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Structural Behaviour Of The Fibre Reinforced Concrete Beams

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Abstract

The developments of new materials and production methods have increased within the field of construction. Using suitable fibres and additives in concrete to advance its performance is an important consideration in the construction industry with regard to structural aspects of concrete. Concrete is inherently a brittle material with highly weak post peak behaviour. When adding fibres in to the concrete these fibres act as secondary reinforcement in the concrete structures to restrain crack propagation. This paper presents the study on the effect of different types of fibre on the structural behaviour of Concrete Beam. The modulus of elasticity of concrete with different type of fibres plays an important role in behaviour of concrete. The fibres used are Steel fibre, Polypropylene Fibre, Polyolefin Fibre, Poly-vinyl Alcohol (PVA 150 and PVA 240) with different percentages of fibres of 0.5% and 1% of all fibres. ANSYS software has been used to analyse and study the behaviour of concrete. The aim of the work is to determine the ultimate strength of beam and to determine actual load deflection curve and crack pattern for ultimate strength of FRC Beam.

Keywords: *Crack Pattern, Load-deflection curve, Modulus of Elasticity, Polypropylene Fibre, Polyolefin Fibre, Poly-vinyl Alcohol, Steel fibre*

Introduction:

In last few decades, the construction materials and technologies have evolved advanced rapidly, have helped civil engineers to achieve great safety, efficiency, economy and functionality of structure built for the need of society. In construction, concrete is mostly used and widely equipped material worldwide. Concrete provides good strength in compression, but as the concrete is weak and brittle in tension and expected to crack tensile stress is applied. Cracking in concrete occur when the tensile stress in the concrete exceeds tensile strength of concrete,increase in tensile strength can achieved by using fibres in concrete.Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrityThese Structures must be checked for crack width and deflection criteria. Deflection in the structure when exceeds the limiting value it can affect the structure in efficiency or sometimes failure of the Structure

Objective:

The main and fundamental purpose of doing this project was to study about load-deflection behaviour and the yield pattern of Fiber Reinforced concrete Beam with simply supported condition. The objectives of the present investigation are quickly recorded as below:

1. To get load deflection curves of Fiber Reinforced Concrete Beams
2. To watch the cracking pattern of Fiber Reinforced Concrete Beams

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3. To compute the Ultimate load for the Beam and to contrast with Conventional Concrete Beam using ANSYS.

Properties:
The fibres used in the FRC Beam are high strength Steel Fibres, Polypropylene Fibre, Polyolefin Fibre, Polyvinyl Alcohol Fibre (PVA) 150 and 240 with different percentages of fibres (0%, 0.5%, and 1%). The dimensions of the beam is 150x150x700mm.

Table 1: Properties of Beams

Type of Fibre	Percentage of Fibres	Designation
Conventional Concrete	0%	Beam 1
Steel Fibre	0.5%	Beam 2
	1.0%	Beam 3
Polypropylene Fibre	0.5%	Beam 4
	1.0%	Beam 5
Polyolefin Fibre	0.5%	Beam 6
	1.0%	Beam 7
PVA 150	0.5%	Beam 8
	1.0%	Beam 9
PVA 240	0.5%	Beam 10
	1.0%	Beam 11

Designation	Compressive Strength (kN)	Split Tensile Strength (MPa)	Modulus of Elasticity (MPa)
Beam 1	37.3	3.43	31986.0
Beam 2	37.0	3.60	47245.8
Beam 3	39.1	4.72	49167.7
Beam 4	39.0	3.84	47230.0
Beam 5	45.0	4.12	28683.0
Beam 6	53.0	3.90	33159.0
Beam 7	52.0	4.32	29963.0
Beam 8	42.0	2.75	26250.0
Beam 9	45.0	4.32	32435.0
Beam 10	37.0	3.12	33516.0

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Beam 11	46.0	4.50	31234.0

Methodology:

For the analyses of present work, ANSYS 19.2 software has been used, ANSYS is commercially available Finite Element Method (FEM) Software.

Preprocessor:

On the step of preprocessor, the material properties, section properties, modeling and meshing work is completed.

