Effect of tsunami load on the elementary school building of the 23/24 Padang, Indonesia

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Abstract. West Sumatra Province is one of the provinces in Indonesia that is vulnerable to natural disasters, especially earthquakes and tsunamis. Padang city, as the capital city of West Sumatra, is an area that is included in an area with a high level of vulnerability (High Risk Zone) to tsunamis. Therefore, the construction of public buildings such as hospitals, government offices, and school buildings must have certain technical engineering that is able to anticipate the damage and collapse of buildings due to the earthquake and tsunami. One of the public buildings as an educational facility in Padang city is the Elementary School building of the 23/24 (SD 23/24 Padang), located close to the beach. Based on the evaluation results of the Detail Engineering Design (DED) documents, it is found that this building was designed without taking into account the tsunami loads. Therefore, a building assessment should be carried out to check the capacity of the building to resist the working loads, including the tsunami loads, and to investigate the effect of the tsunami loads on the SD 23/24 Padang building. In this study, the building was analyzed using ETABS v.18 software based on the new Indonesian Seismic Code, SNI 1726-2019 for seismic load and FEMA P646-2019 for calculating tsunami loads. The results show that the SD 23/24 Padang building is strong against earthquake loads, but it doesn't have enough capacity when tsunami loads are applied, in which there are several structural elements (columns/beams) that do not have sufficient capacity to withstand the combined earthquake and tsunami loads. The effect of tsunami loads on the building structure is also discussed in this paper.

1 Introduction

West Sumatra Province is one of the provinces in Indonesia that is vulnerable to natural disasters, especially earthquakes and tsunamis [1]. This is because West Sumatra is traversed by three sources of earthquake threat : the Sumatra Fault Zone, the subduction zone that is a meeting between the India-Australia tectonic plates and the Eurasian plate, and the Mentawai Fault Zone [1,2]. Major earthquakes have occurred several times, one of which was a major earthquake on September 30, 2009, in Padang city, West Sumatra, with a magnitude of 7.6 on the Richter Scale [3]. Although it did not cause a tsunami, the devastating earthquake that hit the coast of West Sumatra has killed around 1700 people and damaged more than 200,000 buildings [3].

Padang city, as the capital city of West Sumatra, is an area that is included in the area with a high level of vulnerability (*High Risk Zone)* to tsunami [4]. Therefore, the construction of public facilities such as hospitals, government offices, sport centers, and school buildings must have certain technical engineering that is able to anticipate the damage and collapse of buildings due to the earthquake and tsunami [5]. One of the public facilities in Padang city as an educational facility is the SD 23/24 Padang building.

SD 23/24 Padang has been operating since January 1, 1976, where this school building is owned by the local government.

The SD 23/24 Padang building consists of three buildings which are three-story and two-story reinforced concrete buildings. Based on the evaluation results of the Detail Engineering Design (DED) documents, this building was designed without taking into account the tsunami loads. This building is located close to the beach, which will have an impact in the event of an earthquake with a potential tsunami. Therefore, a building assessment should be carried out to check the capacity of the building to resist the working loads, including the tsunami loads, and to investigate the effect of the tsunami loads on the SD 23/24 Padang building.

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2 Building's data and analysis

2.1 Location of the building

Fig. 1 shows the location of SD 23/24 Padang on Veteran street No. 90, Padang, West Sumatra by using Google Earth, where this building is located at a distance of ± 474 M from the beach.

Fig. 1. The Location Of The SD 23/24 Padang Building (*Google Earth)*

The location of the building is also in the vicinity of urban areas, offices, and densely populated residential areas.

2.2 Tsunami vulnerability level

Based on the tsunami-prone zone map of Padang city shown in Fig. 2, the SD 23/24 Padang building is located in the West Padang area, an area with a high level of vulnerability (*High Risk Zone)* to tsunamis [1].

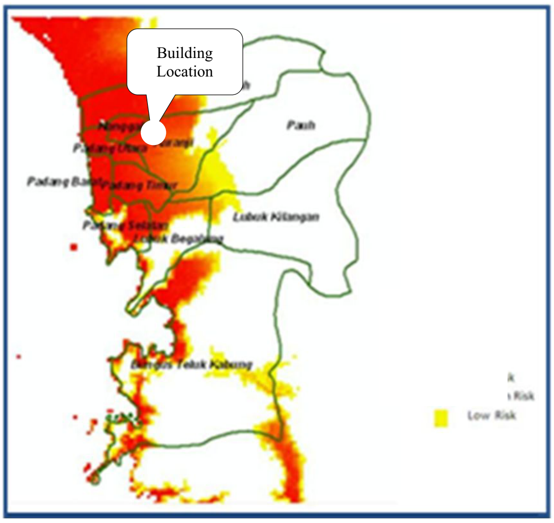


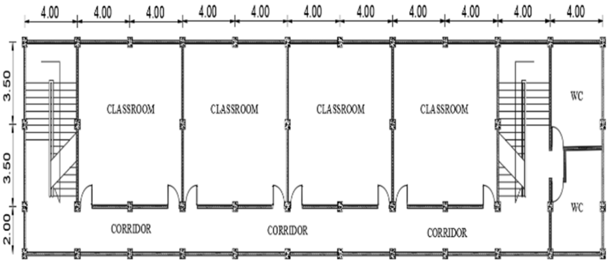
Fig. 2. Tsunami-Prone Zone Of Padang City

