International Journal of Innovative Technology and Interdisciplinary Sciences
www.IJITIS.org
ISSN: 2613-7305
Volume 4, Issue 3, pp. 733-741, 2021
DOI: https://doi.org/10.15157/IJITIS.2021.4.3.733-741
Received June 28, 2021; Accepted August 2, 2021

Numerical Study of Reinforced Concrete Beam by Using ABAQUS Software

Shama Al Hasani[a1], Nasrellah H A*[b1], Aeid A. Abdulraeg[c2]

[1]Department of Civil and Environmental Engineering, College of Engineering and Architecture, University of Nizwa, Sultanate of Oman

[2]Department of Civil Engineering, Omar Al Mukhtar University, El-Beida, Libya

[a]10092379@uofn.edu.om; [*b]nasrellah@unizwa.edu.om; [c]aeid.abdulrazeg@gmail.com

ABSTRACT

Cracks are serious problems in the structural characteristics of a concrete structure due to several failure modes such as, flexural and shear. Reinforced concrete behaviour is complicated, and for a realistic simulation of such behaviour a prober material modelling has to be used. In this work an attempt has been made to simulate concrete and embedded reinforcement steel to predict the crack propagation in RC beam using a plastic damage behaviour by ABAQUS software. The proposed modelling has been validated against experimental results found in the literature. The results have shown that displacement associated with ultimate load is in a good agreement with experiment, as well as the failure load. The crack pattern indicated that the cracks will start from the tension zone in the bottom of RC beam and extended to top of beam.

Keywords: Reinforced concrete beam; Cracks; finite element model; numerical modelling; ABAQUS software.

1. INTRODUCTION

In last century, many structural engineers have used reinforced concrete (RC) in building construction. Reinforced concrete is a composite material from concrete and steel. Steel reinforcing is a steel bar or meshes of steel wires embedded in concrete and uses as a tension device in reinforced concrete by bearing the concrete in compression where RC is resistant from the fire.

Furthermore, RC works like a rigid member with minimum deflection. The RC in the tensile strength correspond to $(\frac{1}{10})$ of the compressive strength. The most problem that comes in RC is flexural crack failure as can be seen in Figure 1. The flexural cracks start at the tension face and will extend, at most, up to the neutral axis. In the general, cracking in reinforced concrete members is of a complex nature. On the one side it involves various mechanisms and parameters related to the interaction between concrete and reinforcement, geometry, type of loading and support conditions.

The finite element method has been used to provide numerical solution to the behaviour of RC failure. One of the commercial software dealing with RC failure is ABAQUS software which is having plasticity damage model for RC. This method is less costly compare to experiment. Finite element method is applied to analyses reinforced concrete structures based on the use of non-linear behaviour of the materials.

Cracks were serious problems in the structural characteristics of a building. They can happen anywhere, but occur especially in walls, beams, columns, and slabs, and usually has caused by strains not considered in the design. Many researches have been reported in the literature considering the numerical modelling of reinforced concrete beam.

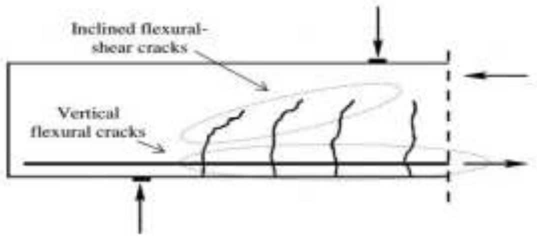

Figure 1. Type of flexural crack failure

However, most of the proposed model considers the plan concrete only where they simplified the embedded reinforced steel or ignored all. Despite that several constitutive materials we have proposed the model for complicated behaviour of concrete and to predict the crack propagation where the few works have been found in the literature by considering the plastic damage behaviour of RC beam. In the present work an attempt has been made to propose a numerical model for concrete and embedded reinforcement steel to predict the crack propagation in RC beam using a plastic damage behaviour to model the materials behaviour.

2. LITERATURE EVIEW

In many researchers works we have found the application of the finite element software's such as (ABAQUS [1], ANSYS, and LS-DYNA) to investigate analytically the experimental response of simply supported RC beams under monotonic loading applied at various rates.

