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Performance evaluation of Amarsvati Condominium Hotel building structure using pushover analysis based on Indonesia Newest Seismic Code

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Abstract. Earthquake is one of the natural disasters that are very dangerous for human survival, therefore it is necessary to mitigate disasters, one of them is by evaluating the performance of building structures, evaluating the performance of building structures is aim to minimize the risk caused by earthquakes. Based on the Performance-Based Evaluation Design, buildings are evaluated using pushover analysis. Pushover analysis is one method of building evaluation, in pushover analysis which is necessary to notice input data such as dead load, live load, and earthquake load. The result of pushover analysis is a capacity curve that connects the base shear force and roof displacement and describes the state of the structure. In this study, the evaluation was conducted on Condominium Hotel Amarsvati Lombok. The purpose of this evaluation is to determine the performance of building structures with SNI 1726: 2019 and to determine the mechanism for the occurrence of plastic hinges in building structures. The results of the pushover analysis are that the performance level of the building for x-direction and y-direction respectively are CP(Collapse Prevention) and CtoD, wherein in this condition the structure is still able to withstand the maximum limit of shear forces but has almost collapsed.

Keywords: Earthquake; pushover analysis; performance level

1. Introduction

Lombok is one of the most admired tourism areas, both local and foreign tourists. In 2016 Lombok won 3 awards in the category of World's Best Halal Beach Resort, World's Best Halal Travel Website, and World's Best Halal Honeymoon Destination. Domestically, Indonesia's Muslim Travel Index (IMTI) 2019 places Lombok in the first place as Indonesia's Leading Halal Travel Destination.To support this, Lombok is constantly improving itself in the tourism sector, starting from transportation, accommodation, and hotel buildings.

Lombok Island is located between 2 earthquake generators from the south and north. From the south, there is a subduction zone of the Indo-Australian plate that points below Lombok Island, while

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from the north there is a geological structure of the Flores Back Arc which makes Lombok Island prone to earthquakes.

Earthquake is one of the natural disasters that are very dangerous for human survival, therefore it is necessary to mitigate disasters. One of them is by evaluating the performance of building structures[1]. Based on the Performance-Based Evaluation Design.,buildings are evaluated using pushover analysis.

Pushover Analysis can give good results if data input and the stages of the process are carried out properly, and refer to the correct standard method [2]. The displacement coefficient method (FEMA 356) provides a larger target displacement than the capacity spectrum method (ATC-40)[3].

2. Methodology

2.1. Research location

The object of research is the Amarsvati Condominium Hotel building, located on Jalan Raya Senggigi 99, Malimbu, Malaka, Pemenang District, North Lombok Regency, West Nusa Tenggara. (Latitude: -8,438022, Longitude: 116,03991).

2.2. Research Flow

2.2.1. Data collection

Collecting the necessary data in the form of general building data, material data, and dimensions of structural elements.

2.2.2. Building structure modeling with SAP2000

After obtaining the supporting data, the building structure is modeled with SAP2000. The elements of the structure that is modeled in the SAP2000 program, namely beam, column and slab.

2.2.3. Loading from live load, dead load according to SNI 1727:2013 and earthquake load SNI 1726:2019.

a. Vertical Load

The vertical load is divided into 3, namely :

1. The dead load was obtained from the weight of its structure.
2. Additional dead load is obtained by finishing weight (ceiling, ME installations, etc.)
3. The live load has been regulated in SNI 1723:2013

b. Horizontal Load

Horizontal loads consist of earthquake loads (SNI 1726: 2019) and wind loads

2.3. Stages of Pushover Analysis.

The non-linear static thrust load analysis will be carried out following the FEMA 356 instructions and is built-in to the SAP2000 program. The steps are as follows:

1. The structure that has been modeled is made of its properties, namely beams and columns
2. Creating lateral load distribution pattern
3. Make 2 cases, namely Push X and Push Y
4. Creating a pushover curve based on various lateral force distribution patterns
5. The pushover curve is then used to determine the displacement target

3. Analysis and Discussion

3.1. General
Amarsvati Condominium Hotel has 13 floors and a total height of 50,05 m above the ground with the main function as a hotel. This structural modeling process is carried out in SAP2000 by modeling columns, beams, and slabs then defining the properties of the structural element, and the loading input that the structure will receive.

