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Experimental Investigation on Behaviour of RC Slabs Under Static Load

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Abstract: *The main objective of this investigation is to study the static behavior of RC slabs with different composite materials like steel and synthetic fibres, steel wire mesh, lathe scrap fiber, SBR latex. This includes the study of flexural behavior of RC slabs with varying percentages of conventional steel reinforcement, with steel wire mesh woven to the steel reinforcement and with SBR Latex (10%) subject to static loading. In this study an investigation is carried out on nine simply supported slabs (RC slabs, RC + Mesh slabs, RC + SBR slabs) with dimensions 1000 mm X 1000 mm X 60 mm are analyzed to investigate the flexural behavior of reinforced concrete slabs with and without SBR LATEX AND CHICKEN MESH. RC slabs with above mentioned composite materials have been tested up to failure with varying reinforcement ratio, the rebar diameter and the rebar spacing. Cracking and deflection of the reinforced concrete slabs are analyzed experimentally. The comparison between loads, deflections and crack configurations of reinforced slabs with Chicken Mesh and SBR Latex and those of conventional steel reinforced concrete slabs is carried out and the different behaviour is analyzed and discussed. Similar slabs are also tested to study the behaviour under impact loading, in this paper only static study is presented*

Keywords*: RCC, Chicken Mesh, SBR LATEX, Static Test, Load –Deflection curves, etc.*

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I. Introduction

A number of studies have been conducted in the past on the behavior of reinforced concrete panels subjected to static and dynamic loads. These include on using different types of wall materials, different arrangement of reinforcements, different quantity of the reinforcements, mixing steel and synthetic fibres in varying quantities, providing steel plates, providing steel wire meshes, mixing different admixtures like SBR Latex, etc. In contrast to ordinary cement mortar and concrete which are apt to cause bleeding and segregation, the resistance of latex modified mortar & concrete to bleeding and segregation is excellent in spite of their larger flow ability characteristics. Setting time of latex modified mortar & concrete is delayed in some extent. In concrete the tensile & flexural strengths are improved over a normal concrete but in compressive strength there is no improvement. Steel wire mesh commercially known as chicken mesh has been extensively used with concrete especially in repairs and retrofitting applications. In its role as a thin reinforced concrete product and as a animated cement-based composite, ferrocement can be used in numerous applications. A significant enhancement in stiffness, strength, and durability can be achieved under compression when concrete is confined with various degree of Ferro-cement confinement. Compressive strength enhancement of the order of 20 to 30% was achieved by Ferro-cement confinement. The main objective of this study is to investigate the static performance of RC slabs with different composite materials like steel and synthetic fibres, steel wire mesh, lathe scrap fibre, SBR latex etc. this paper entrusted with the study of flexural behavior of RC slabs with varying percentages of conventional steel reinforcement, with steel wire mesh woven to the steel reinforcement and with SBR Latex subject to static loading.

II. Literature Review

Investigation on the behavior of Slabs modified with SBR LATEX and fiber reinforced concrete has in the last decade become a very important research field. In terms of experimental application several studies were performed to study the behavior of SBR LATEX modified slabs and analyzed the various parameters influencing their behavior.

Kurihashi, Y., et.al. Have conducted static and impact loading tests for RC beams mixed with PVA short-fiber varying fiber volume mixing ratio *Vf*. From those researches, it has been confirmed that static and impact load-carrying capacity of the RC beams can be upgraded due to bridge effects of the short fiber.

M.Zineddin et. al., studied the dynamic behavior of structural concrete slabs under impact loading to improve the state of the art of protective design. This study investigated the effects of different types of slab reinforcements and the applied impact loads on the dynamic response and behavior of reinforced concrete slabs.
Yaghoob Farnam et.al., Fiber-reinforced concrete (FRC) has been used in structural applications in order to enhance the structural performance under dynamic loading and reduce cracking and spalling phenomena by increasing toughness, ductility, and tensile strength of the concrete.
H. Sudarshan Rao et.al., reported the behaviour of slurry infiltrated fibrous concrete (SIFCON) two-way slabs in punching shear. SIFCON slabs are cast with 8, 10 and 12% fibre volume fr action and for comparison, fibre reinforced concrete (FRC) with 2% fibre volume fraction and reinforced cement concrete (RCC) slabs are cast and tested. The results of the experimentation show that the SIFCON slabs with 12% fibre volume fraction exhibits excellent performance in punching shear among other slabs.

