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Strength of Existing Building against 2017 Indonesian Earthquake Sources and Earthquake Hazards Map

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Abstract:
In connection with the issuance of the 2017 Indonesian Earthquake and Hazard Sources Map, trying to recalculate the strength of the Existing Building due to changes in the 2017 Indonesian Earthquake Sources and Hazard Map is needed. Considering the physical work done only partially, it is necessary to review the design. From the results of the analysis it is necessary to improve the structure of the building including; 60/60 reinforcement column, reinforcement needs to be added, reinforcing beams lengthening 30/50, reinforcement need to be added, shear wall dimensions and reinforcement need to be added, some foundations on the shear wall need to be increased, while 35/70 dimensional beams and reinforcement still meet the requirements.

Keywords: *Map of 2017 Indonesian earthquake source and hazard, reinforcement, shear wall*

1. Introduction

1.1. Background

With the change in the 2010 Earthquake Map into the 2017 Indonesian Earthquake Source and Earthquake Hazard Map, there will be changes in earthquake parameters that affect the strength of the building that has been designed. Considering the above it is necessary to re-evaluate the buildings that have been designed with the 2010 Earthquake Map.

1.2. *Aim*

Recalculate the strength of existing buildings in the style of the 2017 Earthquake source and Hazard Map.

1.3. Benefits

To find out the strength of the existing building againts the 2017 Indonesian Earthquake Source and Hazard Map,

1.4. Restricting the Problem

Location of building is in Surabaya with soft soil conditions. Number of floors are 6 and the building functions is for hospitals. Building area are 14 x 80 m^2. The dimensions of the main column are 60x60 cm^2, transverse beam 35/70 cm2, beam length 30/50 cm^2, thickness of shear wall 35 cm and 25 cm, foundation borepile spun Φ 50 cm.The 1st floor height is 6 m, while the floor above is typically 4 m. With the number of reinforcement and dimensions as follows :

- Reinforcement installed in 60x60 cm^2 columns on the 1st to 6th floors is; 16 D 22, Ace = 6064 mm^2, stirrup 2 Φ 10 - 100.
- Reinforcement installed in 35x70 cm^2 transverse beam, tensile reinforcement 6 D 22, Ace = 2280 mm^2, compressive reinforcement 3 D 22, Ace = 1140 mm2, stirrup Φ 10 - 100 and 10 - 120.
- Reinforced beams are extended 30x50 cm^2, tensile reinforcement 4 D 19, Ace = 1132 mm^2, compressive reinforcement 2 D 19, As = 566 mm^2, stirrups Φ 10 - 100 and 10 – 120.
- Reinforcement is installed on the shear wall 35 cm, vertical reinforcement 2 D 16, distance 150 mm, horizontal reinforcement 2 Φ12, distance 150 mm.
- Reinforcement is installed on a shear wall of 25 cm, vertical reinforcement is 2 D 16, distance is 200 mm, horizontal reinforcement is 2 Φ12, distance is 150 mm.
- Borepile foundation Φ 50 cm, depth of MTA 34 m

2. Literature Review

2.1. Earthquake Analysis Stages

- Determining Building Risk Categories

- Determine the priority factor
- Determining earthquake response spectral parameters for short periods (S_s)
- Determine earthquake spectra response parameters for a 1 second period (S_1)
- Determining Land Site Classification (SA – SF)
- Determining Land Site Coefficient Factors (F_a, F_V)
- Calculates the spectral acceleration parameters for short period design (S_{DS})
- Calculates the spectral acceleration parameters for a 1 second period design (S_{D1})
- Select system and structure parameters (R_1 C_d, Ω_o)
- System structure evaluation related to configuration irregularities
- Determine diaphragm flexibility (flexible, semi-rigid, rigid)
- Determine the redundancy factor (ρ)
- Determine lateral style analysis procedures
- Calculate lateral loads

2.2. Equivalent Static Load Analysis

Basic Seismic Load→ $V = C_s\ W$

Equivalent static earthquake force distribution :

$F_X = C_{VX} V$

$C_{VX} = \frac{Wx\ hx^k}{\sum_i^n Wi\ hi^k}$

F = Earthquake Load

C_V = Distribution coefficient

h_i = High floor on level i

W_i = Effective weight on the floor i

K is for calculate static equivalents

2.3. Spectra Response Analysis

Determine Vibration Time(T)

$T_S = S_{D1}/S_{DS}$

$T_o = 0{,}2\ (S_{D1} / S_{DS})$

Determining Response Spectra of Design Acceleration (S_a)