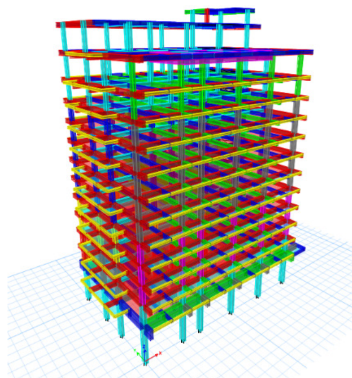
Figure 1. Structure modelling

3.2. Existing Building Data

3.2.1. Material Data
Concrete Quality : fc' = 30 Mpa
Reinforcement Quality :
a. Thread : fy = 400 MPa: D ≥ 10 mm
b. Plain : fy = 240 MPa: D ≤ 8 mm

3.3. Gravity Load

3.3.1. Dead Load (Super Dead)
a. Dead Load on slab
- Total dead load (Qd) on the roof plate= 0.71 kN/m^2
- Total dead load (Qd) on the slab = 0.1,47kN/m^2
- The weight of the pool water with a depth of 1.20 meters = 12 kN/m^2

b. Dead Load on strucutural beams
- Light brick wall load 3.25 meters high = 2.11 kN/m
- Light brick wall load height 4.00 meters = 2.60 kN/m
- Light brick wall load 2.60 meters high = 1.69 kN/m
- Light brick wall load 1.20 meters high = 0.78 kN/m

3.3.2. Live Load
The amount of live load in SNI 1727: 2013 [4]:
1. Floor or engine room = 7.18 kN/m^2
2. Gymnasium = 4.79 kN/m^2

3. Multipurpose room = 4.79 kN/m^2
4. Lobby = 4.79 kN/m^2
5. Restaurant = 4.79 kN/m^2
6. Spa room = 4.79 kN/m^2
7. Park = 4.79 kN/m^2
8. Balcony = 2.88 kN/m^2
9. Stairs = 1.33 kN/m^2
10. Corridor = 1.92 kN/m^2
11. Lodging space = 1.92 kN/m^2
12. Roof floor = 0.96 kN/m^2

3.4. Horizontal Load

3.4.1. Wind Load

With the steps required in SNI 1727: 2013 article 27.2.1, the wind pressure value "p" is obtained as follows:

- P (wind) press = q x G x Cp
  = 0.363 x 0.85 x 0.8
  = 0.247 kN / m^2
- P (wind) press = q x G x Cp
  = 0.363 x 0.85 x 0.3
  = 0.093 kN / m^2
- P (wind) press = q x G x Cp
  = 0.363 x 0.85 x 0.7
  = 0.216 kN / m^2

3.4.2. Earthquake load

a. Total Building Weight
   In this study, the weight of the building was obtained from manual calculations.

b. Response Spectrum Parameter
   - S_s = 1,105696 g
   - S_1= 0,438465 g
   - T_L= 12 seconds
   - F_a= 1,057721
   - F_v= 1,861535
   - S_{MS}= 1,169519 g
   - S_{M1} = 0,816217 g
   - S_{DS}= 0,779679 g
   - S_{D1}= 0,544145 g
   - T_0 = 0,139582seconds
   - T_S= 0,697909seconds

c. Natural Vibration Period (T)
   $Ta \leq T \leq Cu\ Ta$
   Ta = fundamental approach period
   T = fundamental period of the SAP2000 calculation

Cu = upper limit coefficient for the calculated period

- $Ta = C_t h_n^x = 0,0466 \times 50,05^{0,9} = 1,577$ seconds
- Cu Ta = 1,4 x 1,577 = 2,2078 seconds
- T SAP200 calculation = 2,63 seconds

Table 1. Total weight of each floor

Floor	h (m)	Total Weight (kN)
Roof	50.05	714,054
13	47.45	3815,199
12	43.45	9831,382
11	39.45	8297,832
10	36.20	8276,179
9	32.95	8383,819
8	29.70	8383,819
7	26.45	8383,819
6	23.20	8383,819
5	19.95	8383,819
4	16.70	8383,819
3	13.45	8461,501
2	10,20	8581,141
1	6.95	12105.94
GF	-0.05	997.92
Total		111384.1