For instance, Ali Ahmed [2] studied the impact dynamic test load which was conducted in beam element of structure depending on study of Kishi. He has used 3D finite element (EF) through ABAQUS to predict the dynamic responses under the pressure. The results and observation of study has been focused in the tension damage (cracks) with superimposed experimental beam cracks and concrete stiffness degradation contour plots of the half of beam where the cracks value was between 0 and 0.4mm which means that if the cracks values varied from 0.4 mm till 1mm the concrete will be failure by performing at laboratory experiments.

Analysis of reinforced concrete beam bending failure experimentation based on ABAQUS presented by [3] in this study, compare the results of experimental with results of ABAQUS. Observation of study, the beam is in elastic stage before 8kN of load and having high stiffness and strength. Furthermore, load values are linearly with the deflection in starting the plastic stage. Afterward the load reached the capacity of 24 kN, the deflection corresponds to 10.521mm of Abaqus and 12.795mm of experimental.

In the research work at [4] it has investigated analysis of RCC beams members using ABAQUS. The comparison of numerical and experimental results has been conducted. In this study different reinforcement had been used, it has been noticed the beams which are over reinforced can be carrying more load compared to other beams and the first crack at 36 kN. On other hand, those under reinforced beams are the best type of reinforcement because the tension stress of steel has much better results in comparison to balanced and over steel.

Investigated the mechanism of concrete cracking and its propagation due to corrosion of reinforcement in RCC presented by Jadhav et al [5] the numerical results were compared with experimental results of Hankare at el [6]. Different corrosion percentage was tested (1.5%, 4.5%, and 12%). The results have shown that a good agreement with experimental. The load capacity will not be affected by 1.5 % corrosion. However, 4.5 % and more will reduce the capacity.

Finite element modelling of reinforced concrete beam patch repaired and strengthened with fibre reinforced polymers by Mundeli Salathiel et al [7] the main objective of this study was to investigate the behaviour of reinforced concrete beam patch repaired and strengthened with fibre reinforced plastic (FRP) composites by using ABAQUS software by comparing the results with experimental. This result concludes that the cracking is initiated whenever the maximum principal stress was greater than the tensile strength of concrete. Results from finite elements analysis were in good agreement with experimental findings in terms of load deflection relationships.

Study of Gilberto Rodríguez et al [8] of reinforced concrete beams strengthened by FRP bars and glass fibre reinforce polymer (GFRP) sheet subjected to impact loading conditions was presented. Nine beams built and tested with different configurations and loading conditions by using ABAQUS software and experimental work. The results of experimental and results of finite element model using ABAQUS is very close. The maximum displacements in ABAQUS were 85.43 mm representing only 3.8% difference compare to the experimental output which was 82.3 mm.

Sajjad Roudsari [9] studied the strengthen of Reinforced Concrete Beams Strengthened by FRP bars under Impact Loading which is effectively improve their capacity performance and can slow the progress of damage.

Wani and Mohammed [10] are found that, the tensile strength of the concrete was increased by a maximum of 7.5% for 5% substitution of cement by waste paper pulp and it decreased progressively after 10% substitution.

The study of fibre reinforced geopolymer concrete (FRGC) by Jyotirmoy and Panigrahi [11], is discussed and suggested that, FRGC exhibits good thermal stability, light weight and lesser shrinkage property. Thus, rapid innovation of fibre reinforced geopolymers is highly anticipated in the near future.

3. MODELING OF REINFORCED CONCRETE BEAM

3.1 Geometry Modelling

Simply supported beam is presented by Deng Sihua et al [3] which is RC beam with span of 1500 mm and the section height of 180 mm and breath of 100 mm, cover of beam 20 mm shown in Figure 2. In ABAQUS, the concrete adopted C3D8R element and the reinforced used T3D2 element. It was embedded the reinforced in concrete element to simulate the bonding relationship between the reinforced and concrete.

