International Journal of GEOMATE, Aug., 2024 Vol.27, Issue 120, pp.122-129
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2024.120.g13339
Geotechnique, Construction Materials and Environment

SEISMIC DAMAGE ASSESSMENT AND RETROFITTING OF A HOSPITAL BUILDING IN WEST PASAMAN, INDONESIA

*Fauzan[1], Abdul Hakam[2], Febrin Anas Ismail[3], Zev Al Jauhari[4], and Geby Aryo Agista[5]

[1,2,3,5] Department of Civil Engineering, Faculty of Engineering, Universitas Andalas, Indonesia;
[4]Graduate School of Engineering, Toyohashi University of Technology, Japan

*Corresponding Author, Received: 18 Sep. 2023, Revised: 29 May 2024, Accepted: 06 June

ABSTRACT: The major earthquake that occurred on February 25, 2022, with a magnitude of 6.2 M, and aftershocks in West Pasaman, Indonesia, caused damage to many buildings, including the West Pasaman Ibnu Sina Hospital building. The stability of hospital building structures is paramount for ensuring the safety and functionality of healthcare facilities, particularly in the aftermath of disasters. To assess the feasibility of post-earthquake structures, a rapid visual assessment of the building was carried out, and it was found that there was some damage to the building. Based on the design document (as-built drawings), this reinforced concrete (RC) structure building was built in 2013 and designed using old Indonesian building standards. Therefore, further structural evaluation of the hospital building should be carried out using the current building codes. The analysis results show that structural elements of columns and beams are unable to resist working loads by applicable building standards such as seismic code (SNI 1726:2019), RC structure code (SNI 2847:2019), and minimum loads code (SNI 1727:2020). In addition, the inter-story drift of the building does not meet the requirement in the Indonesian seismic code. The recommendation for retrofitting the building structure is by adding RC shear walls to the corners of the existing building. The retrofitted building shows an increase in the structural capacity of the building. The inter-story drift and the structural elements strength of the retrofitted building have met the requirements based on the current building codes, so this building is safe to use for hospital operations.

Keywords: Hospital Building, Structural Analysis, Earthquake, Retrofit, Shear Wall

1. INTRODUCTION

The structural integrity of hospital buildings is crucial for ensuring the safety and functionality of healthcare facilities, especially against the disaster. Hospital buildings are one of the important structures in the living society as they aid to be the caring as well as curing unit in human society whenever any hazardous situation arises. Hospital buildings play a dynamic role in such situations: 1. Treating the victims and injured people, and 2. It acts as a temporary accommodation for those people who lost their homes in the hazard. Therefore, the hospital buildings should be designed and constructed to have adequate stiffness and strength to not only withstand the disaster, but also can be used as a shelter or accommodation units during post–disaster conditions [1]. In addition, existing hospital buildings need to be evaluated on the strength of the building structure so that the building is resistant to disasters, especially in hospital buildings that were affected after the earthquake disaster [2].

Many studies have been developed to determine the strength of the hospital building structure, such as the seismic performance of the inpatient building of Goeteng Hospital, Purbalingga, Indonesia [3], nonlinear static analysis for seismic evaluation of existing RC hospital building [4], and seismic performance assessment of irregular RC buildings: hospital structure of Avezzano (L'Aquila, Italy) [5]. However, there are differences in building characteristics, design plans, materials used, regulations, and earthquake magnitudes that occur in a hospital building.

Apart from developing methods to determine the structural strength of hospital buildings, there are several studies on retrofitting building structures if the building is not able to withstand the working loads using the current building codes, such as retrofitting using Reinforced Concrete (RC) frame–shear wall buildings [6], seismic retrofitting of RC building with steel plate shear walls [7], and seismic retrofit using fluid viscous dampers [8].

In 2022, the destructive earthquake that occurred on February 25 with a magnitude of 6.2 M, along with aftershocks, in West Pasaman, West Sumatra Province, Indonesia, has caused damage to infrastructure, public buildings, and community settlements. One of the structures affected by the 2022 Pasaman Earthquake is the health facility known as Ibnu Sina Hospital in West Pasaman, Indonesia.

The building is a four-story structure constructed with a reinforced concrete design, which was originally designed in 2013 using the old earthquake standard, SNI 1726-2012 [9]. The building suffered damage during the 2022 West Pasaman Earthquake. Following the earthquake, a rapid visual assessment revealed structural damage to the building [10], as depicted in Figs. 1 and 2.

Therefore, a building assessment should be conducted to ensure structural integrity, safety, and compliance with building codes, provide a comprehensive understanding of its current condition, and identify potential vulnerabilities or areas requiring improvement.

This study focuses on structural evaluation and retrofitting design to the hospital building by considering the current Indonesian building standards.