-

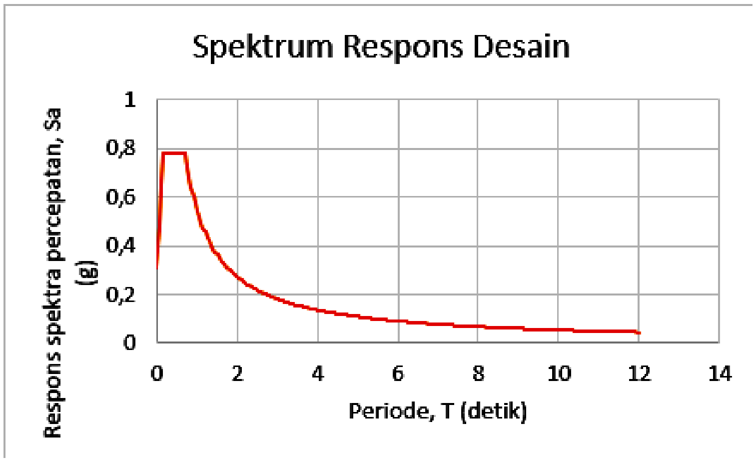

Figure 2. Response Spectrum Design

Since T> Cu Ta, then T = 2.2078 seconds

d. Seismic Response Coefficient (Cs)

Seismic response coefficient (Cs) must be determined using SNI 1726: 2019 Article 7.8.1.1:

Then Cs = 0,0343

e. Base Shear Force
From the above values, the base shear force values are obtained as follows:
V = Cs W = 0,0343 x 11384,0635 = 3820,47 kN

f. Comparison of Static and Dynamic Shear Force
By SNI 1726: 2019 article 7.9.1.4.1 regarding the force scale, this regulation implies that the dynamic shear force must be equal to 100% of the static shear force. Formulated as Vd = 100% Vs [5]. The shear force values are obtained as follows:
Vd (x) = 2330,368 kN<Vs (x) = 2851,683 kN(CHECK)
Vd (y) = 4239,533 kN>Vs (y) = 2330,368 kN(CHECK)
To fulfill the requirements of SNI 1726: 2019 Article 7.9.1.4.1, the nominal level of shear force due to the earthquake on the analysis result of the building structure plan must be multiplied by the Vs / Vd scale factor [5], and after re-running the results are:
Vs =2851,683 kN = Vd = 2851,683 kN (OK).

g. Earthquake Force Vertical Distribution
The lateral seismic force (Fx) arising at all levels must be determined from equations (40) and (41) at SNI 1726:2019 [5].
- Lateral force on the Roof Floor

$$C_{roof\ x\text{-}y} = \frac{714{,}054\ x\ 50{,}05^{1{,}5305}}{17628250{,}74} = 0{,}0166$$

$F_{roof\ x\text{-}y}$ = 0,0166 x 3820,47 kN = 63,70475kN

So that the lateral forces of each floor are obtained as follows :

Table 2. Lateral force on each floor

floor	height from the floor		weight	moment	lateral
	hi	hi ^ k	Wi	Wi x hi ^ k	Fi xy
	(m)	(m)	(kN)	(kN.m)	(kN)
roof	50.05	411,6548	714,054	293943,7539	63.70475
13	47.45	379,2184	3815,199	1446793,682	313,5553
12	43.45	331,1672	9831,382	3255830,928	705,6176
11	39.45	285,4423	8297,832	2368552,105	513,3228
10	36.2	250,0766	8276,179	2069679.06	448,5497
9	32.95	216,3817	8383,819	1814105,126	393,1606
8	29.7	184,4318	8383,819	1546242,784	335,1084
7	26.45	154,3128	8383,819	1293730,425	280,3828
6	23.2	126,1256	8383,819	1057414,237	229,1673
5	19.95	99.99129	8383,819	838308,8291	181.6819
4	16.7	76,05877	8383,819	637662.9432	138,197
3	13.45	54,51791	8461,501	461303,3829	99,97564
2	10.2	35.62307	8581,141	305686,597	66,24971
1	6.95	19,74211	12105.94	238996,8864	51.79643
Total				17628250.74	

3.5. Mass participation control

By SNI 1726: 2019 Article 7.9.1.1 the number of various vibrations/shape modes reviewed in the sum of various responses must reach 100%.And as an alternative to the analysis allowed to enter the number of varieties that minimum to achieve a mass variety of combined most slightly to 90% of the actual mass [5].

