International Journal of Civil Engineering and Technology (IJCIET)
Volume 13, Issue 9, September 2022, pp. 1-13, Article ID: IJCIET_13_09_001
Available online at https://iaeme.com/Home/issue/IJCIET?Volume=13&Issue=9
ISSN Print: 0976-6308 and ISSN Online: 0976-6316
© **IAEME** Publication

SCOPE DATABASE INDEXED

ANSYS MODELLING BEHAVIOUR OF THE REINFORCED CONCRETE BEAM WITH THE EFFECT OF VARIOUS REINFORCEMENT TYPE AND CONCRETE STRENGTH

Darmansyah Tjitradi
Associate Professor, Department of Civil Engineering,
Lambung Mangkurat University, Banjarbaru, Indonesia

Eliatun
Assistant Professor, Department of Civil Engineering,
Lambung Mangkurat University, Banjarbaru, Indonesia

Syahril Taufik
Associate Professor, Department of Civil Engineering,
National Institute of Science and Technology, Jakarta, Indonesia

Mariamah
Postgraduate Student, Department of Civil Engineering,
Lambung Mangkurat University, Banjarbaru, Indonesia

ABSTRACT

The failure behavior of reinforced concrete beam structural elements was modeled using computer software, ANSYS, to create the study presented in this paper. This study's goal was to ascertain how lower concrete and steel quality affected the way single reinforced concrete beam structural parts failed under tensile failure conditions. In this investigation, eight specimens of a straightforward 200x400x3000 mm with 2D16 single-reinforced beam have been modeled. A concentrated load will be applied to the beam in the middle of the beam span until it is collapsed. According to the study's findings, the quality of steel does not significantly change when the ultimate load is a flexural crack, and neither does the quality of concrete, which results in a smaller flexural capacity but a larger deflection. The crack pattern is also not significantly affected by this change. According to SNI 2847:2019, the flexural capacity of the ANSYS software analysis is comparable to the simplified calculation analysis, with a discrepancy of adequately reasonable. It is advisable for the low concrete steam rength beam with a low grade of reinforcement, whilst the higher concrete strength by using high-grade rebar.

Keywords: Concrete Beam, Quality Degradation, Tensile Collapse, FEM and ANSYS

Cite this Article: Darmansyah Tjitradi, Eliatun, Syahril Taufik and Mariamah, Ansys Modelling Behaviour of The Reinforced Concrete Beam with The Effect of Various Reinforcement Type and Concrete Strength, *International Journal of Civil Engineering and Technology (IJCIET).* 13(9), 2022. pp. 1-13.
https://iaeme.com/Home/issue/IJCIET?Volume=13&Issue=9

1. INTRODUCTION

The nature of the concrete beam, which is a structural component of a building, is to carry the load of the building structure. It is subject to internal forces such as moments, shears, and normals as well as deformation [1]. Concrete-based beams are excellent at resisting compressive forces, but having problem to resist tensile stresses, requiring the installation of steel reinforcement in that area [2, 3]. The state of the forming material or the manufacturing process has a significant impact on the use of concrete in a construction. To achieve the best results, it is necessary to regulate the implementation process and material quality. It is difficult to obtain high-quality concrete that meets the requirements for strength and workability (workability) [4], [5]. For concrete to be produced in accordance with the design strength, which is reflected by the results of the evaluation of the compressive strength of the test specimens that fulfill the requirements, it is required to supervise or regulate the production process throughout. An excellent concrete job (quality as planned), according to the test results showing a value that tends to be uniform is one of the indicators. As for the steel used for reinforcement, it does not alter in quality as drastically as concrete does. It is believed that a decline in concrete strength at the time of implementation will weaken the stability and durability of the structural components, which may lead to structural collapse [6]. Therefore, using the computer modeling program ANSYS [7, 8], this research is used to examine the impact of lowering the quality of concrete and steel on the failure behavior of single reinforced concrete beam structural elements.

2. NUMERICAL ANALYSIS

2.1. Reinforced Concrete Beam

An 8-element Solid (SOLID65) model with three degrees of freedom at each point and translation that takes place in the x, y, and z dimensions is used to model the reinforced concrete material. This substance can break and deform plastically in the *x*, *y*, and *z* directions. [9], [10], [11].

The concrete stress-strain curve model utilized is the confined concrete stress-strain model modifed by Sharma [12], as shown in Figure 1:

- Daerah AB: $\varepsilon_c \leq 0{,}002K$

$$f_c = Kf_c^{'} \cdot \left[\frac{2 \cdot \varepsilon_c}{0.002K} - \left(\frac{\varepsilon_c}{0.002K}\right)^2\right] \tag{1}$$

- Daerah BC: $0.002K \leq \varepsilon_c \leq \varepsilon_{20m,c}$

$$f_c = Kf_c^{'} \cdot [1 - z_m \cdot (\varepsilon_c - 0.002K)] \geq 0.2Kf_c^{'} \tag{2}$$

