International Journal of Engineering Trends and Technology
ISSN: 2231–5381 / https://doi.org/10.14445/22315381/IJETT-V71I7P232

Volume 71 Issue 7, 343-348, July 2023

Original Article

Column Cross-Sectional Capacity Due to Eccentric Load on the Construction of the Gor Setara Marabahan

Husnul Khatimi[1], Wesa Prasetya[2], Yuslena Sari[3]

[1,2]*Department of Civil Engineering, Universitas Lambung Mangkurat, Banjarmasin, Indonesia*
[1,3]*Department of Information Technology, Universitas Lambung Mangkurat, Banjarmasin, Indonesia*

[1]*Corresponding Author : hkkhatimi@ulm.ac.id*

Received: 09 May 2023 Revised: 21 June 2023 Accepted: 26 June 2023 Published: 21 July 2023

Abstract *- Gedung Olahraga Setara Marabahan is one of the sports facility buildings built in Marabahan, South Kalimantan. During the construction of the Gedung Olahraga Setara Marabahan, the construction experienced inaccuracies, which resulted in the installation of steel columns. The steel column is not installed parallel to the centroid axis of the concrete column, which causes the concrete column to experience an eccentric load. The eccentric load can be divided into two types of loads: the centric axial force Pn and the bending moment Mn. The eccentricity of a cross-section has a significant impact on the load applied to that section; the eccentricity of the load also allows the column to deform in shape and position, such as the emergence of lateral deflections. Because it will have an impact on column collapse, which is a critical matter that needs to be taken seriously because column collapse will have fatal consequences for the construction that has been built. The analysis uses the planned and existing conditions of the building. The column cross-section size is 50x50 cm, the reinforcement used is 19 mm in diameter as the main reinforcement, and the stirrups are 10 mm in diameter with a spacing of 150 mm. The data used in this study used test and measurement data from the laboratorium structure and laboratorium survey FT ULM. The laboratory data is then processed using 3D analysis software to obtain the internal forces that occur at the structure's cross-section, followed by theoretical calculations. To get the crack pattern, FEM (finite element method)-based software is used. From the results of the analysis of the planned and existing building conditions, it is clear that the eccentricity that occurs in the existing conditions of the building experiences a greater moment increase compared to the planned building conditions. The increased moment results in a deflection, and as the axial load and eccentric distance increase, the resulting deflection increases.*

Keywords *- Column, Eccentricity, FEM, Marabahan, Material.*

1. Introduction

Gedung Olahraga Setara Marabahan is one of the sports facility buildings built in Marabahan, South Kalimantan. Setara Marabahan GOR has main structures such as columns and beams made of reinforced concrete and steel.

During the construction of the Setara Marabahan GOR, the construction experienced inaccuracies, which resulted in the installation of steel columns. The steel column is not installed parallel to the centroid axis of the concrete column, which causes the concrete column to experience an eccentric load.The centric axial force Pn and the bending moment Mn are two different types of loads that make up the eccentric load [1].

A concrete cover that becomes loose at the failure limit before the reinforcing steel loses its position is typically used to identify it [6]. Numerous forces, including the compressive force that exceeds the column's capacity, might collapse or destroy the column structure [4].

2. Theoretical Study

2.1. Concrete Structure

The structural column carries the weight from the beam and is a vertical rod of the frame [7]. In reinforced concrete, the concrete itself resists compression while the reinforcing steel resists tension, making it a column material that is pressure- and tension-resistant [4]. The column supports the axial load (P0) in this scenario without experiencing a bending moment (Mn = 0). According to the loading conditions, columns can be categorized as either axial and uniaxial (mixed axial loads and one-axis bending moment) or biaxial (combined axial loads and two-axis bending moments) [9].

2.2. Centric Load Column

A centric load column is a column that, when the compressive load P is parallel to the column axis, Columns with centric loads experience axial forces but do not experience bending moments. Column failure can occur in concrete crushed in compression or reinforcing steel yielded in tension. The maximum centric load capacity is obtained by adding the contribution of the concrete ($A_g - A_{st}$) 0.85 f'c and the contribution of the reinforcing steel, namely Ast fy, where Ag is the gross cross-sectional area, and Ast is the total area of the steel reinforcement.