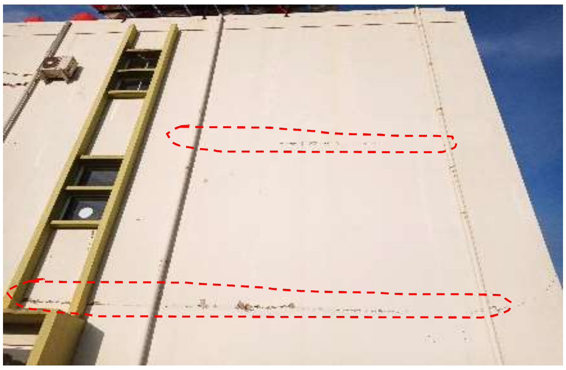


Fig.1 Exterior building damage

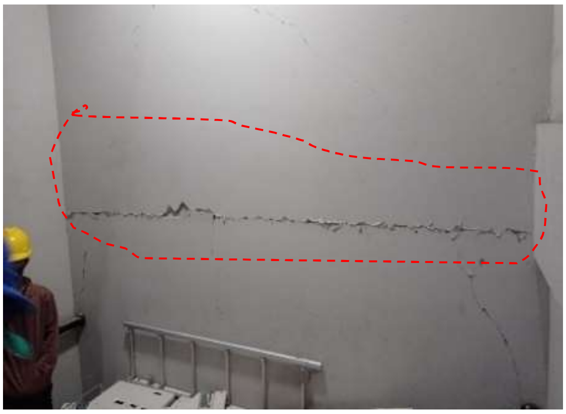


Fig.2 Interior walls damage in the building

2. RESEARCH SIGNIFICANCE

Changes in building standards regarding earthquake resistance reinforced concrete (RC) buildings are issues in assessing the strength of buildings, especially buildings that are planned to remain operational in the event of an earthquake, such as hospital buildings. This is a challenge for engineers in developing research on structural strength evaluation and its retrofitting method solutions. The results of this study are expected to contribute to the development of building reconstruction post-earthquake disaster and as a guideline for assessing and retrofitting building structures, including healthcare facilities due to the change in building standards.

3. EVALUATION OF THE EXISTING BUILDING

3.1 Existing Building Data

Data for the existing building, such as concrete quality, reinforcing steel quality, dimensions of structural elements, and room functions, were obtained from as-built drawings. The Ibnu Sina Hospital building features a reinforced concrete construction structural frame with a concrete quality of 20.35 MPa. The structure includes main columns and beams with reinforcement bars, detailed in Tables 1 and 2.

Table 1 Details of columns

No.	Type	Section		Flex. Reinf. Bar	Shear Reinf. Bar	
		Depth	Width		Support	Midspan
1	K3	500	500	20D19	2Ø10-100	2Ø10-200
2	K7	500	500	20D22	2Ø10-100	2Ø10-200
3	K8	500	500	16D19	2Ø10-100	2Ø10-200
4	K9	500	500	12D19	2Ø10-100	2Ø10-200
5	K10	400	400	12D19	2Ø10-100	2Ø10-200
6	K11	400	400	12D16	2Ø10-100	2Ø10-200

Table 2 Details of beams

No.	Type	Section		Support Area		Midspan Area	
		Depth	Width	Tensile	Compr.	Tensile	Compr.
1	B1	500	300	10D22	4D22	7D22	4D22
2	B2	600	400	7D19	3D19	5D19	3D19
3	B3	600	300	7D19	4D19	6D19	3D19
4	BA7	500	300	4D16	2D16	4D16	2D16
5	BA4	600	250	5D19	3D19	5D19	3D19

The floor slab has a thickness of 120 mm. The structural elements, including columns and beams, were modeled as frame elements, and the floor slabs were modeled as thin shells with a rigid diaphragm simulation. The 3D modeling of the existing building was conducted using the ETABS structural analysis software program, as shown in Fig. 3. The floor plan is illustrated in Fig. 4.

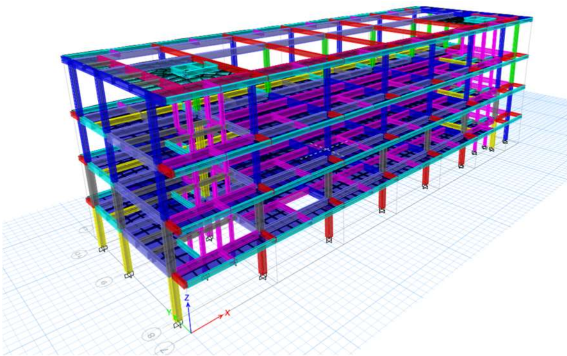


Fig.3 3D modeling using ETABS computer program

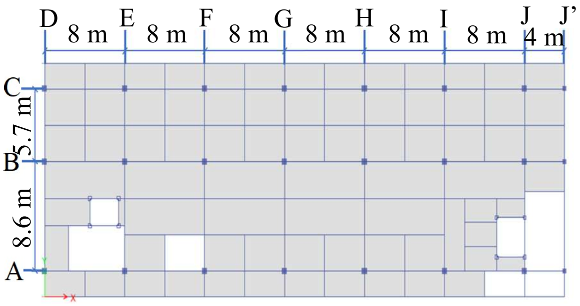


Fig.4 The floor plan for the first floor of the building

The building standards utilized in analyzing existing building structures adhere to the current Indonesian building codes, including SNI 1726:2019 for seismic code [11], SNI 2847:2019 for RC structure code [12], and SNI 1727:2020 for minimum loads code [13].

