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ANALYTICAL INVESTIGATIONS ON REINFORCED METAKAOLIN CONCRETE BEAMS BY ANSYS

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Abstract

Reinforced concrete beams are now one of the most common building elements. The response of simply supported reinforced concrete beams with Metakaolin as a supplementary material in place of cement with River Sand and M-Sand subjected to static load was quantitatively evaluated and highlighted using the Finite Element Method. The dimensions of the examined beam were 150 mm x 250 mm x 3000 mm. To replicate concrete and steel, the SOLID 65 element and LINK 180 were employed.The analytical and experimental findings for a reinforced concrete beam produced with Metakaolin in terms of flexural and crack behaviour for various loading circumstances were compared using 3D FE modelling in ANSYS R 17.0. It was revealed that the experimental and analytical values showed a good association based on the findings.

Keywords: Metakaolin, Load-Deflection, Finite Element Analysis, Flexure

1. Introduction

The most frequently utilised construction material on the planet is concrete. It is also known as the universal substance. The traditional approach of determining the flexure behaviour of a beam through experimentation is costly and time consuming. ANSYS is a finite element technique software that breaks the element into smaller parts and analyses the element under specific loading circumstances, hence evaluating the material's response. Anthony J. et al [1] used ANSYS to investigate the fracture behaviour, load-deflection curve, and reinforcement behaviour of conventional and prestressed concrete beams, concluding that the analytical model's results are equivalent to experimental studies.Amer Ibrahim [2] used ANSYS to investigate the behaviour of RC beams and found that the results from finite element models match the test data well. In comparison to typical concrete, the analytical results were a little on the conservative side. Barbosa et al. [3] looked at the practical application of nonlinear models in the analysis of reinforced concrete structures, as well as the effects of tiny model alterations. The results were obtained that reached ultimate loads, very nearer to the predicted values.

2. Materials and Methods

2.1. Materials Used

Normal Portland Cement of “53” rating was used authorizing to IS: “12269 – 1987” and specific gravity of cement was set up to be “3.15”. Nearby existing River sand devouring bulk density “1.71 kg/m3” was mainly used and the specific gravity is “2.65”. The Fineness modulus of river sand is “2.44”. Bulk density of manufactured sand was “1.75 kg/m3”, specific gravity and fineness modulus was initiated to be “2.73” and “2.87”. Crushed angular amassed with determined grain size of “20 mm” was used with a bulk density of “1.38 kg/m3”. The specific gravity and fineness modulus was found to be “2.82 and 7 correspondingly. Fresh portable form of water, which is found to be free from acid and organic element, was deployed for collaborating the concrete. Metakaolin is a dehydroxylated form of clay mineral kaolinite which was brought from Aastra Chemicals, Chennai, whose specific gravity was “2.3”.

2.2. Control Specimens

Concrete mix for M20 grade was intended as per the strategies specified in IS 10262-2009 and IS 456-2000 with a fraction of 1: 1.9: 3.2 and a water-cement fraction of 0.54. For determining mechanical properties, four different types of mixes were used as described in Table 1 and the experimental plan were given in Table 2. Control Specimens were cast and verified for their “compressive strength, flexural strength, split tensile strength and Elastic Modulus” whose values were given in Table 3.

Table 1 Different types of Mixes

S.No	MIX	Description
1.	Mix-1	MK-0% + River Sand
2.	Mix-2	MK-10% + River Sand
3.	Mix-3	MK-0% + M-Sand
4.	Mix-4	MK-10% + M-Sand

Table 2 Investigational plan and their provisions

S.No.	Tests	Sample	Dimensions (mm)
1.	“Compressive strength Test” (IS 516–1959)	Cube	100x100x100
2.	“Flexural Strength Test” (IS 516-1959)	Prism	100x100x500
3.	“Split Tensile Strength” (IS 516-1959)	Cylinder	100x200
4.	“Elastic Modulus “(IS 516-1959)	Cylinder	150x300