Table 3. Modal participating mass ratios

TABLE: Modal Participating Mass Ratios						
OutputCase	StepType	StepNum	Period	SumUX	SumUY	SumUZ
Text	Text	Unitless	Sec	Unitless	Unitless	Unitless
MODAL	Mode	1	2,360813	0,819	0,000008268	5,823E-07
MODAL	Mode	2	1,249711	0,82284	0,14318	0,000002765
MODAL	Mode	3	1,12174	0,82367	0,8774	0,000004362
MODAL	Mode	4	0,856197	0,94482	0,8775	0,00001123
MODAL	Mode	5	0,551502	0,97756	0,87787	0,00001144
MODAL	Mode	6	0,472951	0,97897	0,91069	0,00002251
MODAL	Mode	7	0,413822	0,97975	0,97331	0,00002968
MODAL	Mode	8	0,382051	0,98681	0,97493	0,00003989
MODAL	Mode	9	0,30164	0,98751	0,97904	0,00004104
MODAL	Mode	10	0,300727	0,98912	0,98146	0,00006059
MODAL	Mode	11	0,237798	0,98982	0,9829	0,00018
MODAL	Mode	12	0,231469	0,99017	0,9866	0,00022
MODAL	Mode	13	0,215472	0,99021	0,98855	0,00699
MODAL	Mode	14	0,198633	0,99021	0,98894	0,0621

Table 4. Drift control on x-direction and y-direction

Floor	hsx (mm)	δx (mm)	δy (mm)	Δx (mm)	Δy (mm)	Δa (drift limit) (mm)	Info
Roof	2600	110,497	76,36	8,6625	9,3115	65	Safe
13	4000	108,922	74,667	24,079	21,0705	100	Safe
12	4000	104,544	70,836	33,7095	22,605	100	Safe
11	3250	98,415	66,726	34,32	22,99	81,25	Safe
10	3250	92,175	62,546	34,1715	25,289	81,25	Safe
9	3250	85,962	57,948	39,369	28,6	81,25	Safe
8	3250	78,804	52,748	44,638	32,032	81,25	Safe
7	3250	70,688	46,924	49,5385	35,3485	81,25	Safe
6	3250	61,681	40,497	54,0375	38,3845	81,25	Safe
5	3250	51,856	33,518	57,915	40,7055	81,25	Safe
4	3250	41,326	26,117	59,708	41,0465	81,25	Safe
3	3250	30,47	18,654	52,162	36,0415	81,25	Safe
2	3250	20,986	12,101	35,838	23,7875	81,25	Safe
1	7000	14,47	7,776	79,585	42,768	175	Safe
GF	0	0	0	0	0	0	Safe

3.6. Drift Control

- Roof floor

  Drift limit = Δa = 0,025hsx = 0,025 x 2600 = 65 mm

  X-direction drift = Δroof = (δroof-δ13floor)Cd/I= (110,497-108,922)5,5/1 = 9,3115 mm

  Y-direction drift = Δroof = (δroof-δ13floor)Cd/I = (76,36 -74,667)5,5/1 = 8,6625 mm

  due to drift in x and y direction <Drift limit, the structure is safe.

3.7. Pushover Analysis

3.7.1. Capacity curve

From the results of the SAP2000 analysis, the results of the basic shear force and displacement for the X and Y-directions are as follows.