2.3 Building structure data

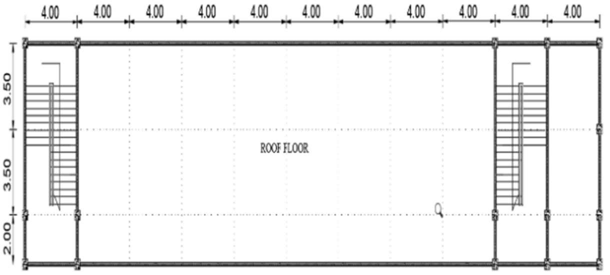
The parameters used in the structural analysis are the technical data of the building and the existing condition of the building obtained from the field survey by LPPM expert of Andalas University with the following data:

Building Name : SD 23/24 Padang
Location : Veteran street No.90 Ujung Gurun, Padang
Distance from the beach : 474 m
Number of building stories : 3 stories
Height between floors : 4.00 m
Height above sea level : 0.80 m

Table 1 shows the cross-sectional dimensions of columns and beams of the SD 23/24 Padang building. The plan and front view and of the building can be seen in Figs. 3 and 4.



a. First and Second Floor Plans



b. Third Floor Plan

Fig. 3. Plan of SD 23/24 Padang Building

Fig. 4. Front View of SD 23/24 Padang Building

Table 1. Column and beam dimensions

No	Column Code	Dimension	
		Height (mm)	Width (mm)
1	C4	450	450
2	C5	350	350
3	C6	450	350
4	CS	250	250

No	Beam Code	Dimension	
		Height (mm)	Width (mm)
1	1G1	700	300
2	1G2	550	300
3	1G3	500	450
1	2G1	700	300
2	2G2	500	300
3	2G3	450	450
1	RG1	700	300
2	RG2	500	300
3	RG3	450	350

2.4 Modeling of the building structure

The SD 23/24 Padang building structure was analyzed using software ETABS v.18 with 3D modeling. The columns and beams of the building structure are modeled as frames, the slab is modeled as a slab element, and the shear wall is modeled as a wall element. The modeling is carried out according to the current condition of the SD 23/24 Padang building. The structural analysis of SD 23/24 Padang building is conducted into two load conditions, namely:

a. Buildings are only subjected to live, dead and earthquake loads.
b. Buildings are subjected to live, dead, earthquake and tsunami loads.

All structural elements such as beams, columns, slabs, and shear walls are modeled in the ETABS v.18 structural analysis application, as shown in Fig. 5.

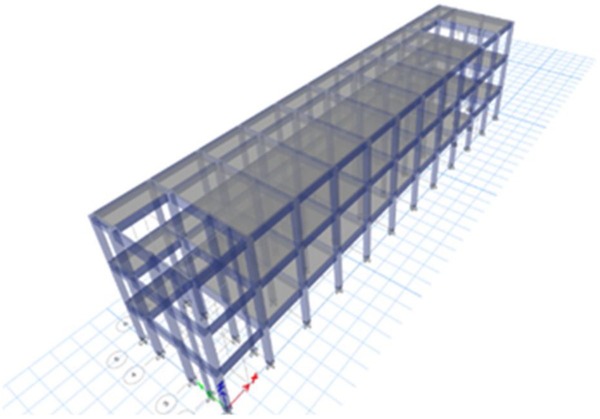


Fig. 5. Modeling of the Building Structure

2.5 Loads analysis

2.5.1 Dead load

Dead loads on the SD 23/24 Padang building are:

a. Self-weight of structural elements was calculated directly by structural analysis program ETABS v.18
b. Flooring material (1 cm thickness)
1 x 48 kg/m^2 = 48 kg/m^2
c. Flooring mortar (2 cm thickness)
2 x 21 kg/m^2 = 42 kg/m^2
d. Ceiling Weight
1 x 20 kg/m2 = 20 kg/m^2
Total = 110 kg/m^2
= 1,078 kg/m^2 ≈ 1,1 kN/m^2 [6]

Self-weight of building materials and components refers to Article 3.1.1, SNI 1727:2020, "Minimum load for designing buildings and other structures" [7].

2.5.2 Live load

Based on Article 4.3.1, SNI 1727:2020, the live load on the SD 23/24 Padang building is taken as 1.92 kN/m² for classrooms and 4.79 kN/m² for corridor [7].

2.5.3 Earthquake load

Analysis of the structure of the SD 23/24 Padang building uses an earthquake response analysis approach to the dynamic response spectrum. The response spectrum of the earthquake plan for the structural analysis of this building can be seen in Table 2. Earthquake loading is calculated based on the new Indonesian Seismic Code, SNI 1726:2019 (Earthquake Resistance Planning Procedures for Building and Non-Building Structures) [8]. Fig. 6 shows the response Spectrum Design of Padang City.