- Daerah CD: $\varepsilon_c \geq \varepsilon_{20m,c}$

$$f_c = 0.2 \cdot Kf_c^{'} \tag{3}$$

Dimana:

$$z_m = \frac{0.5}{\frac{3+0,29 \cdot f_c'}{145 f_c' - 1000} + 0.75 \rho_s \sqrt{\frac{b"}{s_h}} - 0.002K} \tag{4}$$

$$K = 1 + \frac{\rho_s \cdot f_{yh}}{f_c'} \tag{5}$$

$$\rho_s = \frac{2(b+\mathrm{d})A_s}{b"d"s_h} \tag{6}$$

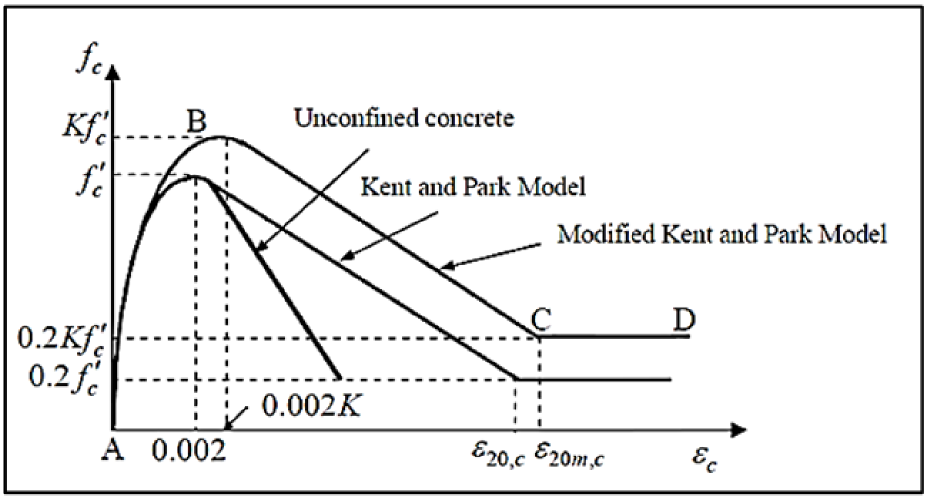


Figure 1. Modified Kent and Park model for confined concrete [12]

2.2. Steel Reinforcement

LINK180 is a 3-D spar that is useful in a variety of engineering applications. The element can be used to model trusses, sagging cables, links, springs, and so on. The element is a uniaxial tension-compression element with three degrees of freedom at each node: translations in the nodal x, y, and z directions. Tension-only (cable) and compression-only (gap) options are supported. As in a pin-jointed structure, no bending of the element is considered. Plasticity, creep, rotation, large deflection, and large strain capabilities are included.

By default, LINK180 includes stress-stiffness terms in any analysis that includes large-deflection effects. Elasticity, isotropic hardening plasticity, kinematic hardening plasticity, Hill anisotropic plasticity, Chaboche nonlinear hardening plasticity, and creep are supported. To simulate the tension-/compression-only options, a nonlinear iterative solution approach is necessary. Added mass, hydrodynamic added mass and loading, and buoyant loading are available [13].

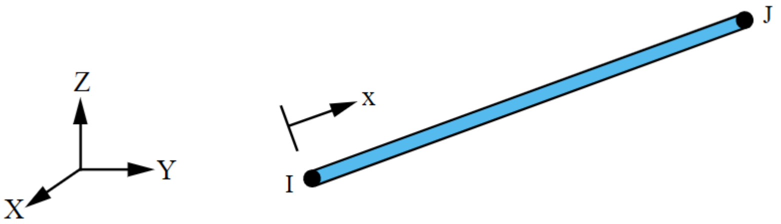
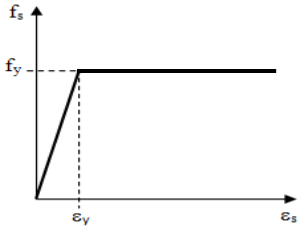


Figure 2. LINK180 Geometry

The steel stress-strain relationship model used is the Bilinear Istrotopic Hardening model, with material data shown in Table 1.

Table 1. Material Data of Steel Reinforcement LINK180

Linear – Elastic - Isotropic		
Modulus of Elasticity, E_s	2.0×10^5 MPa	
Poisson Rasio, ν_s	0.30	
Nonlinear – Inelastic – Rate Independent – Isotropic Hardening plasticity – Mises Plasticity – Bilinear Isotropic Hardening		
Yield stress, f_y	240 MPa, 400 MPa	
Section-Link	2D16 (400 mm^2)	

2.3. Steel Plates Pedestal and Supports

The steel plate used as the basis of concrete pedestal and supports that do not experience excessive local stress concentration which would cause the process to stop running ANSYS. These elements have 8 nodes with 3 degrees of freedom at any point in the x, y, and z. The steel plates using a model SOLID 45 with the material conditions of linear data that can be seen in Table 2.

Table 2. Data Material Steel Plates Pedestal and Supports SOLID 45

Linear – Elastic - Isotropic		Linear Elastic Condition
Modulus of Elasticity, E_s	2.0×10^5 MPa	
Poisson Rasio, ν_s	0.30	

3. RESEARCH METHOD

3.1. Manual Analysis of Reinforced Concrete Beams

The manual analysis of the ultimate flexural capacity of single-reinforced beams based on the strtcural concrete design code of SNI 2847:2019 [14] is as follows:

a) Depth of equivalent rectangular compressive stress block: $a = \frac{A_{st} \cdot f_y}{0.85 \cdot f_c' \cdot b}$ (8)

b) Depth of neutral axis: $c = \frac{a}{\beta_1}$ (9)

c) Efective depth of section: $d_t = h - d_s - \emptyset_s - \frac{1}{2} \cdot \emptyset_{ut}$ (10)

d) Nominal Flexural Strength: $M_n = A_{st} \cdot f_y \cdot \left(d - \frac{a}{2}\right)$ (11)

e) Maximum Flexural Capacity: $P_{max} = \frac{4 \cdot M_n}{L}$ (12)

