughout the mix; this is achieved by the addition of the fibres before the water is added. When mixing in a laboratory mixer, introducing the fibres through a wire mesh basket will help even distribution of fibres. For field use, other suitable methods must be adopted.

DEFLECTIONS

Structures designed by limit state of collapse are of comparatively smaller sections than those designed employing working stress method and limit state method. They, therefore, must be checked for deflection and width of cracks. Excessive deflection of a structure or part thereof adversely affects the appearance and efficiency of the structure, finishes or partitions.

Clause 23.2 of IS 456 stipulates the limiting deflections under two heads as given below:

(a) The maximum final deflection should not normally exceed span/250 due to all loads including the effects of temperatures, creep and shrinkage and measured from the as-cast level of the supports of floors, roof and all other horizontal members.

(b) The maximum deflection should not normally exceed the lesser of span/350 or 20 mm including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes.

It is essential that both the requirements are fulfilled for every structure.

CRACK WIDTH

Crack width calculation is one of the serviceability requirements in the structural concrete elements. The occurrence of cracks in reinforced concrete elements is expected to occur under service loads, due to the low tensile strength of concrete. Control of cracking is important for obtaining acceptable appearance and for long-term durability of concrete structures, especially those subjected to aggressive environments. Excessive crack width may reduce the service life of the structure by permitting more rapid penetration of corrosive factors such as high humidity, repeated saturation with moisture, vapour, salt-water spray and gases with chemicals, to reach the reinforcement. Consequently, there is an increased interest in the control of cracking by building codes and scientific organizations.

In the present study flexural cracks were considered:

The flexural cracks start from the tension face and propagate perpendicular to the axis of the member. The crack width of a flexural crack depends on the following parameters:

Tensile strength of concrete. tensile stress in the longitudinal bars, thickness of the concrete cover, diameter and spacing of longitudinal bars , depth of member and location of neutral axis and bond strength.

OBJECTIVES

The purpose of this study is to reduce the crack width and excessive deflection (serviceability limits) in reinforced concrete beams by adding optimum percentage of asbestos fibres without compromising the strength parameter. The primary and secondary objectives of this project are mentioned under:

Primary objectives

- Comparing the results of crack width in AFRC (asbestos fibre reinforced concrete) beams with regular RCC beams.
- Comparing the results of deflection in AFRC (asbestos fibre reinforced concrete) beams with regular RCC beams.

Secondary objectives

- Effect on load carrying capacity of AFRC beams (strength parameter)
- Effect on ductility ratio

ASBESTOS FIBRE

Asbestos fibre is a mineral fibre and has proved to be most successful of all the fibres as it can be mixed with Portland cement. The tensile strength of asbestos varies between 560 to 980 N/mm^2. The composite product called asbestos cement has considerably high flexural strength than Portland cement paste. Asbestos minerals belong to the class of water silicates of magnesium, iron, partly of calcium and sodium. According to their mineralogical characteristics and crystal structures, asbestos fibres have been divided into 3 types namely: chrysotile, amosite and tremolite.Chrysotile (white asbestos) is a white curly fibre, accounts for 90% of asbestos in products and is a member of serpentine group containing magnesium silicate. Amosite is a brown or grey-colored straight fibres belonging to amphibole group, containing iron and magnesium. Tremolite is a greyish green colored fibre containing calcium, magnesium, and iron silicates.

