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THE USAGE OF BIM BASED STRUCTURE ANALYSIS APPLICATION TO REDESIGN MITRA KASIH JUNIOR AND SENIOR HIGH SCHOOL BUILDING WITH PRECAST CONCRETE

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ABSTRACT

Redesign of Mitra Kasih Junior and Senior High School building in Banjarmasin carried out which is a reinforced concrete structure into a precast concrete structure. Process supported by BIM-based structural analysis applications, Tekla Structural Designer and ETABS Ultimate C19. Results will be validated using Response2000 and SPColumn. Difference between conventional and precast systems required design adjustments. Adjustments began with preliminary design of structural and application of one-way floor slabs (HCS). From structural analysis result, stability of the structure calculate along corbel connection design. From redesign results found difference amount of tensile reinforcement in the beam ranges from 2 to 4 due one-way slab load distribution. Differences in the arrangement of main reinforcement column due differences of width-height column to strengthen weak axis column. HCS slab with thickness of 20 cm to lighten the weight of structural elements. Corbel as connectors resist shear at joint as the redesign results meet the structural stability requirements and the requirements of public buildings.

***Keywords**:* Precast Concrete, HCS, Corbel

1. INTRODUCTION

Background

Concrete has become the most widely used composite material in modern industry. Concrete has developed into various types according to the needs of the building development, one of them is precast concrete. Precast concrete has advantages in terms of quality, faster production, lower costs, can provide complex geometric configurations and is more economical in terms of workmanship

With the advantages of precast concrete, redesign of existing structure was carried out. In this study, the redesign of the Mitra Kasih Junior and High school building in Banjarmasin which is a reinforced concrete structure. The use of precast concrete in this redesign is a solution due obstacles faced in the field which is project vehicle mobilization access due to the school location in the housing complex and through the main road.

The structure redesign process using precast concrete is supported by the use of structural analysis applications that are able to integrate with BIM. The use of BIM based structural analysis applications is based on previous research on the use of BIM based applications to support scheduling, cost calculations and modeling of building structures. This research uses a structural analysis application that facilitates integration with BIM so that the results of the structural analysis on redesign can be developed using file with IFC extension.

Research Objectives

This study aims to get design and reanalyze Mitra Kasih Junior dan High School building using precast concrete.

Limitations of the Issue

Below are the limitations of the problems in the study :

1. The discussion object of this research is Mitra Kasih Junior dan Senior High School Banjarmasin building structure.
2. The redesign structure in this study is upper structure of the Mitra Kasih Junior and Senior High School Citraland Banjarmasin.
3. The redesigned structure in this research is only the reinforced concrete structure.
4. The results of the redesign only compare the dimensional differences between the existing conditions and the redesigned conditions.
5. Implementation of structural analysis and design applications that are integrated with BIM in providing an alternative to the use of precast concrete materials to the use of reinforced concrete in the field.
6. 3D modeling refers to the plan drawings from the project.

Research Benefits

The benefits of this research are expected to be a reference for construction executor in designing buildings using precast concrete. In particular, the implementation of structural analysis applications in supporting the analysis process so that the results of the analysis can be an alternative design for similar buildings. While the main benefit is being able to study, explore and review the process of calculating and analyzing the use of precast concrete materials.

2. THEORITICAL STUDY

Precast Concrete

Precast concrete is a structural component that is not cast on site (cast in-situ) but is molded in a manufacturing process so that the casting process and the curing process of the concrete can be maintained. Structural components that have been produced will be brought to the location and connected to other structural components so that they become a fully integrated structure.

ETABS Ultimate C19

Etabs Ultimate C19 is a structural analysis program developed by Computers and Structures, Incorporated (CSI) located in Barkeley, California, United States. ETABS (Extended Three Analysis Building Systems) is software that functions to design and analyze high-rise building structures quickly and with precision. This program has an attractive user interface and is easy to understand.

2 METHOD

Figure 1 and 2 are the research methods that will be carried out.