For $T < T_o$ → $Sa = S_{DS} x\ [\ 0{,}4 + 0{,}6 \frac{T}{To}\ ]$

For $T < T_o < T_S$ → $Sa = S_{DS}$

For $T > T_S$ → $Sa = \frac{SD1}{T}$

2.4. Load Combination

Ultimit Load Combination

- 1,4DL
- 1,2DL + 1,6LL + 0,5(A or R)
- 1,2DL + 1,0LL±1,6W + 0,5(A or R)
- 1,2DL + 1,0LL± 1,0E
- 0,9DL± 1,6W
- 0,9DL± 1,0E

Allowed Load Combination

- 1,0DL
- 1,0DL + 1,0LL
- 1,0DL + 1,0(A or R)
- 1,0DL + 0,75LL + 0,75(A or R)
- 1,0DL± (0,6W or 0,7 E)
- 1,0DL± 0,75(0,6W or 0,75E) + 0,75LL + 0,75(A or R)
- 0,6DL± 0,6W
- 0,6DL± 0,7E

2.5. Control of Strength and Stability

- Story Drift and Structural Deformation
- Dimensions and Reinforcement of Columns, Beams
- Shear Wall Dimensions and Reinforcement
- Foundation

3. Result and Discussion

3.1. Analysis of Earthquake Force Factors
Risk category: IV (Hospital)
Spektra respons ;
Locationof Surabaya: S_S= 0,90 (Figure D11, Earthquake Map 2017)
: S_1= 0,30 (Figure D12, Earthquake Map 2017)
: S_S= 0,90→ F_a= 0,93 (Table 4, Interpolation, soft soil)
: S_1= 0,30 → F_V= 2,80 (Table 5, Interpolation, Soft soil)
: $S_{DS} = \frac{2}{3} F_a S_S = \frac{2}{3}$ x 0,93 x 0,90 = 0,54
: $S_{D1} = \frac{2}{3} F_V S_1 = \frac{2}{3}$x 2,80 x 0,30= 0,56
: S_{DS} = 0,54 g → table 6
; S_{D1} = 0,56 g→ table 7
From table 6 and 7 enter→Seismic Design CategoryD

Determine the natural vibration time T The fundamental natural vibration time (T) obtained from the results of the analysis of the structural program model is limited not to be greater than the C_U T_a (SNI 1726-2012) article 7.8.2 and table 14, for Surabaya S_{D1} = 0,56 → C_U = 1,4
$T_a = C_t\ h^x_n$ → table 15
Direcion - X, T_a = 0,0488x $26^{0,75}$ = 0,562 sec,
So that T_X max allowed = C_U T_a = 1,4 x 0,562 = 0,787 sec (direction X)
Direction - Y, T_a = 0,0466x $26^{0,90}$ = 0,875 sec,
So that T_X max allowed = C_U T_a = 1,4 x 0,875 = 1,225 sec (direction Y)
The natural vibration time is the structure of the results of capital analysis with the SAP program for cross section conditions, according to the provisions ofSNI 03-2847-2002 article 12.11.1
SAP OutputResult Crack conditionT_{1X} = 0,874 sec, T_{1Y} = 1,337 sec
SAP Output Results Uncrack conditionT_{1X} = 0,534 sec, T_{1Y} = 0,844 sec

The conditions for calculating the fundamental natural vibration time can be summarized as follows:

	SNI-03-1726-2012	Analysis from SAP	
		Crack Condition	Uncrack Condition
T_{1X}	0,787 sec	0,874 sec	0,534sec
T_{1Y}	1,225 sec	1,337 sec	0,844 sec

Table 1

The maximum vibration time limit is the result of calculations based on the empirical formula ofSNI-03-1726-2012.
T_{1X} = 0,787sec, T_{1Y} = 1,225 sec
Based on SNI-03-1726-2012 article 7.6 and table 13 then,
$T_S = S_{D1}/S_{DS}$ = 0,56 / 0,54 = 1,037
T_S = 1,037 sec 3,5 T_S = 3.63
T_{1X} = 0,787 sec < 3,5 T_S
T_{1y} = 1,225 sec < 3,5 T_S
Building with KDS D, regular, and T < 3,5 T_S→can use equivalent static analysis procedures

3.2. Equivalent Static Analysis
Basic Seismic Load → $V = C_S\ W$
S_{D1} = 0,56
S_{Ds} = 0,54 T_{1X} = 0,787 sec, T_{1Y} = 1,225 sec
R_X = 7 (table 9)
R_Y = 8 (table 9)
I_E = 1,5

