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ANALYTICAL AND EXPERIMENTAL STUDY OF REINFORCED FOAM CONCRETE WITH STEEL FIBRE

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Abstract – *The effect of foam concrete when mixed with steel fibre in reinforced beam is studied analytically and experimentally by load deflection behaviour. A total of 3 beams are casted one for conventional concrete mix- - 1, another one for foam concrete mix – 2 and final one for foam concrete with steel fibre mix – 3. Quarry dust is used instead of sand in foam concrete mix. Steel fibre is added in 1% in mix - 3. The beam dimensions are 1200 mm length x 230 mm wide x 230 mm deep with reinforcement 2-Y12 @ top and bottom with 2L - Y8 @ 200 mm c/c as stirrups. Load - Deflection behaviour of the beam is found by testing the beams. The tests are carried on a loading frame and the load is transferred onto the beam by using a hydraulic jack which distributes it into the beam into two-point loads attached onto the head of the jack. From the results, it is found that the foam concrete gives better results when steel fibre is used. The deflection curve of foam concrete with steel fibre is similar to conventional concrete.*

Key Words: **Foam concrete, Conventional concrete, Cement, Steel fibre, Load Deflection behaviour, Abaqus.**

1. INTRODUCTION

Foam concrete is being used widely in construction field due to its light weight property which helps in reduction of self-weight of the structure. The preparation of foam concrete is a simple process. The generated foam fills up the voids in concrete up to 20% of entrapped air. In foam concrete usage of coarse aggregate is eliminated which results in light weight. Due to more usage of conventional concrete we need to look after an alternate way. Normally fine aggregate used is sand for foam concrete due to shortage of sand we have taken quarry dust. From literature studies, foam concrete gives better results when there is increase in density and also increase in period of time. Thus, we have assumed the density of foam concrete as 1500 Kg/m^3 and maintained same density when steel fibre is also added. This is an analytical and experimental study on how the behaviour of foam concrete varied when steel fibre is added and compared with conventional concrete too.

2. MATERIALS

2.1 Cement

Ordinary Portland cement (OPC) of 53 grade conforming to IS 1226: 1978 is used for this study. The properties of cement are tabulated in Table 1.

Table 1: Properties of cement

S. No	Description	Value
1.	Initial setting time	30 min
2.	Final setting time	600 min
3.	Standard consistency	34 %
4.	Specific gravity	3.15

2.2 Fine Aggregate – Sand

Sand conforming to IS 383: 1987 and passing through IS sieve of size 600 microns and specific gravity of sand 2.46 were used.

2.3 Fine Aggregate – Quarry Dust

Quarry dust is obtained in the process of crushing rocks for coarse aggregates in which the remaining residue. It is also used in conventional concrete instead of sand. Quarry dust conforming to IS 383: 1987 and passing through IS sieve of size 600 microns and specific gravity of sand 2.84 were used.

2.4 Coarse Aggregate

Coarse aggregate size 20 mm and crushed angular shaped conforming to IS 383: 1987 and aggregates retained in 4.75 mm IS sieve and specific gravity of sand 2.84 were used. The specific gravity of 20 mm aggregate used is 2.73.

2.5 Water

Potable water in site is used for casting specimens which has a pH value of 7.

2.6 Foaming Agent

Foaming agent is in the form of liquid that generates the foam when blended with water at high speed. There are two types of foaming agent. They are

- Synthetic based – made from chemicals suitable for densities of 1000 kg/m3 and above.
- Protein based – made from animal fat suitable for densities from 400 kg/m3 to 1600 kg/m3.

For this experimental study synthetic based Foaming agent – DewFoam LW was used. Foams from synthetic based have a specific gravity of 1.03. The recommended dosage is 20 ml per litre of water.

2.7 Steel Fibre

Steel fibre is used to increase the resistance of concrete. For this experimental study hooked – end type is used with whose diameter is 1 mm, length is 50 mm and having aspect ratio as 50.