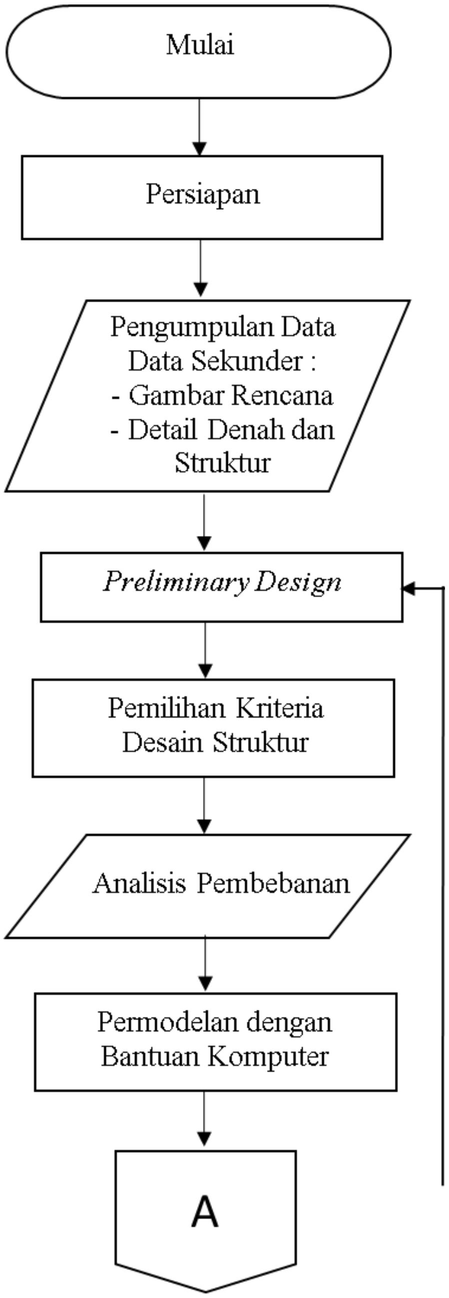


Figure 1 Flowchart

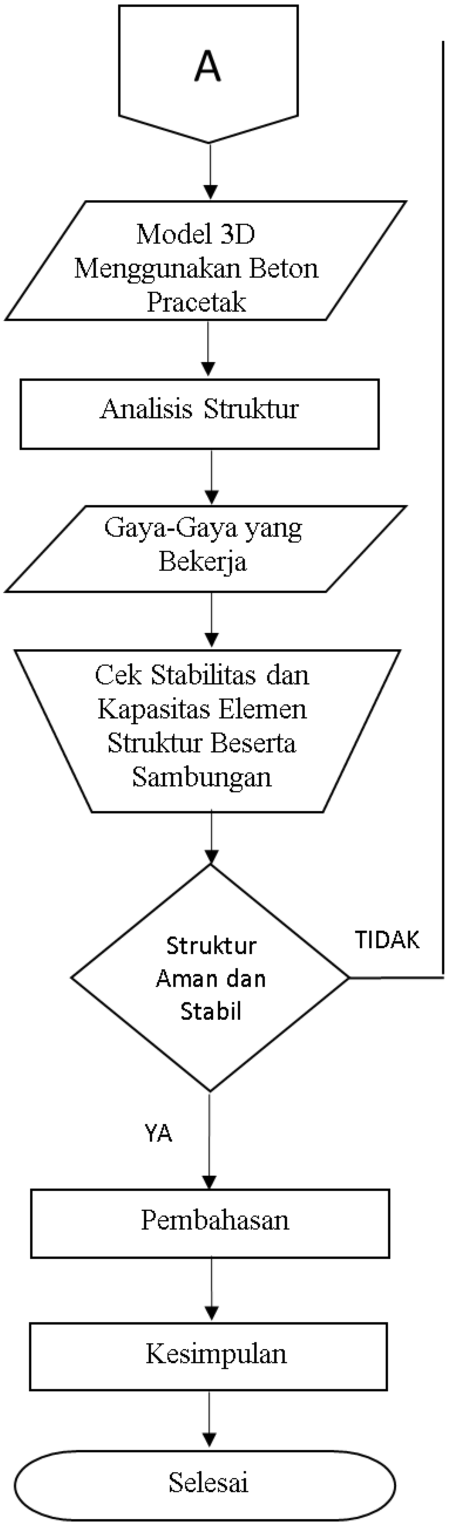


Figure 2 Advanced Flowchard

3 RESULTS AND DISCUSSION

1. Secondary Structure Planning

Structure Stability Check

a. Variety Combinations Check

The calculation of the combination mode of variance is obtained by calculating the difference between periods in order to determine the earthquake analysis method with the formula in equation 1. below.

$$\Delta T = \frac{T(n)-T(n+1)}{T(n)} x\ 100\% \qquad \text{(Equation 1.)}$$

The difference between periods can be seen in table 1. as follows.

Table 1. Calculation of the Difference Between Periods

MODE	PERIODE	SELISIH(%)
1	1,093	24%
2	0,832	4%
3	0,801	16%
4	0,673	39%
5	0,411	3%
6	0,397	9%
7	0,361	7%
8	0,336	23%
9	0,259	2%
10	0,253	11%
11	0,225	10%
12	0,202	10%

Based on table 1. above, the difference is more than 15% so that the analysis is repeated using the SRSS method according SNI 1726:2019 article 7.9.1.3.

b. Natural Vibration Period

Natural vibration period must be reviewed based on direction of the earthquake by notice the characteristics of the bearing elements deformation. The calculation of the natural vibration period refers to SNI 1726:2019 article 7.8.2.1 by comparing the value of approarched natural vibration period with the fundamental period from structure analysis application. The calculation of the natural vibration period uses equation 2. and equation 3. as follows.

Cu = 1,6

$T_a = 0{,}1N$ (Equation 2.)

$T_a = 0{,}6$

$T = C_u T_a$ (Equation 3.)

$T = 0{,}96$

Figure 3. Natural Vibrations Period Direction X dan Y

Mode 1 - Period 0,873320438291009