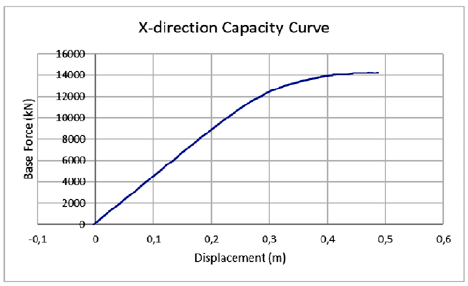

Figure 3. X-direction capacity curve

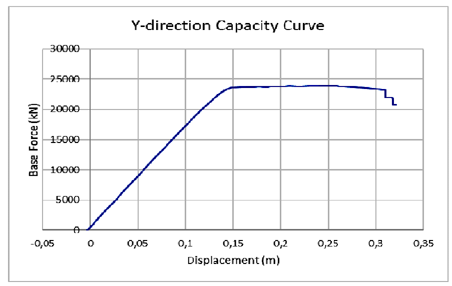

Figure 4. Y-direction capacity curve

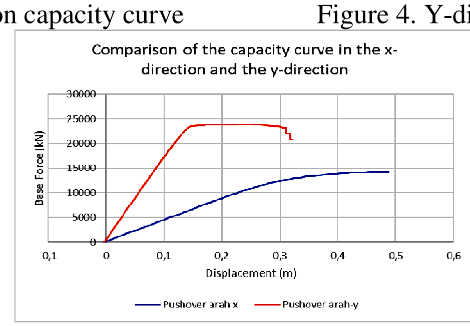

Figure 5. Comparison of the capacity curve in the x-direction and y-direction

3.7.2. Displacement target using the transfer coefficient method (FEMA 273/356)

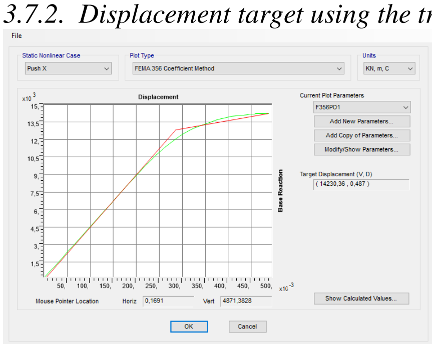

Figure 6. X-direction displacement target

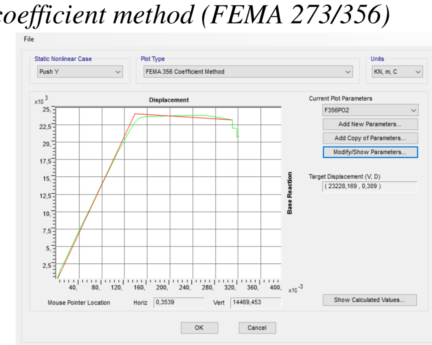

Figure 7. Y-direction displacement target

The displacement target obtained for the x-direction: δ_T = 0.487 m with a shear force of 14230,36kN, and for the y-direction : δ_T = 0,309 m with a shear force of 23228,169 kN.

3.7.3. Structure Performance Evaluation

Table 5. X-direction capacity curve

LoadCase	Step	Displacement	BaseForce	A-B	B-O	IO-LS	LS-CP	CP-C	C-D	D-E	>E	Total
		m	KN									
Push X	0	-0,003667	0	7764	316	0	0	0	0	0	0	8080
Push X	1	0,001383	222,097	7758	322	0	0	0	0	0	0	8080
Push X	2	0,011483	666,289	7754	326	0	0	0	0	0	0	8080
..........Sebagian sengaja dihapus												
Push X	103	0,487165	14229,851	5802	2158	112	8	0	0	0	0	8080
Push X	104	0,487204	14229,69	5802	2158	112	8	0	0	0	0	8080
Push X	105	0,487215	14230,174	5802	2158	112	8	0	0	0	0	8080
Push X	106	0,487333	14230,969	5802	2158	112	8	0	0	0	0	8080
Push X	107	0,487372	14230,688	5802	2158	112	8	0	0	0	0	8080

Table 6. Y-direction capacity curve

LoadCase	Step	Displacement	BaseForce	A-B	B-IO	IO-LS	LS-CP	CP-C	C-D	D-E	>E	Total
		m	KN									
..........Sebagian sengaja dihapus												
Push Y	34	0,267545	23816,485	7326	658	76	6	0	14	0	0	8080
Push Y	35	0,277645	23703,287	7326	658	72	4	0	20	0	0	8080
Push Y	36	0,29738	23414,358	7326	658	70	2	0	24	0	0	8080
Push Y	37	0,30748	23255,631	7326	658	66	2	0	28	0	0	8080
Push Y	38	0,310005	23212,453	7326	658	64	2	0	30	0	0	8080
Push Y	39	0,310044	23211,086	7326	658	64	2	0	30	0	0	8080
Push Y	40	0,310046	23210,52	7326	658	64	2	0	30	0	0	8080
..........Sebagian sengaja dihapus												
Push Y	63	0,31801	20802,344	7324	660	56	2	0	36	0	2	8080
Push Y	64	0,318049	20773,268	7324	660	56	2	0	34	0	4	8080
Push Y	65	0,320574	20801,65	7324	660	56	2	0	34	0	4	8080
Push Y	66	0,321127	20803,358	7324	660	54	2	0	36	0	4	8080