Asbestos (different volume %age) is the fibre used in this study as local reinforcement

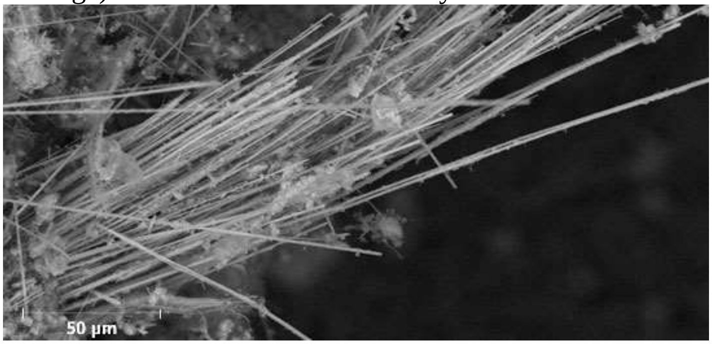

Figure 1 asbestos fibre under microscope

METHODOLOGY

Fabrication of beams

In all 6 beams in concrete M20 nominal mix (1:1.5:3) were cast with same dimensions under similar environmental conditions. Out of six beams two beams were set as reference beams, to obtain an exact benchmark for comparison. The specifications of the beams and the percentage of asbestos fibre added to each sample

Sample 1: Reference (control) beam 1
Sample 2: Reference (control) beam 2
Sample 3: AFRC beam with 0.5% asbestos fibre (by volume)
Sample 4: AFRC beam with 1% asbestos fibre (by volume)
Sample 5: AFRC beam with 1.5% asbestos fibre (by volume)
Sample 6: AFRC beam with 2% asbestos fibre (by volume)
While adding asbestos fibre, some of the precaution taken are mentioned as:

Fibres were uniformly distributed throughout the material mixture.
Asbestos fibre was added before adding water to the mix.
Fibres were properly checked for lumps or foreign materials

TESTING OF BEAMS

All the samples (control beams & AFRC beams) were tested on the loading frame(two point loading) under similar conditions. The effective span of the beams was kept as 1.8 m. The beams were made to rest on a bearing length of 0.2 m that in turn rested on the supports.

Deflection

Table 1 Load vs Deflection of control beams

S no	**Load (in kN)**	**Gauge(1/3span) mm**	**Gauge (centre) mm**	**Gauge(2/3span) Mm**
1	0	0	0	0
2	5	.38	0.41	.37
3	10	.79	0.84	.80
4	15	1.11	1.17	1.12
5	20	1.59	1.65	1.55
6	25	2.08	2.13	1.98
7	30	2.46	2.52	2.56
8	35	2.80	2.91	2.81
9	40	3.15	3.75	3.07
10	45	3.59	4.2	3.53
11	50	3.87	4.82	3.84
12	55	4.25	5.4	4.24
13	60	4.60	5.98	4.64
14	65	5.00	6.52	5.07
15	70	5.46	6.95	5.54
16	75	6.05	7.43	6.10
17	80	6.50	7.93	6.52
18	85	7.14	8.93	7.15
19	90	7.92	9.88	7.94
20	95	9.60	10.75	9.55

Table 2 Crack Width for Control Beam

S no	Load (in kN)	1/3span (mm)	centre (mm)	2/3span (mm)	REMARKS
1	0	0	0	0	-
2	5	0	0	0	-
3	10	0	0	0	-
4	15	0	0	0	-
5	20	0	0	0	-
6	25	0	0	0	-
7	30	0	0	0	-
8	35	0.01	0.02	0.01	Crack visible
9	40	0.02	0.04	0.02	-
10	45	0.04	0.045	0.035	-
11	50	0.055	0.08	0.06	-
12	55	0.066	0.10	0.07	-
13	60	0.085	0.118	0.09	-
14	65	0.098	0.135	0.102	-
15	70	0.11	0.15	0.115	-
16	75	0.125	0.165	0.130	-
17	80	0.14	0.18	0.15	-
18	85	0.15	0.21	0.18	-
19	90	0.18	0.35	0.21	-
20	95	0.22	0.45	0.25	Failure

Table 3 Load vs Deflection Curve of sample 3 (0.5% asbestos)