2.3. Eccentric Load Column

Suppose the compressive load P coincides with the longitudinal axis of the column. In that case, it means that, without eccentricity, theoretical calculations produce uniform compressive stresses on the surface of the cross-section. When the compressive force acts at e from the longitudinal axis, the column flexes as the moment M = P(e) arises. The distance e is called the eccentricity of the force about the column axis[10]. It is not the same as in the event of a load without eccentricity, where the compressive stress that occurs is not evenly distributed over the entire cross-sectional surface but will appear larger on one side than the other [3]. The minimum eccentricity limit for stirrup columns in the direction perpendicular to the bending axis is 10% of the column thickness and 5% for round columns [9].

2.4. Finite Element Method (FEM)

FEM is an abbreviation for the finite element method, also known as the finite element method in Indonesian. Most of the fundamental ideas of FEM involve breaking the object of study down into smaller pieces to address problems. One of the numerical methods is the FEM method. It resolves a variety of technical issues, including those relating to magnetic fields, heat transport, fluid mechanics, hydrodynamics, aerodynamics, structural mechanics, soil mechanics, rock mechanics, nuclear mechanics, aeronautics, acoustics, and medical mechanics, among others [4].

2.5. Elastic Properties of Plastic Material

Elastic is plastic; elastic is deformation due to loads that do not exceed Young's point, which is a mechanical property that measures the stiffness of material during an elastic deformation when stress is applied to the material. Concrete has permanent (constant) deformation, even under low loads. According to Neville (1998), the ASTM C 469-94 modulus of elasticity can be calculated as material yield (yield strength) [1].

The elastic modulus is used to calculate the secant modulus in the 25-50% range and the compressive strength fc. Specifically for planning the value of the modulus of elasticity in SKSNI T15-1991-03 article 3.1.5 for normal concrete:

$$Ec = 4700\sqrt{fc} \quad (1)$$

2.6. Material Strain Stress

The fc stress value reaches its maximum when the strain reaches 0.002, its minimum when the strain reaches 0.00005 strain, and its maximum when the stress reaches the final strain of 40%[12], [14]. The elastic modulus is very important in determining the strength and deflection of concrete by using the following figure, which presents a concrete stress and strain curve.

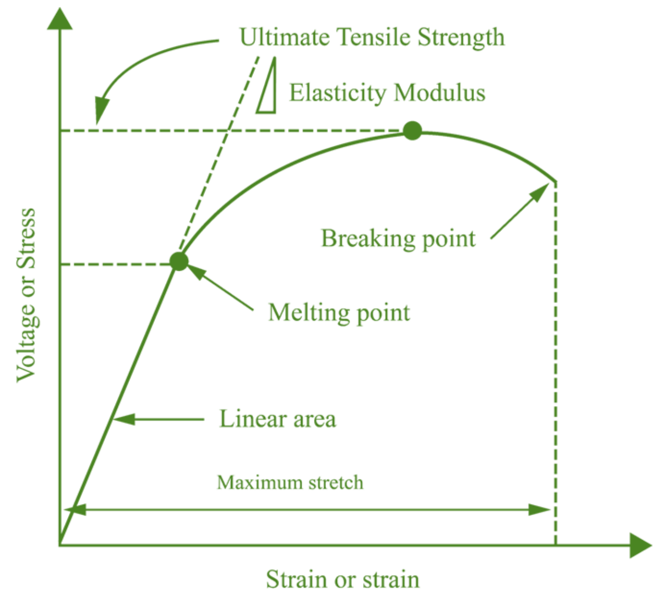

Fig. 1 Concrete stress and strain curve

The stress-strain ratio of reinforcing steel is obtained from the results of the monotonic tensile strength test (hereinafter referred to as the monotonic stress-strain ratio). as shown in the picture.

2.7. Linear and Non-Linear Materials

Linear elasticity is a mathematical model for analyzing the deformation of solids. It is useful for calculating the relationship between the force applied to an object and the corresponding deformation. In other words, it refers to the stresses and strains in the material. For the deformation process to be considered linear and elastic, the following conditions must make the deformation small IN terms of material strain. When the load is removed, the material naturally returns to its original shape without deformation. In other words, the stress level of the material does not reach the yield point. The magnitude of the deformation is proportional to the applied load [12,16,18,20,21] .