Table 3 Mechanical Properties of Control Specimens

S.No	Mix	Compressive Strength(N/mm^2)	Flexural Strength (N/mm^2)	SplitTensile Strength(N/mm^2)	Elastic Modulus(N/mm^2)
1.	Mix-1	26.35	3.62	2.06	25368
2.	Mix-2	35.80	4.25	3.46	29196
3.	Mix-3	27.75	3.74	2.38	25934
4.	Mix-4	33.73	4.14	3.22	28756

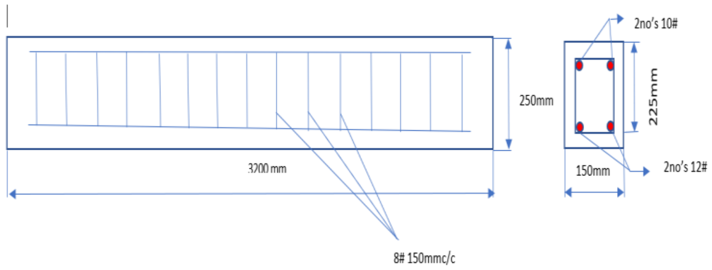
2.3. Description of the Beam

A total of 8 rectangular beams were cast and tested. All the beams were casted in wooden moulds. The beams were 150 mm × 250 mm in cross-section and 3000 mm long. The beams were tested in two-point loading over a simply supported span of 2800 mm. The reinforcing cage consisted of 2 nos of 12mm diameter HYSD bars at the tension side, 2 nos of 10 mm HYSD bars as hanger bars, 8 mm twolegged stirrups space at 150mm c/c and the reinforcement ratio used was 0.603

2.4. Geometry of the Beam

The beam was simply held at one end by a hinge and at the other end by a roller. At one-third of the span, two point loads are applied. Figure 1 shows the details of the beam.

Figure 1: Details of the Beam



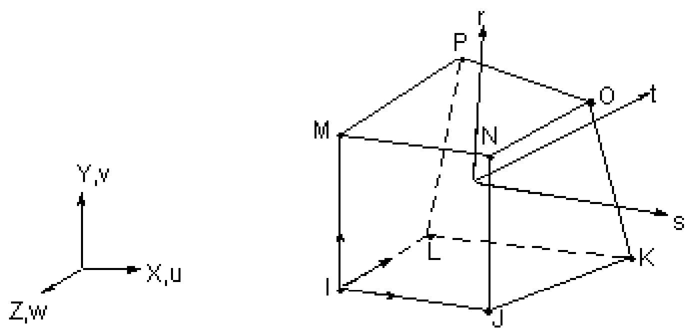
2.5. Material Properties

In the beam model, the reinforcing bar grade was Fe550, with an elastic modulus of $2x10^5$ MPa and a Poison ratio of 0.3, whereas the concrete grade was M20, with an elastic modulus of roughly 28000 MPa and a Poison ratio of 0.15.

2.6. Element Types

The SOLID 65 is used to simulate concrete beams with or without rebars in three dimensions. In tension, the concrete might crack, and in compression, it can crush. In ANSYS, the concrete is modelled with SOLID 65, and the steel reinforcement is modelled with LINK 180. Figure 2 depicts the shape and node positions for this element. In the nodal x, y, and z directions, the element is defined by eight nodes, each with three degrees of freedom. The global coordinate system is the default element coordinate system.racking in three orthogonal dimensions, plastic deformation, and crushing are all unique to SOLID65.

Figure 2 Solid65 Element



LINK180 is a three-dimensional bar that can be used in a wide range of technical applications. Trusses, sagging cables, linkages, springs, and other structures can all be modelled with this element. The element is a three-degree-of-freedom uniaxial tension-compression element having translations in the nodal x, y, and z axes. Because it is a pin jointed piece, no bending is taken into account.