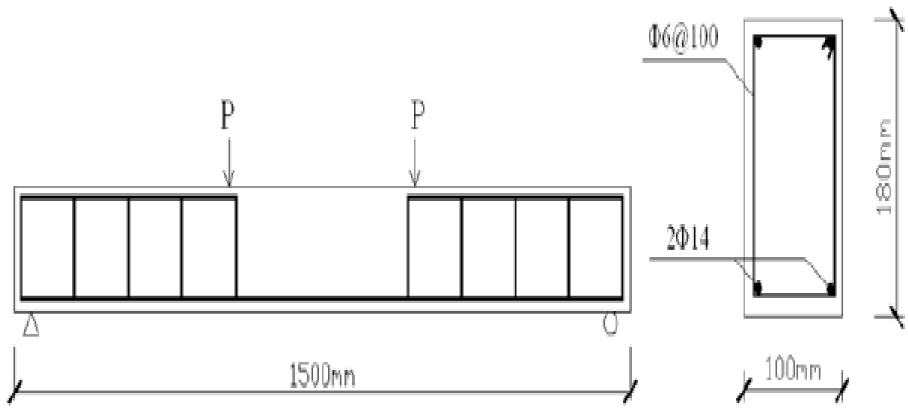

Figure 2. Modelling of the simply supported beam

3.2 Material Modelling

Deng Sihua et al [2] Constitutive model for concrete axial compressive is based on the model formula suggested by Hognestad at el [12].

$$\sigma = \begin{cases} f_c\left[2\frac{\varepsilon}{\varepsilon_0} - \left(\frac{\varepsilon}{\varepsilon_0}\right)^2\right] & \varepsilon \le \varepsilon_0 \\ f_c\left[1 - 0.15\,\frac{\varepsilon - \varepsilon_0}{\varepsilon_u - \varepsilon_0}\right] & \varepsilon_0 \le \varepsilon \le \varepsilon_u \end{cases} \qquad (1)$$

Where, f_c = 14.2 MPa, compressive strength of concrete, ε_0=0.002, yield strain and ε_u= 0.0038, ultimate strain. The constitutive model of concrete unidirectional tensile uses the formula in specification for design of reinforced concrete structure:

$$\sigma = \begin{cases} f_c\left[1.2\,\frac{\varepsilon}{\varepsilon_t} - 0.2\left(\frac{\varepsilon}{\varepsilon_0}\right)^6\right] & \varepsilon \le \varepsilon_t \\ f_c\left[\dfrac{\frac{\varepsilon}{\varepsilon_t}}{\alpha_t\left(\frac{\varepsilon}{\varepsilon_t}-1\right)^{1.7} + \frac{\varepsilon}{\varepsilon_t}}\right] & \varepsilon \ge \varepsilon_t \end{cases} \qquad (2)$$

Where, f_c = 1.5 MPa, tensile strength of concrete and ε_t=73,64 X 10^{-6}, peak tensile strain, the Concrete damaged plasticity parameters shown in table 1.

Plasticity	**Value**
Dilation angle	30
Eccentricity	0.1
fb0/fc0	1.16
k	0.6667
Viscosity parameter	0
Density of concert = $\mathbf{2.4 \times 10^{-6}}$N/mm^3 Density of steel = $\mathbf{7.65 \times 10^{-5}}$N/mm^3	
modulus of elasticity of concrete =14.2 GPa modulus of elasticity of steel =245 GPa	
Poisson's ratio of concrete = 0.2 Poisson's ratio of steel = 0.3	
Concrete strength is C25	

Table 1. Damaged plasticity parameters

3.3 Loading and Constrains

Apply uniform load on two plates shown in figure 3. The dimensions of plate are 100 x 50 mm at specific distance from the support. The uniform load is 5 N/mm in each plate.

Figure 3. Loading and constrains

4. RESULTS AND DISCUSSION

4.1 Displacement

Figure 4 and 5 shows the deflection of the present study and Deng's model respectively in elastic stage. It indicates that a similar deformation shape for both cases, where the maximum displacement in elastic stags is 2.25 mm and 2.21 mm for the present study and Deng's model respectively, maximum displacement in plastic stags is 11 mm and 14 mm for the present study and Deng's model respectively. The maximum displacement for present study shown in Figure 6.

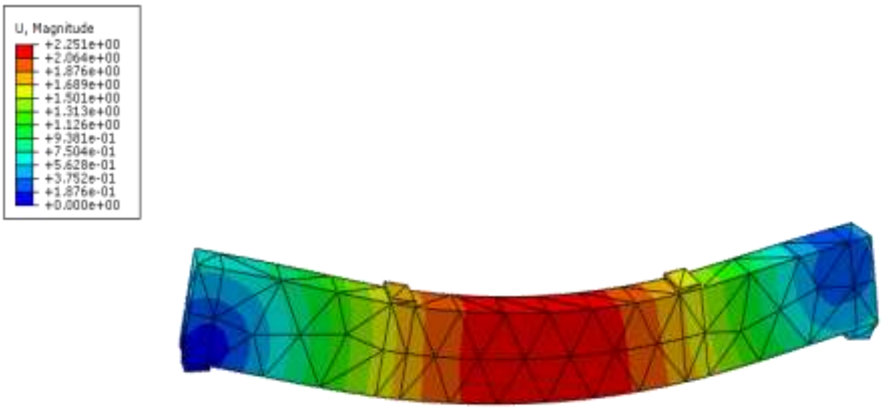

Figure 4. Beam displacement (mm) (Present study)