Mode 2 - Period 0,660646241725753

Based on Figure 3. above, it can be concluded that Tc < T so that the structure meets the requirements for the natural vibration period.

c. Mass Participation

Mass participation is amount of mass or building weight carried by each mode to ensure that the dynamic response cause by earthquake can be met. Mass participation must meet a value above 90% referring to SNI 1726:2019 article 7.9.1.1. The following in Figure 4. is the result of the analysis of mass participation.

Figure 4. Mass Participation

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
Modal	137	0,027	0	0,0001	0	0,9944	0,9954
Modal	138	0,027	0	2,31E-06	0	0,9944	0,9954
Modal	139	0,027	3,571E-06	3,506E-05	0	0,9944	0,9954
Modal	140	0,027	4,433E-05	5,455E-06	0	0,9944	0,9954
Modal	141	0,027	1,988E-05	2,942E-05	0	0,9944	0,9955
Modal	142	0,027	0	6,053E-06	0	0,9944	0,9955
Modal	143	0,027	0	6,955E-07	0	0,9944	0,9955
Modal	144	0,026	0	5,73E-07	0	0,9944	0,9955
Modal	145	0,026	2,077E-06	0,0001	0	0,9944	0,9956
Modal	146	0,026	0	0,0001	0	0,9944	0,9957
Modal	147	0,026	0,0002	2,644E-05	0	0,9946	0,9957
Modal	148	0,026	3,098E-05	0	0	0,9946	0,9957
Modal	149	0,025	4,533E-05	0,0001	0	0,9947	0,9958
Modal	150	0,025	1,822E-06	2,818E-06	0	0,9947	0,9958

d. Drift

Drift calculation refers to the deflection enlargement factor and the building priority category. The drift calculation refers to equations 4. and 5. as follows.

$Cd = 4{,}5$

$Ie = 1{,}5$

$\Delta i = \Delta_n - \Delta_{(n-1)}$ (Formula 4)

$\Delta allowed = 0{,}01 h_{sx}$ (Formula 5)

With equations 4. and 5. above, the results of the calculation of the deviation can be seen in tables 2. and 3. below.