Defining Element Type:

Preprocessor – Element Type – Add/Edit/Delete – Add – Solid – concrete 65 – OK

Add – Beam – 2 node 188 - OK

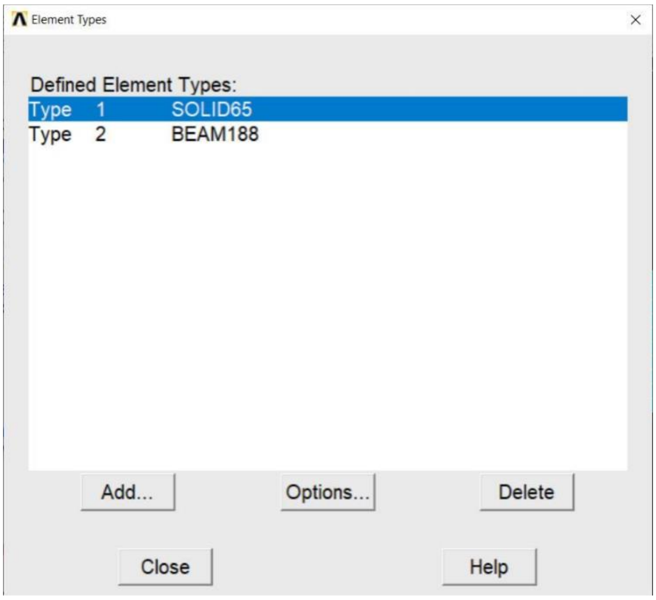

Figure 1: Defined Element Type

Material Properties:

This step consist of defining the properties of the model i.e. Elastic Modulus, Compressive Strength, etc., as shown in below figure.

Preprocessor – Material Props – Material Models

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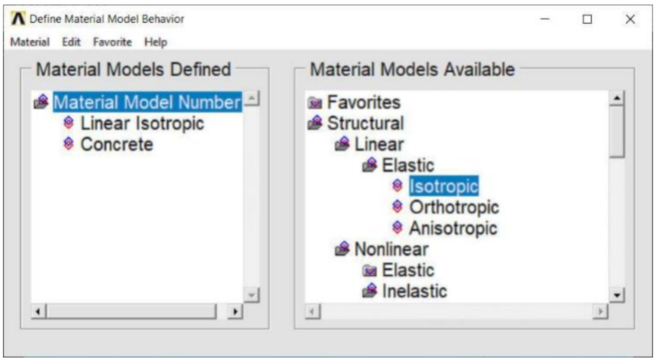

Figure 2: Define Material Model Behavior (Linear)

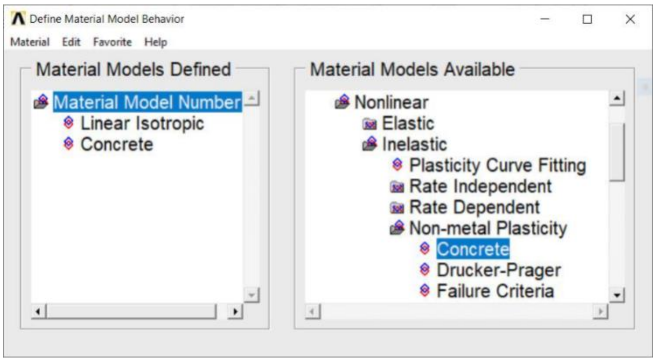

Figure 3: Define Material Model Behavior (Nonlinear)

Modeling:

This step consist of modeling and defining the section property of the model.

Preprocessor – Modeling – Create – Volume – Block – By Dimensions

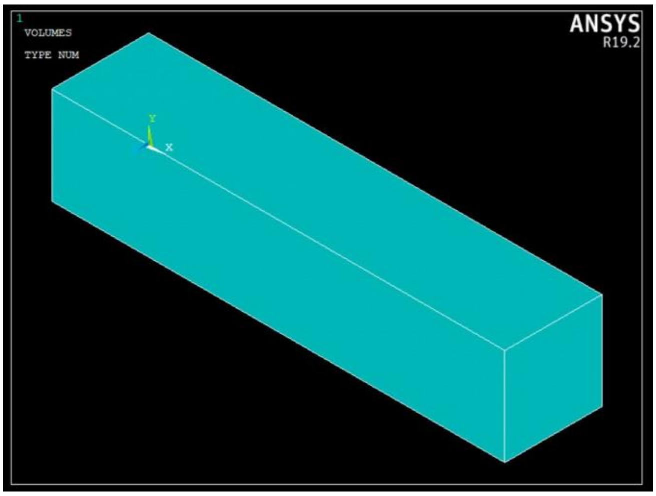

Figure 4: Model of Beam

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Meshing of Model:

Meshing as its name says dividing the model into smaller element for the accurate results of analyses. The meshing can be done based on requirement. In this analyses mapped mesh has been used, size of mesh is 15mm quadrilateral (square) size. When the meshing completed the model is divided in smaller elements, these elements will have individual nodes.

Preprocessor – Meshing – Mesh tool – Hex – Mapped – Mesh – OK

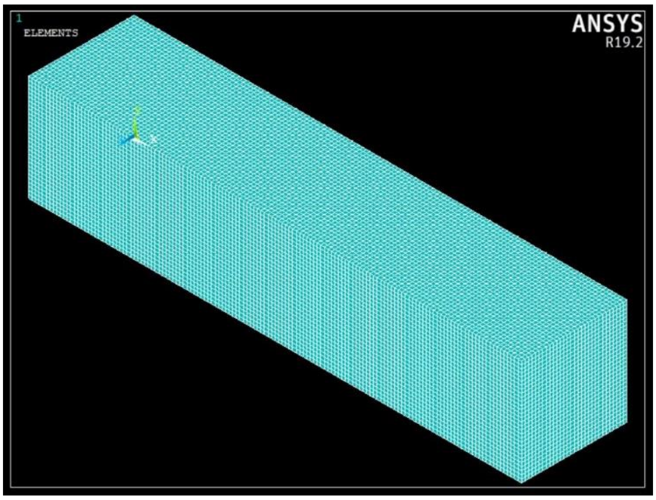

Figure 5: Mapped mesh to the Beam

Support:

This Step consist of applying boundary condition to the model. In this analyses the boundary condition of the beam is Simply Supported.

Preprocessor – Load – Define Load – Apply – Structure – Displacement – On Lines – Single – OK

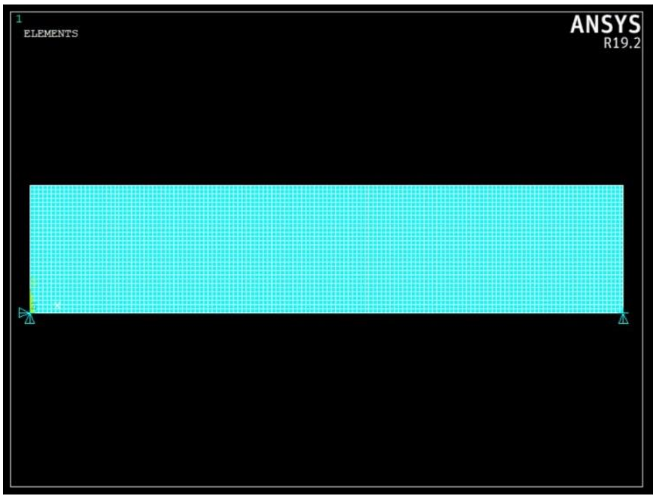

Figure 6: Applied Boundary Conditions

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Loading:

Application of the load on the model is carried out in this step. Uniformly Distributed Load has been applied on the Beam.

Preprocessor – Load – Define Load – Apply – Structure – Force/Moment – On Nodes – OK

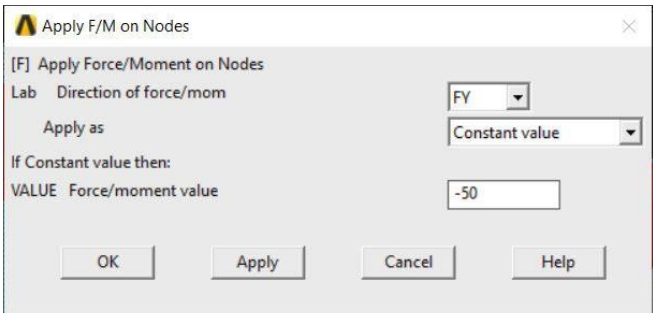

Figure 7: Application of Force/ Load on the Beam

Results:

After solving/analyzing the model, the results of the model of the load applied for the corresponding deflection were plotted in a graph as load in vertical axis and corresponding deflection in horizontal axis to form Load-Deflection Curve. Using Load-Deflection Curve Ultimate Load carrying capacity of the Beam was determined. From the results of the model, the Crack pattern was also determined.