	$C_{s\ min}$	C_S	$C_{S\ max}$	C_S
	0,044 S_{DS} I_E	S_{DS} / (R/I_E)	S_{DS} / [T (R/I_E)]	Used
Direction-X	0,024	0,116	0,147	**0,147**
Direction-Y	0,024	0,101	0,083	**0,083**

Table 2

Equivalent Static Earthquake Force Distribution
$F_X = C_{VX}\ V$
$C_{VX} = \frac{Wx\ hx^k}{\sum_i^n Wi\ hi^k}$
F = Earthquake Load

C_V = Distribution coefficient
h_i = High floor on level i
W_i = Effective weight on the floor i
K is for calculating equivalent static

T (sec)	K
$T \leq 0,5$	1
$0,5 < T < 2,5$	Interpolation
$T \geq 2,5$	2

Table 3

T_{1X} = 0,787 → k = 1,07
T_{1Y} = 1,225 → k = 1,36
Earthquake Scale Factor= (g x I) / R :
R_x = 7 I = 1,5
R_x = 8 I = 1,5
g (gravity) = 9,81 m/sec^2
Direction X = 100% (9,81 x 1,5) / 7 = 2,102 m/sec^2
Direction Y = 30% (9,81 x 1,5) / 7 = 0,630 m/sec^2
Direction Y = 100% (9,81 x 1,5) / 8 = 1,839 m/sec^2
Direction X = 30% (9,81 x 1,5) / 8 = 0,552 m/sec^2

3.3. Analysis of Design Spectra Response
Determining Period T
$T_S = S_{D1}/S_{DS}$ = 0,56 / 0,54 = 1,037
T_o = 0,2 (S_{D1} / S_{DS}) = 0,2 (0,56 / 0,54) = 0,207
Determine Sa
For $T < T_o$ → $Sa = S_{DS} \times [\,0,4 + 0,6 \frac{T}{To}\,]$
For $T < T_o < T_S$ → $Sa = S_{DS}$
For $T > T_S$ → $Sa = \frac{SD1}{T}$
T = 0 → Sa = 0,207
T = T_o=0,207 → Sa = 0,540
T = T_S=1,037 → Sa = 0,540
T = 1,1 → Sa = 0,509
T = 1,2 → Sa = 0,467
T = 1,3 → Sa = 0,431
T = 1,4 → Sa = 0,400
T = 1,5 → Sa = 0,373
T = 1,6 → Sa = 0,350
T = 1,7 → Sa = 0,329
T = 1,8 → Sa = 0,311
T = 1,9 → Sa = 0,295
T = 2 → Sa = 0,280
T = 2,1 → Sa = 0,267
T = 2,2 → Sa = 0,255
T = 2,3 → Sa = 0,243
T = 2,4 → Sa = 0,233
T = 2,5 → Sa = 0,224
T = 2,6 → Sa = 0,215
T = 2,7 → Sa = 0,207
T = 2,8 → Sa = 0,200
T = 2,9 → Sa = 0,193
T = 3 → Sa = 0,187
T = 3,1 → Sa = 0,181
T = 3,2 → Sa = 0,175
T = 3,3 → Sa = 0,170
T = 3,4 → Sa = 0,165
T = 3,5 → Sa = 0,160
T = 3,6 → Sa = 0,156
T = 3,7 → Sa = 0,151
T = 3,8 → Sa = 0,147
T = 3,9 → Sa = 0,144
T = 4 → Sa = 0,140

T = 4.1 → Sa = 0,137
Earthquake Scale Factor = (g x I) / R :
R_X = 7 I = 1,5
R_Y = 8 I = 1,5
g (gravity) = 9,81 m/sec^2
Direction X = 100% (9,81 x 1,5) / 7 = 2,102 m/sec^2
Direction Y = 30% (9,81 x 1,5) / 7 = 0,630 m/sec^2
Direction Y = 100% (9,81 x 1,5) / 8 = 1,839 m/sec^2
Direction X = 30% (9,81 x 1,5) / 8 = 0,552 m/sec^2

3.4. Building Eccentricity

Floor	Mass Centre		Rotation Centre		Eccentricity (e)		ed = e + 0,05 Ax (Lx/Ly)		ed = e - 0,05 b (Lx / Ly)	
	X	Y	X	Y	X	Y	X	Y	X	Y
Tie Beam	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
2nd Floor	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
3rd Floor	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
4th F	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
Lantai 5	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
Lantai 6	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
Atap	12,5	43	10,68	44,45	1,82	1,45	2,91	5,22	0,73	-2,32
Lx =	25									
Ly =	86									
Ax =[δmax/1,2δavg]² =	0,88		< 3,0							
δmax =	56,88	mm								
δmin =	44,42	mm								