2.7. Modelling of Beam

A finite element model takes more time from an ANSYS user than any other portion of the study. The element is then defined, followed by the type's real constants and model geometry. In this scenario, a beam with the dimensions illustrated in Figure 1 has been drawn. The beam was modelled in ANSYS version 17, and the analysis was also carried out in the software. To see the effect of load and deflection, a 2.5 kN starting load was used. The model is 3000 mm long and has a 150 mm x 250 mm cross section. Figure 3 depicts the finite element model..

2. 8. Meshing of Beam

A mesh was proposed in order to receive the actual results from the Solid65 element. In comparison to volumes, the reinforcing meshing was a unique case. The beam was meshed to the point where it may be regarded a 10mm square element. Before the volume was meshed, the relevant mesh properties were set. Figure 4 depicts the meshing of the beam. To avoid mistakes caused by many nodes at the same position, nodes and key points were merged.

Figure 3 Modelling of Beam

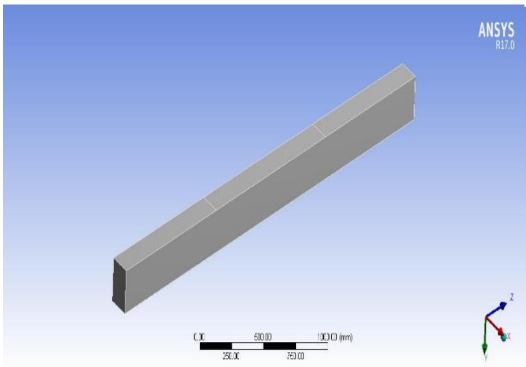
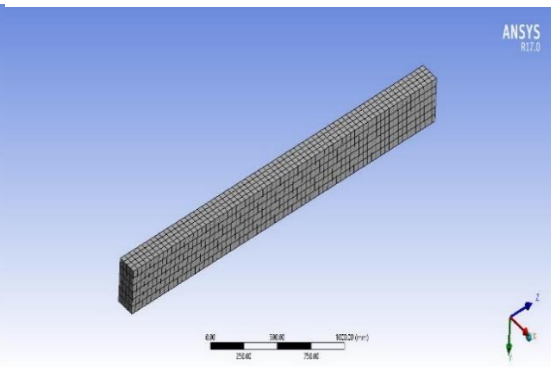


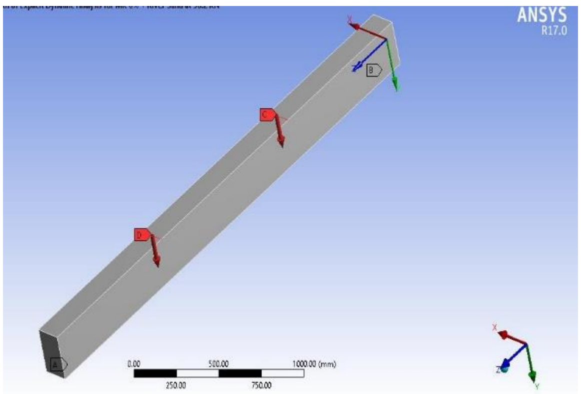
Figure 4 Meshing of Beam



2.9. Loads and Boundary Conditions

To limit the model and provide a unique solution, displacement criteria were required. The support was designed to be a permanent support on one end and a hinged support on the other. External loads were applied as concentrated forces at a distance of one-third of the beam's length. Figure 5 depicted the beam's loading and boundary conditions.