Table 2. Response spectrum parameters

No	Data	Variabel	Nilai
1	Risk Category Office Buildings	K	Category IV
2	Priority Factors for Earthquake	I	1.5
3	Parameters of Land Acceleration (Ss, S1)		
	a. Acceleration of MCE Spectral Response from Earthquake Map in Short Period	SS	1.500
	b. MCE Spectral Response Acceleration from Earthquake Map in 1 second Period	S1	0.600
4	Location Class/Site Classification	KS	Medium (SD)
5	Site Coefficient Factor (Fa,Fv)		
	a. Site coefficient for short period	Fa	1.000
	b. Site Coef for long period	Fv	1.700
6	Acceleration Spectrum Response Parameters (SMS and SM1)		
	a. MCE Spectral Response Acceleration Short	SMS	1.500
	b. MCE Spectral Response Acceleration Period 1 second adjusted for site class (SM1	SM1	1.020
7	Design Spectral Acceleration Parameters (SDS and SD1)		
	a. Acceleration of Spectral Response in a Short Period (SDS = 2/3 SMS	SDS	1.000
	b. Acceleration Spectral Response Over a period of 1 second (SD1 = 2/3 SM1)	SD1	0.680
8	Design Response Spectrum Time		
	a. To = 0,2 SD1/SDS	T_0	0.136
	B. Ts = SD1/SDS	T_s	0.680
9	Seismic Design Category	KDS	D

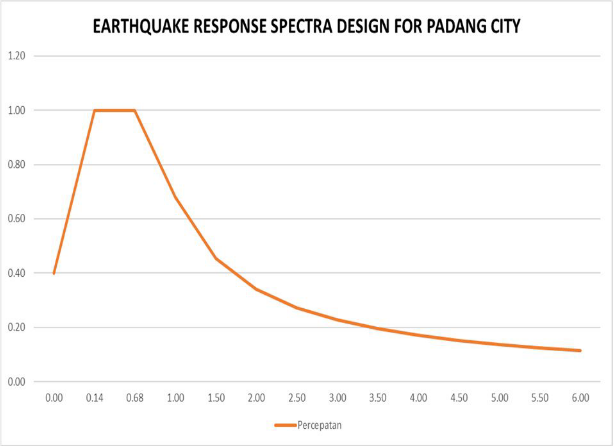


Fig. 6. Response Spectra Design of Padang City

2.5.4 Tsunami load

The calculation of the tsunami load is conducted based on the FEMA P646-2019 "Guidelines for Design of Structures for Vertical Evacuation from Tsunamis" [9]. There are several types of tsunami loads that are taken into account in the structural analysis, where the magnitude of each load value is calculated based on the predicted tsunami wave height, subgrade elevation of the design area, distance to the coast [10, 11], as shown in Fig. 7.

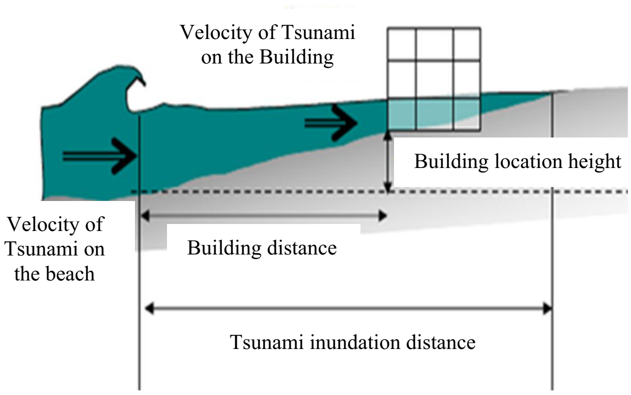


Fig. 7. Sketch of Tsunami Inundation

According to point 8.7 FEMA-2019, it is explained that not all tsunami loads affect the structural components of a building dépends on the layout of the building [9]. In this study, the tsunami loads calculated in this building are illustrated in Figs. 8 – 10.

a. Hydrostatic Force

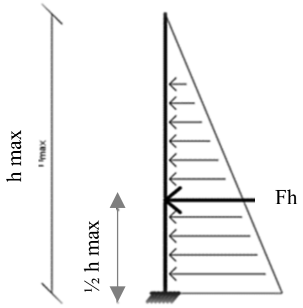


Fig. 8. Tsunami Hydrostatic Force

$$F_h = \frac{1}{2}\rho_S\ x\ g\ x\ b\ x\ h_{max^2} \tag{1}$$

The fluid density including sediment, ρ_S = 1100 kg/m^3
The breadth (width) of the wall , b = 4 m
The gravitational acceleration g = 9,81 m/s^2
The maximum water height, h_{max} = 5,7 m

$$F_h = 78.885\ kN$$

b. Hydrodynamic Force

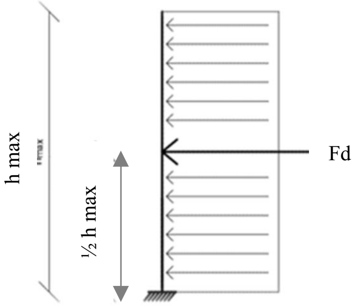


Fig. 9. Tsunami Hydrodynamic Force

$$F_d = \frac{1}{2}\rho_S\ x\ c_d\ x\ (hu^2)_{max} \tag{2}$$

The drag coefficient, c_d = 2
$F_d = 20{,}053\ kN$

c. Impulse Force

$$F_d = 1.5\ F_d \tag{3}$$

$$= 30.080\ kN$$

d. Force Due to Debris Impact

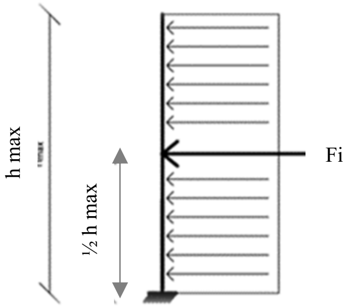


Fig. 10. The Force Due to the Impact of the Tsunami Debris

$$F_i = 1{,}3u_{max}\ x\ \sqrt{[km_d(1+c)]} \tag{4}$$

The maximum flow velocity, u_{max} = 10.575 m/s
Mass of the debris , m_d = 450 kg
Hydrodynamic mass coefficient, c = 2
The effective net combined stiffness , k = 2400000 N/m