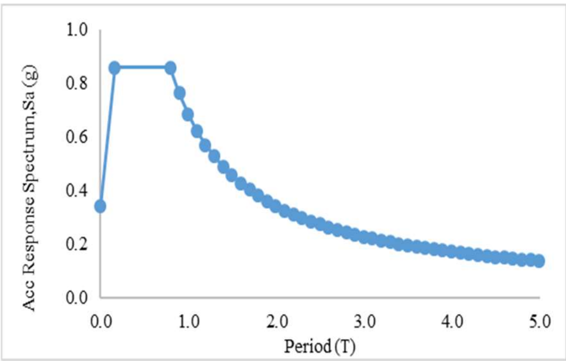


Fig.5 Spectrum response design of West Pasaman, Indonesia

The load analysis incorporates gravity loads, including dead loads (DL + SIDL) and live loads (LL). Additionally, earthquake loading is considered with parameters based on the Indonesian seismic code (SNI 1726:2019), specifying a risk category IV and a priority factor (Ie) of 1.5. As the system employs a special moment resisting frame system (SMRF), the response modification coefficient (R) is set at 8, the over-strength factor system (Ω) at 3, and the deflection magnification factor (Cd) at 5.5. The reinforcement parameter (Ct) is approached as 0.0466, and the period parameter (x) is 0.9. The acceleration spectrum parameters for SDS and SD1 designs are 0.857 and 0.68, respectively. These values will be utilized for spectrum response calculations, considering the location of West Pasaman, Indonesia, as depicted in Fig. 5.

3.2 Analysis of the Existing Building's Structure

3.2.1 Inter-story drift

Table 3 Results of inter-story drift in the building

Story	Inelastic Drift (mm)		Drift Limit	Δ < Drift Limit
	Δ_X	Δ_Y		
4	88.91	133.62	57.58	NOT OK
3	142.45	165.85	49.50	NOT OK
2	163.68	193.32	49.50	NOT OK
1	117.82	132.42	49.50	NOT OK

The determination of inter-story drift must be calculated as the difference in displacement at the center of mass above and below the level under review. Based on calculations of inter-story drift in SNI 1726: 2019, inelastic story drift Δ = δ * Cd / Ie and drift limit, Δa = 0.015 h in terms of X-direction and Y-directions. The calculation results of the building inter-story drift are shown in Table 3. From the table, the inter-story drift of the existing building does not meet the permit requirements in Indonesian building standard SNI 1726:2019, chapter 7.8.6 [11].

3.2.2 Load-bearing capacity of column

The column capacity was analyzed using the column P-M interaction diagram. Based on the P-M interaction diagram for each type of existing building column, as depicted in Figs. 6-11, it is observed that most of the P-M values (points) in both X and Y directions exceed the capacity limit for all types of existing building columns. Consequently, all columns in the existing building are unable to withstand the loads specified by the current building codes [14].

