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Design of Comfortable Structure of Junior High School Building By Using ETABS Software

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ABSTRACT
Ibnu Abbas Foundation intends to build a four-story school building for junior high school in Talun District, Cirebon Regency. This study aims to design a school building structure that is comfortable, safe, and meets earthquake-resistant standards using ETABS software. The design process includes structural planning, analysis of building response to static and dynamic loads such as dead load, live load, wind load, and earthquake load, as well as detailed design of structural elements such as floors, columns, beams, and foundations. This research method uses a calculation approach that refers to the applicable Indonesian National Standards (SNI), namely SNI 2847: 2019 for structural planning, SNI 1727: 2020 for load planning, and SNI 1726: 2019 for earthquake resistant planning. The planning process uses the Response Spectrum SRPMK method and is assisted by ETABS software for structural analysis and design. The planning results show that the four-story school building structure can be built safely using a pile foundation with a depth of 4.4 meters and diameters of 50 and 60 cm. The foundation is able to withstand the load of the planned structure. The structural elements of the school building are planned using reinforced concrete with a material quality of K-300 for the frame and K-350 for the columns. The main reinforcement used is BJTS 420A, and the transverse reinforcement is BJTP 280.

Keywords: building structure; ETABS; Response Spectrum SRPMK; earthquake resistant building design; pile foundation.

INTRODUCTION
Ibnu Abbas Foundation is located in Talun District, Cirebon Regency, on Angsana Raya Street No. 101 RT. 03RW. 10 Bumi Arum Sari Girang Village Cirebon. Ibnu Abbas Foundation currently operates two schools, TKIT and SDIT. By building a four-story school facility, the organization hopes to expand to an IT high school level.SNI 2847:2019 regulates the structural planning of buildings; SNI 1727:2020 regulates load planning; and reinforced concrete is the latest regulation revised to take into account technical advances. In addition, SNI 1726:2019 must also be consulted in earthquake engineering calculations.

The construction of school buildings, especially in earthquake-prone areas such as Cirebon Regency, has its own challenges, including ensuring structural safety and comfort for students. The current building standards must not only fulfill aesthetic and functional aspects, but must also meet earthquake resistance requirements (D'Urso & Cicero, 2019; Marini & Sarwindah, 2017; Papadopoulos, 2016). The specific issue addressed in this research is the need for a reliable design that can withstand various loads, including dynamic forces from earthquakes, while providing a comfortable learning environment (Bedon et al., 2018; Filiatrault & Sullivan, 2014; Shahjalal et al., 2024; Takewaki & Akehashi, 2021) .

The urgency of this research stems from the increasing frequency of earthquake events in Indonesia, necessitating immediate action to improve the safety of educational facilities. With many school buildings potentially failing to meet modern safety standards, there is an urgent need to adopt more advanced design methodologies using tools such as ETABS (Alwani, 2022; Mahamood & Fathi, 2022; Memon et al., 2020; Thai et al., 2020). This research aims to develop a robust structural design that prioritizes student and staff safety, ensuring uninterrupted educational activities even in the face of natural disasters.

This research introduces a new approach by integrating advanced software such as ETABS with the established Indonesian National Standard (SNI) for earthquake-resistant building design. By using the Response Spectrum method, this research not only improves the accuracy of structural analysis but also provides a framework for future projects. The innovative aspect lies in the application of these modern techniques in the context of local regulations, thus paving the way for safer and more efficient school building design.

Previous research in the field of earthquake-resistant design has mainly focused on residential and commercial buildings, often neglecting educational institutions. While there are foundational works on structural engineering principles and modelling techniques, few specifically address the unique requirements of school buildings in earthquake zones. This research builds on those foundations and specifically targets the design of junior high school facilities, thus filling a critical gap in the existing literature.

RESEARCH METHODS

The flowchart of the building structure planning stages is presented in the following figure:
Here are some outline planning data: The activity is called Structural Planning of Four-Storey IT Junior High School Building in Talun District, Girang Village, Cirebon Regency; Building Location: Talun, Cirebon Regency; School Building is the function of the building.