Table 2. Drift Calculation Direction X

Lantai	H kumulatif	H lantai	δx	Δ	Δi	Δijin	Ket
	mm	mm	mm	mm	mm	mm	
Top Service	18150	600	16,716	50,148	1,65	6	OK
Top Atap	17550	2150	16,166	48,498	4,383	21,5	OK
Atap	15400	3400	14,705	44,115	7,17	34	OK
Lantai 4	12000	4000	12,315	36,945	11,376	40	OK
Lantai 3	8000	4000	8,523	25,569	11,397	40	OK
Lantai 2	4000	4000	4,724	14,172	14,172	40	OK
Lantai 1/Dasar							

Table 3. Drift Calculation Direction Y

Lantai	H kumulatif	H lantai	Δy	Δ	Δi	Δijin	Ket
	mm	mm	mm	mm	mm	mm	
Top Service	18150	600	8,032	24,096	0,369	6	OK
Top Atap	17550	2150	7,909	23,727	0,774	21,5	OK
Atap	15400	3400	7,651	22,953	3,417	34	OK
Lantai 4	12000	4000	6,512	19,536	6,372	40	OK
Lantai 3	8000	4000	4,388	13,164	6,735	40	OK
Lantai 2	4000	4000	2,143	6,429	6,429	40	OK

e. *Base Shear*

Base shear check from the results of the response spectrum analysis requires that at least the dynamic shear force must be greater than or equal to the static shear force that occurs. The following table 4. is a comparison of the static and dynamic shear forces resulting from the application analysis

Table 4. Comparison Between Vs and Vd

Arah Gaya	Vs	Vs 100%	Vd	Kontrol	Skala baru
X	2019,515	2019,515	2025,998	OK	-
Y	2019,515	2019,515	2025,998	OK	-

f. Beam Capacity Analysis

The analysis of beam capacity is carried out by taking the largest moment from the results of the analysis using the ETABS application and performing reinforcement based on the moment and shear values that occur in the beam. From the calculations using the assumption of 2-layer double reinforcement, the following values are obtained:

Ast Positive Moment = 3039,52 mm^2

Ast Negative Moment = 1573,94 mm^2

n Positive Moment $= \frac{4.3039,52}{\pi.22^2}$

= 8 D 22

n Negative Moment $= \frac{4.1573,94}{\pi 22^2}$

= 5 D 22

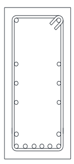
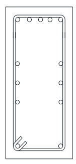
Transversal Reinforcement = D10-200

n Shrinkage Reinforcement $= \frac{Asst}{Ad}$

= 6D10

Based on the above calculations, it can be seen the image of the reinforcement in Figure 4. as follows.

Figure 4. B8 Beam Reinforcement

Tipe	B8	
Lokasi	Lapangan	Tumpuan
Gambar Potongan		
Dimensi	350 x 750	350 x 750
Tulangan Atas	2 D 22	5 D 22
Tulangan Bawah	8 D 22	2 D 22
Tulangan Pinggang	6 D 10	6 D 10
Sengkang	D 10 - 200	D 10 - 200

g. Column Capacity Analysis

The analysis of column capacity by referring to SNI 2847-2019 Article 18.7.4.1 regarding the minimum requirement for longitudinal reinforcement is at least 0.01Ag and not exceed 0.06Ag. The following is the calculation of column K1 with the maximum factored load value from the ETABS application and analysis using the SPColumn application which can be seen in table 5.