3.2. Modeling of Reinforced Concrete Beams using ANSYS

In this study, 8 elements of normal strength reinforced concrete beams were taken which represent single reinforced beams under reinforced conditions [15], with a total tensile reinforcement of 2D16. Dimensions of the beam model: 200 mm wide, 400 mm high, the total length of the beam under review is 3000 mm, and the beam span is 2800 mm, the reinforced concrete structure model can be seen in Figure 3 and Table 3. The beam is then subjected a concentrated load in the middle of the span. and observed the value of the load, deflection, stress, and crack pattern.

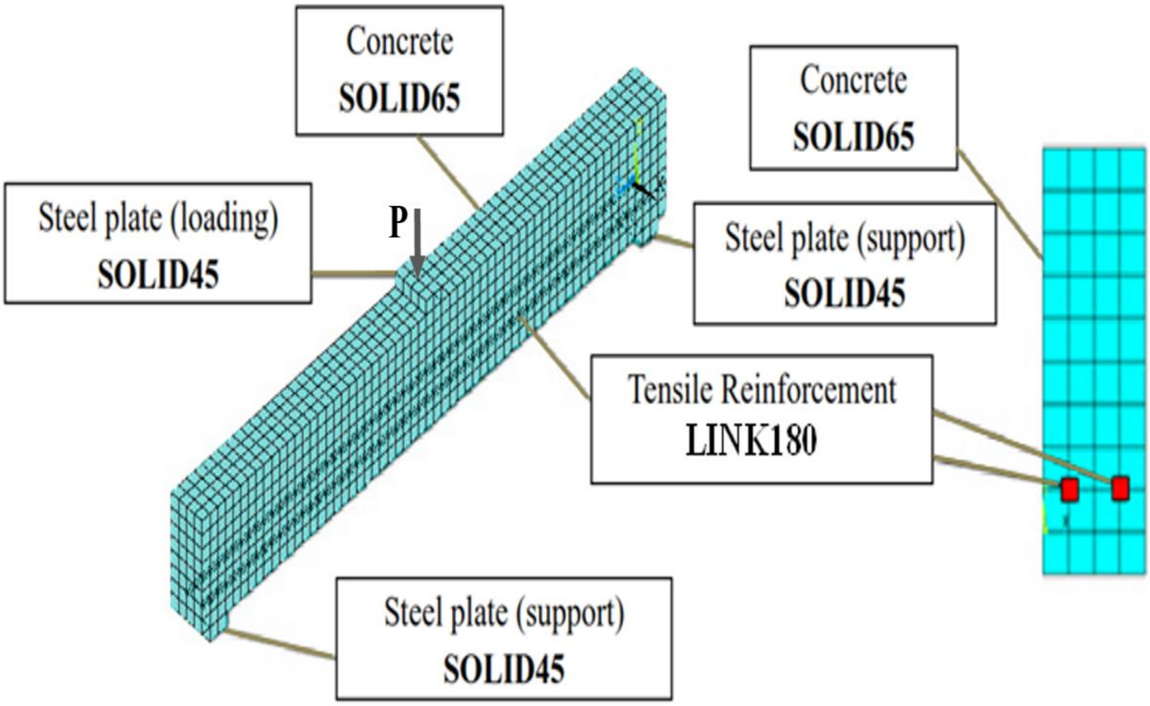


Figure 3. Element Types of ANSYS Modeling

Table 3. Element Configuration Model of Single Layer RC Beam

No.	Speciment	Steel	Concrete
		f_y (MPa)	f_c' (MPa)
1	B.240.17	240	17
2	B.240.21		21
3	B.240.25		25
4	B.240.30		30
5	B.400.17	400	17
6	B.400.21		21
7	B.400.25		25
8	B.400.30		30