3. MIX PROPORTION

3.1 Conventional Concrete

In this study for conventional concrete - M20 as per IS: 10262 – 2019. From the properties arrived from the tests the concrete mix has to be designed for the target mean strength, which is higher than the characteristic strength. The mix proportioning for M20 is as follows. (Units are in Kg/m^3)

Table 2: Mix Proportion

Cement	Fine aggregate	Coarse aggregate	Water
359	675	1171	197
1	1.88	3.26	0.55

3.2 Foam Concrete

In this study, foam concrete mix proportion is obtained from previous literatures as there is no standard for foam concrete. The assumed target density is 1500 Kg/m^3.

Target Density = Cement content + Fine aggregate
= C + 0.5C + F
Cement content = 450 Kg/m^3
Fine aggregate = 900 Kg/m^3
Water = 225 Kg/m^3 (0.5 x 450)
Density = 450 + 900 + 225 = 1575 Kg/m^3
V (m^3 of concrete) = V (foam) + V (cement) + V (water) + V (F.A)

$1\ m^3$ = Vf + (450 / (3.15 x 1000)) + (225 / (1 x 1000)) + (1000 / (2.84 x 1000))
$1\ m^3$ = Vf + 0.1428 + 0.225 + 0.35
$1\ m^3$ = Vf + 0.7178
Vf = $0.2822\ m^3$

- In addition to the above, 1% steel fibre is used for foam concrete with steel fibre mix – 3.

4. TESTS AND RESULTS

4.1 Water Absorption Test

Water absorption test is done only for Foam concrete specimens. The water absorption test is to check the amount of water being absorbed in the surface. The specimens (3 nos) were kept in water for one day and weighed (M2) then they kept in a ventilated oven for one hour and weighed (M1).

% Of water absorption = ((M2 – M1) / M1) x 100

The water absorbed percentage by foam concrete with steel fibre mix - 3 is slightly more than the foam concrete mix - 2. But the water absorbed percentage by both mixes is less than 20 percent by weight up to class 12.5 and 15 as per IS 1077: 1992, clause 7.2. The water absorption percentage values were given in Table 3 and variations in values are shown in Chart 1.

Table 3: Percentage of Water Absorption

Specimens		**Mix – 2**	**Water Absorption %**	**Mix – 3**	**Water Absorption %**
-		**Weight (Kg)**	**((M2 - M1) / M1) x 100**	**Weight (Kg)**	**((M2 - M1) / M1) x 100**
Specimen - 1	M1 – Dry	5.18	5.41%	5.2	5.57%
	M2 – Wet	5.46		5.49	
Specimen - 2	M1 – Dry	5.23	5.35%	5.13	5.65%
	M2 – Wet	5.51		5.42	
Specimen - 3	M1 – Dry	5.32	5.64%	5.02	5.77%
	M2 – Wet	5.62		5.31	
Average			5.47%	5.66%	

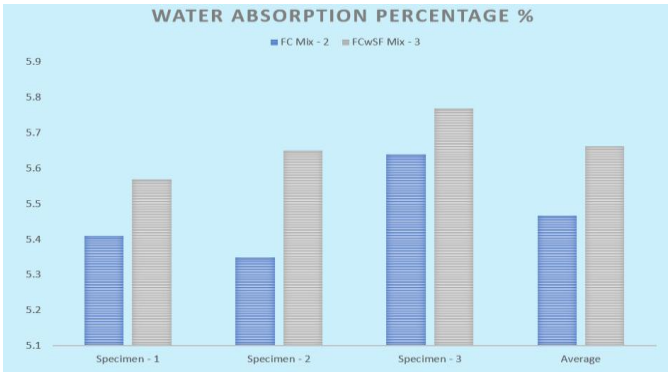

Chart - 1: Percentage of Water Absorption

4.2 Compressive Strength Test

Compressive strength is the ability of the element to convey the loads on its surface with no deflection or cracking. A material under pressure will in general lessen the size, while in strain, estimate prolongs. Compressive strength formula for any material is the heap connected at the purpose of inability to the cross-section area of the face on which load was connected.

Compressive Strength = Load (N) / Cross-sectional Area (mm^2)

The compressive strength of cubes at an age of 7th and 28th days of all cubes for different mixes has been observed and results has been arrived. From the obtained results, the compressive strength of conventional concrete is more than other foam concrete mixes. Also, the foam concrete with steel fibre mix - 3 is higher than the foam concrete mix – 2. From the comparison in graph, we see that the strength gained between 7th and 28th days of foam concrete mixes shows that the strength is increasing gradually and not as conventional concrete. The compressive strength values were given in Table 4 and variations in values are shown in Chart 2.