III. Materials

Cement (C): Ordinary Portland cement of brand Birla super of grade 53with specific gravity of 3.02 and fineness of 2.57% conforming to 12269:1987 was used.
Fine Aggregate (FA): locally available river sand was used as fine aggregate conforming to zone II. The specific gravity was 2.65 and bulk density was 1736 kg/$m^{3.}$
Coarse Aggregate (CA): Crushed aggregate available from local sources has been used. To obtain a reasonably good grading, 50% of the aggregate passing through 20 mm IS sieve and retained on 12.5 mm IS sieve and 50% of the aggregate passing through 12.5mm IS sieve and retained on 10 mm IS sieve was used in preparation of fibre reinforced concrete and plain concrete slab specimens. The average specific gravity of the coarse aggregate was 2.63 and bulk density 1629 kg/$m^{3.}$
Water (W): Potable water was used for the preparation of the specimens and for curing purpose.
SBR LATEX : A Milky White colour SBR LATEX having density 1 kg / liter with Solid Content of 42 % and PH range of 10 – 11 is used. The shelf life: 1 year in original sealed condition.

3.1 Reinforcement Steel:

High Yield Strength Deformed (HYSD) bars of 8, 10, 12 mm diameter is used as a main bar and 8 mm diameter bar is used as distribution bars. Tension test is performed on this material as per IS code specifications, to determine the Yield strength, Ultimate strength, Stress, Breaking load and the % of Elongation of the rod revealed that the material confines to IS Specifications. The properties of the rod and reinforcement

Table 1: Physical Properties of Steel Bars (IS: 1786-2008)

Sl .No.	Diameter of bars	Yield strength (N/mm^2)	Ultimate strength	Percentage Elongation (%)
1	12 mm	550	610	16.2
2	10 mm	445.55	509.2	15.5
3	8 mm	559.5	634.13	20.3

IV. Experimental Programme

The slabs having dimensions (1000X1000X60mm) were cast using M 20 grade concrete. The mix proportion of material comes out to be 1:1.72:2.75.
Nine reinforced concrete slabs have been tested up to failure. The slabs are named as below:

RCC slabs	focused on the flexural behavior of simply Supported RCC slabs with conventional reinforcement
RCC + Mesh slabs	Flexural behavior of simply Supported RC slabs with Chicken mesh
RCC + SBR slabs	flexural behavior of simply supported Slabs with 10% SBR Latex

Table 2: The Details of Slab Reinforcements and Their Combinations

Sl no	Slabs	D mm	Rebars	Percentage (pt)	MESH / SBR LATEX
1	RCC-0.3	60	#8@135c/c	0.33	-
2	RCC-0.5	60	#10@135c/c	0.50	-

3	RCC-0.7	60	#12@135c/c	0.70	-
4	RCC+MESH-0.3	60	#8@135c/c	0.33	MESH
5	RCC+MESH-0.5	60	#10@135c/c	0.50	MESH
6	RCC+MESH-0.7	60	#12@135c/c	0.70	MESH
7	RCC+SBR -0.3	60	#8@135c/c	0.33	SBR
8	RCC+SBR-0.5	60	#10@135c/c	0.50	SBR
9	RCC+SBR-0.7	60	#12@135c/c	0.70	SBR

Table 3: Mix Proportions

Sl. No	Series	Concrete Grade	Mix proportion	W/C Ratio	Reinforcement	Admixture
1	RCC-0.3	M20	1 : 1.72 : 2.75	0.5	0.30%	-
2	RCC-0.5	M20	1 : 1.72 : 2.75	0.5	0.50%	-
3	RCC-0.7	M20	1 : 1.72 : 2.75	0.5	0.70%	
4	RCC+MESH	M20	1 : 1.72 : 2.75	0.5	0.3% + Chicken mesh	-
5	RCC+MESH	M20	1 : 1.72 : 2.75	0.5	0.5% +Chicken mesh	-
6	RCC+MESH	M20	1 : 1.72 : 2.75	0.5	0.7% +Chicken mesh	-
7	RCC+SBR	M20	1 : 1.72 : 2.75	0.5	0.30%	10% SBR Latex
8	RCC+SBR	M20	1 : 1.72 : 2.75	0.5	0.50%	10% SBR Latex
9	RCC+SBR	M20	1 : 1.72 : 2.75	0.5	0.70%	10% SBR Latex

V. Casting of Test Specimens

Wooden moulds of size 1000X1000X60 mm clear were prepared using plywood boards. The moulds were coated initially with oil so as to enable easy removal of the moulds. The moulds were placed on an even surface.