$$F_i = 782.533\ kN$$

2.6 Loads combination

Structural loads combination refers to the New Indonesian Seismic Code (SNI 1726:2019) [4]:

1. 1,4 *D*
2. 1,2 *D* + 1,6 *L* + 0,5 (*Lr* or *R*)
3. 1,2 *D* + 1,6 (*Lr* atau *R*) + (*L* or 0,5 *W*)
4. 1,2 *D* + 1,0 *W* + *L* + 0,5 (*Lr* or *R*)
5. 0,9 D+ 1,0 W
6. 1,2 *D* + *EV* + *EH* + *L*
7. 0,9 *D* - *EV* + *EH*

Combination of tsunami loads acting on the structure refers to FEMA P-646 [8]:

1. 1,2 *DL* + 1,0 *TS* +1,0 *Lref* + 0,25 *LL*
2. 0,9 *DL* + 1,0 *TS*

Where:

DL = Dead Load
LL = Live Load
Lr = Live Load on the Roof
W = Wind Load
R = Rain Load
EQX= Earthquake Load on X Direction
EQY = Earthquake Load on Y Direction
EV = 0,2SDS x D
EH = Rho x QE
Rho = 1,3 (Redundancy)
Ts = Tsunami Load
Lref = Live Load in Refuge Area

The loading combination in this analysis is shown in Table 3.

3 Results and discussion

3.1 Inter story drift

3.1.1 Inter story drift of the building

Based on article 7.8.6 of SNI 1726:2019, the determination of inter story drift (Δ) must be calculated as the difference in the deviation at the center of mass above and below the level under consideration [8]. Table 4 shows the results of inter story drift for the SD 23/24 Padang building**.**

From Table 4, it can be seen that the inter story drift in the X and Y directions, without and with the Tsunami loads, are still in the allowable range. The increase in maximum inter story drift due to the tsunami loads in the X direction and Y direction is 118.75% and 77.67%, respectively.

3.2 Structural sectional capacity

3.2.1 Coulomn sectional capacity

To determine the capacity of the column in carrying the load, it can be observed from the column interaction diagram [12 - 14]. The P-M interaction diagram is a diagram that describes the capability or capacity of the column based on the relationship between the moment and the axial load of the column [15, 16]. The P-M interaction diagrams of building columns without and with tsunami loads are shown in Figs. 11 and 12.

From Fig. 11, it can be seen that the column on the 1st floor of the building is strong enough to carry the working loads because the axial moment and compression forces do not outside the design axial moment line.

While when tsunami loads are added, the column on the 1st floor of the building is not strong enough to carry the working loads because there are axial moment and compression force that passes through the design axial moment line, as shown in Fig. 12.

Table 3. Load Combination

Earthquake Load Combination											
1	1.4	DL									
2	1.2	DL	+	1.6	LL						
3	1.378	DL	+	1	LL	+	1.3	EQX	+	0.39	EQY
4	1.378	DL	+	1	LL	+	1.3	EQX	-	0.39	EQY
5	1.378	DL	+	1	LL	-	1.3	EQX	+	0.39	EQY
6	1.378	DL	+	1	LL	-	1.3	EQX	-	0.39	EQY
7	1.378	DL	+	1	LL	+	0.39	EQX	+	1.3	EQY
8	1.378	DL	+	1	LL	+	0.39	EQX	-	1.3	EQY
9	1.378	DL	+	1	LL	-	0.39	EQX	+	1.3	EQY
10	1.378	DL	+	1	LL	-	0.39	EQX	-	1.3	EQY
11	0.722	DL	+	1.3	EQX	+	0.39	EQY			
12	0.722	DL	+	1.3	EQX	-	0.39	EQY			
13	0.722	DL	-	1.3	EQX	+	0.39	EQY			
14	0.722	DL	-	1.3	EQX	-	0.39	EQY			
15	0.722	DL	+	0.39	EQX	+	1.3	EQY			
16	0.722	DL	+	0.39	EQX	-	1.3	EQY			
17	0.722	DL	-	0.39	EQX	+	1.3	EQY			
18	0.722	DL	-	0.39	EQX	-	1.3	EQY			
19	Envelope										
Tsunami Load Combination											
1	1.2	DL	+	0.25	LL	+	1	Ts	+	1	Lref
2	0.9	DL	+	1	Ts						

Table 4. Inter story drift of the building on X and Y directions without and with tsunami load