General PostProc – Plot Results – Contour Plot – Nodal Solution

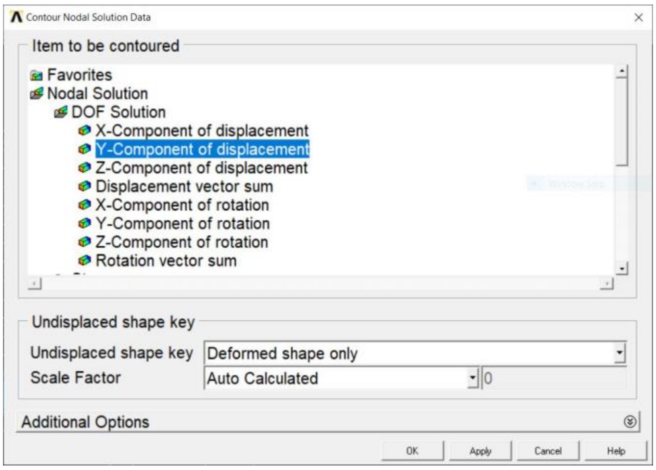

Figure 8: Contour Nodal Solution

Comparison of Load-Deflection Results:

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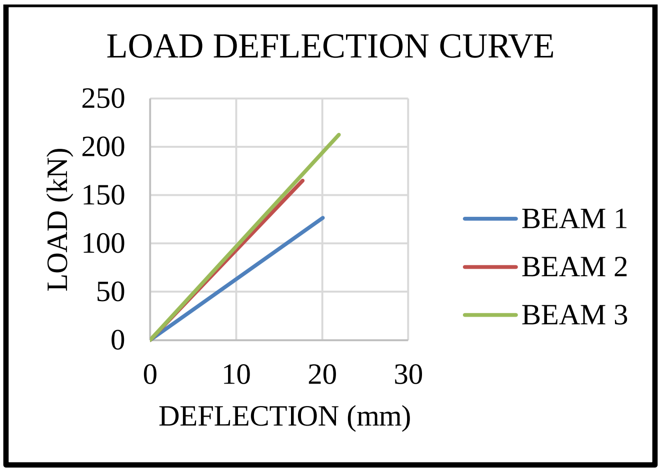