Linear elastic materials can be seen as a generalization of Hooke's law for springs.

$$F = Ku \quad (2)$$

Where:

F = The tensile force applied to the spring,
u = The resulting extension of the spring
K = Stiffness constant, spring property which is determined by material and geometry.

The stress-strain ratio of reinforcing steel is obtained from the results of the monotonic tensile strength test (hereinafter referred to as the monotonic stress-strain ratio). as shown in the picture.

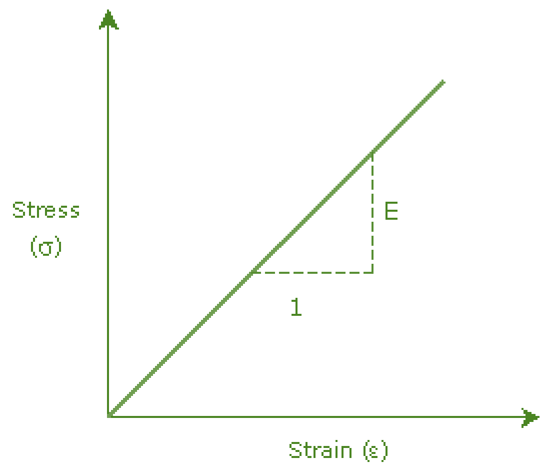

Fig. 2 Stress and strain curve for the elastic material

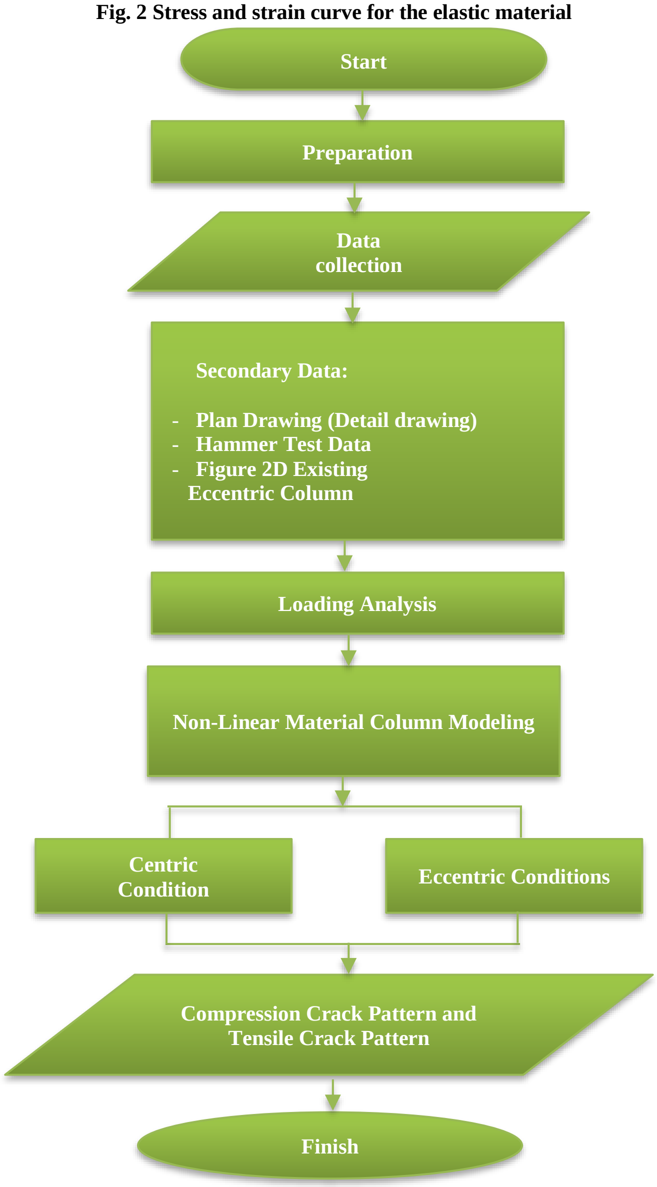

Fig. 3 Flowchart

2.8. Crack Pattern on Structural Element

Cracks are the most common type of damage in concrete structures where there is a separation between relatively long and narrow concrete blocks. Visually, the cracks look like lines. Cracks in concrete structures occur before or after the concrete has hardened. Cracks will occur when the concrete begins to harden but has been loaded; concrete hardens in winter due to shrinkage, settlement, and formwork [23].