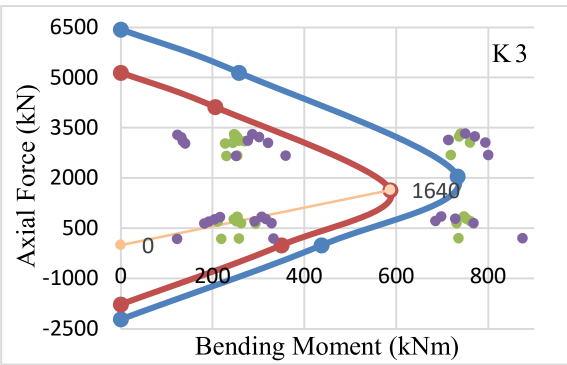


Fig.6 The P-M interaction diagram of K3 column

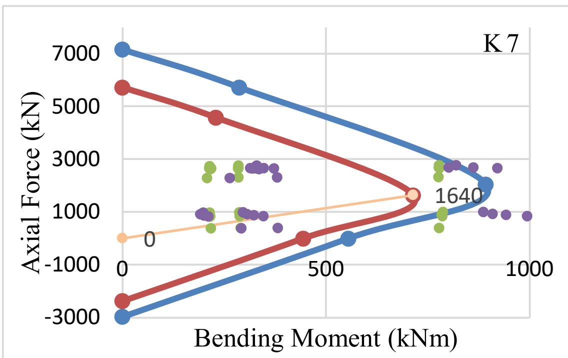


Fig.7 The P-M interaction diagram of K7 column

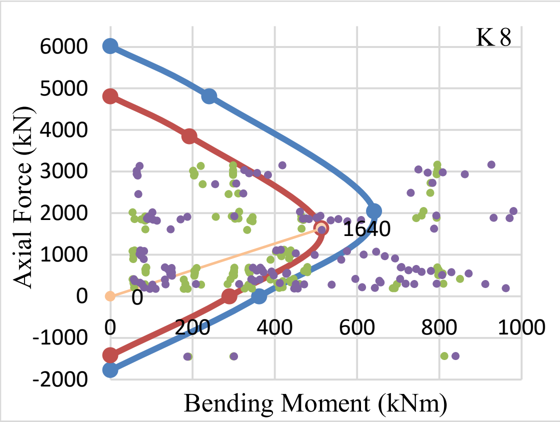


Fig.8 The P-M interaction diagram of K8 column

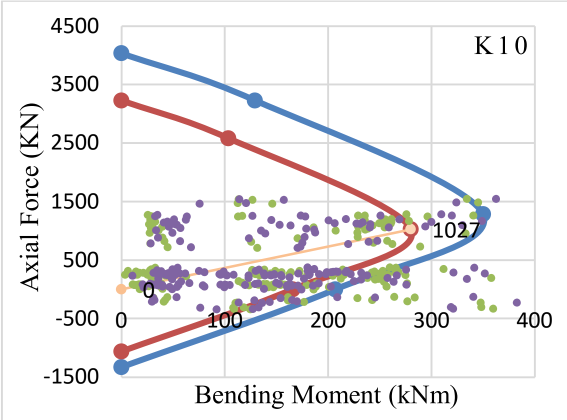


Fig.10 The P-M interaction diagram of K10 column

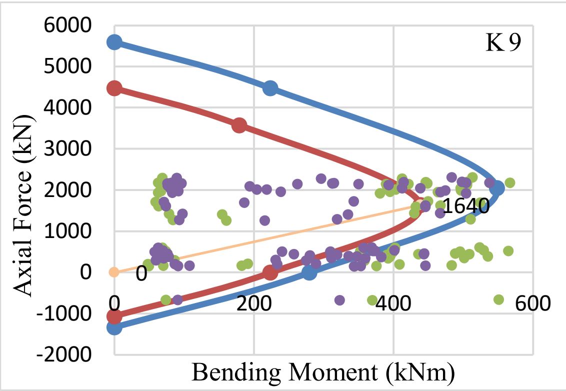


Fig.9 The P-M interaction diagram of K9 column

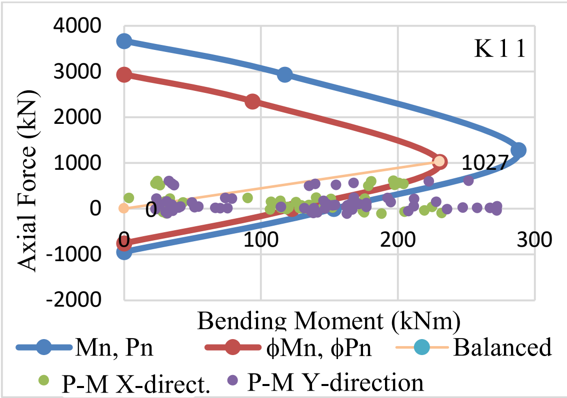


Fig.11 The P-M interaction diagram of K11 column

3.2.3 Load-bearing capacity of beam

The beam capacity was assessed considering the strength of the bending moment and shear strength. The calculation results indicate that the beam capacity fails to withstand the load, particularly in bending moment at the support area, shear strength at the midspan area BA7 on each floor, and B1, B2, and B3 on the 2nd floor, as detailed in Table 4.

Table 4 The beam capacities of the existing building

Story	Type Beam	Results of Bending Moment Strength Analysis					Shear Strength Analysis Results			
		Flex. Reinf. Bar		ϕMn	Mu	ϕMn ≥Mu	Shear Reinf. Bar	ϕVn	Vu	ϕVn ≥Vu
		Compr.	Tensile	kNm	kNm			kN	kN	
1	B2	4D22	10D22	749.33	796.52	NOT OK	Ø10-200	332.35	174.22	OK
	B3	3D19	7D19	400.53	548.33	NOT OK	Ø10-200	238.29	153.94	OK
	B1	4D19	7D19	325.81	525.31	NOT OK	Ø10-200	195.74	187.76	OK
	BA7	2D16	4D16	135.75	410.84	NOT OK	Ø10-200	195.74	212.33	NOT OK
	BA 4	3D19	5D19	289.21	524.83	NOT OK	Ø10-200	221.44	124.15	OK
2	B2	4D22	10D22	749.33	763.11	NOT OK	Ø10-200	332.35	355.32	NOT OK
	B3	3D19	7D19	400.53	536.13	NOT OK	Ø10-200	238.29	254.67	NOT OK
	B1	4D19	7D19	325.81	405.44	NOT OK	Ø10-200	195.74	238.48	NOT OK
	BA7	2D16	4D16	135.75	337.80	NOT OK	Ø10-200	195.74	259.97	NOT OK
	BA 4	3D19	5D19	289.21	442.65	NOT OK	Ø10-200	221.44	209.38	OK
3	B2	4D22	10D22	749.33	774.79	NOT OK	Ø10-200	332.35	326.16	OK
	B3	3D19	7D19	400.53	413.09	NOT OK	Ø10-200	238.29	214.65	OK
	B1	4D19	7D19	325.81	439.79	NOT OK	Ø10-200	195.74	213.58	NOT OK
	BA7	2D16	4D16	135.75	226.02	NOT OK	Ø10-200	195.74	190.29	OK
	BA 4	3D19	5D19	289.21	442.65	NOT OK	Ø10-200	221.44	209.38	OK

4. SEISMIC RETROFITTING USING SHEAR WALLS

The selection of structural retrofitting is based on the outcomes of the structural analysis, revealing that all major structural elements, including columns and beams, are incapable of withstanding the overall working loads. As a result, there is a need for a comprehensive retrofitting approach, such as global retrofitting [15]. The recommended global retrofitting strategy for the Ibnu Sina West Pasaman Hospital building is by adding shear walls to the existing structure. Retrofitting with shear walls is an effective method for mitigating internal forces acting on structural elements [16].