Figure 9: Comparison of Steel FRC Beam with Conventional Concrete Beam

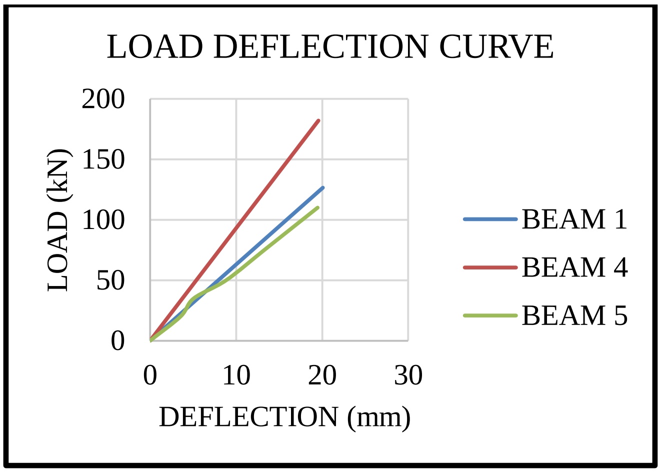

Figure 10: Comparison of Polypropylene FRC Beam with Conventional Concrete Beam

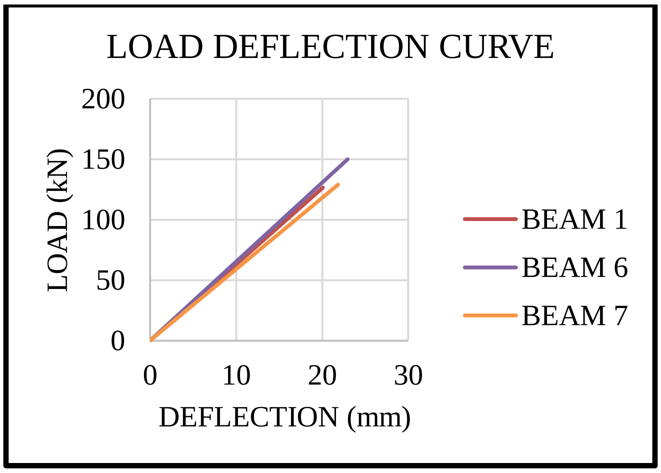

Figure 11: Comparison of Polyolefin FRC Beam with Conventional Concrete Beam

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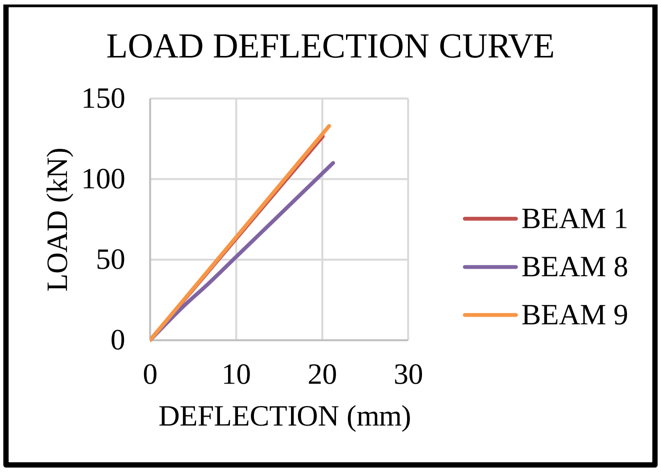

Figure 12: Comparison of PVA 150 FRC Beam with Conventional Concrete Beam

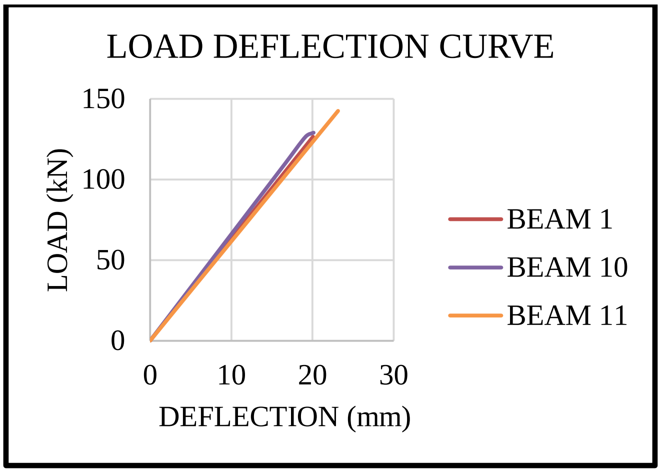

Figure 13: Comparison of PVA 240 FRC Beam with Conventional Concrete Beam

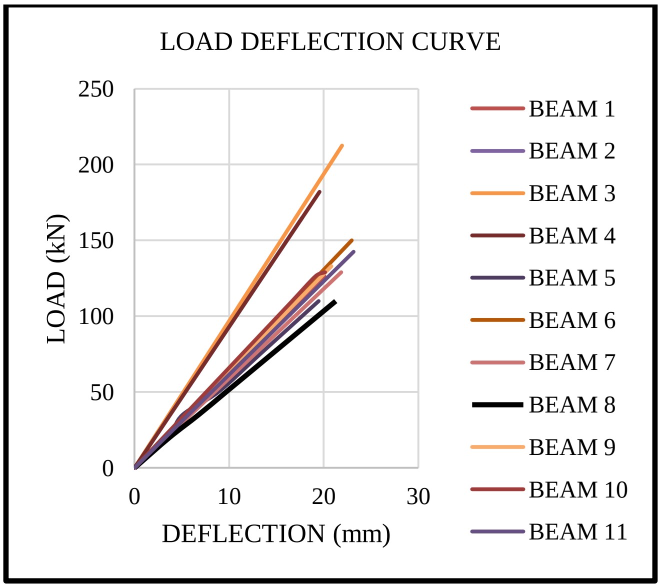

Figure 14: Comparison of Load-Deflection Curve of All Beams

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Crack Pattern:

The Cracking pattern from the analysis can be obtained by the steps shown in figure below. The Crack pattern in the software is shown as dots.