If the structure is loaded with a load that causes the bending moment to be less than the cracking moment, the resulting stress is still smaller than the modulus of rupture of the concrete, fr = 0.70 f'c (7.5 f'c psi) [24]. Flexural cracks occur in areas with the greatest bending moment values and the smallest shear forces. These cracks occur where no bending cracks are present. This happens because the shear force is greater than the resulting moment.

3. Method

The research method is illustrated in the figure 3.

3.1. Research Data

The data used in this study are data obtained previously from the project, the structure and material laboratory of FT ULM, and the survey laboratory of FT ULM. The data obtained from the project is plan drawings and detailing in the form of 2D and 3D modeling.

In contrast, the data obtained from the structure laboratory is hammer test data and data obtained from the FT ULM survey laboratory in the form of position data for concrete columns and steel columns. All data is obtained in the form of a softcopy.

3.2. Stages of Research

The stages carried out in this study are:

1. Initial Condition Analysis Using ETABS Software.
2. Eccentric Loading Variations.
3. Analysis Using P-M Software.
4. Analysis using ABAQUS Software.

4. Results and Discussion

4.1. Plan Condition Non-Linear Centric Load

The results of the crack pattern analysis with centric load can be seen in the following figure 4, figure 5, figure 6, figure 7, figure 8, and figure 9.

- Parameter Damagec and Damaget Kolom K1 No 3

  The results of the cross-sectional analysis of column K1 No 3, damagec parameters, can be seen in Figure 4. The pattern of cracking that occurs due to centric compressive axial load occurs at the top of the column body. The results of the cross-sectional analysis of column K1 No 3, damaget parameters, can be seen in Figure 5. The cracking pattern that occurs due to centric pull axial loads occurs at the top of the column body. The cracks due to pulling in column K1 no 3 are very small.