Load (kN)	gauge L (mm)	gauge C (mm)	gauge R (mm)	Remarks
0	0	0	0	-
5	0.23	.26	.24	-
10	0.45	.50	.44	-
15	0.73	.76	.72	-
20	1.00	1.02	.99	-
25	1.26	1.29	1.25	-
30	1.48	1.50	1.45	-
35	1.78	1.79	1.74	-
40	1.93	1.96	1.92	-
45	2.45	2.48	2.40	-
50	3.02	3.11	2.98	crack visible
55	3.54	3.70	3.58	-
60	4.13	4.40	4.25	-
65	4.70	5.04	4.85	-
70	5.27	5.65	5.45	-
75	6.15	6.63	6.40	-
80	7.05	7.60	7.42	-
85	7.65	8.34	8.12	-
90	8.40	9.10	8.90	-
95	9.38	10.10	9.85	-
100	10.25	11.02	10.65	-
105	11.05	12.45	11.45	-
110	12.50	13.68	12.80	-
120	14.10	15.10	14.50	failure

Table 4 Crack Width For sample 3

Load (kN)	Left (mm)	Centre (mm)	Right (mm)	Remarks
0	0	0	0	-
5	0	0	0	-
10	0	0	0	-
15	0	0	0	-
20	0	0	0	-
25	0	0	0	-
30	0	0	0	-
35	0	0	0	-
40	0	0	0	-
45	0	0	0	-
50	0	0.015	0	Crack visible
55	0	0.02	0.01	-
60	0.02	0.025	0.015	-
65	0.025	0.03	0.02	-
70	0.035	0.04	0.035	-
75	0.04	0.0425	0.0375	-
80	0.045	0.0525	0.045	-
85	0.05	0.065	0.05	-
90	0.0525	0.07	0.055	-
95	0.055	0.075	0.06	-
100	0.06	0.08	0.0625	-
105	0.065	0.085	0.07	-
110	0.0725	0.095	0.075	-
120	0.0825	0.125	0.085	failure

Table 5 Load vs Deflection of sample 4 (1% asbestos)

Load (KN)	Centre (mm)	1/3L from span (mm)	Remarks
0	0.00	0.00	-
5	0.23	0.22	-
10	0.47	0.38	-
15	0.94	0.65	-
20	1.35	1.08	-
25	1.95	1.52	-
30	2.35	1.80	-
35	2.86	2.15	-
40	3.25	2.53	-
45	3.85	2.80	-
50	4.25	3.12	-
55	4.79	3.63	-
60	5.35	4.20	-
65	5.98	4.88	-
70	6.45	5.23	-
75	7.04	5.60	Crack visible
80	7.44	6.15	-
85	8.15	6.75	-
90	8.85	7.60	-
95	9.55	8.25	-
100	10.25	9.20	-
105	11.25	10.30	-
110	12.35	11.20	-
115	13.65	11.95	-
120	14.85	12.88	-
125	15.77	13.97	-
130	16.55	15.03	-
135	17.95	16.10	Shear failure

Table 6 Crack Width for sample 4

loading (kN)	Centre (mm)	1/3L from support (mm)	Remarks
0	0	0	-
5	0	0	-
10	0	0	-
15	0	0	-
20	0	0	-
25	0	0	-
30	0	0	-
35	0	0	-
40	0	0	-
45	0	0	-
50	0	0	-
55	0	0	-
60	0	0	-
65	0	0	-
70	0	0	-
75	0.015	0	Crack visible
80	0.02	0	-
85	0.025	0.015	-
90	0.03	0.02	-
95	0.035	0.02	-
100	0.04	0.025	-
105	0.04	0.03	-
110	0.045	0.03	-
115	0.05	0.035	-
120	0.055	0.0375	-
125	0.06	0.045	-
130	0.075	0.065	-
135	0.11	0.09	Shear Failure

Table 7 Load vs Deflection of sample 5 (1.5% asbestos)