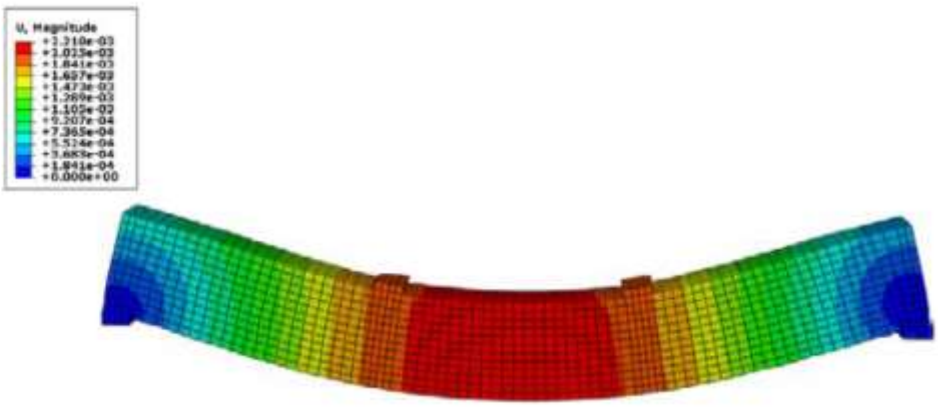

Figure 5. Beam displacement (m) (Deng Sihua)

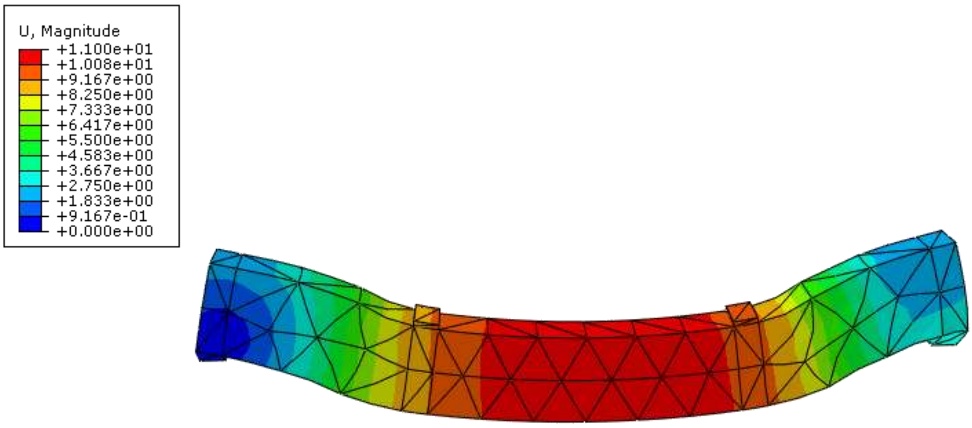

Figure 6. Max displacement (mm) (present study)

4.2 Stress

Figure 7 and 8 shows the stress distribution for the present study and Deng's model respectively. The maximum stress has been observed at the support in both cases, 39.22 MPa and 41.16 MPa in the present study Deng model.

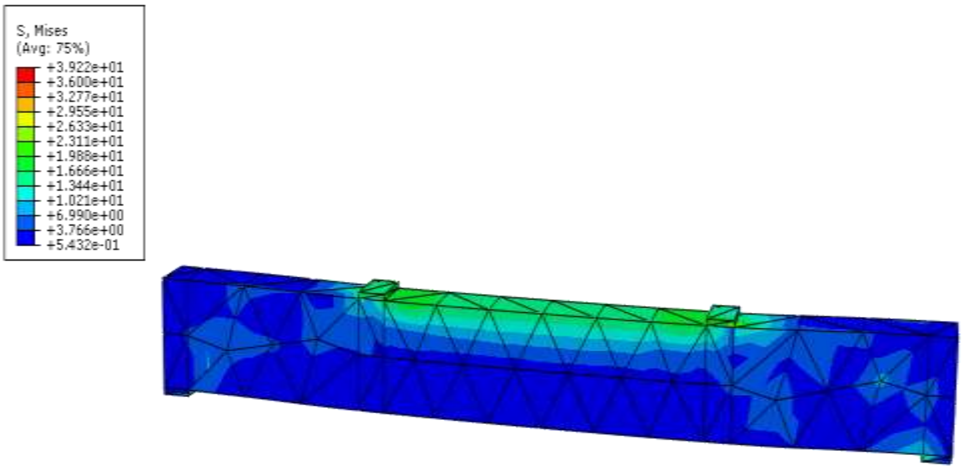

Figure 7. Beam stress (present study)