Story	Displacement - X		Delta Limit	CHECK	Percentage Increase
	Without Tsunami Load	With Tsunami Load			
	Δx (mm)	Δx (mm)	mm	Δ Izin > Δx	mm
3	12.04	26.33	40.00	OK	118.75%
2	20.03	39.65	40.00	OK	97.96%
1	16.84	30.02	40.00	OK	78.26%
0	0.00	0	0	-	0.00%

Story	Displacement - Y		Delta Limit	CHECK	Percentage Increase
	Without Tsunami Load	With Tsunami Load			
	Δx (mm)	Δx (mm)	mm	Δ Izin > Δx	mm
3	9.33	16.57	40.00	OK	77.67%
2	16.83	29.22	40.00	OK	73.61%
1	16.56	26.88	40.00	OK	62.31%
0	0	0	0	-	0.00%

- **Without Tsunami**

First Floor P-M Interaction Diagram

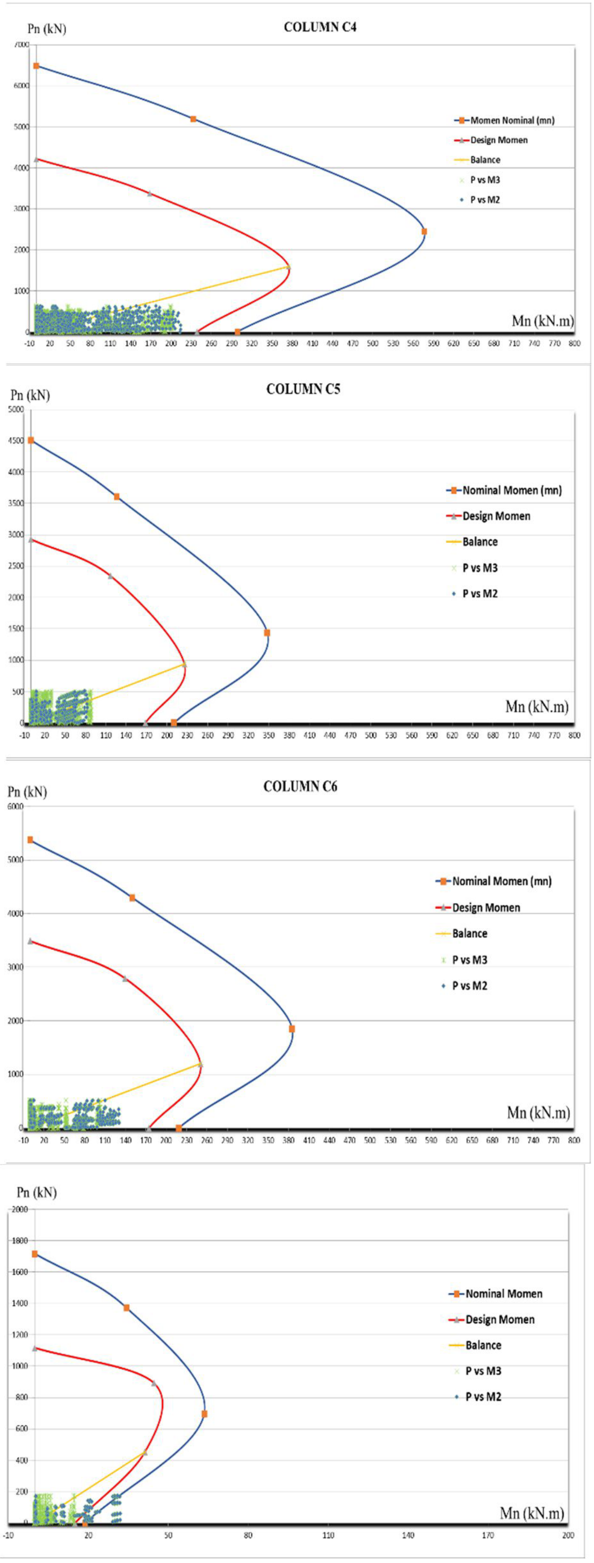


Fig. 11. Interaction Diagram of Column on 1st Floor Building Without Tsunami Load