4.1 Shear Walls Location

The placement of shear walls in existing buildings must consider the dominant earthquake that works (weak axis of the building), aesthetic and functional factors of space in the building, minimize the eccentricity of the diaphragm for each floor of the building, and reduce the torque moment in the existing building in order to get maximum structural retrofitting results.

Fig. 12 shows the shear wall placement plan in the existing building. The shear walls have 30 MPa concrete quality, installed as high as the existing building (Fig. 13). Table 5 shows the retrofitting detail of the shear walls.

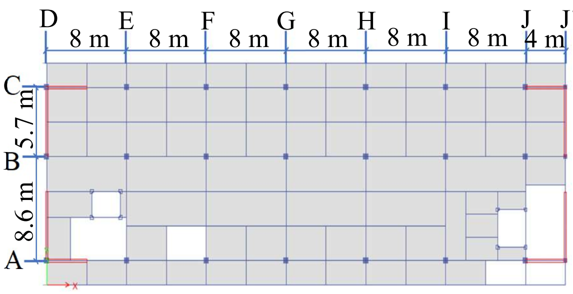


Fig.12 Placement plan for shear walls

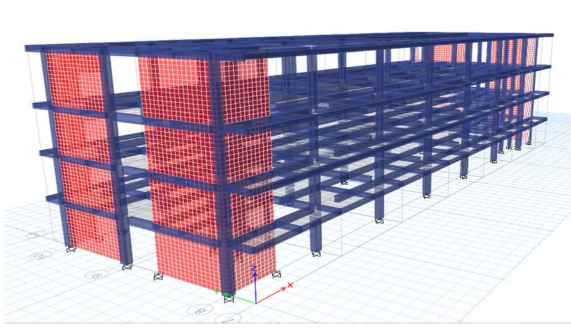
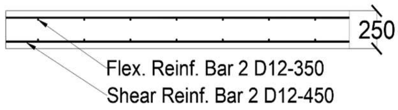


Fig.13 3D model of building retrofit with shear walls

Through retrofitting of the structure with shear walls, a transformation occurs in the building's structural system, transitioning into a dual system. This alteration affects earthquake parameters, including the adjustment of the response modification coefficient (R) to 7, the over-strength factor system (Ω) to 2.5, the reinforcement parameter (Ct) to 0.0488, and the period parameter (x) to 0.75.

Table 5 The shear wall section

Shear Wall	
Thickness	250 mm
Flex. Reinf. Bar	2D12-350
Shear Reinf. Bar	2D12-450

4.2 Structural Re-Analysis Results for the Retrofitted Building

The re-analysis of the retrofitted building is carried out in the same way as the analysis of the existing building structure with dual system earthquake parameters due to adding shear walls to the existing building.

4.2.1 Inter-story drift of the retrofitted building

Table 6 illustrates the inter-story drift of the retrofitted building. From this table, it can be seen that the building's inter-story drift complies with the permissible limit stipulated in SNI 1726:2019.

Table 6 Inter-story drift of the retrofitted building

Story	Inelastic Drift (mm)		Drift Limit (mm)	$\Delta <$ Drift Limit
	Δ_X	Δ_Y		
4	30.595	13.409	38.385	OK
3	29.146	12.602	33.00	OK
2	26.272	11.315	33.00	OK
1	15.374	6.974	33.00	OK

4.2.2 Column capacity of retrofitted building

Figs. 14-19 shows the P-M interaction diagram of a retrofitted building column. It is clear from these figures that all columns have sufficient capacity to withstand the working load, as shown by all P-M values (points) that are within the P-M interaction diagram line.

To assess the impact of implementing shear walls for the structural retrofitted building, a comprehensive examination of internal forces was conducted at a designated column observation point for each column type, as illustrated in Fig. 20. The retrofitting of the building using shear walls has notably increased the building structural capacity, resulting in a maximum reduction in axial force by 17% and moment and shear forces by approximately 88% for structural columns, as shown in Table 7.