Fig - 1: Compressive Strength on Cube Specimen

Table 4: Compressive Strength Test of Cubes

Mix Name	Specimens	7th Day	Average	28th Day	Average
-	-	N/mm^2	N/mm^2	N/mm^2	N/mm^2
Mix 1 - Conventional Concrete	Specimen - 1	13.69	13.88	21.22	21.48
	Specimen - 2	13.43		20.87	
	Specimen - 3	14.53		22.35	
Mix 2 - Foam Concrete	Specimen - 1	7.93	8.1	12.36	12.43
	Specimen - 2	8.41		13.05	
	Specimen - 3	7.83		11.89	
Mix 3 - Foam Concrete with Steel Fibre	Specimen - 1	9.18	9.5	14.25	14.57
	Specimen - 2	9.23		13.97	
	Specimen - 3	10.09		15.48	

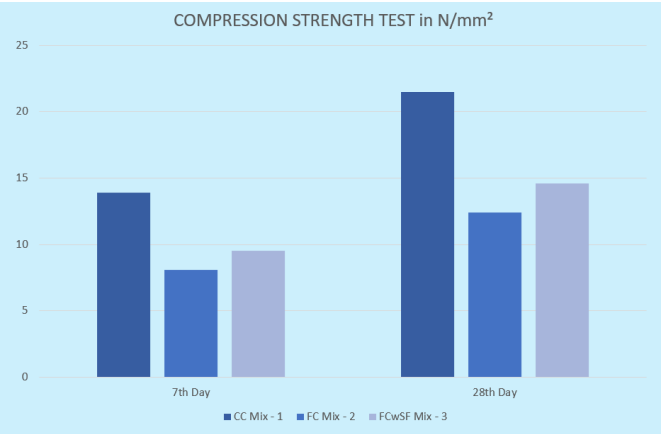

Chart - 2: Compressive Strength of Cubes

4.3 Split Tensile Strength Test

Split Tensile strength of concrete is one of the fundamental and critical properties which significantly influence the degree and size of splitting in structures. In addition, the concrete is extremely failed in tension because of its weak nature. Subsequently, it isn't required to oppose the immediate tension. In this way, concrete creates splits when tensile powers surpass its tensile strength.

$$T = 2P / \pi LD$$

The tensile strength of cylinders at an age of 28th days of all cylinders for different mixes has been observed and results

has been arrived. From the obtained results, the spit tensile strength of conventional concrete is more than other foam concrete mixes. Also, the foam concrete with steel fibre mix - 3 is slightly more than the foam concrete mix – 2. The split tensile strength values were calculated and tabulated in Table 5 and variations in values are shown in Chart 3.

Fig – 2: Split Tensile Strength on Cylinder Specimen

Table 5: Split Tensile Strength Test of Cylinders

Mix Name	Specimens	28th Day	Average
-	-	N/mm²	N/mm²
Mix 1 - Conventional Concrete	Specimen - 1	3.14	3.23
	Specimen - 2	3.2	
	Specimen - 3	3.35	
Mix 2 - Foam Concrete	Specimen - 1	2.05	2.03
	Specimen - 2	2.13	
	Specimen - 3	1.92	
Mix 3 - Foam Concrete with Steel Fibre	Specimen - 1	2.03	2.21
	Specimen - 2	2.36	
	Specimen - 3	2.23	