- **With Tsunami**

First Floor P-M Interaction Diagram

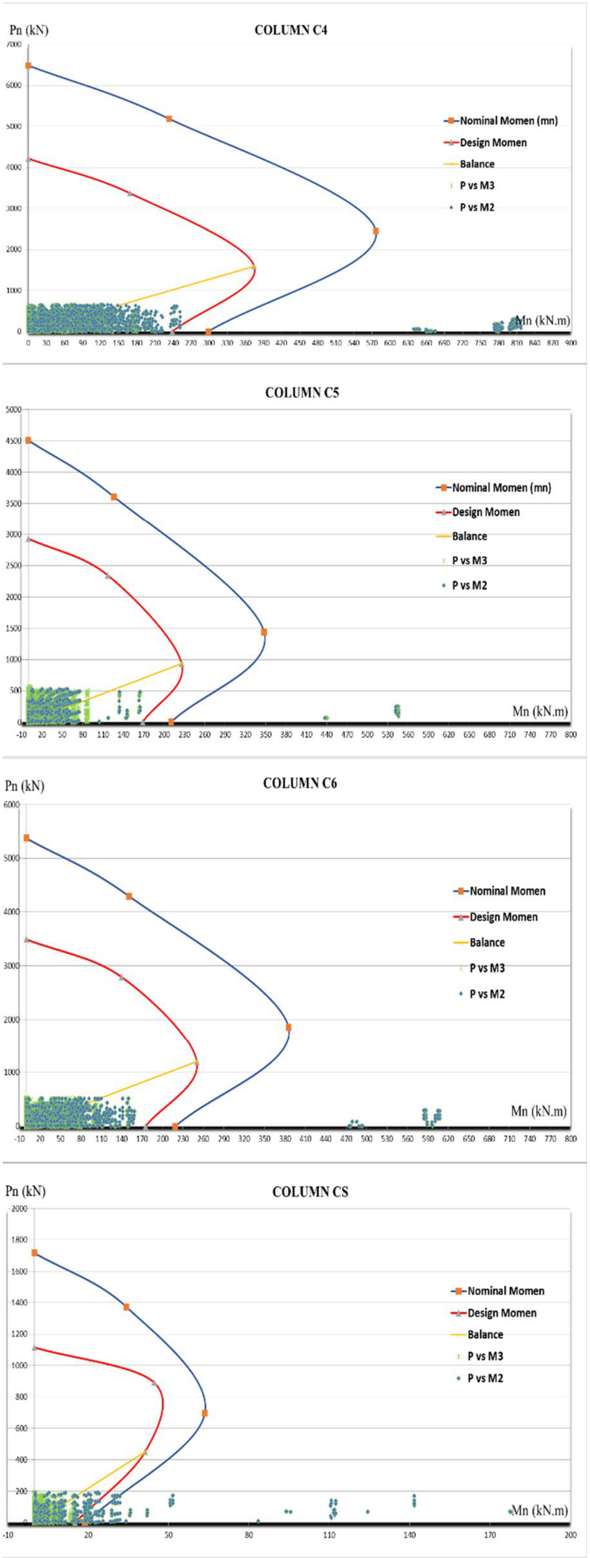


Fig. 12. Interaction Diagram of Column on 1st floor of Building with Tsunami Load

The calculation results of the column shear capacity without and with tsunami load are shown in Tables 5 and 6.

Table 5. Column shear capacity of the building without tsunami load

	Column Type	Cross-Section dimention	Stirrup Diameter	Distance between Stirrup	ΦVn	Vu	Note
		(B x H) mm	(mm)	(mm)	(kN)	(kN)	
1st Floor	C4	450 x 450	10	100	345.731	110.413	OK
	C5	350 x 350	10	100	239.129	42.900	OK
	C6	450 x 350	10	100	261.406	75.316	OK
	CS	250 x 250	10	100	146.899	19.083	OK
2nd Floor	C4	450 x 450	10	100	345.731	85.277	OK
	C5	350 x 350	10	100	239.129	33.364	OK
	C6	450 x 350	10	100	261.406	72.908	OK
	CS	250 x 250	10	100	146.899	20.662	OK
3rd Floor	C4	450 x 450	10	100	345.731	42.120	OK
	C5	350 x 350	10	100	239.129	13.277	OK
	C6	450 x 350	10	100	261.406	41.309	OK
	CS	250 x 250	10	100	146.899	11.091	OK

As seen in Table 5, the building columns are able to withstand the shear forces acting on the structure.

Table 6. Column shear capacity of the building with tsunami load

	Column Type	Cross-Section dimention	Stirrup Diameter	Distance between Stirrup	ΦVn	Vu	Note
		(B x H) mm	(mm)	(mm)	(kN)	(kN)	
1st Floor	C4	450 x 450	10	100	345.731	716.812	NOT OK
	C5	350 x 350	10	100	239.129	271.705	NOT OK
	C6	450 x 350	10	100	261.406	359.573	NOT OK
	CS	250 x 250	10	100	146.899	177.263	NOT OK
2nd Floor	C4	450 x 450	10	100	345.731	88.734	OK
	C5	350 x 350	10	100	239.129	35.755	OK
	C6	450 x 350	10	100	261.406	75.522	OK
	CS	250 x 250	10	100	146.899	22.131	OK
3rd Floor	C4	450 x 450	10	100	345.731	45.577	OK
	C5	350 x 350	10	100	239.129	16.734	OK
	C6	450 x 350	10	100	261.406	44.766	OK
	CS	250 x 250	10	100	146.899	14.548	OK

Table 7. Percentage change in shear capacity of building columns due to tsunami load

	Column Type	Vu (kN)		Percentage Increase
		Without Tsunami Load	Without Tsunami Load	
1st Floor	C4	110.413	716.812	549.21%
	C5	42.900	271.705	533.35%
	C6	75.316	359.573	377.42%
	CS	19.083	177.263	828.92%
2nd Floor	C4	85.277	88.734	4.05%
	C5	33.364	35.755	7.17%
	C6	72.908	75.522	3.59%
	CS	20.662	22.131	7.11%
3rd Floor	C4	42.120	45.577	8.21%
	C5	13.277	16.734	26.04%
	C6	41.309	44.766	8.37%
	CS	11.091	14.548	31.17%

While the columns on the 1st floor of the building are unable to withstand the shear forces acting on the structure due to the addition of the tsunami loads, as shown in Table 6.

From Table 7, it can be seen that the 1st floor column experienced an increase in the maximum shear force due to the influence of the tsunami load of 828.92%.