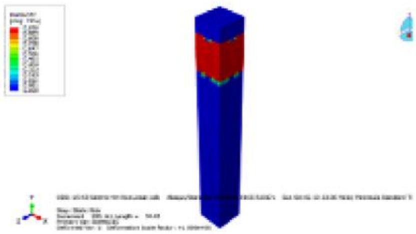

Figure 4. Damagec Column K1 No 3 Non Linear Centric Load Material

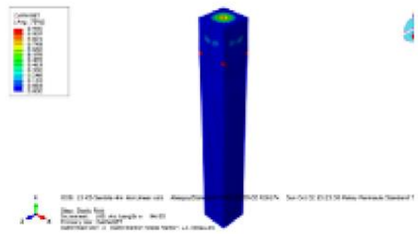

Figure 5. Damaget Column K1 No 3 Non Linear Centric Load Material

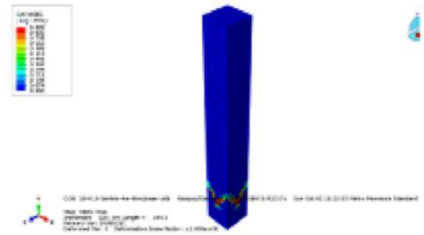

Figure 6. Damagec Column K1 No 15 Non Linear Centric Load Material

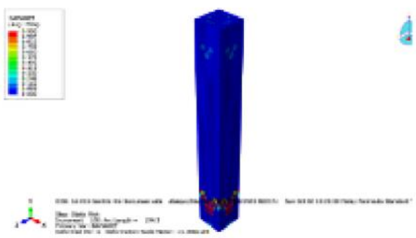

Figure 7. Damaget Column KI No 15 Non Linear Centric Load Material

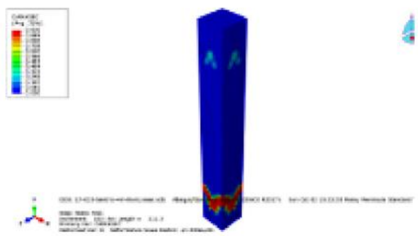

Figure 8. Damagec Column KI No 25 Non Linear Centric Load Material

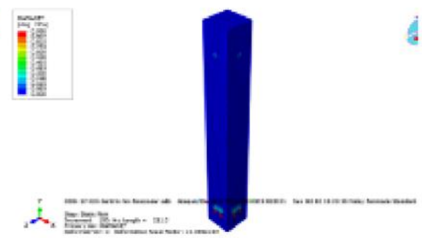

Figure 9. Damaget Column K1 No 25 Non Linear Centric Load Material

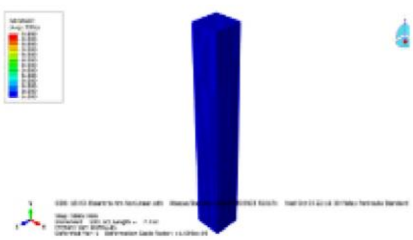

Figure 10. Damagec Column K1 No 3 Non Linear Eccentric Load Material

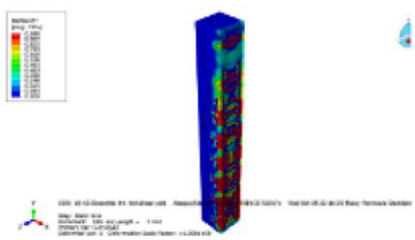

Figure 11. Damaget Column KI No 3 Non Linear Eccentric Load Material

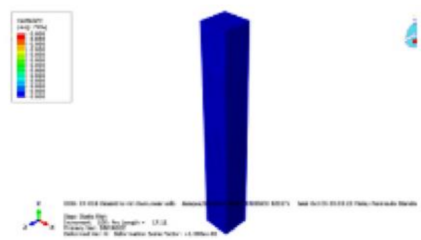

Figure 12. Damagec Column K1 No 15 Non-Linear Eccentric Load Material

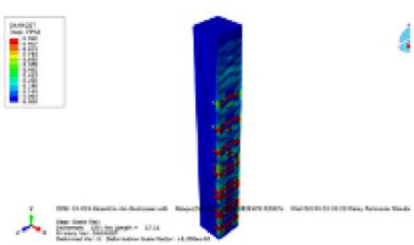

Figure 13. Damaget Column KI No 15 Non-Linear Eccentric Load Material

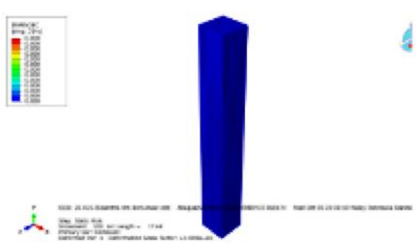

Figure 14. Damagec Column KI No 25 Material Non Linear Eccentric Load

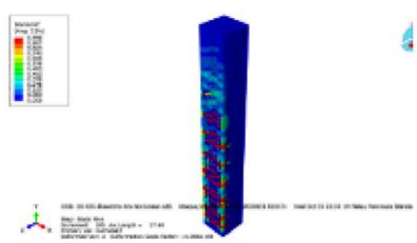

Figure 15. Damaget Column K1 No 25 Material Non-Linear Eccentric Load

- Parameter Damagec and Damaget Kolom K1 No 15
  The results of the cross-sectional analysis of column K1 No 15, damagec parameters, can be seen in Figure 6. The pattern of cracking that occurs due to axial compressive load centric occurs at the bottom of the column body. The results of the cross-sectional analysis of column K1 No 15, damaget parameters, can be seen in Figure 7. The pattern of cracks that occur due to axial loads of centric pull occurs at the bottom of the column body, cracks due to pulling on the column.

- Parameter Damagec and Damaget Kolom K1 No 25
  The results of the cross-sectional analysis of column K1 No 25, damagec parameters, can be seen in Figure 8. The pattern of cracking that occurs due to axial compressive load centric occurs at the bottom of the column body. The results of the cross-sectional analysis of column K1 No 25, damaget parameters, can be seen in Figure 9. The pattern of cracking that occurs due to axial compressive load centric occurs at the bottom of the column body.

4.2. Existing Condition Non-Linear Eccentric Load

The results of the crack pattern analysis with centric load can be seen in the following figure 10, figure 11, figure 12, figure 13, figure 14, and figure 15.

- Parameter Damagec and Damaget Kolom K1 No 3
  The results of the cross-sectional analysis of column K1 No 3, damagec parameters, can be seen in Figure 10. The results of the cross-sectional analysis of column K1 No 3, DAMAGEC parameters the concrete column did not experience pressure due to axial load, so at increment to 100, the value obtained was 0, so that the cross-section of column K1 No 3 did not experience cracks due to eccentric axial load. The results of the cross-sectional analysis of column K1 No 3, damaget parameters, can be seen in Figure 11. The pattern of cracking that occurs due to the axial load of the excentric pull occurs on the side of the column that is deflectioned.