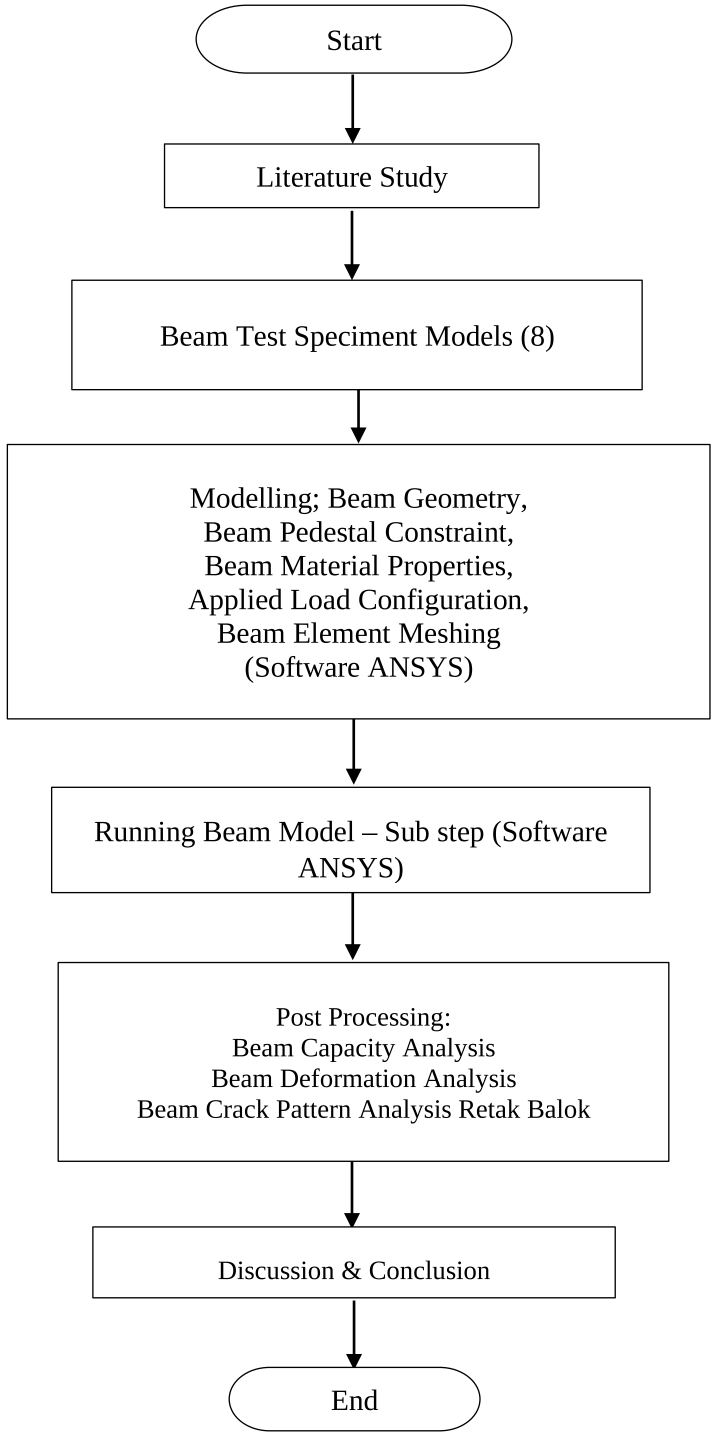


Figure 4. The flow chart of methodology

The research stages of this reinforced concrete beam (Figure 4) are as follows: 1) Making models of reinforced concrete test beams with various variations of concrete quality 2) Analysis of beam flexural capacity manually based on SNI 2847:2019 3) Modeling the collapse of the test object beam using ANSYS software 4) Analysis of the results of computer modeling which includes: a. Load and deformation relationship graph b. Stress and deformation relationship graph c. Concrete crack pattern 5) Analysis of computer modeling results between beam test objects 6) Discussion and Conclusion

4. RESULTS AND DISCUSSION

4.1. Load and Deflection

Based on the results of the ANSYS software analysis, it can be seen the relationship between load and deflection that occurs in concrete beams with tensile failure conditions. From Table 4 and Figure 5 it can be seen that with the use of steel quality of 240 MPa, the decrease in concrete quality is not significant causing a decrease in flexural capacity, but the deflection that occurs will be greater, this indicates that the ductility of the beam will be more ductile.

Table 4. Analysis Data of Load-Displacement (f_y = 240 MPa)

B.240.17		B.240.21		B.240.25		B.240.30	
Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
0	0	0	0	0	0	0	0
5.000	0.079	5.000	0.071	5.000	0.066	5.000	0.061
10.000	0.157	10.000	0.143	10.000	0.132	10.000	0.121
15.000	0.236	15.000	0.214	15.000	0.198	15.000	0.182
20.000	0.317	20.000	0.286	20.000	0.264	20.000	0.243
25.000	0.402	25.000	0.357	25.000	0.330	25.000	0.304
30.000	0.598	30.000	0.517	30.000	0.396	30.000	0.364
35.000	1.437	35.000	1.251	35.000	0.560	35.000	0.513
40.000	2.062	40.000	1.756	40.000	1.548	40.000	1.260
45.000	2.590	45.000	2.337	45.000	2.126	45.000	1.823
50.000	3.073	50.000	2.801	50.000	2.575	50.000	2.293