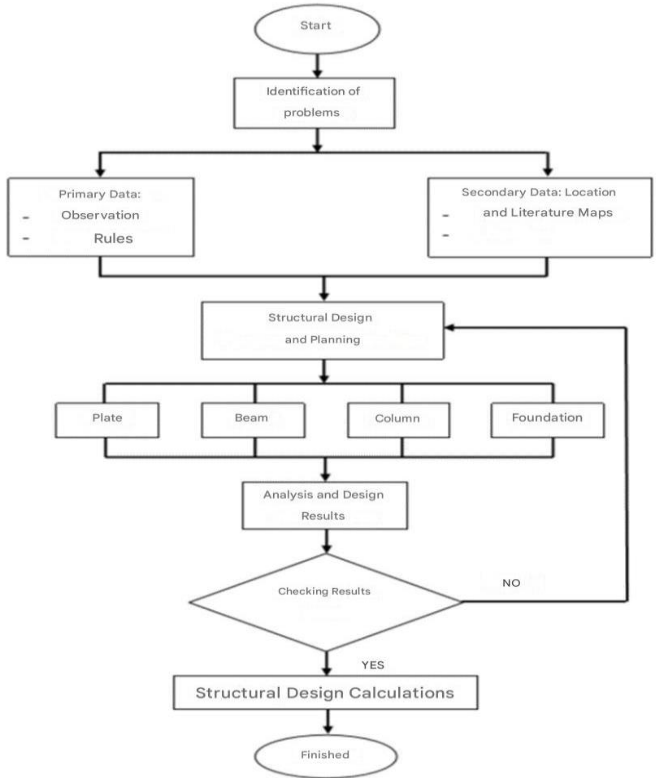

Figure 1 Building Planning Flowchart

RESULTS AND DISCUSSION

a. General Planning Data

1. Activity name = Building Design
   Building Structure SMP IT IBNU ABBAS 4 Floors
2. Location = Talun, Cirebon Regency
3. Concrete quality Fc = columns and beams: Thirty (30) Mpa
4. Steel Reinforcement = (420) Mpa (threaded iron) and 280 Mpa Plain Iron
5. Foundation = Pile
6. Soil condition = medium soil

b. Load Combination

The following loads were considered while designing this school building namely live, dead, earthquake and wind loads.

1. Analysis of loading resistance

Analysis of the earthquake resistance of buildings includes determining the visibility of the subgrade using sondirs and N-SPT testing to identify soil characteristics. This information is then incorporated into the calculation of the response spectrum. The analysis focused on the function of the building and any associated structures, and then categorized the seismic zoning map to determine the zoning. The following is the building's seismic planning data:

1. Location : West Java
2. Cause (e) : 1.0
3. Risk Group : II
4. Response Coef : 8

The following are the stages of the earthquake load plan through the dynamic response spectrum method:

a. Establish key criteria and construction risk categories.
b. Define ss and s1
c. Ensure Site Class
d. Find Site coefficient

The above procedure produces the results viz:

Table 1. Acceleration Spectral Data

Variables	Value
Ss (g)	0,681
S1 (G)	0,273
sms {G}	0,855
Sm1 {G}	0,523
Sds {G}	0,57
Sd1 (G)	0,338
FA	1,256
FV	1,9
T0 (sec)	0,119
Ts (sec)	0,593

Based on the findings of the Design Acceleration Response Spectrum calculation, the following is the graph:

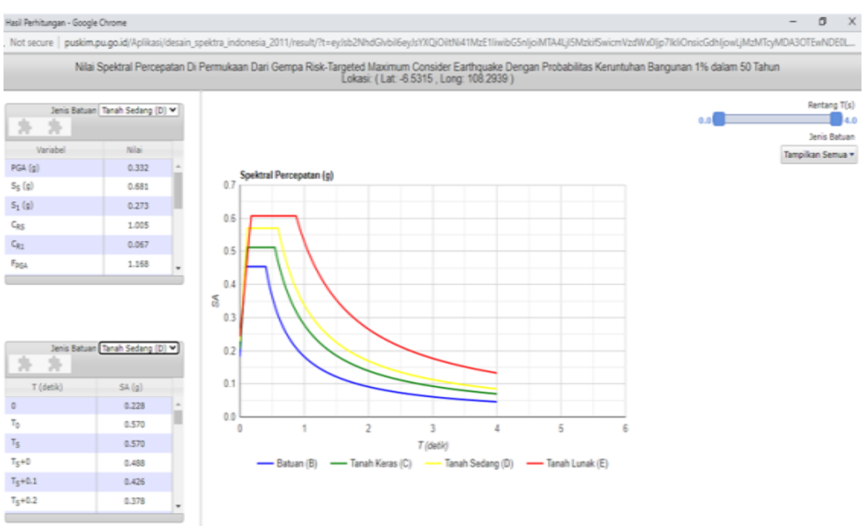

Figure 2 Acceleration Spectral Graphs and Values Modelling Structures with SRPMK

1. Determining the mass of the structure
   In ETABS, it functions as a mass quantity that determines the loads entered into the modelling, also known as the mass source. The mass of the structure is calculated based on the weight of the individual structure, additional dead load, and constant live load (Kamjoo & Eamon, 2018; Taghinezhadbilondy et al., 2016; Udoeyo, 2020).

2. Determine the modal and range of analysis
   To achieve a combined variance mass participation of not less than 90% of the real mass perpendicular to the assessed model response in each horizontal direction, there must be sufficient variance in the analysis (Serdar & Folić, 2018).