Figure 5 Boundary Conditions of Beam



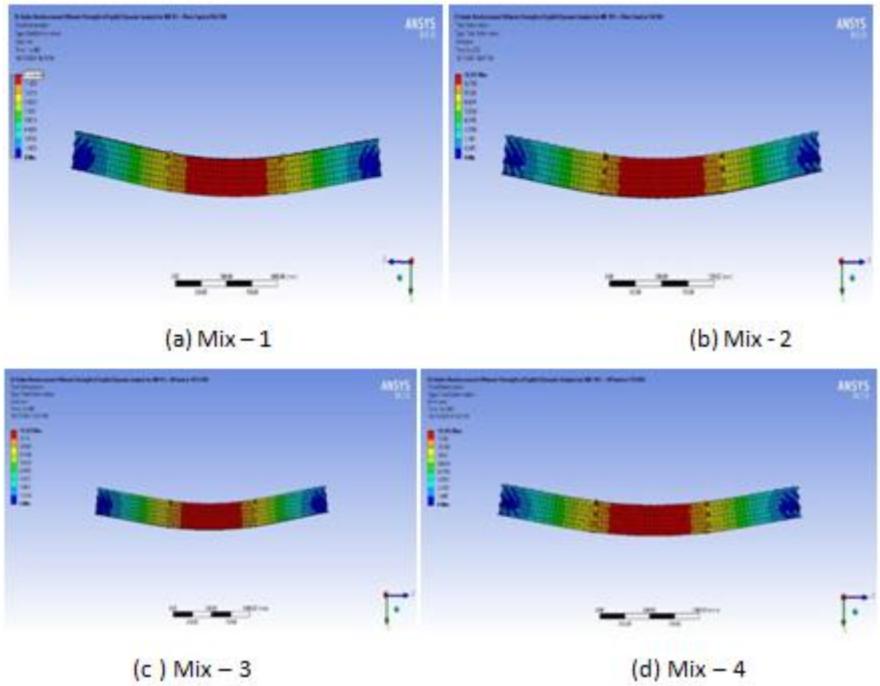
The static analysis type was used for the model's analysis. 'Small displacement static circumstances' were the subject of the investigation. Then, for various models, the frequency was set to 'Write every Nth subset,' and the maximum and lowest number of subsets were increased, while the rest of the commands were left as they were in ANSYS.

3. Results and Discussions

3.1. Load Deflection Behaviour

Figure 6 depicts the deflected forms of the specimens analysed with ANSYS. When compared to other specimens, specimens containing 10% Metakaolin with River Sand exhibit the greatest deflection. For all mixes derived from the study, the load-deflection relationships until failure were obtained and compared to the experimental data.

Figure 6 Load Deflection Behaviour of all mixes



When the load-deflection response recorded by FEM was compared to experimental results, excellent agreement was found. Figure 5-8 illustrates that the load-deflection curves depict the extended behaviour of FEM, which is in good accord with experimental beam test results. There could be two reasons for the modest variance in load-deflection curves. Micro-cracks may be found in experimentally tested beams, which could be caused by drying shrinkage in the concrete, however micro-cracks have no influence in FEM.The second reason is that optimal bonding between the concrete and the steel reinforcement is assumed in the FEM, but this is not the case for empirically tested beams.

Table 4 Comparison of Experimental and Analytical Results

S.No.	Mix	Experimental Results		Analytical Results	
		Ultimate Load in kN	Ultimate Deflection in mm	Ultimate Load in kN	Ultimate Deflection in mm
1.	Mix-1	51.5	20	51.5	21.8
2.	Mix-2	61.3	24.2	61.3	24.9
3.	Mix-3	53.9	21	53.9	22.5
4.	Mix-4	58.8	22.5	58.8	23.7

As indicated in Table 4, the ultimate loads and mid-span deflections predicted by FEM are compared to the experimental findings, and it is discovered that the experimental results and the ANSYS result have a good correlation. The percentage discrepancy between analytical and experimental values for Mix-1, Mix-2, Mix-3, and Mix-4 is 9 percent, 3 percent, 7 percent, and 5 percent, respectively, according to the same table. As a result, the variation in the ultimate load and its related deformation acquired from experimental and analytical data is minimal. The FEM clearly predicts the behaviour of beams with a high degree of precision.