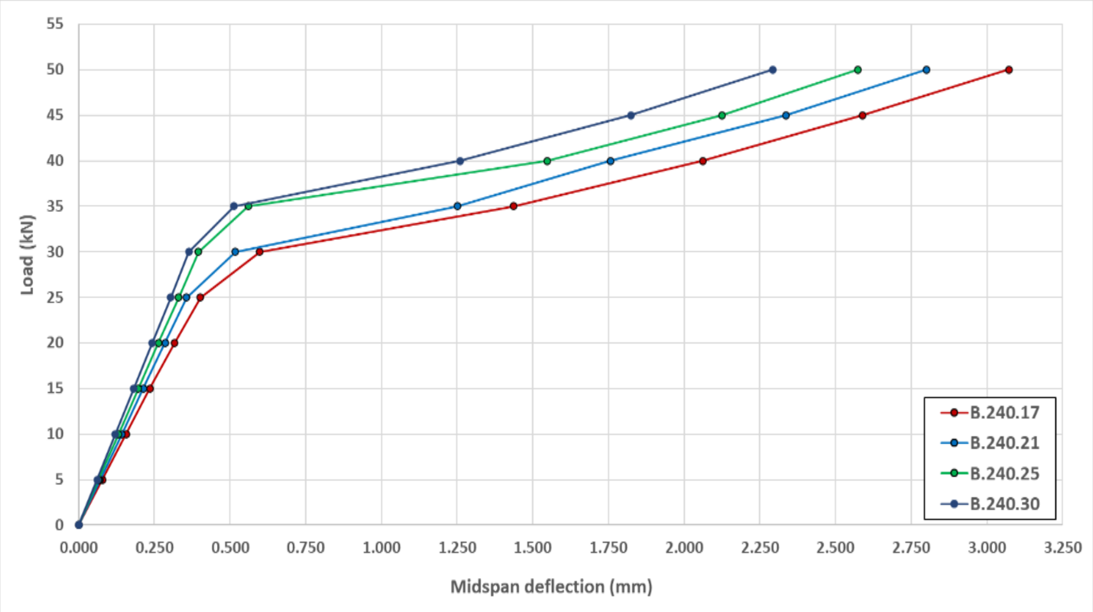


Figure 5. FEA Load-Displacement (f_y = 240 MPa) with various compressive strength of concrete

Meanwhile, from Table 5 and Figure 6 it can be seen that with the use of steel quality of 400 MPa, the decrease in concrete quality is not significant causing a decrease in flexural capacity, but the deflection that occurs will be greater, this indicates that the ductility of the beam will be more ductile.

Table 5. Analysis Data of Load-Displacement (f_y = 400 MPa)

B.400.17		B.400.21		B.400.25		B.400.30	
Load (kN)	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**	**Load (kN)**	**Deflection (mm)**
0	0	0	0	0	0	0	0
7.500	0.118	7.500	0.107	7.500	0.099	7.500	0.091
15.000	0.236	15.000	0.214	15.000	0.198	15.000	0.182
22.500	0.358	22.500	0.321	22.500	0.297	22.500	0.273
30.000	0.598	30.000	0.517	30.000	0.396	30.000	0.364
37.500	1.744	37.500	1.547	37.500	1.101	37.500	0.550
45.000	2.588	45.000	2.288	45.000	1.923	45.000	1.808
52.500	3.300	52.500	2.946	52.500	2.636	52.500	2.485
60.000	3.976	60.000	3.623	60.000	3.216	60.000	3.097
67.500	4.716	67.500	4.263	67.500	3.835	67.500	3.660
75.000	5.463	75.000	4.993	75.000	4.400	75.000	4.160

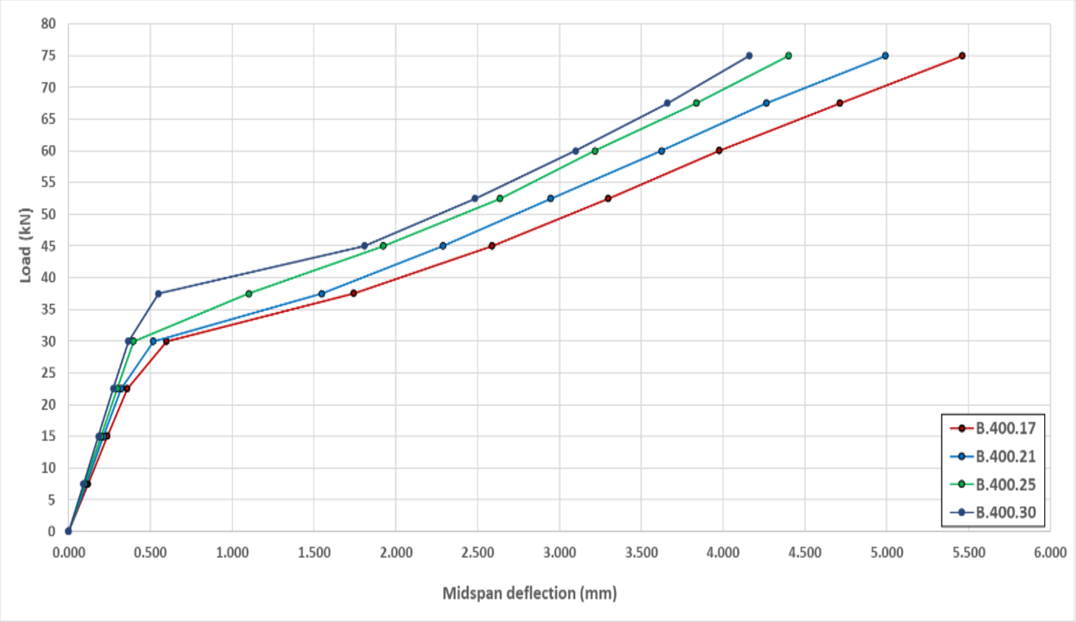


Figure 6. FEA Load-Displacement (f_y = 400 MPa) with various compressive strength of concrete

4.2. Bending Capacity of Beams

The flexural capacity based on manual analysis according to SNI 2837:2019 and ANSYS software analysis can be seen in Figure 7 and Table 6. It can be seen that the flexural capacity of the ANSYS software analysis is close to the results of manual analysis, and there is a difference below 9%.