Modal Participating Mass Ratios

File Edit Format-Filter-Sort Select Options

Units: As Noted Hidden Columns: No Sort: None Modal Participating Mass Ratios

Filter: None

Case	Mode	Period sec	UX	UY	UZ	SumUX	SumUY	SumUZ	RX	RY	RZ	SumRX	SumRY
Modal	1	1.84	0.6849	0	0	0.6849	0	0	0	0.2592	0.0485	0	0.2592
Modal	2	1.761	5.833E-06	0.7361	0	0.6849	0.7361	0	0.2746	2.244E-06	4.827E-05	0.2746	0.2592
Modal	3	1.737	0.0486	0.0001	0	0.7334	0.7362	0	1.911E-05	0.0187	0.6872	0.2746	0.2779
Modal	4	1.244	0	0	0	0.7334	0.7362	0	0	0	0	0.2746	0.2779
Modal	5	0.59	0.1002	0	0	0.8336	0.7362	0	0	0.3486	0.0064	0.2746	0.6265
Modal	6	0.569	0	0.1046	0	0.8336	0.8408	0	0.3763	8.956E-07	2.362E-06	0.6509	0.6265
Modal	7	0.562	0.0063	2.389E-06	0	0.8399	0.8408	0	8.953E-06	0.0225	0.0992	0.6509	0.649
Modal	8	0.554	1.322E-06	6.8E-07	0	0.8399	0.8408	0	2.671E-06	3.38E-06	4.586E-06	0.6509	0.649
Modal	9	0.536	0.0001	0	0	0.84	0.8408	0	5.254E-07	0.0002	8.311E-06	0.6509	0.6492
Modal	10	0.398	6.04E-07	0	0	0.84	0.8408	0	0	8.796E-06	4.223E-06	0.6509	0.6492
Modal	11	0.325	0.0398	0	0	0.8797	0.8408	0	0	0.049	0.0019	0.6509	0.6982
Modal	12	0.318	0	0.0408	0	0.8797	0.8816	0	0.049	0	0	0.7	0.6982
Modal	13	0.317	0	0.0004	0	0.8797	0.882	0	0.0005	0	3.432E-06	0.7005	0.6982
Modal	14	0.313	0.0019	0	0	0.8817	0.882	0	0	0.0023	0.0393	0.7005	0.7005
Modal	15	0.28	0	0	0	0.8817	0.882	0	0	0	0	0.7005	0.7005
Modal	16	0.274	3.295E-06	0	0	0.8817	0.882	0	0	3.584E-06	0	0.7005	0.7005
Modal	17	0.248	0	1.797E-06	0	0.8817	0.882	0	4.526E-06	0	0	0.7005	0.7005
Modal	18	0.239	0	0	0	0.8817	0.882	0	0	0	1.916E-06	0.7005	0.7005
Modal	19	0.216	6.92E-06	0	0	0.8817	0.882	0	0	2.376E-05	4.772E-05	0.7005	0.7005
Modal	20	0.211	0.0202	0	0	0.9018	0.882	0	0	0.0559	0.0009	0.7005	0.7564
Modal	21	0.208	5.715E-06	2.524E-06	0	0.9019	0.882	0	7.7E-06	1.508E-05	2.487E-06	0.7005	0.7565
Modal	22	0.207	0	0.0205	0	0.9019	0.9025	0	0.0579	0	0	0.7584	0.7565

Record: 1 of 22 Add Tables... Done

Figure 3 Combined Variety Mass Participation

Calculation of Response Spectrum Scaling Factor

The following equation is used to calculate the earthquake force factor scale:

Earthquake load scale factor = '1'/'r' 'xg'

= "1"/"8" "×9,8"

= 1,225

Thus, the scale factor of the earthquake load force is taken into account in ETABS. How to Calculate Base Period Control

In 7.9.4.1 SNI 1726:2019 states if the structure (T) in question has a base period as follows:

If tc is more than Cu Ta so use Tc = Cu Ta

If (ta) < (cu) < (cu) ta then use t = (tc)
If Tc < Ta so use T = Ta
Tc = 0.983s, Ta = 0.844s, and CuTa = 1.182 can be found from the analysis findings of the ETABS program. obtained (tc) < (ta). the basic time of the structure used is T = (ta) (0.844s).

Table 2: Basic Reactions

V		
Load Case	(Fx)	(Fy)
	(Kn)	(Kn)
(Ex Max)	10862.6359	3.4675
EY MAX	3.5505	11664.6605

Inter-Storey Deviation Control

Table 3. Deviation Control

Story	**UX**	**UY**
	Kg	Kg
Roof Top	3676570.49	3676570.49
4th floor	4761872.09	4761872.09
3rd floor	4906239.99	4906239.99
2nd floor	5089269.39	5089269.39
1st floor	4282894.28	4282894.28
Pedestal	335160	335160
Total	19040275.75	19040275.75

Structure Load

Table 4. Additional Dead Load

No.	**Load**	**Load Value**
1	Wall	98 Kg/m2
2	Ceiling & Truss	0.20 Kn/m2
3	MEP installation	0,30
4	Ceramic (1 cm thickness)	0,24
5	Water Profing	14
6	Speci	0,21
7	Sand	16

Additional dead load on 1st floor
Ceramic Weight 1 x 0.24 = 0,24
Speci weight 0.03 x 0.21 = 0,0063
Weight of sand 0.05 x 16 = 0,8
Total = 1,046

Additional dead load on floors 2 - 4
Ceramic weight 1 x 0.24 = 0,24
Speci weight 0.03 x 0.21 = 0,0063
Weight of sand 0.05 x 16 = 0,8
MEP1 Installation x 0.30 = 0,30
Ceiling and frame 1 x 0.20 = 0,20 KN/m^2
Total = 1.546 Kn/m2

Additional Matii loading of roof
Waterproofing 0.02 x 14 = 0,28
Speci weight 0.03 x 0.21 = 0,0063
Weight of sand 0.05 x 16 = 0,8
MEP1 Installation x 0.30 = 0,30
Total = 1,386 KN/m^2