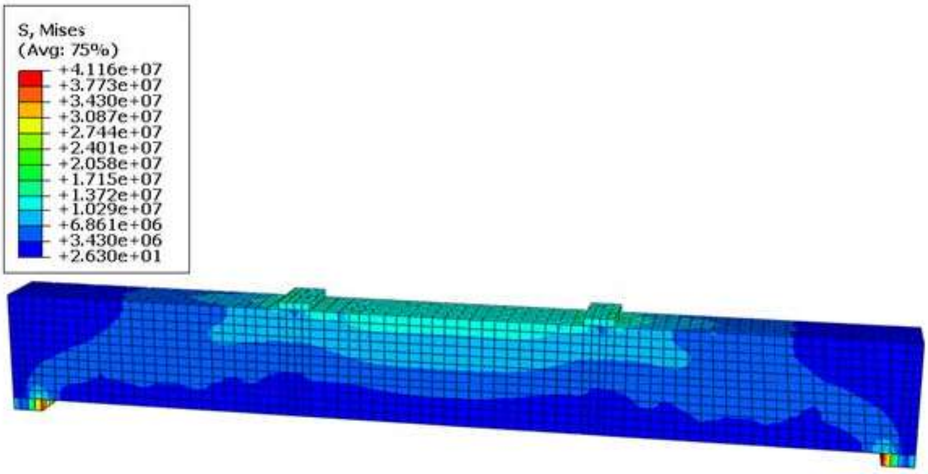

Figure 8. Beam stress (Deng Sihua) [3]

4.3 Load Displacement Curve

Load-displacement curve obtained from present study is compared with study of Deng Sihua in Figure 9, the maximum displacement under failure and ultimate loads are shown in Table 3.

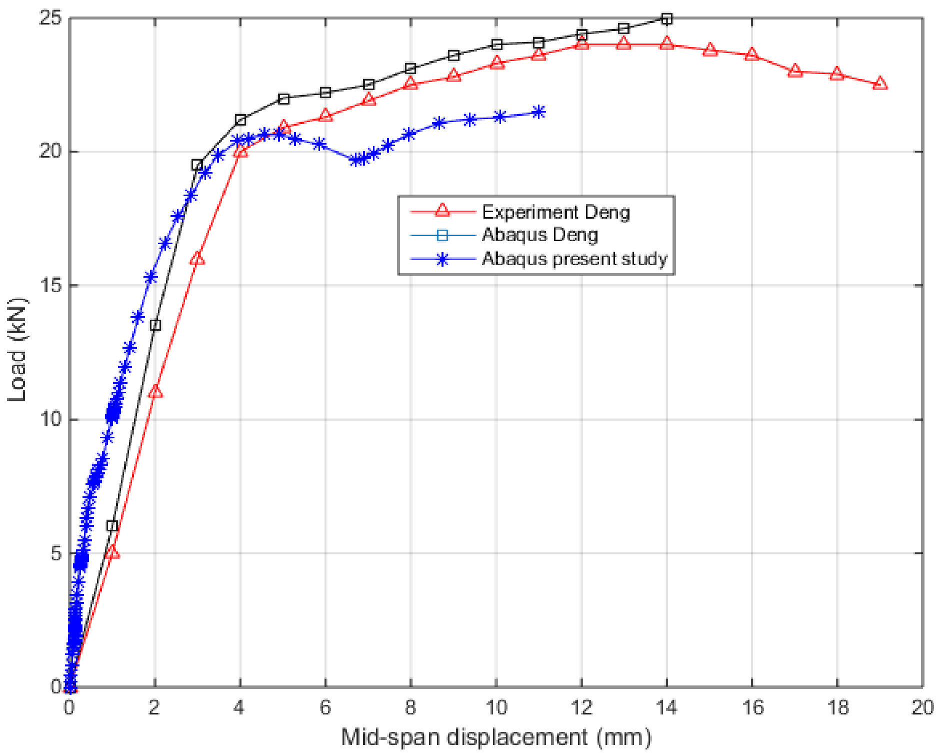

Figure 9. Load-displacement curve

Table 3: Displacement at Failure load

	load at Failure kN		**Mid – span displacement (mm) at failure**		**Mid – span displacement (mm) at ultimate**
	Experiment	ABAQUS software	Experiment	ABAQUS software	Experiment
Deng study	23	25	19.5 mm	14	12.795
present study	-	21.47	-	11	-