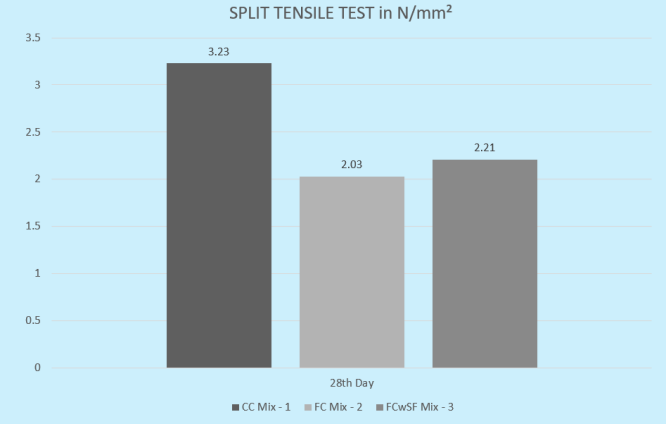

Chart - 3: Split Tensile Strength of Cylinders

4.4 Deflection Behaviour of Beams – Experimental

The beams are loaded onto the loading frame. Three dial gauges are loaded in three points. One gauge is placed at the center and the other are placed at the left exactly below the first point load (L/3) and the remaining one gauge is placed at the right exactly below the second point load (L/3). The span between the two dial gauges is 40 cm. A hydraulic jack with a capacity of 500 kN is used for loading the slab.

The load - deflection behaviour test is done at an age of 28th days of all beams for different mixes has been observed and results has been arrived. From the graphs plotted above, the conventional concrete mix – 1 withstands more load followed by foam concrete mix – 3 and then foam concrete with steel fibre mix – 2. Then the deflection of foam concrete mix – 2 is more than compared to other conventional and foam concrete with steel fibre mixes. The deflection behaviour values are shown in Chart 4, 5 & 6.

Fig – 3: Test Setup of Beam in Loading Frame for Deflection Behaviour

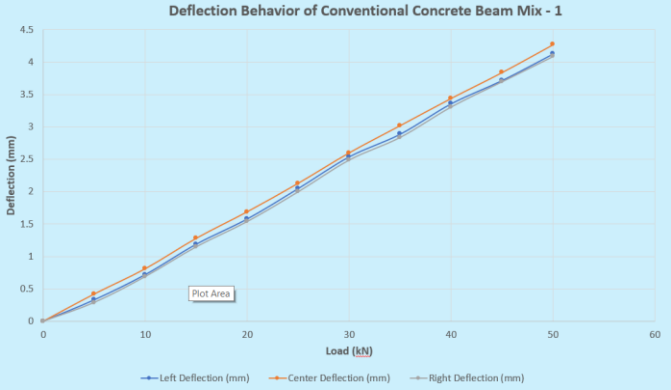

Chart - 4: Deflection Behaviour of Conventional Concrete Beam – Mix – 1

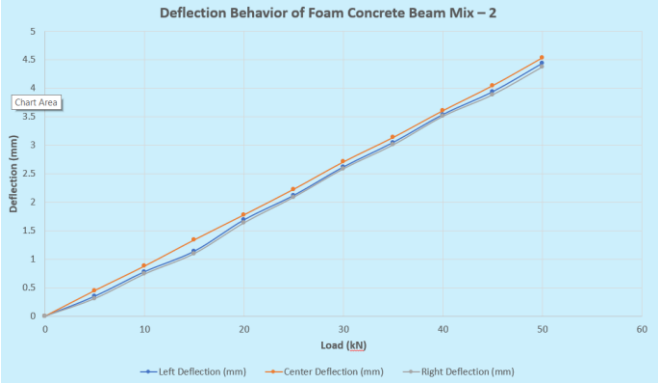

Chart - 5: Deflection Behaviour of Foam Concrete Beam – Mix – 2

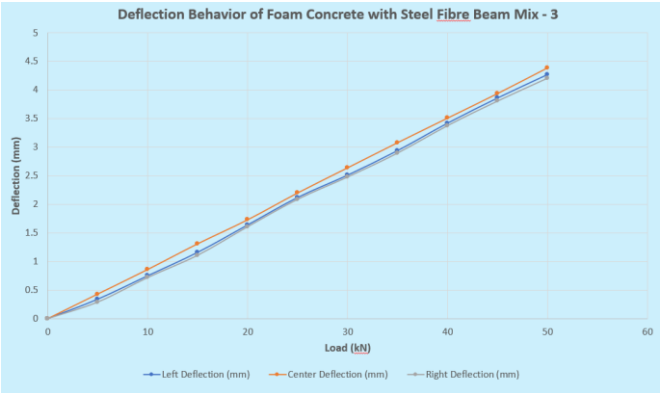

Chart - 6: Deflection Behaviour of Foam Concrete with Steel Fibre Beam – Mix – 3

Comparison:

The graph is plotted between the deflection at centre values of all mixes with respective loads. The foam concrete with steel fibre mix - 3 values are slightly less than conventional concrete mix – 1 in failure and deflection. The foam concrete mix – 2 is deflected more than compared to other mixes and failure load is less. The deflection behaviour values were compared with all mix values are compared in Chart 7.