Additional Dead Load on sloof/beams
Wall Load: 1.0 x 3.5 = 3.5 KN/m^2

Table 5. Living Load for School

No.	Designation	Live Load (KN/m^2)
1	Private Plates	1,92
2	Public Plates	4,79
3	Roof Plates	0,96

Plate Planning
Reinforcement of 1st floor slab
From the analysis results obtained Mu : 13.25 KNm
Plan reinforcement is used : D12-125
As = 1/4πd^2 x b/s
= 1/4 x 3.14 x 12^2 x 1,000/125
= 〖904.3mm〗^2
A = (AsxFy)/(0.85 x fc^' x b)
= (904,3x 280)/(0.85 x 30x1000)
= (9.495 mm〗^2
ØMn = (as x Fy x (124-A/2) x 10"(-6)) x 0,8
= (904.3 x 280 x (124-9.495/2) x 10^(-6)) x 0,8
= 24.156 KNm
ØMn ≥ Mu
24.156 KNm ≥ 13.25 KNmOK !!!

Reinforcement of 2nd floor slab
From the analysis results obtained Mu : 4,153 KNm
Plan reinforcement is used : D12-125
As = 1/4πd^2 x b/S
= ¼ x 3.14 x 12^2 x 1000/125
= 9.043 〖mm〗^2
α = (As x Fy)/(0.85 x fc^' x b)
= (904.3x 280)/(0.85 x 30x1000)
= 〖〖9.495mm〗^2〗^
ØMn = (As x fy x (124-a/2) x 10^(-6)) x 0.8
= (904.3 x 280 x (124-9.495/2) x 10^(-6)) x 0,8

= 24.156 KNm

ØMn ≥ Mu

24.156 KNm ≥ 4.153 KNm OK!!!

Reinforcement of 3rd floor slab

From the analysis results obtained Mu : 4,147 KNm

Used plan reinforcement : D12-150

As = 1/4πd^2 x b/S

= ¼ x 3.14 x 12^2 x 1000/125

= 9.043 〖mm〗^2

α = (As x Fy)/(0.85 x fc^' x b)

= (904.3x 280)/(0.85 x 30x1000)

= 9.495 mm

ØMn = (As x fy x (124-a/2) x 10^(-6)) x 0.8

= (9.043x 280 x (124-9.495/2) x 10^(-6)) x 0,8

= 24.156 KNm

ØMn ≥ Mu

24.156 KNm ≥ 4.147 KNm OK!!!

Reinforcement of 4th floor slab

From the analysis results obtained Mu : 4,139 KNm

Plan reinforcement is used : D12-125

As = 1/4πd^2 x b/S

= ¼ x 3.14 x 12^2 x 1000/125

= 9.043 〖mm〗^2

α = (As x Fy)/(0.85 x fc^' x b)

= (904.3x 280)/(0.85 x 30x1000)

= 9.495 mm

ØMn = (As x fy x (124-a/2) x 10^(-6)) x 0.8

= (9.043x 280 x (124-9.495/2) x 10^(-6)) x 0,8

= 24.156 KNm

ØMn ≥ Mu

24.156 KNm ≥ 4.147 KNm OK!!!

Roof slab reinforcement

From the analysis results obtained Mu : 1,426 KNm

Plan reinforcement is used : D12-100

As = 1/4πd^2 x b/S

= 1/4 x 3.14 x 12^2 x 1000/100

= 113.0 (mm)^2

α = (as x fy)/((0.85 x Fc^' x b)

= (113.0x 280)/(0.85 x 30x1000)

= 1.116 mm

ØMn = (As x fy x (124-a/2) x 10^(-6)) x 0.8
= (113.0x 280 x (124-1.116 /2) x 10^(-6)) x 0,8
= 1.726 KNm

ØMn ≥ Mu

1.726 KNm ≥ 1.426 KNm OK!!!

Table 6. Plate Reinforcement Plan

Plate Type	Function	Support Reinforcement		Field Reinforcement	
		X direction	Y direction	X direction	Y direction
(5 x 5)	Public 1st Floor	Ø 12-125	Ø 12- 125	Ø 12 - 125	Ø 12 - 125
(5 x 5)	Public 2nd,3rd,4th Floor	Ø 12-125	Ø 12- 125	Ø 12 - 125	Ø 12 -125
(5 x 5)	Roof Plates	Ø 12-100	Ø 12- 100	Ø 12 - 100	Ø 12 - 100

Column Planning

Table 7. Etabs output on column

Column Type	Inner Style		
	Axial Force	Ultimate Moment	Shear Force
K1 700 x 700	2206.310 kN/m	62.6834 kN/m	48 kN/m
K2 600 x 600	1172.190 kN/m	62.7449 kN/m	31 kN/m

Table 8. Column Reinforcement Plan

Column Type	Reinforcement Planning	
	Longitudinal	Shear
K1 700 x 700 - Lt 1	12 D 22	4 Ø 12 - 200
K2 600 x 600 - Lt 2,3 & 4	10 D i22	4 Ø 12 - 200