Figure 7 Load Deflection behaviour for Mix-1

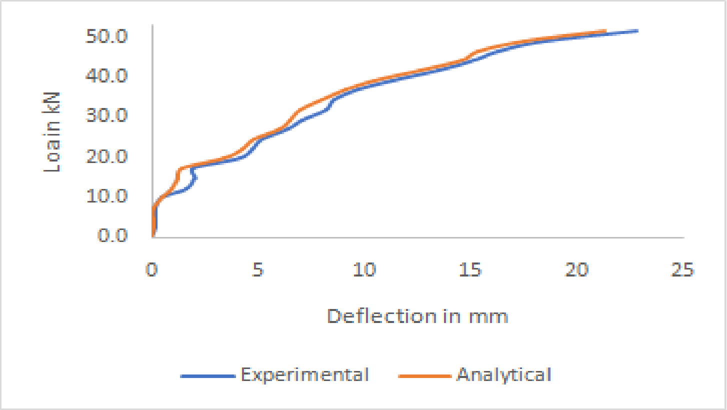


Figure 8 Load Deflection behaviour for Mix-2

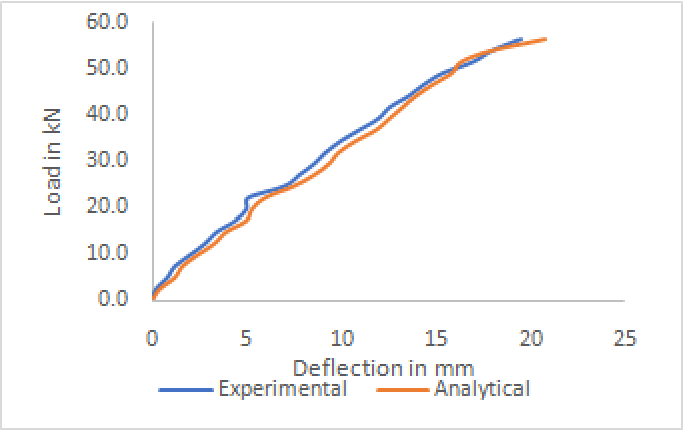


Figure 9 Load Deflection behaviour for Mix-3

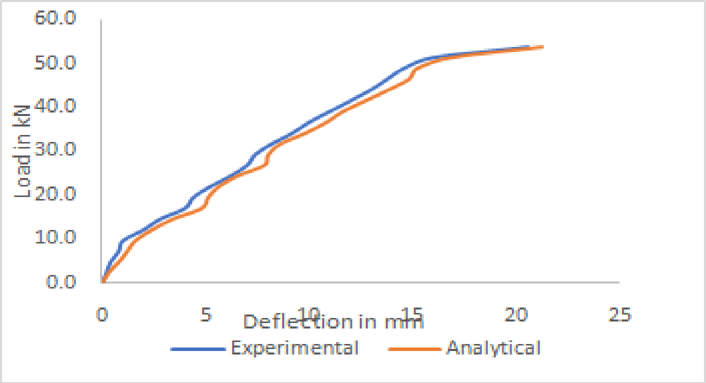
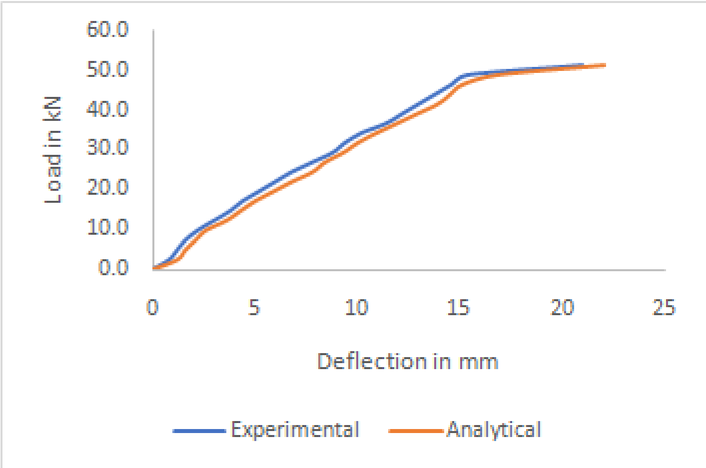
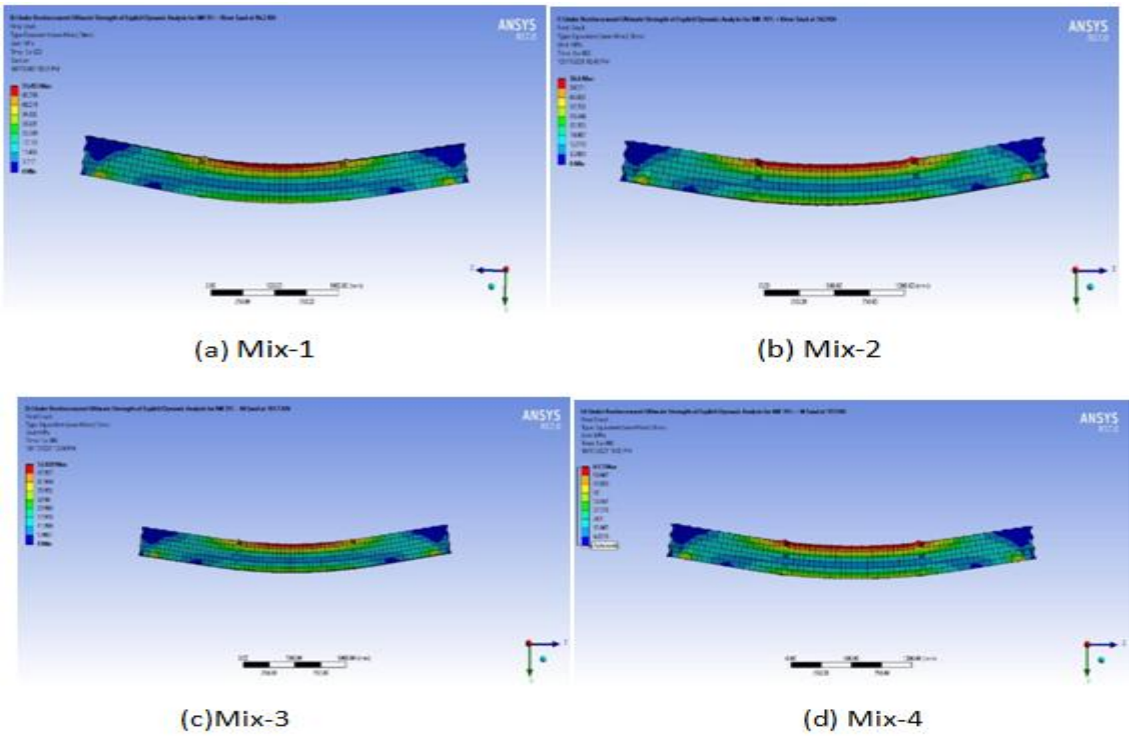


Figure 10 Load Deflection behaviour for Mix-4



The model created with ANSYS can anticipate the failure of concrete materials. To define a concrete failure surface, both cracking and crushing failure modes are required. When the predominant tensile stress in any direction falls outside the failure surface, cracking occurs. When all major stresses are compressive and fall outside the failure surface, crushing occurs. Under varied loading circumstances, the following crack patterns were observed. As higher stresses are applied to the beam in the nonlinear portion of the response, subsequent cracking ensues.

Figure 11 Crack Pattern



4. CONCLUSIONS

• The FEA findings were compared to the experimental results, and it was discovered that there was a strong connection between the experimental and ANSYS results.

• The experimental and analytical results were within 10% of each other in terms of ultimate deflection.