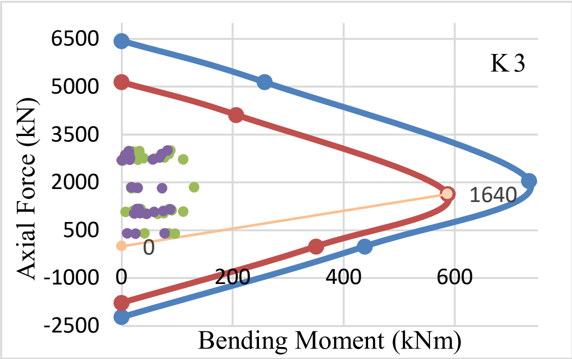


Fig.14 The interaction diagram for K3 column

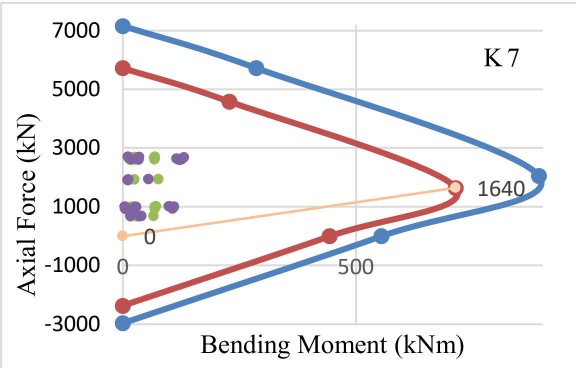


Fig.15 The interaction diagram for K7 column

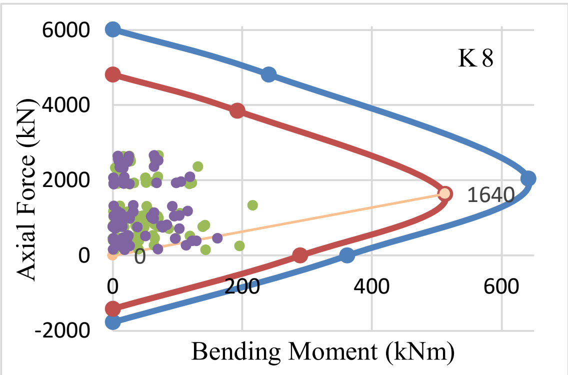


Fig.16 The interaction diagram for K8 column

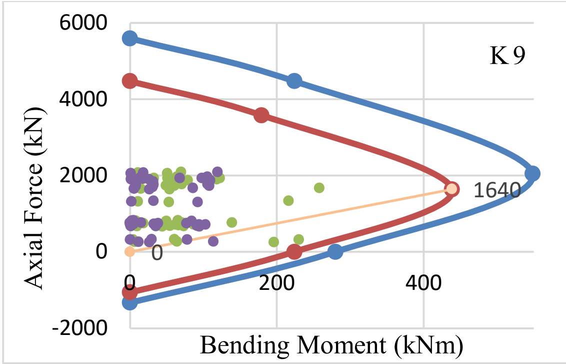


Fig.17 The interaction diagram for K9 column

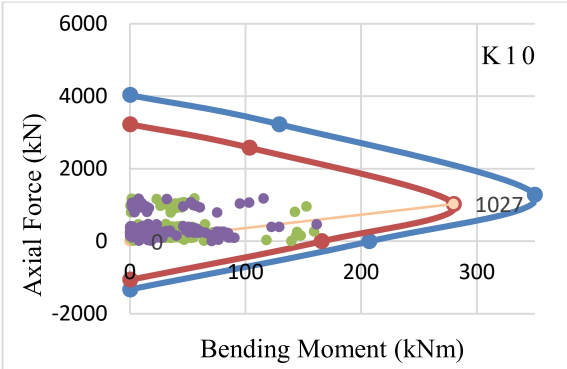


Fig.18 The interaction diagram for K10 column

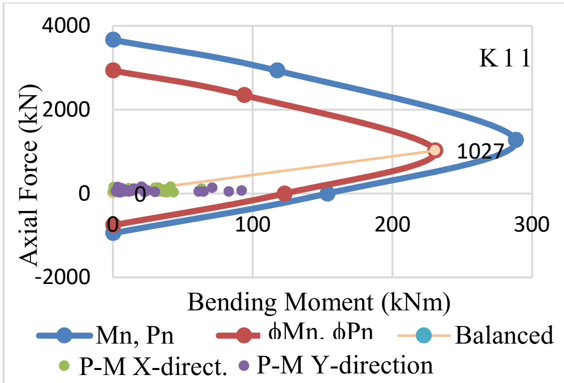


Fig.19 The interaction diagram for K11 column

Table 7 The percentage of increase in the column capacity

Column	Axial (kN)		Increasing	Moment (kNm)		Increasing	Shear (kN)		Increasing
	Existing	Retrofitting	(%)	Existing	Retrofitting	(%)	Existing	Retrofitting	(%)
K3	3243.72	2900.16	10.6	752.34	90.52	88.0	271.92	31.36	88.5
K7	2714.25	2646.44	2.5	739.05	91.77	87.6	268.09	31.59	88.2
K8	2991.61	2576.33	13.9	744.21	91.19	87.7	266.3	30.55	88.5
K9	2190.48	1968.08	10.2	478.06	83.85	82.5	246.37	39.77	83.9
K10	265.267	247.39	6.7	137.29	42.69	68.9	60.87	18.37	69.8
K11	111.93	92.73	17.2	138.55	43.88	68.3	54.45	18.84	65.4