Beam and Sloof Planning

Table 9. Force in Beams and Sloofs

Beam Type	Moment of Force	Field Moment	Shear Force
B 1 450x300	74.860 kN/m	70.747 kN/m	73.257 kN
B 2 400x250	7.568 kN/m	4.674 kN/m	8.970 kN
BA 1 200X150	11.576 kN/m	6.351 kN/m	9.795 kN
SL 1 600X500	55.184 kN/m	53.447 kN/m	71.104 kN
SL 2 500x350	62.082 kN/m	60.128 kN/m	17.295 kN

Table 10. Reinforcement Plan for Beams and Sloofs BALOK/SLOOF REINFORCEMENT PLAN

Reinforcement	Shear		
Main Beam 1 (600x450)	Pedestal	3 D16	Ø10 - 150
	Field	3 D16	Ø10 - 150
Main Beam 2 (500x350)	Pedestal	2 D14	Ø10 - 150
	Field	2i D14	Ø10 - 150
Child Beam 1 (450x250)	Pedestal	2 D14	Ø10 - 150
	Field	2 D14	Ø10 - 150
Sloof 1 (600x500)	Pedestal	3 D14	Ø10 - 100
	Field	4 D14	Ø10 - 100
Sloof 2 (500x350)	Pedestal	2 D14	Ø10 - 100
	Field	3 D14	Ø10 - 100

Foundation Planning

Table 11. Pile Cap Reinforcement Plan

NO	FOUNDATION TYPE	PILECAP DIMENSIONS	NUMBER OF PANCANGES	RETURN	
				X DIRECTION	Y DIRECTION
1	PONDATION 1	1.5 x 2 x 0.80	2	D 19 - 150	D 19 - 150
2	PONDATION 2	2.5 x 2.5 x 0.70	3	D 19 - 150	D 19 - 150