In case of RCC+MESH slabs , 8 layers of chicken mesh was placed on the reinforcing steel mat and it was tied well to the reinforcing bars using the binding wires. In case of RCC+SBR slabs, the required amount of the SBR latex was mixed with the fresh concrete while mixing the concrete. The specimen thus cast was allowed to set for 24 hours. The plywood moulds were then removed. Curing was done by ponding as well as using wet gunny bags for 28 days.

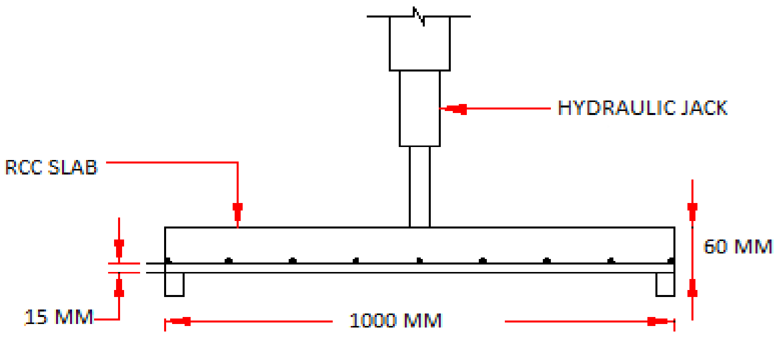

Fig. 1. Experimental Test Setup

Testing The Specimen

The slabs after curing for 28 days, were placed vertically for surface cleaning. Later white washing was done on the tension face for clear visibility of the cracks. The next day, the slabs were placed on the supports as shown in the figure 1. The slabs were simply supported with a bearing width 70mm on either side, with an effective span of 930mm. The slabs were placed in such a way that the loading jack is exactly at the centre of the slab. A dial gauge with a least count of 0.01mm was placed below the slab to measure the central deflection.
Loading was done using a man operated hydraulic jack of maximum capacity of 2000 kN and a least count of 10 kN. The load was applied gradually and the deflection was recorded at an interval of 20kN. The load at first crack was recorded for each of the slabs. The loading was continued further till ultimate failure of the slab. The load at failure and the corresponding deflection were recorded.

VI. Results And Discussions

Testing of hardened concrete place an important role in controlling and confirming the quality of cement concrete works. Systematic testing of raw materials, fresh concrete and hardened concrete are inseparable part of any quality control program for concrete which helps to achieve higher efficiency of the material used and greater assurance of the performance of concrete with regard to both strength and durability. One of the purpose of testing hardened concrete is to confirm that the concrete used at site has developed the require strength. As the hardening of concrete takes time one will not come to know the actual strength of concrete for some time. Tests are made by casting cubes or cylinders from the representative concrete or cores cut from the actual concrete.

6.1 Mechanical Properties of Concrete

Table 4: Mechanical Properties of concrete

Sl.No	Type of Test	**7 day strength (N/mm^2)**			**28 day strength (N/mm^2)**		
		Sl. No	Strength	Average Strength	Sl. No	Strength	Average Strength
1	Compressive strength	1	18.75	**18.17**	1	27.03	**26.60**
		2	17.44		2	26.60	
		3	18.31		3	26.16	
2	Split Tensile Strength	1	2.08	**2.13**	1	2.50	**2.54**
		2	2.22		2	2.64	
		3	2.08		3	2.50	
3	Flexural Strength	1	5.0	**4.87**	1	5.800	**5.80**
		2	5.2		2	6.000	
		3	4.4		3	5.600	

6.2 Load- Deflection Behaviour

The load v/s deflection curves for the various slabs tested are tabulated below:

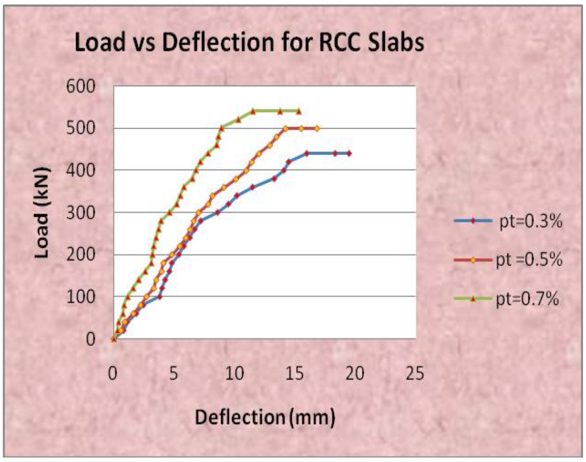

Fig . 2 Load v/s Deflection Curves for RCC Slabs Slabs with different p_t

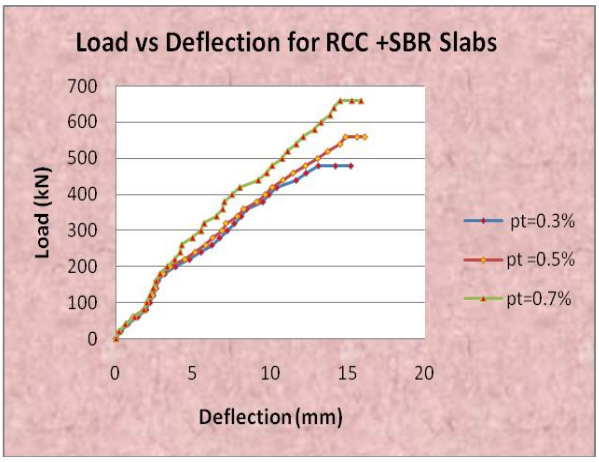

Fig . 3 Load v/s Deflection Curves for RCC+SBR Slabs with different p_t

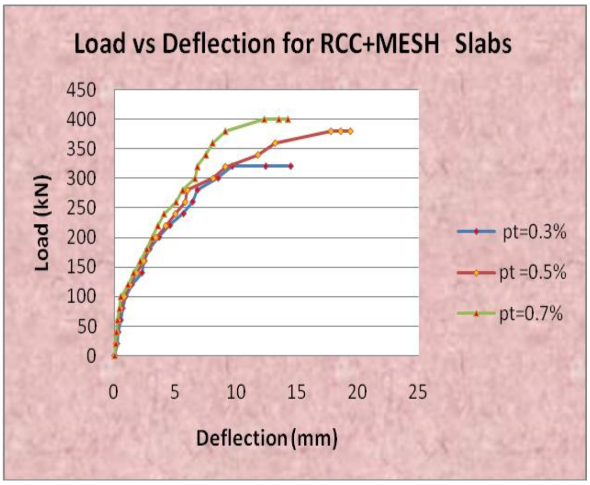

Fig. 3 Load v/s Deflection Curves for RCC+MESH Slabs with different p_t

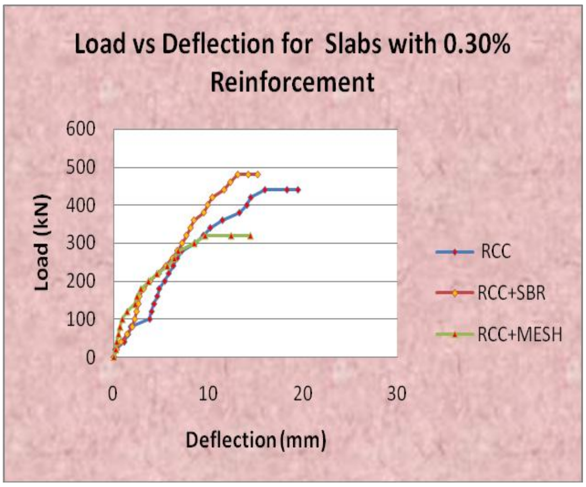

Fig. 5 Load v/s Deflection Curves for different slabs with 0.30% steel

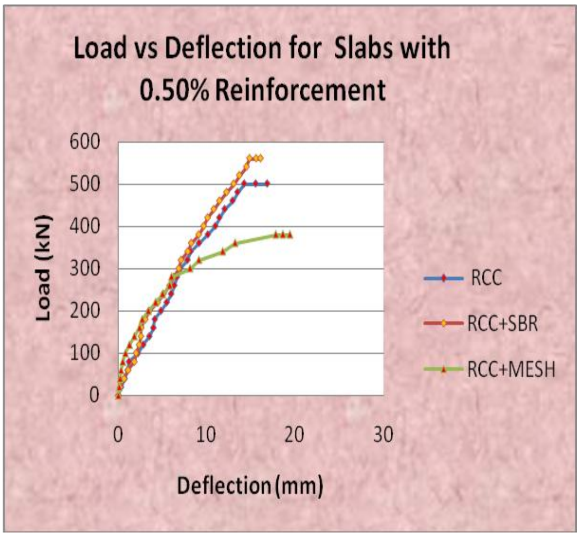

Fig. 6 Load v/s Deflection Curves for different slabs with 0.50% steel

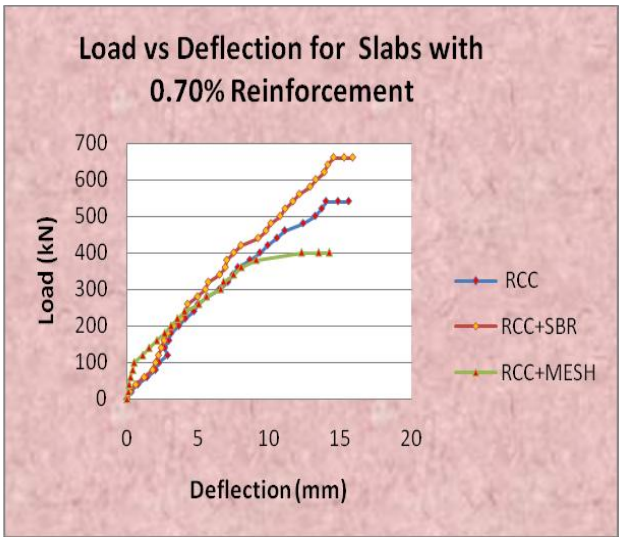

Fig. 7 Load v/s Deflection Curve for different slabs with 0.70% steel

Table: 5 Maximum Central Deflection at First Crack Load and at Ultimate Load

Slno	Nomenclature	First crack load kN	Max. central deflection at first crack load mm	Ultimate load kN	Max. central deflection at ultimate load mm
1	RCC-0.30%	240	5.65	440	18.35
2	RCC-0.50%	280	6.00	500	14.20
3	RCC-0.70%	320	6.80	540	11.50
4	RCC+MESH-0.30%	240	5.65	320	9.65
5	RCC+MESH-0.50%	280	6.00	380	17.8
6	RCC+MESH-0.70%	300	6.60	400	12.30
7	RCC+SBR -0.30%	280	6.70	480	13.10
8	RCC+SBR-0.50%	320	7.10	560	14.85
9	RCC+SBR-0.70%	340	6.50	660	14.50

6.2.1. First crack load:-

The first crack loads obtained for RCC, RCC+MESH and RCC + SBR LATEX slab specimens are presented in Table 5. From this table it can be observed that the slabs with increase in percentage of steel shows increase in first crack load. The first crack load was almost similar for the slabs with the same percentage of steel and with or without MESH. For example, for a reinforcement percentage of 0.30%, the first crack load was 240 kN for RCC slab and for RCC+MESH. Similarly for