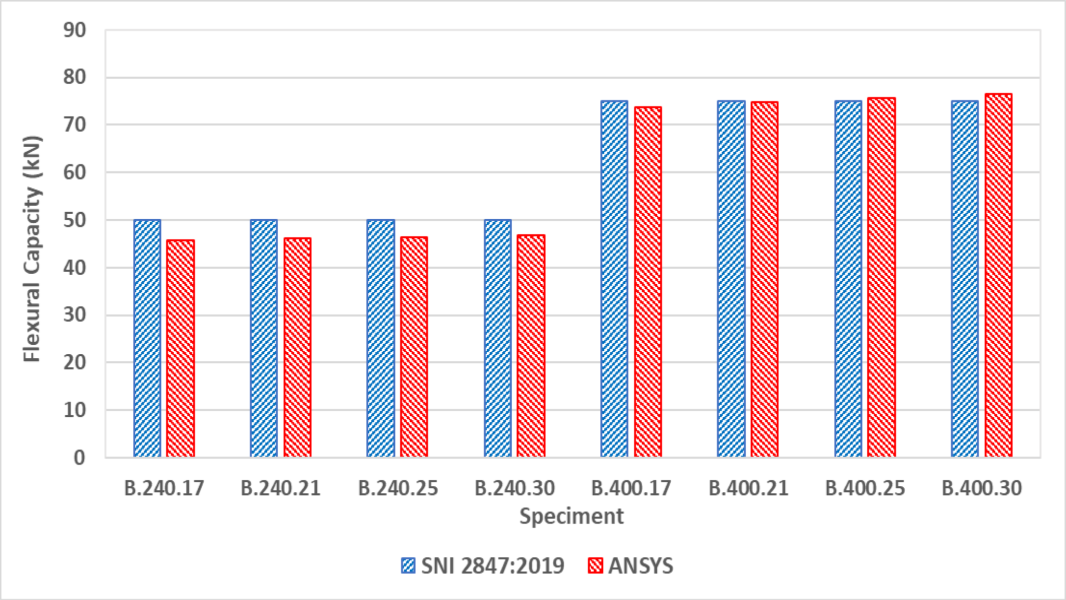


Figure 7. Comparsion of Flexural Capacity of the RC Beam

Table 6. Comparison of Deformation Capacity under *P* = 50 kN

No.	**Speciment**	**Maximum Deformation Capacity δ_{max} (mm)**		**Deformation Ratio**
		SNI code	**ANSYS**	
1	B.240.17	3.264	3.073	0.942
2	B.400.17	3.254	3.069	0.943
3	B.240.21	3.071	2.801	0.912
4	B.400.21	3.071	2.801	0.912
5	B.240.25	2.864	2.575	0.899
6	B.400.25	2.864	2.575	0.899
7	B.240.30	2.570	2.293	0.892
8	B.400.30	2.570	2.293	0.892

Table 7. Comparison of Flexural Capacity

No.	**Speciment**	**Maximum Flexural Capacity P_{max} (kN)**		**Load Ratio**
		SNI code	**ANSYS**	
1	B.240.17	50.000	45.722	0.914
2	B.240.21	50.000	46.156	0.923
3	B.240.25	50.000	46.451	0.929
4	B.240.30	50.000	46.709	0.934
5	B.400.17	75.000	73.673	0.982
6	B.400.21	75.000	74.878	0.998
7	B.400.25	75.000	75.697	1.009
8	B.400.30	75.000	76.415	1.019

4.2. Crack Patterns at Final Collapse

Based on the results of the ANSYS software analysis, it can be seen that the pattern of concrete cracks that occur at the ultimate is flexural cracks. From Figures 8 – 11, it can be seen that with the use of steel reinforcement of 240 MPa in yield stress, a decrease in the quality of concrete causes the distribution of concrete cracks to increase, this means that the beam is more ductile. And it can be seen that the crack development of the beam has not yet reached the concrete compression area.

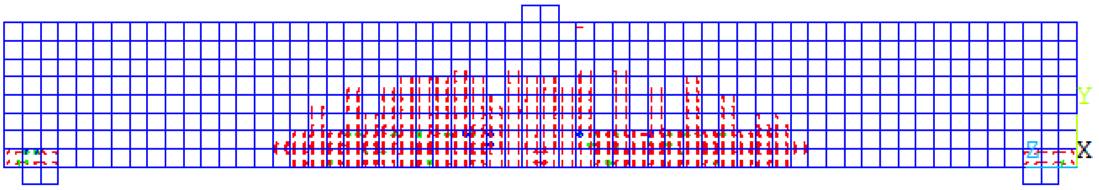


Figure 8. Crack Pattern under Tensile Collapsed Mechanism (B.240.17)

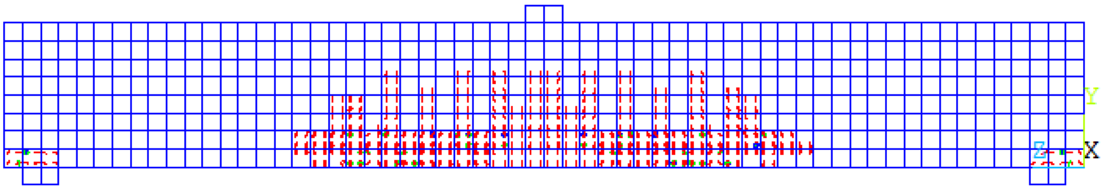


Figure 9. Crack Pattern under Tensile Collapsed Mechanism (B.240.21)