c. Research Location

Figure 4. Research Location

d. Structure Design

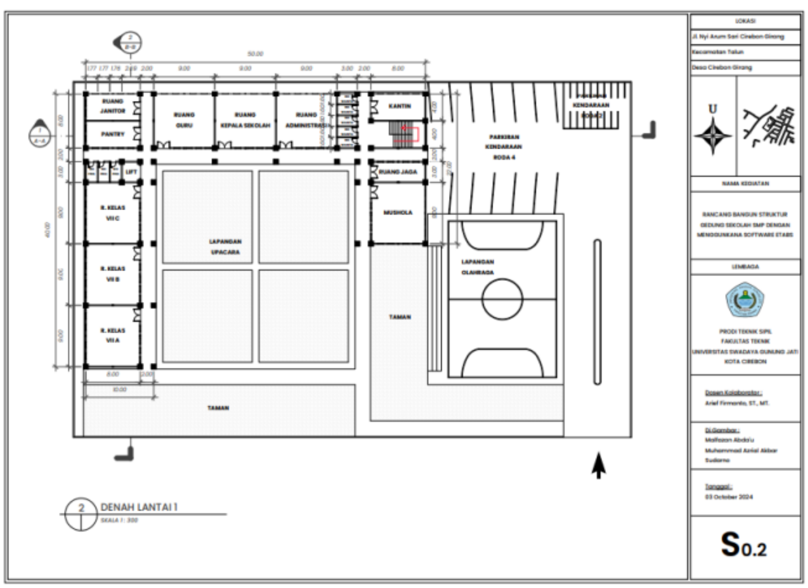

Figure 5. 1st Floor Plan

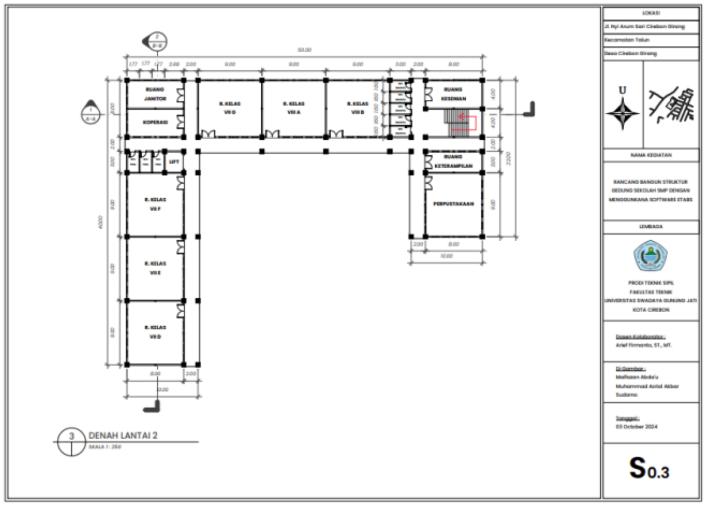

Figure 6. 2nd Floor Plan

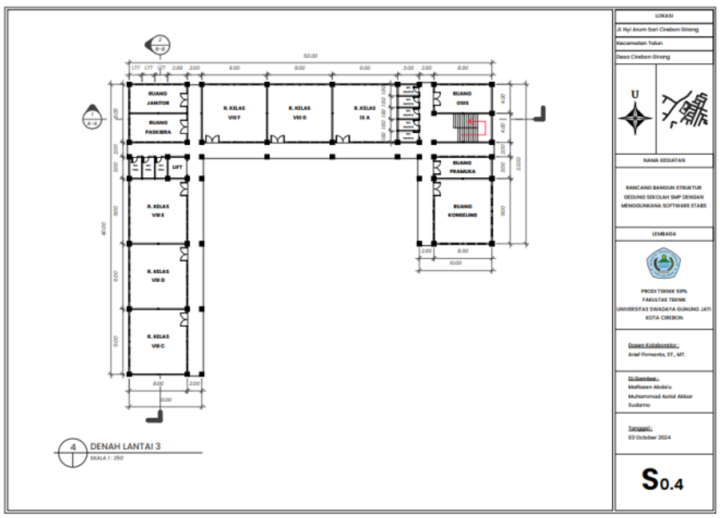

Figure 7. 3rd Floor Plan

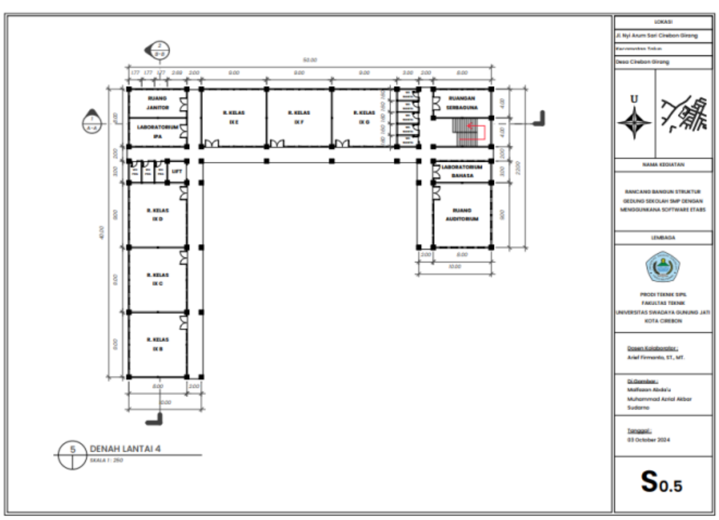

Figure 8. 4th Floor Plan

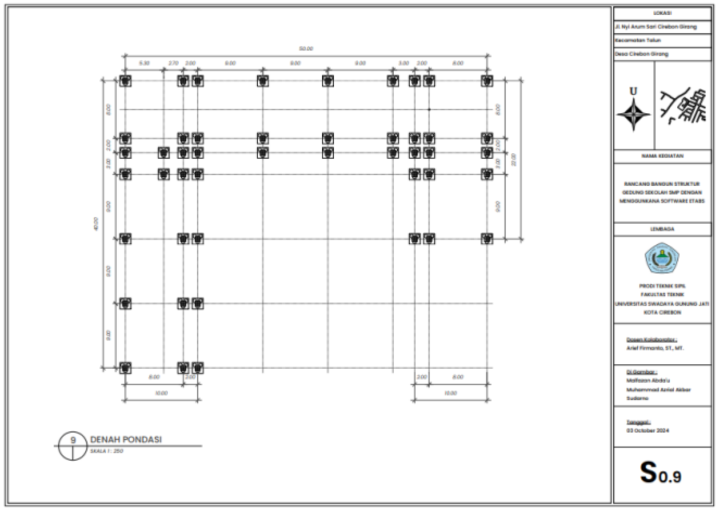

Figure 9. Foundation plan

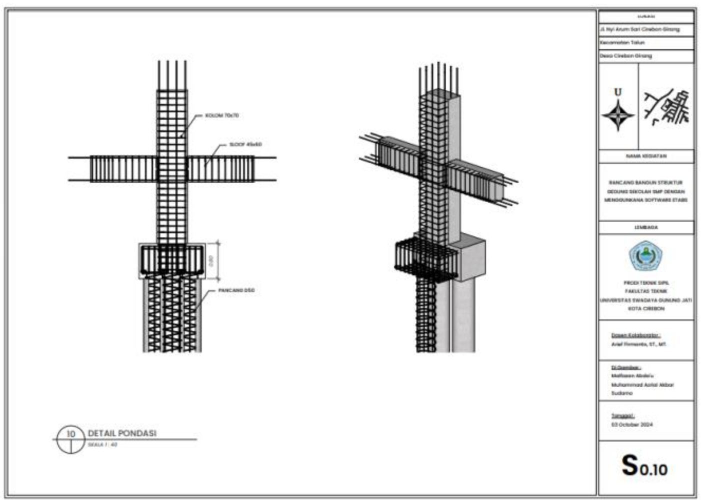

Figure 10. Foundation Detail

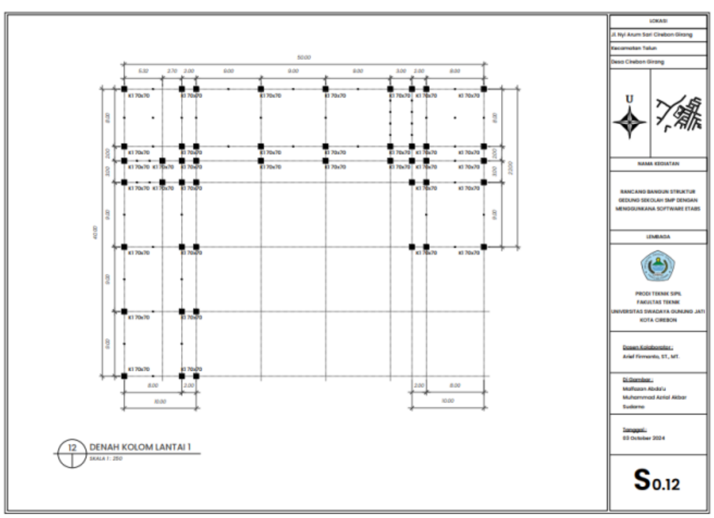

Figure 11. Plan of Column K1

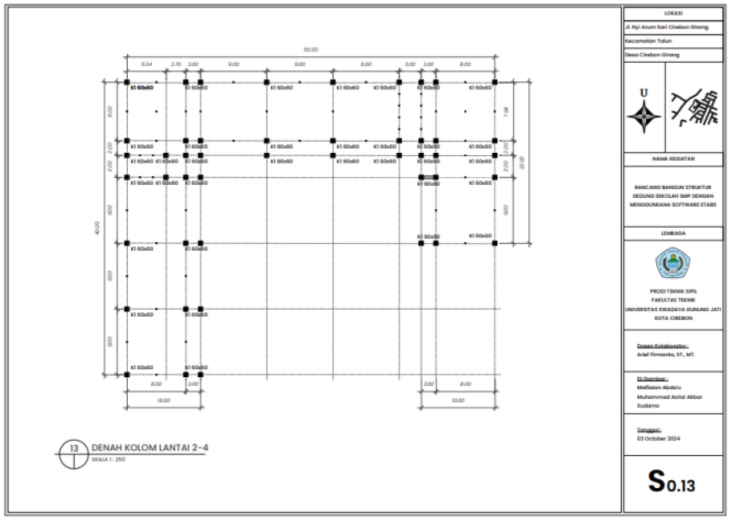

Figure 12. Plan of Column K2