• The load-deflection response and load carrying capacity predicted by the FEA were similar to the testing results.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Anthony J. Wolanski, B.S., Flexural Behavior of Reinforced and Prestressed Concrete Beams Using Finite Element Analysis, Master's Thesis, Marquette University, Milwaukee, Wisconsin, 2004.

Amer M. Ibrahim, Wissam D. Salman, Finite element analysis of reinforced concrete beams strengthened with CFRP in flexural, Diyala Journal of Engineering Sciences, Vol. 02, Dec. 2009, pp. 88-104.

Antonio F. Barbosa and Gabriel O. Ribeiro, Analysis of Reinforced Concrete Structures Using Ansys Nonlinear Concrete Model‖, Computational Mechanics, New Trends And Applications, Barcelona, Spain ,1998.

Vasudevan and Kothandaraman, G, "Parametric study on Nonlinear Finite Element Analysis on flexural behaviour of RC beams using ANSYS", International Journal of Civil and Structural Engineering,2(1),2011,pp-98-111.

N. Sundar, P. N. Raghunath and G. Dhinakaran, Flexural Behavior of RC beams with Hybrid FRP Strengthening. International Journal of Civil Engineering and Technology, 7(6), 2016, pp.427–433.

Banu D., Barros R. C. D. and Taranu N., Numerical Modelling of Two-Way Reinforced Concrete Slabs Strengthened With Carbon Fibber Reinforced Polymers Strips, International Conference on Experimental Mechanics, 22-27. 2012.

Parandaman P. and Jayaram M., Finite element analysis of reinforced concrete beam retrofitted with different fibre composites, Middle-East Journal of Scientific Research

22(7), 948-953, 2014.

Prof. Dr. Ammar Yaser Ali and Ali Abdul Ameer Abdul Abbas, Structural Behavior of Reinforced Lightweight Concrete Corbels Strengthened with NSM-CFRP Bars. International Journal of Civil Engineering and Technology (IJCIET), 7(4), 2016, pp.380–392.

Patil, S. and Niranjan, R., "Non Linear Finite Element Method of Analysis of Reinforced Concrete Deep Beam" International Journal of Modern Engineering Research,2 (6),2012, pp-4622-4628.

Subramanian, T. and Jayalakshmi, J,"Analytical Investigation of Bonded Glass Fibre Reinforced Polymer Sheets with Reinforced Concrete Beam Using Ansys", International Journal of Application or Innovation in Engineering & Management, 4(5),2015, pp-105-112.

Jayajothi, P., Kumutha, R. and Vijai, K., Finite element analysis of FRP strengthened RC beams using ANSYS, Asian Journal of Civil Engineering (BHRC), Vol. 14, No. 4, Feb. 2013, pp. 631-642.

YE, YOUSIF JABBAR LAFTA1&KUN. "STRUCTURAL BEHAVIOR OF DEEP REINFORCED CONCRETE BEAMS UNDER INDIRECT LOADING CONDITION." International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD) 5. 4, (2015), 53-72.

Mathew, Hema, and Nivin Philip. "Strength and Permeability of High Performance Concrete Containing Metakaolin." International Journal of Civil Engineering (IJCE) 4.6 (2015): 19-28.

REDDY, A. CHENNAKESAVA. "FINITE ELEMENT ANALYSIS OF INJURIES IN SHOULDER BONES AND JOINTS: A REVIEW." International Journal of Bio-Technology and Research (IJBTR) 6.1 (2016): 29-42.

Sharma, Ashwani, and Murtaza MA. "Modeling and Finite Element Analysis of Vertical Axis Wind Turbine Rotor Configurations." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)6.3 (2016): 23-34

KHARE, SUMIT, and DAS MITTAL NARAIN. "PREDICTION OF NATURAL FREQUENCIES OF THICK CIRCULAR PLATES USING FINITE ELEMENT ANALYSIS." International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) 7.4 (2017): 99-108.