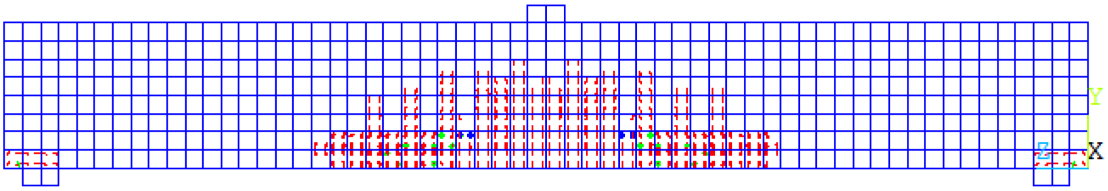


Figure 10. Crack Pattern under Tensile Collapsed Mechanism (B.240.25)

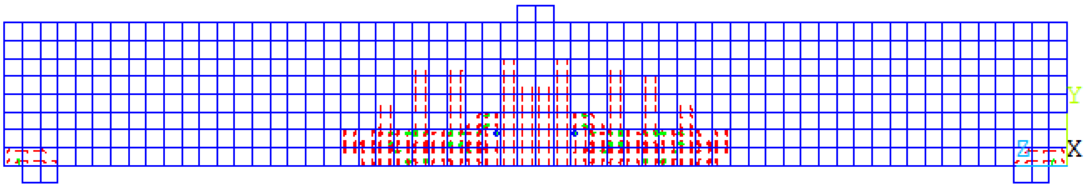


Figure 11. Crack Pattern under Tensile Collapsed Mechanism (B.240.30)

Meanwhile, from Figures 12 -15, it can be seen that the model steel grade of 400 MPa, the decrease in the quality of concrete causes the distribution of concrete cracks to increase, this means that the beam is more ductile. And it can be seen that the crack development of the beam to the concrete compression area occurs in the specimens B.400.17 to B.400.25.

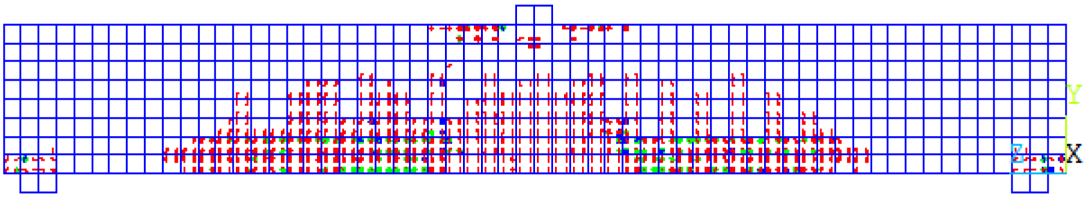


Figure 12. Crack Pattern under Tensile Collapsed Mechanism (B.400.17)

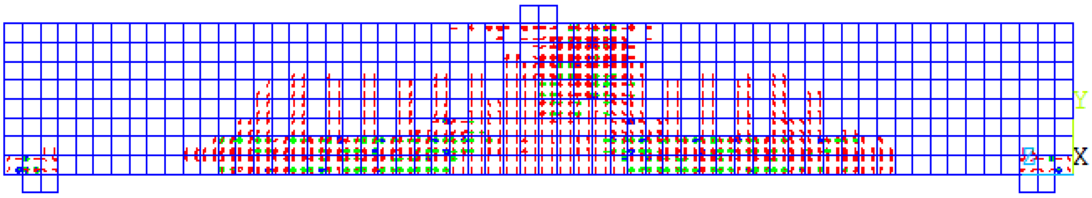


Figure 13. Crack Pattern under Tensile Collapsed Mechanism (B.400.21)

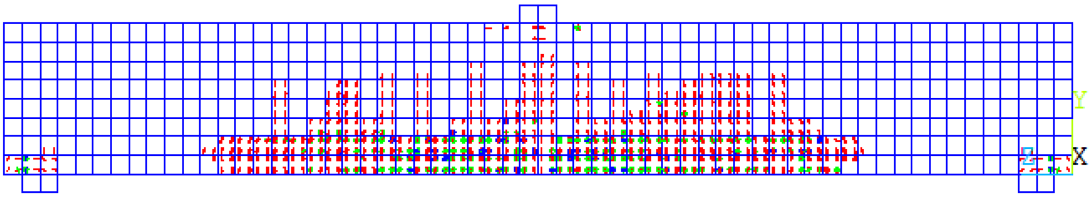


Figure 14. Crack Pattern under Tensile Collapsed Mechanism (B.400.25)

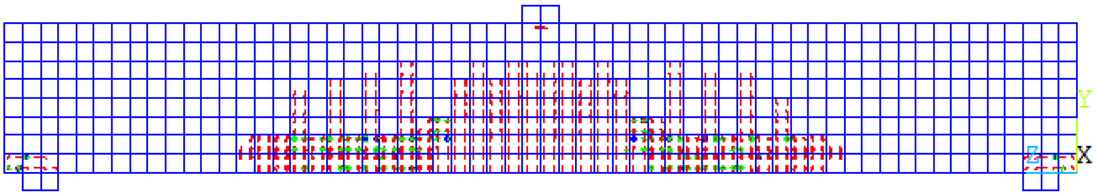


Figure 15. Crack Pattern under Tensile Collapsed Mechanism (B.400.30)

The third crack distribution is concentrated within the bottom region of the beam mid span, with the development of the crack region is significantly decreased due to enhanced concrete strength, as depicted in Table 8.