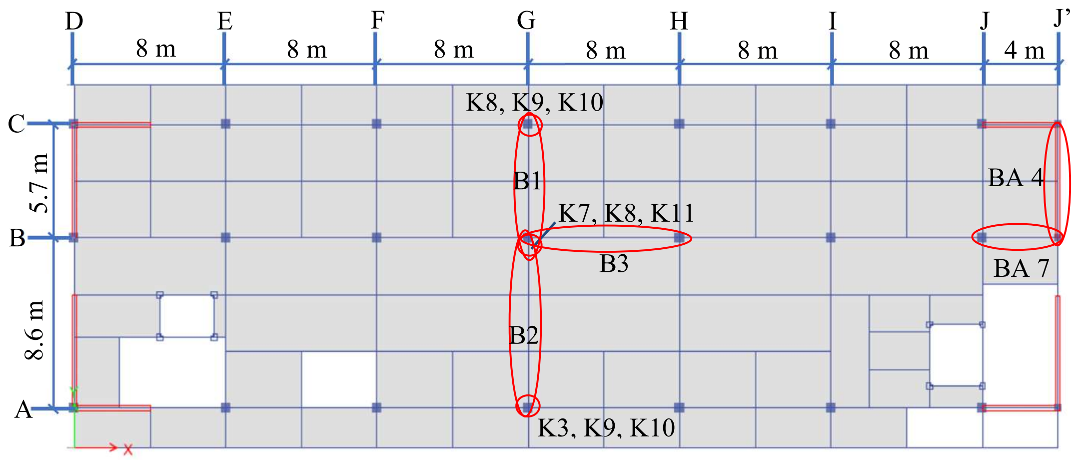


Fig.20 Location of observation points for comparing internal forces in structural elements

4.2.3 Load-bearing capacity of beam

Table 8 The beam capacity of the retrofitted building

Story	Type Beam	Results of Bending Moment Strength Analysis					Shear Strength Analysis Results			
		Flex. Reinf. Bar		ϕMn	Mu	ϕMn ≥Mu	Shear Reinf. Bar	ϕVn	Vu	ϕVn ≥Vu
		Compr.	Tensile	kNm	kNm			kN	kN	
1	B2	4D22	10D22	749.33	434.29	OK	Ø10-200	529.96	272.42	OK
	B3	3D19	7D19	400.53	357.15	OK	Ø10-200	375.51	239.73	OK
	B1	4D19	7D19	325.81	158.84	OK	Ø10-200	308.46	129.45	OK
	BA7	2D16	4D16	135..75	96.65	OK	Ø10-200	308.46	96.91	OK
	BA 4	3D19	5D19	289.21	219.73	OK	Ø10-200	358.67	173.59	OK
2	B2	4D22	10D22	749.33	350.52	OK	Ø10-200	529.96	279.36	OK
	B3	3D19	7D19	400.53	251.14	OK	Ø10-200	375.51	244.02	OK
	B1	4D19	7D19	325.81	105.70	OK	Ø10-200	308.46	125.74	OK
	BA7	2D16	4D16	135..75	97.21	OK	Ø10-200	308.46	97.81	OK
	BA 4	3D19	5D19	289.21	205.16	OK	Ø10-200	358.67	153.36	OK
3	B2	4D22	10D22	749.33	483.16	OK	Ø10-200	529.96	338.71	OK
	B3	3D19	7D19	400.53	240.73	OK	Ø10-200	375.51	253.82	OK
	B1	4D19	7D19	325.81	214.21	OK	Ø10-200	308.46	174.57	OK
	BA7	2D16	4D16	135..75	104.83	OK	Ø10-200	308.46	82.68	OK
	BA 4	3D19	5D19	289.21	223.50	OK	Ø10-200	358.67	156.63	OK

Table 9 The percentage of increase in the beam capacity

Beam	Moment (kNm)		Increasing	Shear (kN)		Increasing	Torque (kNm)		Increasing
	Existing	Retrofitting	(%)	Existing	Retrofitting	(%)	Existing	Retrofitting	(%)
B1	915.01	433.39	52.6	434.36	288.58	33.6	58.46	8.66	85.2
B2	573.32	281.54	50.9	293.79	195.89	33.3	29.68	10.62	64.2
B3	474.10	160.40	66.2	275.06	130.37	52.6	22.53	3.76	83.3
BA7	420.06	105.07	75.0	290.78	101.75	65.0	16.33	2.00	87.8
BA4	637.49	248.52	61.0	328.89	187.14	43.1	29.41	16.23	48.2

Table 8 presents the beam capacity of the retrofitted building. The table illustrates that the beams exhibit sufficient capacity to withstand the working loads. To evaluate the effects by adding shear wall on the existing structural building, a thorough examination of internal forces was carried out at a specified beam observation point for each beam type, as shown in Fig. 20. Table 9 provides a reduction in the maximum beam moment force by 75% and shear force by 65% due to adding shear walls to the existing building.