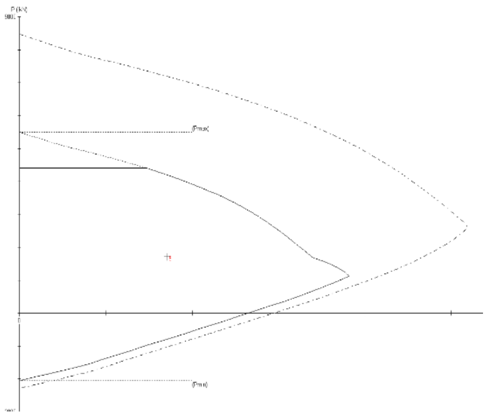
Column Section Area (A)	= 297500 mm^2
0,02Ag	= 5950 mm^2
Reinforcement Area D19	= 284 mm^2
Required Reinforcement Area	= 0,02Ag/Ast
	= 5950/284
Amount of Reinforcement Requirement	= 20,95 ≈ 20 pieces

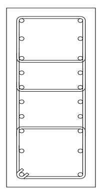
Table 5. Factored Loads and SPColumn Validation

Aksial Lentur Kolom 35x85				ØMnx	ØMny	$Ø_{Mn/Mu}$	NA Depth	dt Depth	εt	Ø	Validasi
Kondisi	P (kN)	M2 (kNm)	M3 (kNm)	kNm	kNm						
P max	199,8106	-30,2146	2,3415	-593.85	39.59	19.795	227	838	0.00808	0.900	SAFE
P min	-3882,9135	-68,7967	-4,5757	-440.39	-25.91	6.476	778	841	0.00024	0.650	SAFE
M2 Max	-3145,4897	93,5539	54,8225	320.07	185.85	3.442	414	532	0.00086	0.650	SAFE
M2 Min	-3697,0011	-127,68	-62,6577	-306.13	-149.45	2.410	481	561	0.00050	0.650	SAFE
M3 Max	-1721,328	-7,4155	171,4066	-13.77	336.37	1.967	181	300	0.00197	0.650	SAFE
M3 Min	-3567,3273	-85,8718	-179,279	-103.42	-217.79	1.217	341	373	0.00026	0.650	SAFE

From the results of table 5. above it, it can be seen the interaction diagram of the column and column reinforcement in Figure 5. as follow

Figure 5. Interaction Diagram and K1 Column Reinforcement



Tipe	K1
Lokasi	LT GF-2
Gambar Potongan	
Dimensi	350 x 850
Tulangan	20D19
Sengkang	2D10-100
Cross Tie	3D10-150

h. Slab Capacity Analysis

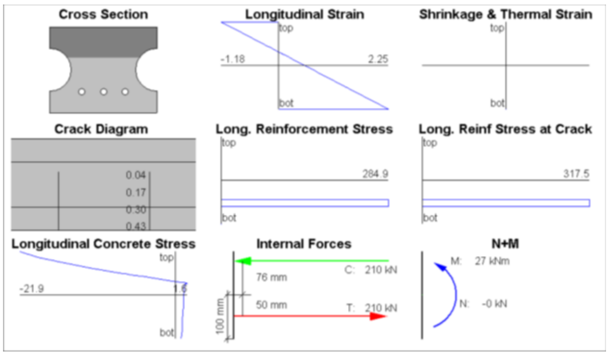
The capacity analysis of structural elements, especially the floor slab, the Response2000 application is used to make a non-prestressed hollow core slab section. Floor slab planning is done with the following data.

Mu	= 25 kNm
Slab Thickness	= 20 cm

Distance Each Cores	= 25 cm
Cores Diameter (dh)	= 10 cm
Longitudinal Reinforcement Diameter	= 16 mm
Core Center Height From Bottom	= 10 cm
Concrete Quality *(fc')*	= 25 MPa
Steel Quality *(fy)*	= 400 MPa
Amount of main reinforcement each core spacing	= 3 piece

From the planning data above, the hollow core slab floor slab planning was carried out using Response2000. The results of the analysis can be seen in Figure 6. as follows

Figure 6. Section Define Using Response2000



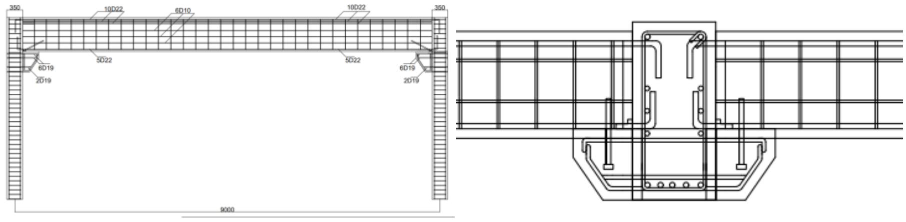
i. Main Beam-Column and Main Beam-Sub Beam Connections