Loading (kN)	Centre (mm)	1/3L from support (mm)	Remarks
0	0	0	-
5	0.30	0.28	-
10	0.49	0.35	-
15	0.75	0.55	-
20	1.18	.90	-
25	1.65	1.26	-
30	2.25	1.77	-
35	2.65	2.10	-
40	3.05	2.43	-
45	3.45	2.68	-
50	3.88	2.95	-
55	4.35	3.39	Shear crack
60	4.98	3.88	-
65	5.79	4.30	-
70	6.90	5.25	Tension crack
75	8.40	6.80	-
80	10.05	7.70	-
85	11.25	8.97	-
90	12.65	10.66	Shear failure

Table 8 Crack Width For sample 5

load (kN)	Centre (mm)	1/3 L from support (mm)	Remarks
0	0	0	-
5	0	0	-
10	0	0	-
15	0	0	-
20	0	0	-
25	0	0	-
30	0	0	-
35	0	0	-
40	0	0	-
45	0	0	-
50	0	0	-
55	0	0	-
60	0	0	-
65	0	0	-
70	0.02	0	Tension crack
75	0.025	0.015	-
80	0.04	0.03	-
85	0.055	0.045	-
90	0.075	0.06	Shear failure

Table 9 Load vs Deflection of sample 6 (concrete with 2% asbestos)

Load (kN)	Centre (mm)	1/3L from support (mm)	Remarks
0	0.0	0.0	-
5	0.51	0.38	-
10	1.05	0.84	-
15	1.60	1.39	-
20	2.10	1.84	-
25	2.74	2.40	Shear crack
30	3.35	3.01	-
35	3.95	3.55	Flexural crack detected
40	4.85	4.25	-
45	6.10	4.97	-
50	7.52	5.88	failure due to shear

Table 10 Crack Width for sample 6

load (kN)	At 1/3L (mm)	At centre (mm)	At 2/3L (mm)	Remarks
0	0	0	0	-
5	0	0	0	-
10	0	0	0	-
15	0	0	0	-
20	0	0	0	-
25	0	0	0	-
30	0	0	0	-
35	0	0.015	0	crack detected
40	0.02	0.025	0.02	-
45	0.025	0.03	0.0225	-
50	0.035	0.045	0.035	failure due to shear

CONCLUSIONS

The following conclusions are made:

For 0.5% volume fraction of AFRC beams there has been increase in strength and reduction in crack width and deflection (serviceability limits) when compared to the reference sample.

Strength parameter of AFRC beam with 1% asbestos fibre (sample 4) proved to be highest of all the samples (3, 5, 6 & reference). Again the yield load for this particular sample was found to be more than rest of the samples. Deflection and crack width (serviceability limits) for this beam were minimum of all samples (except for AFRC beam with 0.5% asbestos fibre at yield point).

For AFRC beam with 1.5% asbestos fibre (sample 5) has its strength compromised by 8% compared to reference sample. But deflection and crack width were considerably reduced which implies the effect of asbestos fibre in reducing the crack and deflection in beams.

For AFRC beam with 2% asbestos fibre (sample 6) has its strength considerably reduced by 47.36%. Still deflection and crack width of this sample are considerably reduced even when the strength is compromised.

It was observed that there is reduction in crack width and deflection with increase in the volume fraction of asbestos fibres when compared to control specimen. Hence the asbestos fibres act as crack arrestors. But with increase in the % age of asbestos beyond the optimum level (1% in this study) strength of the beam is considerably compromised.

It is concluded from the comparison of samples that %age of asbestos fibre of 0.5-1% satisfy all the requirements concerned with this study i.e. maximum increase in the strength of beam, minimum deflection and crack width corresponding to a particular load and maximum ductility ratio.

As per IS 5748 – 1969 of asbestos fibre which specifies the suitable length of asbestos fibre to 20mm but doesn't specify what optimum volume percentage of asbestos should be used in structural members. This project specifies the volume percentage of asbestos fibre of 0.5% - 1% should be used to increase the serviceability of flexural member without compromising its safety.

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