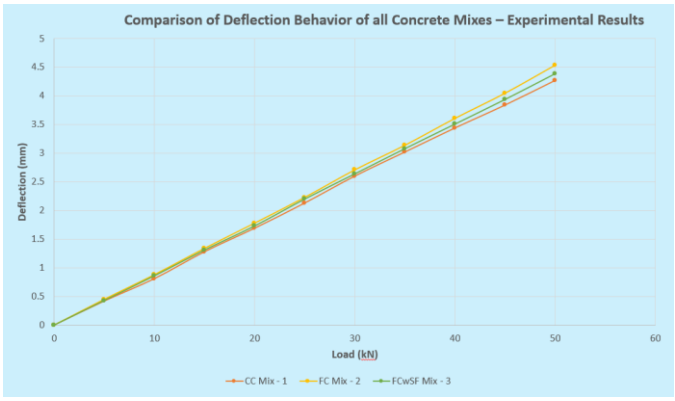

Chart - 7: Comparison of Deflection Behaviour of all Concrete Mixes – Experimental Results

4.5 Deflection Behaviour of Beams – Analytical

The graph is plotted between the deflection values obtained from abaqus software for all mixes with respective loads. From the graph, we found that the foam concrete mix – 2 gets more deflected when compared to other mixes with same loads. The deflection of the conventional concrete mix – 1 and foam concrete mix with steel fibre mix – 3 is almost similar. The load – deflection curve increases gradually is visible in the graph. The deflection behaviour of all concrete mixes in Abaqus are compared in Chart 8.