Figure 9 shown load-displacement curve obtained using ABAQUS which is compared with Deng's study, the results of displacement using ABAQUS are an agreement to each other, where the maximum displacement is 11 mm and 14 mm for the present study and Deng's model respectively. However, the results of displacement for the present study (11 mm) are very close with the result of experiment at the ultimate load which was 12.795 mm.

5. CONCLUSION

The main concluding remarks are listed as follows:

1. In the present work, an attempt has been made to propose a numerical model for concrete with embedded reinforcement steel to predict the crack propagation in RC beam by using a plastic damage model which is simulate the nonlinear materials behaviour.
2. The maximum displacement is 11 mm and 14 mm for the present study and Deng's model respectively. However, the results of displacement for the present study (11 mm) are very close with the result of experiment at the ultimate load which was 12.795 mm.
3. It is recommended to use finite element model with a fine mesh and smaller load increment which could leads to more accurate result.

CONFLICT OF INTEREST

The authors confirm that there is no conflict of interests associated with this publication and there is no financial fund for this work that can affect the research outcomes.

REFERENCES

[1] Abaqus Analysis User's Guide (6.14), 2019.

[2] Ahmed A. Modeling of a reinforced concrete beam subjected to impact vibration using ABAQUS. *International Journal of Civil and Structural Engineering*, 2015; 4; 227-236.

[3] Sihua D., Qie and Wang Li Z. Nonlinear Analysis of Reinforced Concrete Beam Bending Failure Experimentation Based on ABAQUS. International Conference on Information Sciences, Machinery, Materials and Energy (ICISMME 2015), April 11-13, 2015, Chongqing, China, p. 440-444

[4] Tejaswini T. and Rama Raju M.V. Analysis of RCC Beams using ABAQUS. *International Journal of Innovations in Engineering and Technology (IJIET)*, 2015; 5; 248-255.

[5] Jadhav A.M. and Munot H.K. Analytical study of mechanism of concretre cracking and propagation due to corrosion of Reinforcement in RCC, Open journal of civil engineering, 2016, 6, p. 286-294.

[6] Hankare A.V., Patil A.N., Deshmukh A.R. Flexural strength of normal beam by replacing tension reinforcement as waste tyre, *International Journal of Engineering Research*, 2014; 3(5); 330-332.

[7] Salathiel M., Leopold M., Moyo P. Finite element modeling of reinforced concrete beam patch repaired and strengthened with fiber reinforced polymers. *International Journal of Engineering and Technical Research (IJETR)*, 2016; 4; 47-54.

[8] Rodríguez G., Douglas J., José J. and Pudipedi L. Study of the behavior of reinforced concrete deep beams. Estimate of the ultimate shear capacity. *Manuscript Code*, 2017; 16; 43-56.

[9] Roudsari S., Hamoush S., Soleimani S., Abu-Lebdeh T. and HaghighiFar M. Analytical Study of Reinforced Concrete Beams Strengthened by FRP Bars Subjected to Impact Loading Conditions. *American Journal of Engineering and Applied Sciences*, 2018; 11(2); 407-425.

[10] Wani, S. B. and Mohammed, M. S. H. S. Experimental Study on Fractional Replacement of Cement with Waste Paper Pulp in Concrete. *International Journal of Innovative Technology and Interdisciplinary Sciences*, 2020; 3(4); 521–529.

[11] Jyotirmoy M. and Panigrahi, R. Mini-Review on structural performance of fiber reinforced geopolymer concrete. *International Journal of Innovative Technology and Interdisciplinary Sciences*, 2020; 3(2); 435–442.

[12] Hognestad E., Hanson N.W., McHenry D. Concrete stress distribution in ultimate stress design. *ACI Journal*, 1955; 27(4); 455-479.