the slabs with 0.50% and 0.70% steel. However, the first crack load for RCC+SBR slabs was higher when compared to the other slabs. Among all the specimens the RCC+SBR slab with 0.70%steel showed the highest first crack load of 340 kN The percentage increase in the first crack load when compared to 0.30% and 0.5% is 25% and 12.5% respectively.

6.2.2. Ultimate load

The ultimate loads obtained for different RCC, RCC+MESH and RCC + SBR LATEX slab specimens are presented in Table 5. From the table, it can be observed that the maximum ultimate load of 660kN has been obtained for RCC 0.7%+SBR slab. When compared to the normal RCC slab with the same 0.7% steel, the ultimate load was increased by 22.22%. In the same manner, the ultimate load of RCC + SBR Slab with 0.30% steel showed an increase of 9% and with 0.50% steel showed an increase of 12% when compared to the normal RCC slabs.

As far as the slabs with RCC+MESH, the ultimate load carrying capacity has come down when compared to the normal RCC slabs. The ultimate load of RCC Slab with 0.30% steel was 440 kN where as the ultimate load for RCC + MESH Slab was 320kN. Similarly ,for 0.5% steel, the ultimate load for RCC Slab and RCC + MESH slab was 500kN and and 380 kN respectively and that for 0.70% steel it was 540kN and 400kN respectively. The decrease in load carrying capacity of the RCC+MESH Slabs is probably because of the reason that the layer of mesh tied to reinforcement mat creates separation of the concrete above and below the reinforcement mat because the coarse aggregates cannot pass through the mesh layers. As the monolithic action of concrete gets affected, the load carrying capacity of the RCC+MESH slabs have come down drastically.