3.2.2 Capacity of beams

a. Bending capacity of beams

The calculation results of beam flexural capacity without and with tsunami load can be seen in **Tables 8** and **9**.

Table 8. Bending capacity of building beam without tsunami load

	BEAM TYPE	Cross-Section dimention	Note	ØMn (kN)		Mu (kN)		ØMn ≥ Mu	
				Positive	Negative	Positive	Negative	Positive	Negative
1st Floor	1G1	30 X 70	At Support	252.68	252.68	214.83	216.86	OK	OK
			At Field	252.68	252.68	138.75	134.12	OK	OK
	1G2	30 X 55	At Support	145.85	145.85	141.65	157.44	OK	NOT OK
			At Field	145.85	145.85	76.10	73.55	OK	OK
	1G3	45 X 50	At Support	130.96	130.96	130.42	134.28	OK	NOT OK
			At Field	130.96	130.96	71.70	69.17	OK	OK
2nd Floor	2G1	30 X 70	At Support	190.50	190.50	141.86	151.06	OK	OK
			At Field	190.50	190.50	95.92	98.22	OK	OK
	2G2	30 X 50	At Support	130.96	130.96	97.61	117.50	OK	OK
			At Field	130.96	130.96	55.77	50.27	OK	OK
	2G3	45 X 45	At Support	118.07	118.07	79.92	99.03	OK	OK
			At Field	118.07	118.07	50.42	43.40	OK	OK
3rd Floor	RG1	30 X 70	At Support	190.50	190.50	61.30	75.56	OK	OK
			At Field	190.50	190.50	43.74	59.33	OK	OK
	RG2	30 X 50	At Support	130.96	130.96	53.83	72.39	OK	OK
			At Field	130.96	130.96	36.09	28.08	OK	OK
	RG3	35 X 45	At Support	116.08	116.08	33.81	41.29	OK	OK
			At Field	116.08	116.08	25.80	17.81	OK	OK

Table 9. Bending capacity of building beams with tsunami load

	BEAM TYPE	Cross-Section dimention	Note	ØMn (kN)		Mu (kN)		ØMn ≥ Mu	
				Positive	Negative	Positive	Negative	Positive	Negative
1st Floor	1G1	30 X 70	At Support	252.68	252.68	227.46	229.49	OK	OK
			At Field	252.68	252.68	170.92	146.75	OK	OK
	1G2	30 X 55	At Support	145.85	145.85	148.95	164.73	OK	NOT OK
			At Field	145.85	145.85	83.39	80.84	OK	OK
	1G3	45 X 50	At Support	130.96	130.96	136.96	140.83	OK	NOT OK
			At Field	130.96	130.96	78.82	75.72	OK	OK
2nd Floor	2G1	30 X 70	At Support	190.50	190.50	147.58	156.77	OK	OK
			At Field	190.50	190.50	101.63	103.94	OK	OK
	2G2	30 X 50	At Support	130.96	130.96	101.54	121.43	OK	OK
			At Field	130.96	130.96	59.70	54.20	OK	OK
	2G3	45 X 45	At Support	118.07	118.07	83.46	102.57	OK	OK
			At Field	118.07	118.07	53.96	46.95	OK	OK
3rd Floor	RG1	30 X 70	At Support	190.50	190.50	63.20	77.47	OK	OK
			At Field	190.50	190.50	45.64	61.24	OK	OK
	RG2	30 X 50	At Support	130.96	130.96	55.14	73.70	OK	OK
			At Field	130.96	130.96	37.40	29.39	OK	OK
	RG3	35 X 45	At Support	116.08	116.08	34.97	42.45	OK	OK
			At Field	116.08	116.08	26.96	18.97	OK	OK

As can be seen in Tables 8 and 9, almost all the beams in the building without and with tsunami loads are able to withstand the working loads, but some beam structural elements do not have sufficient capacity to withstand the earthquake and tsunami loads, that are the 1G2 and 1G3 beams.

Table 10. Percentage change in bending capacity of building block due to tsunami load

	BEAM TYPE	Note	Mu (kN)				Percentage Increase	
			Without Tsunami Load		WithTsunami Load			
			Positive	Negative	Positive	Negative	Positive	Negative
1st Floor	1G1	At Support	214.83	216.86	227.46	229.49	5.88%	5.83%
		At Field	138.75	134.12	170.92	146.75	23.19%	9.42%
	1G2	At Support	141.65	157.44	148.95	164.73	5.15%	4.63%
		At Field	76.10	73.55	83.39	80.84	9.58%	9.92%
	1G3	At Support	130.42	134.28	136.96	140.83	5.02%	4.88%
		At Field	71.70	69.17	78.82	75.72	9.93%	9.47%
2nd Floor	2G1	At Support	141.86	151.06	147.58	156.77	4.03%	3.78%
		At Field	95.92	98.22	101.63	103.94	5.96%	5.82%
	2G2	At Support	97.61	117.50	101.54	121.43	4.02%	3.34%
		At Field	55.77	50.27	59.70	54.20	7.04%	7.81%
	2G3	At Support	79.92	99.03	83.46	102.57	4.43%	3.58%
		At Field	50.42	43.40	53.96	46.95	7.03%	8.16%
3rd Floor	RG1	At Support	61.30	75.56	63.20	77.47	3.11%	2.52%
		At Field	43.74	59.33	45.64	61.24	4.36%	3.21%
	RG2	At Support	53.83	72.39	55.14	73.70	2.43%	1.81%
		At Field	36.09	28.08	37.40	29.39	3.63%	4.66%
	RG3	At Support	33.81	41.29	34.97	42.45	3.43%	2.81%
		At Field	25.80	17.81	26.96	18.97	4.50%	6.52%

From Table 10, it can be seen that due to the effect of the tsunami load on the building, there was no significant increase in the flexural capacity of the beams. The increase in the flexural capacity of the beams is 1.81% - 23.19%.

b. Shear Capacity of the beam

The calculation results of the shear capacity of the beams can be seen in Tables 11 and 12.