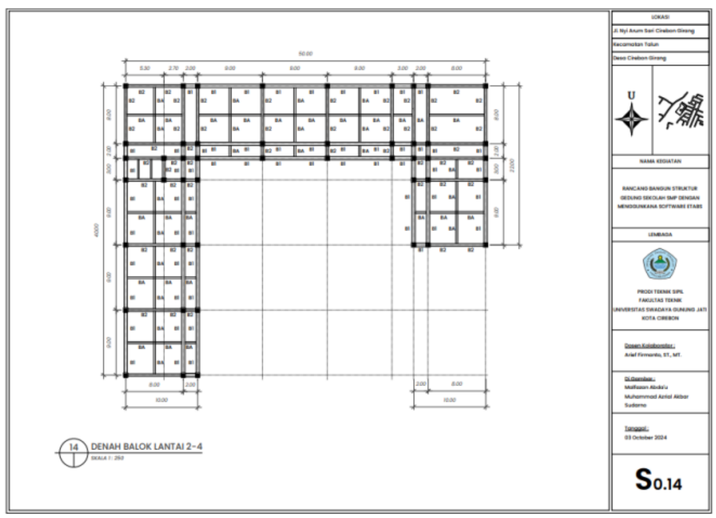

Figure 13. Floor Beam Plan 2-4

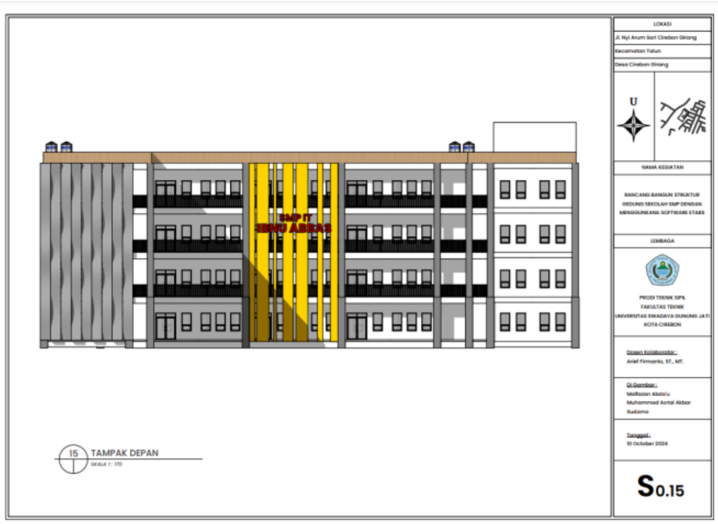

Figure 14. Front View

Figure 15. Left Side View

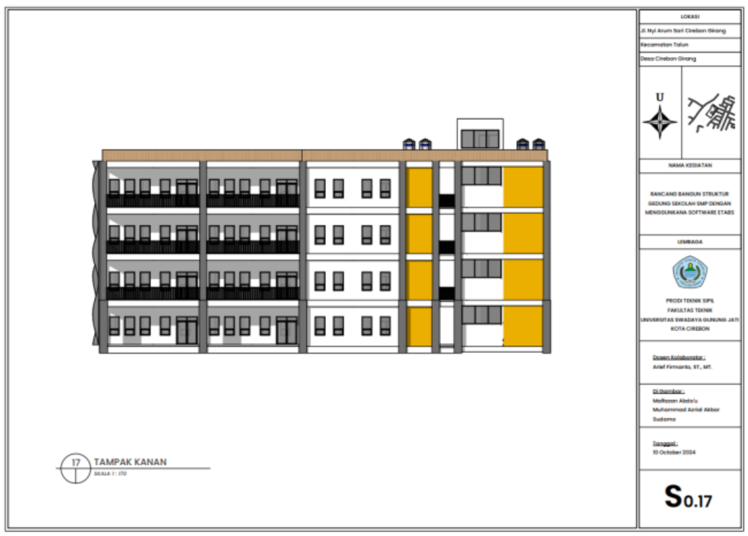

Figure 16. Right Side View

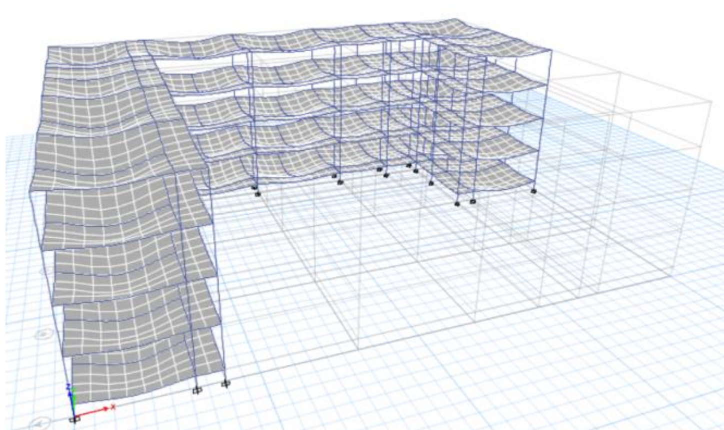

Figure 17. Load Check Results

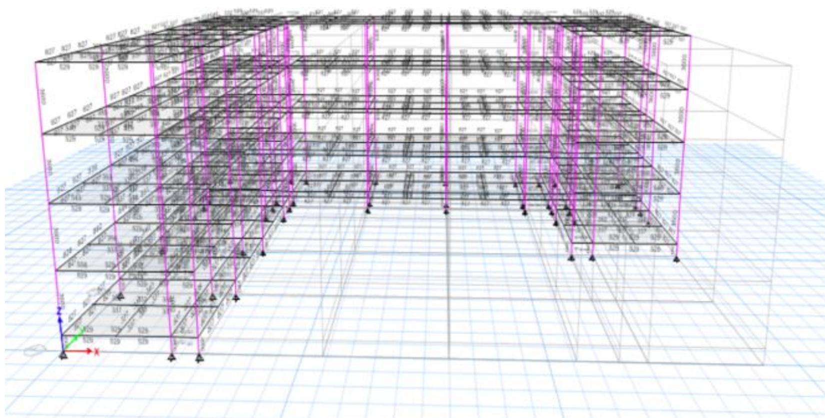

Figure 18. Results of the structural check using Etabs software

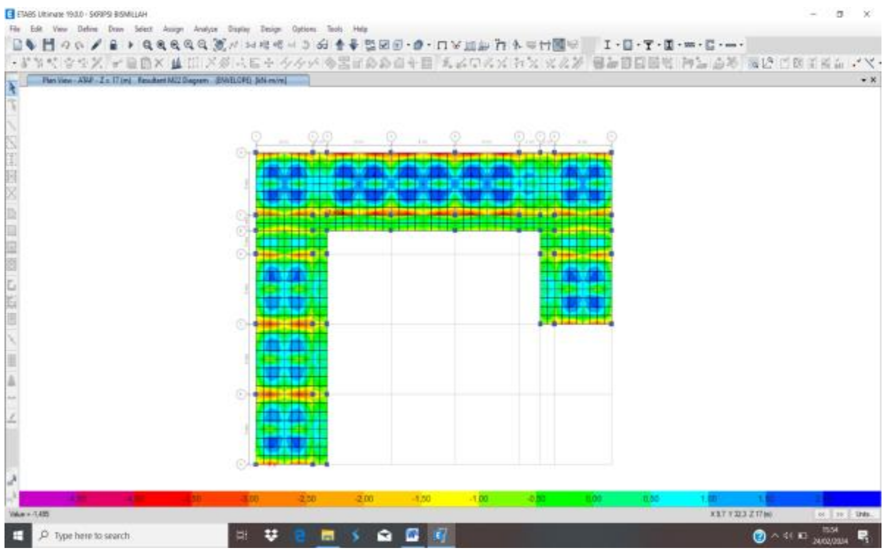

Figure 19. Final Results of The Run Using Etabs Software

CONCLUSION

The design of this four-storey school building is made of reinforced concrete, where beams and slabs use K-300 with fc' 30 Mpa, while columns use K-350 with fc' 30 Mpa. For longitudinal reinforcement, BJTS 420A was used, while transverse reinforcement used BJTP 280. This school building is included in risk class II with I = 1 and R = 8 values, where the concrete structure planning was developed using the SRPMK approach. The foundation of the building uses piles with a depth of 4.4 meters and pile diameters of 50 and 60 centimeters. The planning of this school refers to SNI 1727:2020 for load design and SNI 1726:2019 for earthquake plan.

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