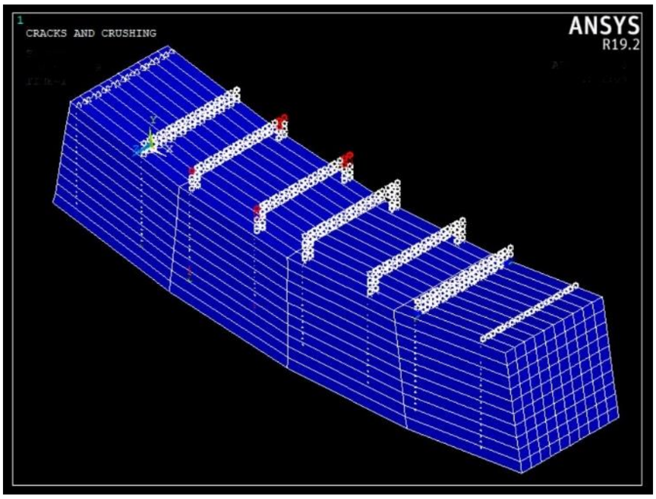

Figure 15: Typical Crack Pattern of the Beams

Table 2: Ultimate Load and Maximum Deflection of the analyzed Beams

Type of Fibre	Percentage of Fibres	Designation	Ultimate Load (kN)	Maximum Deflection (mm)
Conventional Concrete	0%	Beam 1	126.5	20.073
Steel Fibre	0.5%	Beam 2	165	17.725
	1.0%	Beam 3	212.5	21.936
Polypropylene Fibre	0.5%	Beam 4	182	19.558
	1.0%	Beam 5	110	19.465
Polyolefin Fibre	0.5%	Beam 6	150	22.960
	1.0%	Beam 7	129	21.851
PVA 150	0.5%	Beam 8	110	21.269
	1.0%	Beam 9	133	20.812
PVA 240	0.5%	Beam 10	129	20.141
	1.0%	Beam 11	142.5	23.156

Conclusion:

The total number of beam analyzed were 11, to obtain Ultimate Load, Load-Deflection Curve, and Crack Pattern.

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The conclusion made from the analyses results are as follows:

1. When the Steel FRC Beam is compared with Convention Concrete Beam, the Beam with 1.0% Steel fibre has the Ultimate Strength 67.98% more than the Ultimate Strength of Conventional Concrete Beam and 28.79% more than the Ultimate Strength of Beam with 0.5% Steel Fibre.
2. When the Polypropylene FRC Beam is compared with Convention Concrete Beam, the Beam with 0.5% Polypropylene fibre has the Ultimate Strength 43.87% more than the Ultimate Strength of Conventional Concrete Beam and 65.45% more than the Ultimate Strength of Beam with 1.0% Polypropylene Fibre.
3. When the Polyolefin FRC Beam is compared with Convention Concrete Beam, the Beam with 0.5% Polyolefin fibre has the Ultimate Strength 18.58% more than the Ultimate Strength of Conventional Concrete Beam and 16.28% more than the Ultimate Strength of Beam with 1.0% Polyolefin Fibre.
4. When the PVA 150 FRC Beam is compared with Convention Concrete Beam, the Beam with 1.0% PVA 150 fibre has the Ultimate Strength 5.14% more than the Ultimate Strength of Conventional Concrete Beam and 20.91% more than the Ultimate Strength of Beam with 0.5% PVA 150 Fibre.
5. When the PVA 240 FRC Beam is compared with Convention Concrete Beam, the Beam with 1.0% PVA 240 fibre has the Ultimate Strength 12.65% more than the Ultimate Strength of Conventional Concrete Beam and 10.46% more than the Ultimate Strength of Beam with 0.5% PVA 240 Fibre.
6. In comparison with all beams the Steel FRC Beam with 1.0% content has the Ultimate Strength of 212.5kN which is maximum among all the other beams.

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