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SEISMIC ANALYSIS OF TEN-STORY OLD BUILDINGS

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ملخص البحث باللغة العربية:

هناك الكثير من المبانى فى مصر التى صممت تحت تأثير الأحمال الرأسية فقط (أحمال الجاذبية) دون الأخذ فى الإعتبار أحمال الزلازل. لذلك يهدف هذا العمل إلى تقييم سلوك المنشآت الخرسانية المسلحة (القديمة والقائمة) متعددة الطوابق والتى تم تصميمها دون أخذ أحمال الزلازل فى الإعتبار. تم التطبيق على مبنى سكنى قائم بمصر يتكون من عشرة طوابق بإرتفاع 31 متر وبنظام إنشائى كمرات وأعمدة (solid slab) حيث تم دراسته بالكود المصرى للأحمال ECL 2011 ، وكود البناء الدولي IBC 2015 وتمت مقارنه النتائج لكل منهم. يفترض أن هذا المبنى يقع فى المنطقة الثالثة زلزالياً طبقاً للكود المصرى. تم تطبيق طرق التحليل الديناميكي (the Modal Response Spectrum (RS) analyses methods) لكى نوضح تأثير أحمال الزلازل معتمداً على حساب الزمن الدورى بالطريقة الأكثر دقة التى تعتمد على التحليل الديناميكى للمنشأ (method B). وتم إستخدام برامج العناصر المحددة (Finite Element Programs) وإستخدام برنامج (Etabs Non linear Version9.7.1) فى التحليل الإنشائى الثلاثى الأبعاد.

ABSTRACT

Old buildings were designed for gravity loads only without considering seismic forces. Also, they are the existing RC buildings designed according to earlier codes before 1992 earthquake in Egypt. The aim of this work is to check the safety of these old buildings. This research presents numerical simulation for ten stories residential RC old building under seismic forces. The earthquake forces are calculated using the optimum seismic case which produces minimum base shear. This optimum seismic case utilizes IBC, response spectrum analysis method and method B time period. Another case is conducted by applying ECL instead of IBC to make the comparison requirements. The RS analysis of the studied modal structures is carried out using the three-dimensional computer program "ETABS (2010)".

Keywords: Old Building, Seismic, Reinforced Concrete, Gravity Loads, ECL, IBC.

1. INTRODUCTION

Despite the fact that Egypt does not lie in a highly active seismic zone, it suffers from time to time from earthquakes. Due to the rabid and uncontrollable increase of population, coupled with low quality of construction work and the lack of lows that enforce seismic design regulation; the building environment in Egypt is highly vulnerable to damage from earthquakes. In 1960, Egypt was considered free seismic-hazard country and therefore the structural engineers developed building design codes without considering the seismic forces. Subsequently, in eighties time, the structural engineers changed this attitude, especially after issuing "the Egyptian Society for Earthquake Engineering; ESEE" (Sobaih, M., 1996). It was the first start for thinking in the Egyptian code for calculating loads and forces in structural works and masonry

(ECL). Several versions from ECL code are released from time to time. The last one is ECL 2011 (Egyptian Code Committee, 2011). The International Building Code, first released in 2000 (International Code Council, ICC 2000).The International Building Code was coming to replace UBC within USA and in various parts of the world. This code is remaining in a revision cycles with a new release every three years (Nahhas, T., 2011). There a many researches were conducted to study old building: ([Shaheen, A. and EL-Attar, A., (1996)]- [EL-Masry, M. and EL-Kordi, E., 2010] – [Maher, M., 2010] – [Elassaly, M., (2011)]).

During the last decades, an extensive use of a new reinforced concrete building environment has prevailed in Egypt. Twelve-story buildings are being built in many districts of the country; that is the maximum height allowed by local authorities in most districts Elassaly, M., (2011). This research presents numerical simulation for ten stories residential RC old building under seismic forces. The old reinforced concrete buildings were the buildings designed under gravity loads only without considering seismic forces. Also, it was the existing reinforced concrete buildings designed using earlier codes, before 1992 earthquake in Egypt.

2. Problem Statement (Methodology)

Two runs were conducted; the first run utilized IBC, response spectrum analysis method and (method B) time period. Method B employs the minimum time of (modal dynamic analysis) and ($C_t h^{0.75} Cu$) where C_t calculated from code formulas and C_u is the upper limit coefficient. The second run employed ECL instead of IBC. Ten -story old building is considered in this study. The building design did not include seismic forces. The building is simulated under seismic forces using optimum case.

3. Building Properties and Loads

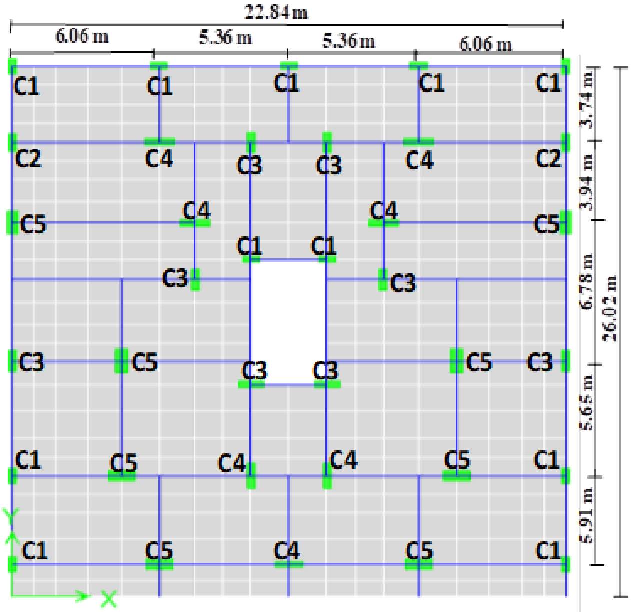
The building is ten-story occupancy category residential RC structure located in Giza city inside Egypt (third region of seismic intensity). The plan dimensions are 22.85 X 26 m. The typical story height is three meters. The ground floor height is four meters. Table 1 presents the input data for this building according to IBC and ECL. The characteristic strength of concrete is 30 MPa for the vertical members and 25 MPa for slabs and beams members. In addition, the yield strength of steel is 360 MPa. Figure 1 illustrates the typical plan and the sections of columns and beams. Figure 2 clarifies the sample selected columns for presenting straining actions. Figure 3 shows the 3-D model. The columns sections are completely symmetric around Y-axis. For the vertical loads, The provisions of ECL are used to calculate the design loads. The RC specific weight (γ) is 2500 kg/m3 to calculate own weight. Table 2 provides the values of flooring, wall weight and live load.