6.3 Ductility Factor

Ductility factor may be defined, in general, as the ability of a structure to undergo inelastic deformation beyond the initial yield deformation with no decrease in the load resistance. The ductility of a member can be measured using Load-deflection response. The deformation may be strain / rotation / curvature/ deflection etc. The ratio of ultimate deformation at the first yield is defined as ductility factor. Generally for RCC flexural member like beams, slabs, the allowable ductility factor in terms of deflection especially for RCC slabs is 1.5.
Ductility factor is an important parameter consider in the design of structures subjected to large deformation. Generally, it is defined in the case of member subjected to flexure as:

$$\text{Ductility Factor} = \frac{\text{Ultimate deformation}}{\text{Deformation at first yield}} = \frac{\Delta_u}{\Delta_y}$$

An attempt was made to obtain the ductility factor for specimens tested in this study. The Values of displacement ductility factor were computed from Graph for each specimen and values are given in Table .6

Table: 6 Displacement Ductility Factor

Type of Slab	Ultimate Deformation Δ_u (mm)	Deflection at First Yield Δ_y (mm)	Ductility Factor Δ_u/Δ_y
RCC-0.30%	18.35	9.50	1.93
RCC-0.50%	14.20	10.10	1.40
RCC-0.70%	11.50	6.80	1.69

RCC+MESH-0.30%	9.65	5.65	1.71
RCC+MESH-0.50%	17.8	6.00	2.96
RCC+MESH-0.70%	12.30	6.60	1.86
RCC+SBR -0.30%	13.10	8.45	1.55
RCC+SBR-0.50%	14.85	10.10	1.47
RCC+SBR-0.70%	14.50	10.75	1.35

VII. Conclusions

Based on the limited study carried out the following conclusions have been drawn, and similar slabs are also tested to study the behaviour under impact loading, in this paper only static study is presented ;

1. The load at first crack increase with the increase in the percentage of steel reinforcement.
2. The first crack load with same percentage of steel reinforcement for RCC Slabs and RCC+MESH Slabs were nearly the same. The first crack load for 0.30% of steel were 240 kN for both normal RCC and RCC+ MESH Slabs. Similarly for 0.50% of steel reinforcement the first crack load was 280kN and the same for 0.70% was around 320kN for RCC and RCC+MESH Slabs. This indicates that the mesh layer had little effect until the first crack load. The first crack load for RCC+SBR Slabs was higher when compared to the normal RCC slabs.
3. The ultimate load increased with increase in percentage of steel reinforcement. The RCC+SBR Slabs showed higher ultimate load when compared to the normal RCC Slabs. The ultimate load for 0.30%, 0.50%, and 0.70% for normal RCC were 440kN, 500kN and 540kN and the same for RCC+MESH Slabs were 480kN, 560kN and 660kN respectively.
4. Hence the addition of SBR Latex has improved the load carrying capacity of slabs both at first crack and at ultimate loads.
5. As far as the RCC+MESH slabs are concerned, the first crack load has remained the same as that of the normal RCC slabs for all 0.30%, 0.50% and 0.70% of steel.
6. Where as the ultimate load has come down for all the RCC+MESH Slabs when compared to the normal RCC Slabs. The ultimate loads for RCC+MESH Slabs are 320kN, 380kN, 400kN for 0.30%, 0.50% and 0.70% of steel reinforcement as against 440kN, 500kN and 540kN for normal RCC Slabs.
7. The decrease in load carrying capacity of the RCC+MESH Slabs is probably because of the reason that the layer of mesh tied to reinforcement mat creates separation of the concrete above and below the reinforcement mat because the coarse aggregates can not pass through the mesh layers. As the monolithic action of concrete gets affected.
8. Generally moment curvature ductility factor for RCC structures is around 5, from theoretical calculation ductility factor in terms of moment curvature for 0.3%, 0.5% and 0.7% of reinforcement for RC slabs is 8.40, 4.637 and 3.097, therefore as the percentage of steel increases the ductility factor decreases, it means the slab moves from ductile to brittle nature. From these results 0.35% to 0.45% of steel is sufficient for RCC slabs.
9. The cracks propagate radially from the point of application of load for normal RCC slabs and the RCC+SBR Slabs. Where as the cracks propagate circumferentially along with the radial cracks from the point of application of load in case of slabs with MESH.

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