Table 4

3.5. Correction of Earthquake Scale Factors

EQX	LinStatic		2633	789					
EQY	LinStatic		691	2303					
RSPX	LinRespSpec	Max	1036	260					
RSPY	LinRespSpec	Max	275	746					
		85%EQX =	2238		V Dynamic < 85% V Static				
		85%EQY =		1958					
Multiplier Earthquake Scale Factor Di			2,161		Early Spectra Response= (g x I) / Rx =				2,102
Multiplier Earthquake Scale Factor Di			2,624		Early Spectra Response = (g x I) / Ry =				1,839
Early	RPSX U1	2,102	then	4,542					
	RPSX U2	0,631	then	1,363					
	RPSY U1	0,552	then	1,448					

Table 5

3.6. The Calculation Results

Earhquake Slide Force EQX :					
Floor	Effective Weight	High	Wi hi^k	Fx	Story Shear
	(ton)	(m)		(ton)	(ton)
Roof	1357	26	73431	567	567
6	1853	22	85708	662	1229
5	1853	18	69146	534	1763
4	1853	14	52843	408	2172
3	1853	10	36866	285	2456
2	1853	6	21343	165	2621

Table 6

Earthquake Slide Force EQY					
Floor	Effective Weight (ton)	High (m)	Wi hi^k	Fy (ton)	Story Shear (ton)
Roof	1357	26	1529933	518	518
6	1853	22	1862110	631	1149
5	1853	18	1417363	480	1629
4	1853	14	1007035	341	1970
3	1853	10	637251	216	2186
2	1853	6	318124	108	2293

Table 7

Earthquake Slide Force RSPX :					
Floor	Effective Weight (ton)	High (m)	Wi hi^k	Fx (ton)	Story Shear (ton)
Roof	1357	26	73431	439	439
6	1853	22	85708	512	951
5	1853	18	69146	413	1364
4	1853	14	52843	316	1679
3	1853	10	36866	220	1899
2	1853	6	21343	127	2027

Table 8

Earthquake Slide Force RSPY :					
Floor	Effectivte Weight (ton)	High (m)	Wi hi^k	Fy (ton)	Story Shear (ton)
Roof	1357	26	1529933	515	515
6	1853	22	1862110	627	1143
5	1853	18	1417363	478	1620
4	1853	14	1007035	339	1960
3	1853	10	637251	215	2174
2	1853	6	318124	107	2282

Table 9

3.7. Graphic of Slide Force

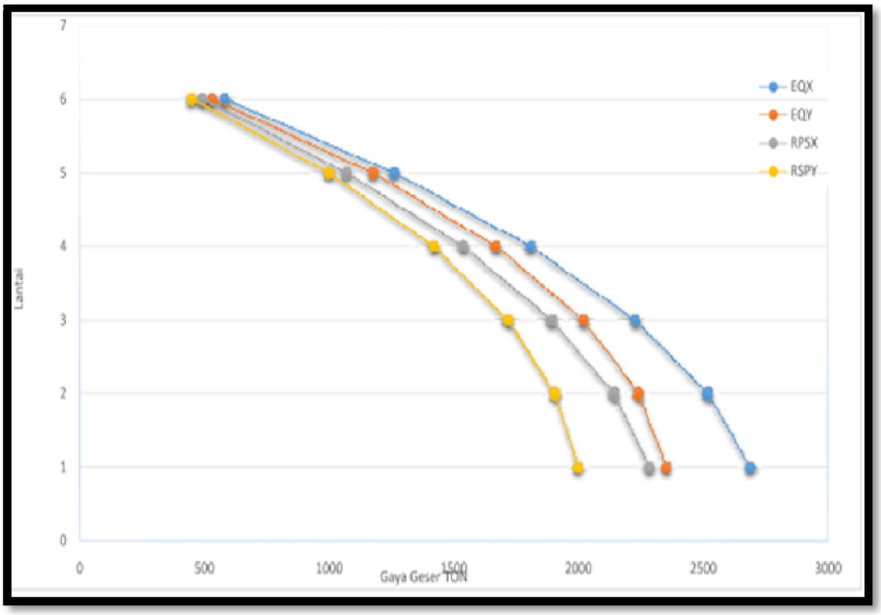

Figure 1

Deflection at Level X :

$\delta_X = \frac{Cd\ \delta xe}{Ie}$

C_d = deflection enlargement factor, direction x = 5,5 direction y = 5,5 (in Table 9)