Table 11. Shear capacity of building beams without tsunami load

	BEAM TYPE	Cross-Section dimention	Note	ØVn (kN)	Vu (kN)	ØVn ≥ Vu
1st Floor	1G1	30 X 70	At Support	419.77	261.96	OK
			At Field	359.29	256.13	OK
	1G2	30 X 55	At Support	324.36	144.07	OK
			At Field	277.63	130.38	OK
	1G3	45 X 50	At Support	312.40	226.00	OK
			At Field	312.40	221.55	OK
2nd Floor	2G1	30 X 70	At Support	359.29	185.99	OK
			At Field	359.29	178.58	OK
	2G2	30 X 50	At Support	292.56	113.40	OK
			At Field	250.41	100.14	OK
	2G3	45 X 45	At Support	278.44	156.41	OK
			At Field	278.44	150.72	OK
3rd Floor	RG1	30 X 70	At Support	359.29	115.64	OK
			At Field	359.29	133.19	OK
	RG2	30 X 50	At Support	250.41	87.03	OK
			At Field	250.41	73.58	OK
	RG3	35 X 45	At Support	223.20	68.68	OK
			At Field	223.20	63.68	OK

Table 12. Shear capacity of building beams with tsunami load

	BEAM TYPE	Cross-Section dimention	Note	ØVn (kN)	Vu (kN)	ØVn ≥ Vu
1st Floor	1G1	30 X 70	At Support	419.77	385.58	OK
			At Field	359.29	377.93	NOT OK
	1G2	30 X 55	At Support	324.36	153.80	OK
			At Field	277.63	138.71	OK
	1G3	45 X 50	At Support	312.40	235.37	OK
			At Field	312.40	230.92	OK
2nd Floor	2G1	30 X 70	At Support	359.29	193.18	OK
			At Field	359.29	185.77	OK
	2G2	30 X 50	At Support	292.56	119.25	OK
			At Field	250.41	105.15	OK
	2G3	45 X 45	At Support	278.44	161.98	OK
			At Field	278.44	156.29	OK
3rd Floor	RG1	30 X 70	At Support	359.29	119.23	OK
			At Field	359.29	136.78	OK
	RG2	30 X 50	At Support	250.41	89.54	OK
			At Field	250.41	76.08	OK
	RG3	35 X 45	At Support	223.20	70.91	OK
			At Field	223.20	65.92	OK

As seen in Table 11, almost all beams in the building are able to withstand the loads acting on the structure. While one element of the beam (1G1) does not have sufficient capacity to withstand the working loads when the tsunami loads are applied (Table 12).

Table 13. Percentage change in shear capacity of building block due to tsunami load

	BEAM TYPE	Note	Vu (kN)		Percentage Increase
			Without Tsunami Load	WithTsunami Load	
1st Floor	1G1	At Support	261.96	385.58	47.19%
		At Field	256.13	377.93	47.56%
	1G2	At Support	144.07	153.80	6.75%
		At Field	130.38	138.71	6.39%
	1G3	At Support	226.00	235.37	4.15%
		At Field	221.55	230.92	4.23%
2nd Floor	2G1	At Support	185.99	193.18	3.86%
		At Field	178.58	185.77	4.02%
	2G2	At Support	113.40	119.25	5.16%
		At Field	100.14	105.15	5.00%
	2G3	At Support	156.41	161.98	3.56%
		At Field	150.72	156.29	3.69%
3rd Floor	RG1	At Support	115.64	119.23	3.11%
		At Field	133.19	136.78	2.70%
	RG2	At Support	87.03	89.54	2.88%
		At Field	73.58	76.08	3.40%
	RG3	At Support	68.68	70.91	3.25%
		At Field	63.68	65.92	3.50%

The effect of the tsunami load on the building shown in Table 13 shows that there was no significant increase in the load on the shear capacity of the beam. The load on the shear capacity of the beam increased by 2.70% - 47.56 %.

4 Conclusion

Based on this study, it can be concluded that:

1. SD 23/24 Padang building is strong against earthquake load, but it does not have enough capacity when tsunami loads are applied, in which there are several structural elements (columns/beams) that do not have sufficient capacity to withstand the combined earthquake and tsunami loads.
2. The addition of the tsunami loads on the SD 23/24 Padang building increases the inter story drift by around 78 – 119% in the X direction and 62 – 78% in the Y direction.
3. Due to the addition of the tsunami loads, there was an increase in the maximum column shear force around 828.92%.
4. In beam elements, there is a maximum increase in bending and shear forces due to the addition of tsunami loads, which are around 23.19% and 47.56%, respectively.

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