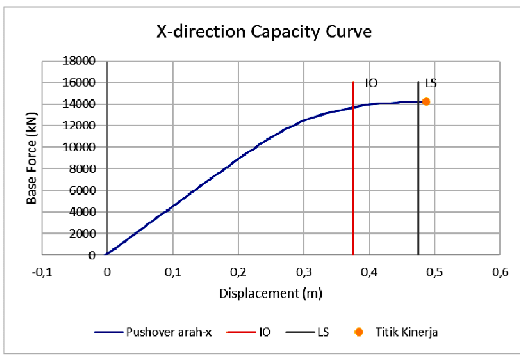

Figure 8. X-direction performance point

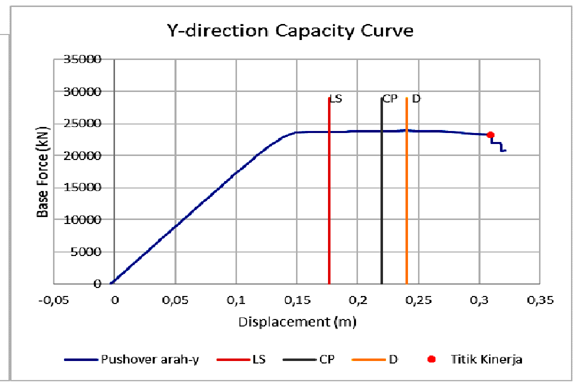

Figure 9. Y-direction performance point

With the displacement target for the X-direction, δ_T = 0.487 m, it can be seen that in step 105 where the displacement reaches 0.4872>δ_T and the basic shear force for δ_T = 14230.36 kN. The performance shown by the structure is already at the point of CP (Collapse Prevention).

For the Y-direction,δ_T = 0.309 m, it can be seen that in step 35 where the displacement reaches 0.310>δ_T with the basic shear force for δ_T = 23228.169 kN, the performance shown by the structure is already within the CtoD limit.

3.7.4. Plastic hinge mechanism

X-direction pushover analysis yields 107 steps. Plastic hinges have been formed in step 1, namely on the corridor beams on each floor with B to IO performance with a total of 316 points. For the next step, there is an increase in the number of points that experience plastic hinges but are still within the B to IO limit. In step 38, there has been an addition of plastic hinges to the beams and plastic hinges have been formed in several columns on the 3rd floor with an IO to LS limit of 6 points. For the last step, to be precise, at the foot of the GF floor column, a plastic joint has been formed with the CP (Collapse Prevention) performance.

Y-direction pushover analysis resulted in 66 steps. Plastic joints have been formed in step 1, namely in the corridor beams, balcony beams, and beams in the lodging room on each floor with B to IO performance with a total of 316 points. For the next step, there is an increase in the number of points that experience plastic hinges but are still within the B to IO limit. In step 21 a plastic hinge has been formed with IO to LS performance, namely on the 1st-floor column. At step 29 the column on the 1st floor has decreased the LS to CP performance. In step 32, as the load increases, the column on the 1st-floor decreases in performance, namely C to D, and in the last step, step 66, the performance on the 1st-floor column is already in condition E.

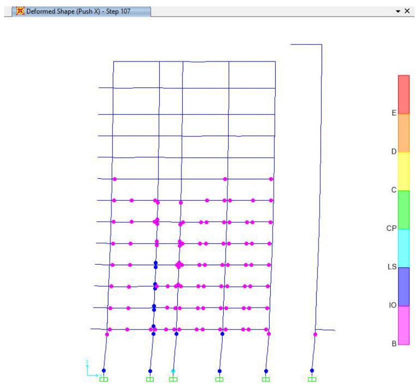

Figure 10. Step 107 x-direction pushover

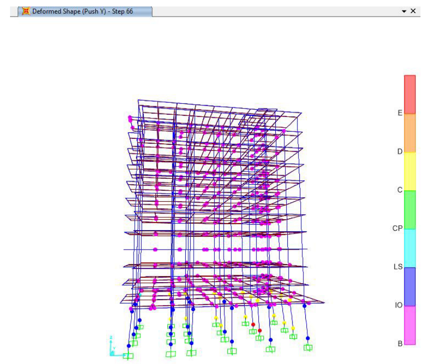

Figure 11. Step 66 y-direction pushover

4. Conclusions

Based on FEMA 356, the δ_T displacement target for the X-direction is 0.487 m with a baseshear force of 14230.36 kN and for the Y-direction the δ_T displacement target is 0.309 m with a baseshear force of 23228.169 kN.

The performance of the Amarsvati Condominium Hotel for the X-direction is CP (Collapse Prevention), which means that there has been significant damage to structural and non-structural components. The structure's strength and stiffness decreased a lot, almost collapsing. Whereas for the Y direction, the performance obtained is C to D, which means that the structure is still able to withstand the maximum limit of shear forces that occur but has almost collapsed.

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