- Parameter Damagec and Damaget Kolom K1 No 15
  Results of the cross-sectional analysis of column K1 No 15, damagec parameters can be seen in Figure 12. The results of the cross-sectional analysis of column K1 No 15, DAMAGEC parameters, concrete columns did not experience damage due to compression so that in increment to 100, the value obtained 0 so that the cross-section of column K1 No 15 did not experience cracks due to eccentric axial loads. Results of the cross-sectional analysis of column K1 No 15, damaget parameters can be seen in Figure 13. The results of the cross-sectional analysis with the DAMAGET parameter showed that the concrete column had compressive damage. The pattern of cracking that occurs due to the axial load of the excentric pull occurs on the side of the column that is deflectioned.

- Parameter Damagec and Damaget Kolom K1 No 25
  Results of the cross-sectional analysis of column K1 No 25, damagec parameters can be seen in Figure 14. The results of the cross-sectional analysis with DAMAGEC parameters, column K1 No. 25 concrete does not experience deformation due to compression, and concrete does not crack due to pressure. Results of the cross-sectional analysis of column K1 No 15, damaget parameters can be seen in Figure 15. The results of the cross-sectional analysis with DAMAGET parameters show the pattern of cracking that occurs due to the axial load of the excentric pull occurring on the side of the column that is deflectioned.

5. Conclusion

Based on the results of the study obtained, the following are the conclusions of this study. Results of the analysis of crack patterns on concrete columns with eccentric load conditions tensile collapse occurs, crack patterns occur on one side of the column, crack patterns due to deflection that occurs by eccentric axial loads, while in axial centric load conditions, compressive collapse occurs so that crack patterns occur at the top and bottom of the column.

References

[1] Sahril Afandi S. Freddy Franciscus, and Muhammad Faisal Afrianto, "Effect of Smooth Particle Hydrodynamics Modeling for Bird Strike Leading Edge Numerical Simulation Applications," *Jurnal Teknologi Kedirggantaraan*, vol. 4, no. 2, pp. 10–15, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[2] Hassan Bagheri, and Kourosh Mirzaie, "Predicting the Response of Concrete Columns to Eccentric Loading using Finite Element Analysis," *SSRG International Journal of Civil Engineering*, vol. 10, no. 4, pp. 1-7, 2023. [CrossRef] [Google Scholar] [Publisher Link]

[3] Rolly R Oroh, "Ductility of Reinforced Concrete Column Due to Eccentric Axial Compression," *Arskon: Journal of Architecture and Construction*, vol. 1, pp. 18–24, 2020. [Google Scholar] [Publisher Link]

[4] Desy, and Lisa Purnama Sari, "*Pemodelan Kolom Dengan Variasi Eksentrisitas Modelling Columns with Different Types of Eccentricity*," Doctoral Thesis S1, Universitas Mataram, 2020. [Google Scholar] [Publisher Link]

[5] Ahmed S. Rashed, and Heba M. Issa, "Behavior of Reinforced Concrete Planted Columns Supported on Reinforced Concrete Beams," *SSRG International Journal of Civil Engineering*, vol. 6, no. 5, pp. 16-22, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[6] Madutujuh, N. and Suryoatmono, B. 2009 "Non-Linear Analysis for Steel Structures (Advanced Analysis for Steel Structures)". *National Seminar on Structural Engineering Latest Developments in the Utilization of Steel Materials in the Construction Industry*, pp. 0-7, 2009.

[7] Raditya Adi Prakosa, Study of the Effect of Eccentricity on the Reduction Factor in Rectilinear Reinforced Concrete Columns Using Visual Basic 6.0 Program On Rectilinear Reinforced Concrete Columns Using Visual Basic 6.0 Program, pp. 1–15, 2010. [Online]. Available: https://pdfs.semanticscholar.org/a979/5bee42b8d3245c1adc5f599928d44347fb1f.pdf

[8] R.Thirumalai et al., "Behaviour of Steel Concrete Composite Columns under Lateral Load," *SSRG International Journal of Civil Engineering*, vol. 3, no. 11, pp. 1-6, 2016. [CrossRef] [Publisher Link]