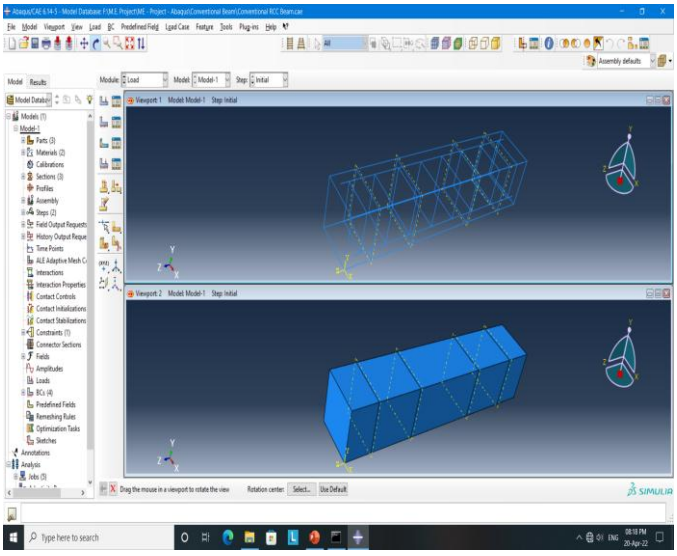

Fig - 4: Beam Model in Abaqus Software

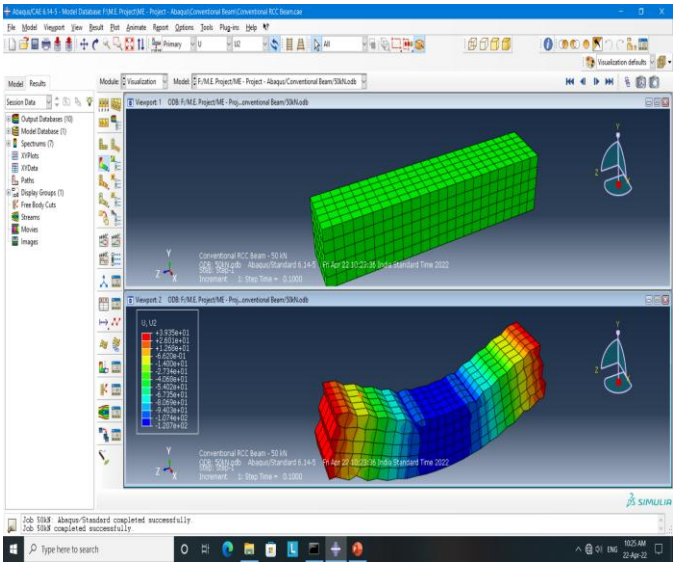

Fig - 5: Deflected Beam Before and After Load Application in Abaqus

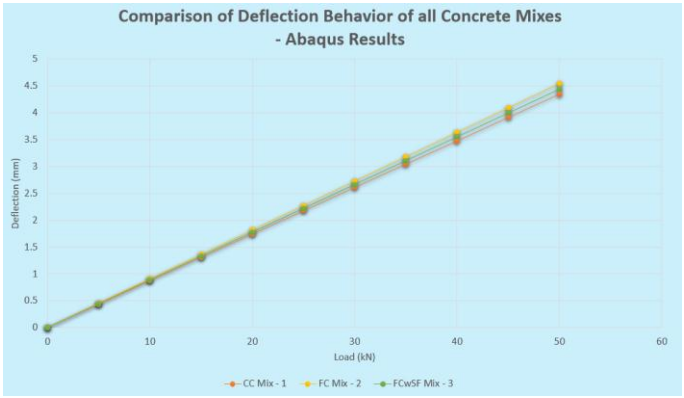

Chart - 8: Comparison of Deflection Behaviour of all Concrete Mixes – Analytical Results - Abaqus

Comparison:

The graph is plotted between the load - deflection values arrived obtained from experimental and analytical - Abaqus software for all mixes. From the graph, we found that the deflection of the experimental results is slightly lower than the software results. The load – deflection curve is similar when compared with experimental and analysis result values. The deflection behaviour values were compared with all mixes as shown in Chart 9.

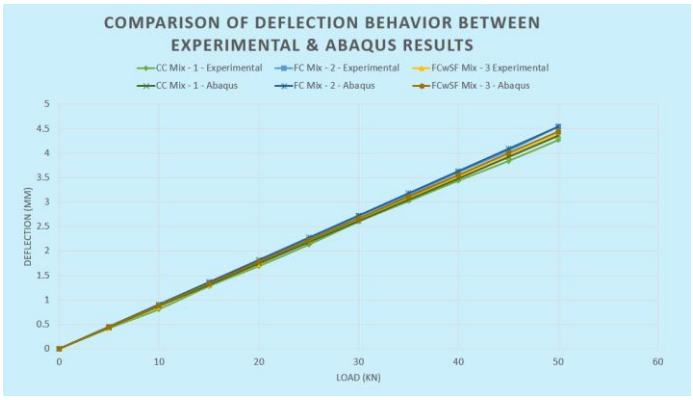

Chart - 9: Comparison of Deflection Behaviour of all Concrete Mixes – Experimental & Analytical Results

5. CONCLUSION

From the results,

- Based on the results, the maximum water absorption of foam concrete specimens is well below the allowable limit of 20%.
- Based on the results, the compressive strength of foam concrete increased by 17.22% when steel fibre is added in the foam concrete mix.
- Based on the results, the split tensile strength of foam concrete increased by 8.86% when steel fibre is added in foam concrete mix.
- Based on the experimental results of beams, the load deflection behaviour shows that the failure load of foam concrete mix – 2 is less when compared to foam concrete with steel fibre mix – 3 and conventional concrete mix -1 and mix -2 deflects more than other mixes.
- Based on the analytical results of beams, the deflection of foam concrete mix – 2 is slightly higher than the other mixes same as the experimental values.
- Based on the comparison of experimental and analytical results, the load deflection values of the foam concrete mix – 2 deflects more followed by foam concrete with steel fibre mix – 3 and then finally conventional concrete mix – 1.
- Maximum deflection of the beam was at the centre. Both conventional and foam concrete beams start to fail at centre of beam.
- Thus, adding steel fibre in foam concrete gives better results. Also foam concrete gains strength in time.

The density of the conventional concrete is more whereas the foam concrete density is less when added steel fibre we can get results similar to conventional concrete and from literature studies we conclude that foam concrete strength increases in time.

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