Table 8. Crack region of the various concrete strength model

No.	Speciment	Crack region R_{cr} (mm^3)		Crack Ratio
		Load (P_{max})	Third crack	
1	B.240.17	50	62.500	0.0781
2	B.240.21	50	58.500	0.0731
3	B.240.25	50	53.500	0.0669
4	B.240.30	50	43.500	0.0544
5	B.400.17	75	89.500	0.1119
6	B.400.21	75	86.000	0.1075
7	B.400.25	75	81.500	0.1019
8	B.400.30	75	72.000	0.0900

CONCLUSION

The conclusions of this study are; the decrease in concrete quality is not significant causing a decrease in flexural capacity, but the deflection that occurs will be even greater. The decrease in steel quality is not significant causing a decrease in flexural capacity and mid-span deflection. Decreasing the compressive strength of the concrete will cause the beam collapse behavior to become ductile. The flexural capacity of ANSYS software analysis is close to that of manual analysis, and there is a difference of less than 9%, which is adequately reasonable. The crack pattern is also not significantly affected by the change of the concrete strength

ACKNOWLEDGMENT

The authors would like to thank the Institute for Research and Community Service at Lambung Mangkurat University through the Compulsory Research Lecturer Program year 2022 which has funded this research.

REFERENCES

[1] M M A Pratama, B S Umniati, N Nindyawati, D I Margaretha, R K Suhud, P Puspitasari, A A Permanasari, Effect of concrete strength configuration on the structural behaviour of reinforced graded concrete beams, Journal of Physics: Conference Series, doi:10.1088/1742-6596/1808/1/012017, 2021.

[2] Asdam T.,Priyo S., Predicting The Flexural Response of A Reinforced Concrete Beam Using The Fracture-Plastic Model, Journal of Civil Engineering, Vol. 34 No. 2, pp. 61-67, December 2019.

[3] Tjitradi, D., Eliatun, Taufik, S., 3D ANSYS Numerical Modeling of Reinforced Concrete Beam Behavior under Different Collapsed Mechanisms, International Journal of Mechanics and Applications, Vol. 7 No.1, pp.14-23, p-ISSN: 2165-9281, e-ISSN: 2165-9303, Doi:10.5923/j.mechanics.20170701.02, 2015.

[4] N.Ajay, S.Girish, A Scientific Approach for Determining the Workability of Concrete, Proceedings Recent Development In Infrastructural Development, doi.org 10.2139 ssrn.3415547, Bangalore, 2015.

[5] Komal, R., Swati, A., A Review on Factors Affecting Workability of Concrete, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 7, Issue 8, August 2018, pp.9087-9098, ISSN(Online): 2319-8753, ISSN (Print): 2347-6710, Doi:10.15680/IJIRSET.2018.0708024, 2018.

[6] Olanitori, Lm, Gbadamosi, Ia, Effects of Concrete Grades on Strength Characteristics of Reinforced Concrete Slender Beams, Journal of Applied Sciences and Environmental Management, Vol. 23 (5), pp. 847-850, DOI: https://dx.doi.org/10.4314/jasem.v23i5.12, May, 2019.

[7] Subramani T., Manivannan R., Kavitha M., Crack Identification in Reinforced Concrete Beams Using Ansys Software, Int. Journal of Engineering Research and Applications, Vol. 4, Issue 6 (Version 6), pp.133-141, June, 2014.

[8] Vasudevan, G., Kothandaraman, S., Parametric study on Nonlinear Finite Element Analysis on Flexural Behavior of RC beams using ANSYS, International Journal of Civil and Structural Engineering, Volume 2, No 1, 2011.

[9] Agung Y.P., Darmansyah T., Irfan P., Horizontal Web Reinforcement Configuration Analysis of Deep Beam Capacity and Behavior using Finite Element Modeling, Engineering, Technology & Applied Science Research, Vol. 10, No. 1, Feb. 2020, pp. 5242-5246, DOI: https://doi.org/10.48084/etasr.3256, eISSN: 1792-8036, pISSN: 2241-4487, 2020.

[10] L. Dahmani, A. Khennane, and S. Kaci, Crack Identification In Reinforced Concrete Beams Using Ansys Software, Strength of Materials, Vol. 42, No. 2, Springer Science + Business Media, Inc., 2010.

[11] Al-Shimmari I.K., Hamad N.T., Waryosh W.A., Investigation of the Behavior for Reinforced Concrete Beam Using Non-Linear Three-Dimensional Finite Elements Model, Eng. & Tech. Journal, Vol. 29, No.10, 2011.

[12] Sharma A. et al., 2012, “Nonlinear seismic analysis of reinforced concrete framed structures considering joint distortion”, Scientific Information Resource Division, Bhabha Atomic Research Centre, Mumbai.

[13] Kent, D. C. and Park, R., Flexural Members with Confined Concrete, Journal of the Structural Division, ASCE, Vol. 97, pp. 1969 – 1990, 1971.

[14] ANSYS, ANSYS User’s Manual Revision 19.2, ANSYS, Inc., USA, 2019.

[15] BSN, SNI 2847:2019: Concrete Code for Structural Building (ACI 318M-14 dan ACI 318RM-14, MOD), 2019.

[16] Al-Eyssawi, Talib Abdul Jabbar, Comparative Study on the Required Tension Reinforcement for Singly Reinforced Concrete Rectangular Beams According to Different Codes, Journal of Babylon University/Engineering Sciences, Vol. 23, No.2, 2015.