In connection planning, a corbel connection system is used. With this system, the main beam and the sub beam will be supported by corbel connection. The corbel connection design refers to SNI 2847:2019 Article 16.5. and PCI Handbook Design 7th Edition Section 5.6.2. Corbel connection planning takes the largest shear value from ETABS with the following planning data.

Vu	= 503242 N
Bw	= 350 mm
H	= 450 mm
Longitudinal Reinforcement Diameter	= 19 mm
Transversal Reinforcement Diameter	= 19 mm

Based on the data above, the amount of joint reinforcement is 6D19 for main reinforcement, 2D19 for shear reinforcement, and 4D19 and 2D19 as friction reinforcement to prevent horizontal and vertical cracks at the supports. The following in Figure 7. is a picture of the corbel connection between elements.

Figure 7. Main Beam-Column and Main Beam-Sub Beam Connection



j. Beam-Slab Bearing Stress Check

According to SNI 2847:2019 Article 16.3.1.3 requires a minimum support distance of 50 mm for massive slabs or hollow cores. The following is a calculation of the modulus of crushed concrete against stress per area along with a connection picture which can be seen in Figure 9. below.

$fr = 0{,}62\sqrt{fc}$

$fr = 3{,}1$

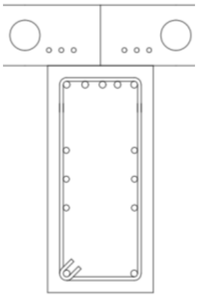
Bearing Stress Each Area

$\sigma = \frac{Vu}{A}$

$= \frac{76800}{700000}$

$= 0{,}11 > 3{,}1$ (OK)

Figure 8. Beam-Slab Connections



k. Bolt Anchors Calculation

In the beam console, anchors are installed in order to avoid the occurrence of shear forces that occur in the beam with a Vu value is 161136 N. The calculation refers to SNI 2847:2019 article 17.5 Calculation of bolt anchors considers the following 3 conditions.

- Bolt Anchors Strength Due Shear Force

  Vsa = 0,6AsevFut

  = 266564,57 N ≥ 161136 N (Fulfil)

- Breakdown Bolt Anchors Strength Due Shear Force

  $$Vcbg = \frac{Avc}{Avco}\Psi ec, v\Psi ed, v\Psi c, v\Psi cp, vVb$$

  Vcbg = 167633,3 N ≥ 161136 N (Fulfil)

- Pryout Bold Anchors Strength Due Shear Force

  Vcp = Kcp.Nbg

Vcp = 554132,2 N ≥ 161136 N (Fulfil)

4 CONCLUSIONS AND SUGGESTIONS

Conclusion

1. The redesign results and structure analysis of Mitra Kasih building from conventional to precast structures with certain assumptions obtained changes to structural elements that are able to withstand the forces that occur in each of its elements so that this design can be an alternative design for similar precast buildings.

2. The difference in the assumption of partially fixed and the effect of one-way slab load distribution causes changes to the results of the reinforcement of structural elements so that the results of the reinforcement with precast assumptions cause differences in the number of main reinforcement about 2 to 4 main reinforcement caused by the use of one-way slabs.
3. The usage of precast system, implementation of one way slab hollow core slab eliminates sub beams that parallel with direction of load distribution and sub beam size changes which have same dimension with main beam so that able to design corbel connections.

Suggestions

1. There is a review of the details of connection elements or corbel connections using a non-linear-based finite element method to review the characteristic of connection against earthquakes.
2. There is a review of the structural foundation also roof design which not calculated in this study
3. There is further research to integrate the results of structural analysis into applications that support scheduling, cost calculations and automatic drawing designs.

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