δ_{Xe} = deflection determined by elastic analysis

I_e = priority factor (1,5)

3.7.1. Column Drift

Floor	h (m)	Lateral Load Direction X			Lateral Load Direction X			Δa
		δ_{Xe} (mm)	δx (mm)	Δx (mm)	δy_e (mm)	δy (mm)	Δy (mm)	(mm)
Roof	26	43,33	158,88	**29,92**	106,66	391,09	**67,61**	80
6	22	35,17	128,96	**31,79**	88,22	323,47	**76,38**	80
5	18	26,50	97,17	**30,51**	67,39	247,10	**76,85**	80
4	14	18,18	66,66	**27,43**	46,43	170,24	**71,43**	80
3	10	10,70	39,23	**22,00**	26,95	98,82	**56,32**	80
2	6	4,70	17,23	**17,23**	11,59	42,50	**42,50**	120

Table 10

3.8 .Determining the Effect of P - Δ

StabilityCoeficient (θ) can be calculated based on formula as follows :

$\theta = \frac{Px\ \Delta\ Ie}{Vx\ hsx\ Cd}$

Calculationθ as the effect of P – Δ

3.8.1. Direction X

Floor	h (m)	P (ton)	Δx (mm)	Vx (ton)	Θ	θ max
Roof	26	1357,00	29,92	437,00	0,0006	0,25
6	22	1853,00	31,79	948,00	0,0005	0,25
5	18	1853,00	30,51	1359,00	0,0004	0,25
4	14	1853,00	27,43	1674,00	0,0004	0,25
3	10	1853,00	22,00	1894,00	0,0004	0,25

Table 11

3.8.2. Direction Y

Floor	h (m)	P (ton)	Δy (mm)	Vy (ton)	Θ	θ max
Roof	26	1357,00	67,61	515,00	0,0012	0,25
6	22	1853,00	76,38	1143,00	0,0010	0,25
5	18	1853,00	76,85	1620,00	0,0009	0,25
4	14	1853,00	71,43	1960,00	0,0009	0,25
3	10	1853,00	56,32	2174,00	0,0009	0,25

Table 12

$\Theta < \Theta_{minimum}$ = 0,10, Then the Effect of P - Δ s Ignored

3.9. Soft Strory Examination

Lantai	H_{SX} (m)	Arah – X			Arah – Y		
		Δ (mm)	Drift rasio	1,3 drif rasio	Δ (mm)	Drift rasio	1,3 drif rasio
Atap	4	29,92	0,007	0,010	67,61	0,017	0,022
6	4	31,79	0,008	0,010	76,38	0,019	0,025
5	4	30,51	0,008	0,010	76,85	0,019	0,025
4	4	27,43	0,007	0,009	71,43	0,018	0,023
3	4	22,00	0,006	0,007	56,32	0,014	0,018
2	6	17,23	0,003	0,004	42,50	0,007	0,009

Table 13

3.10. Dimensions and Reinforcement Required

- Column 60x60 $cm^2$1st to 6th floorrequires maximum reinforcement = 8530 $mm^2$and minimum = 3600 mm^2, maximum stirrup = 4,002 mm^2/mm, mimimum = 0,862 mm^2/mm.
- 35x70 cm^2 transverse beam, tensile reinforcement is needed = 1798 mm^2, compressive reinforcement = 869 mm^2, stirrup support = 1,518 mm^2/mm and pitch crossing = 1,291 mm^2/mm.
- The beams lengthwise 30x50 cm^2, tensile reinforcement is needed = 1238 mm^2, compressive reinforcement = 858 mm^2, stirrup support= 1,513 mm^2/mm andpitch crossing = 1,336 mm^2/mm.
- Side shear wall thickness required is 40 cm, vertical reinforcement is 2 D 16, distance is 150 mm, Horizontal reinforcement 2 D 13, distanceis 150 mm.
- Shear wall lift thickness required is 30 cm, vertical reinforcement is 2 D 16, distance is 150 mm, horizontal reinforcement is 2 D 13, distance is 150 mm
- The number of foundations on the Shear Wall section needs to be added.

4. Conclusion

From the evaluation results can be concluded:

- The 60/60 column dimension still meets the requirements, for reinforcement and stirrups some need to be added.
- 35/70 transverse beams both dimensions and longitudinal bars and stirrups still meet the requirements.
- The bars extend 30/50, longitudinal bars and stirrups need to be added.
- Shear Wall, both thickness and reinforcement need to be added.
- Shear Wall foundation needs to be added.

5. References

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