5. CONCLUSIONS

Based on the structural assessment and retrofitting analysis conducted on the building structure of the Ibnu Sina Hospital building, the following conclusions can be drawn:

1. The existing building does not meet the requirements for inter-story drift, and the structural elements of columns and beams are not able to carry the working loads according to the current building standard, so retrofitting of the

building structure is needed so that the building becomes stronger than its original strength.
2. The retrofitting of the building structure was recommended by adding shear walls to the existing building to reduce the internal forces acting on the structure and increase the stiffness of the building.
3. Based on the results of the re-analysis of the retrofitted building structure, there is a reduction in the internal force in the column by 17% for the maximum axial force and around 88% for the moment force and shear force. For beams, the internal force reduction is 75% for the maximum moment force and 65% for the shear force.
4. The use of the shear walls as the retrofitting method on the hospital building shows that the inter-story drift and the strength of structural elements have met the building codes' requirements, so the building will be earthquake-resistant and safe to use for hospital operations.

6. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support provided by Universitas Andalas via RPT Grant in the fiscal year 2023 (Contract No.: T/69/UN16.19/PT.01.03/IS-RPT/2023).

7. REFERENCES

[1] Hooda Y and Goyal P K, Seismic Assessment of a Hospital Building, in IOP Conference Series: Earth and Environmental Science, IOP Publishing, Vol.796, No. 1, p. 012006, 2021, pp.1-13.
[2] Fauzan, Nulhakim L., Nugraha D. A. M., Jauhari Z. A., and Agista G. A., Structural Evaluation of the Melati Hospital Building at Sungai Penuh City, Indonesia, International Journal of GEOMATE, Vol. 25, Issue 112, 2023, pp.123-30.
[3] Widyaningrum A., Haryanto Y., Sudibyo G. H., and Hermanto N. I. S., Seismic Performance of the Inpatient Building of Goeteng Hospital, Purbalingga, Indonesia, in IOP Conference Series: Earth and Environmental Science, IOP Publishing, Vol.1367, 2019, pp.1-8.
[4] Kuria K. K. and Kegyes-Brassai O. K., Nonlinear Static Analysis for Seismic Evaluation of Existing RC Hospital Building, Appl. Sci, Vol. 13, No. 11626, 2023, pp.1-17.
[5] Ferraioli M., Case Study of Seismic Performance Assessment of Irregular RC Buildings: Hospital Structure of Avezzano (L'Aquila, Italy), Earthquake Engineering and Engineering Vibration, Vol. 14, No. 1, 2023.
[6] Xie, Linlin, Wang X., Zeng D., Jia J., and Liu Q., Resilience-Based Retrofitting of Adjacent Reinforced Concrete Frame–Shear Wall Buildings Integrated into a Common Isolation System, Journal of Performance of Constructed Facilities, Vol. 36, Issue 1, 2022, No. 04021100.
[7] Aziz, Ramdhani R., and Hidayat I., The Effect of Retrofitting High-Rise Buildings with Steel Plate Shear Walls, in E3S Web of Conferences, vol. 426, p. 01028. EDP Sciences, 2023.
[8] Pérez C., Gladys, Alata N. P., and Cárdenas G. H., Seismic Retrofit in Hospitals using Fluid Viscous Dampers, in 2020 Congreso Internacional de Innovación y Tendencias en Ingeniería (CONIITI), IEEE, 2020, pp. 1-6.
[9] Indonesian National Standardization Agency, SNI 1726:2012 Seismic Resistance Design Codes for Building and Other Structures, BSN, Jakarta, 2012, pp.1-138.
[10] Fauzan, Ismail F. A., Agista G. A., and Melinda A. P., Rapid Assessment of the Public Buildings After the February 25th, 2022 West Pasaman Earthquake, in Proc. E3S Web of Conferences Vol. 464, No. 03004, 2023, pp.1-7.
[11] Indonesian National Standardization Agency, SNI 1726:2019 Seismic Resistance Design Codes for Building and Other Structures, BSN, Jakarta, 2019, pp.1-238.
[12] Indonesian National Standardization Agency, SNI 2847:2019 Structural Concrete Requirements for Buildings, BSN, Jakarta, 2019, pp.1-695.
[13] Indonesian National Standardization Agency, SNI 1727:2020 Minimum Load for Planning of Buildings and Other Structures, BSN, Jakarta, 2020, pp.1-302.
[14] Pamungkas A., Example of a Reinforced Concrete Building Structure Planning Report for a Special Moment Bearing Frame System (SRPMK) in Accordance with SNI-1727:2020, SNI-1726:2019, SNI-2847:2019, Yogyakarta: Deepublish, 2021, pp.1-111
[15] Sakurai M., Kuramoto H., Matsui T., and Akita T., Seismic Performance of RC Shear Walls with Multi-Openings, in Proc. 14 World Conference on Earthquake Engineering, 2008, pp.1-8.
[16] Fauzan, Ismail F. A., and Jauhari Z. A., Seismic Retrofitting Analysis Using Concrete Jacketing and Shear Wall on Dental Hospital Building of Andalas University, in IOP Conference Series: Materials Science Engineering, IOP Publishing, Vol. 602, No. 012108, 2019, pp.1-12.