[9] Ayad Zeki Saber Agha, and Mereen Hassan Fahmi Rashid, "Effect of Load Eccentricity on the Strength of Concrete Columns," *Journal of Civil & Environmental Engineering*, vol. 8, no. 2, 2018. [CrossRef] [Publisher Link]

[10] Dmitry Yu. Sarkisov et al., "Analysis of Changes in the Survivability of Building Structures Reinforced After an Emergency Dynamic Impact in the Context of Assessing the Security of Buildings in the Oil and Gas Industry," *International Journal of Advanced and Applied Sciences*, vol. 8, no. 12, pp. 23-35, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[11] Gunderao V Nandi, G S Hiremath, "Seismic Behavior of Reinforced Concrete Frame with Eccentric Steel Bracings," *SSRG International Journal of Civil Engineering*, vol. 2, no. 6, pp. 1-5, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[12] Khanh Son Trinh, and Hai Luu Le, "Changes in Structural, Physicochemical Properties and Digestibility of Partial Hydrolyzed and Annealed Maize Starch," *International Journal of Advanced and Applied Sciences*, vol. 9, no. 3, pp. 82-89, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[13] Mohit K. Parmar, Snehal V. Mevada, and Vishal B. Patel, "Pushover Analysis of Asymmetric Steel Buildings," *SSRG International Journal of Civil Engineering*, vol. 4, no. 6, pp. 31-36, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[14] Marouan Kouki, "Impact of the Ownership Structure on the Diversification Strategy," *International Journal of Advanced and Applied Sciences*, vol. 8, no. 10, pp. 151-160, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[15] B. K. Raghuprasad, S. Vinay, and K. Amarnath, "Seismic Analysis of Buildings Symmetric & Asymmetric in Plan," *SSRG International Journal of Civil Engineering*, vol. 3, no. 5, pp. 24-28, 2016. [CrossRef] [Publisher Link]

[16] Mostafa A. Ismail et al., "Response of A 3-D reinforced Concrete Structure to Blast Loading," *International Journal of Advanced and Applied Sciences*, vol. 4, no. 10, pp. 46–53, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[17] Upasana R. Rana, Snehal V. Mevada, and Vishal B. Patel, "Seismic Risk Assessment of Asymmetric Frame Buildings using Fragility Curves," *SSRG International Journal of Civil Engineering*, vol. 7, no. 5, pp. 1-9, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[18] Makhmud Kharun, and Alexander P. Svintsov, "Reliability of Technological Systems of Building Construction in Permanent EPS Formwork," *International Journal of Advanced and Applied Sciences*, vol. 4, no. 11, pp. 94–98, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[19] Gonugunta Venkata Nagavalli, and Y. Anand Babu, "Behaviour of Cohession Less Soil with Square Plate," *SSRG International Journal of Civil Engineering*, vol. 2, no. 9, pp. 18-28, 2015. [CrossRef] [Google Scholar] [Publisher Link]

[20] Alireza Bahrami et al., "The Behavior of Cross-Laminated Timber and Reinforced Concrete Floors in a Multi-Story Building," *International Journal of Advanced and Applied Sciences*, vol. 9, no. 6, pp. 43-50, 2022. [CrossRef] [Google Scholar] [Publisher Link]

[21] Makhmud Kharun, and Alexander P. Svintsov, "Polystyrene Concrete as the Structural Thermal Insulating Material," *International Journal of Advanced and Applied Sciences*, vol. 4, no. 10, pp. 40–45, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[22] D. Brindha, and Adarsh Paul, "Seismic Analysis of G+5 Steel Structure using Bracings," *SSRG International Journal of Industrial Engineering*, vol. 4, no. 1, pp. 25-28, 2017. [CrossRef] [Publisher Link]

[23] G. A. Sarojo, "Fundamental Physics of Mechanics Series," Jakarta Salemba Tek., 2002. [Online]. Available: https://lib.ui.ac.id/detail?id=20155532

[24] Hormoz Zareh, Introduction to Nonlinear Structural Problems, Class notes from ME-565: Advanced Finite Element Analysis, Portland State University, Portland, Spring, 2008. [Online]. Available: http://web.cecs.pdx.edu/~hormoz/me565/sp08/lectures/nonlinearity.pdf