Table 1: Input Data

Item	ECL	IBC
Soil type	C	D
Seismic zone and intensity	Third region, 0.15	S_s = 0.4 & S_1= 0.095
Seismic (site) coefficient	S =1.5, T_B= 0.1, T_C= 0.25, T_D =1.2	F_a = 1.48 F_v = 2.4
Other factors	η = 1 & λ = 1	----
Important factor	γ_1 = 1	I = 1
Occupancy category	III	II
Response modification factor	5	5
C_t	0.05	0.049
T^A (Approximate method)	0.657	0.644
Upper limit (C_U)	1.2	1.6
$T^B = C_U C_t H^{0.75}$ (sec)	0.788	1.024
T^D = Model analysis (sec)	2.39	2.34
Base shear scale factor	0.85	0.85
Actual scale factor (x)	1.2923	3.55
Actual scale factor (y)	1.2918	3.49

Table 2: Design Loads

Load	Load Intensity (Pa)
Flooring Weight	2000
Wall Weight	4000
Live Load	2000



Columns / Beams	Section
C1	30X70
C2	30X80
C3	30X100
C4	30X120
C5	45X110
Edge Beam	25X60
Internal Beam	12X60

Fig. 1: Typical Plan

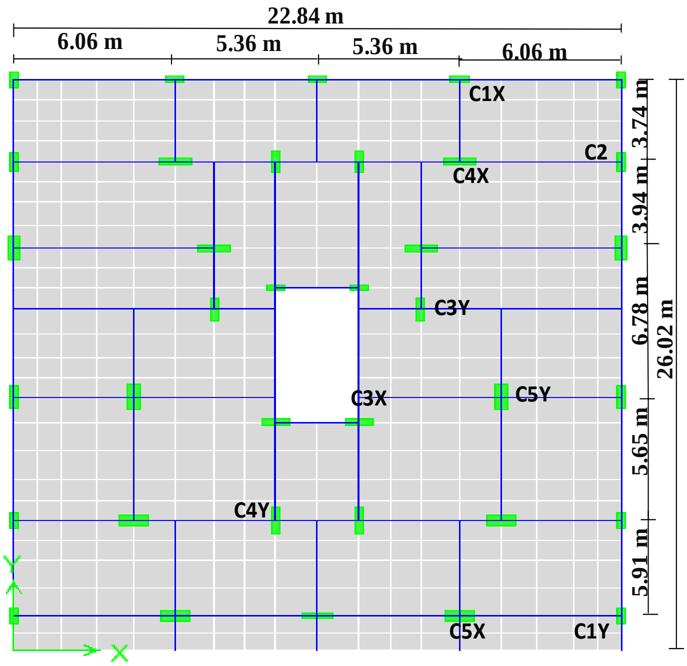


Fig. 2: Selected Sample Columns for Showing the Straining Actions

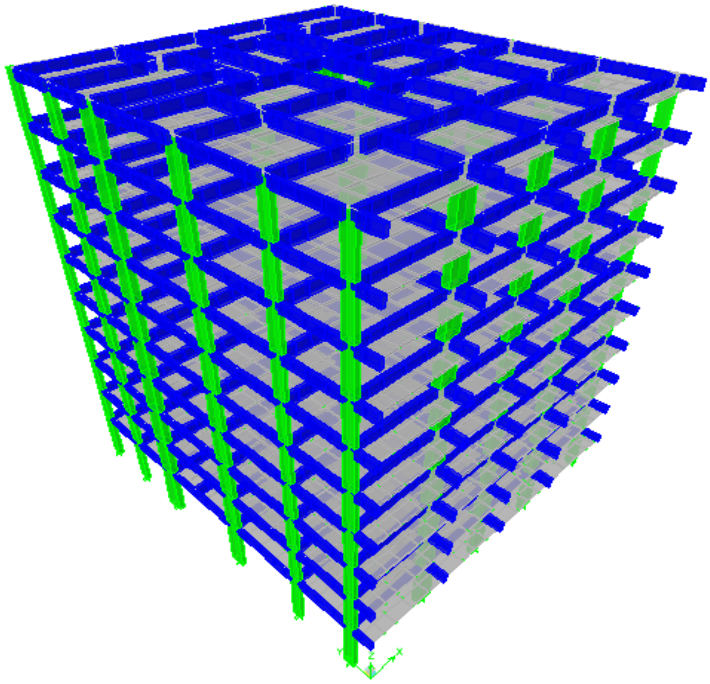


Fig. 3: 3-D Model

4. Structural System

The structural system consists of solid slab with thickness of 14 cm. Projected beams (25X60 cm cross section) are used along the building boundaries, whereas beams of (12X60 cm cross section) are used inside the building. The building has regular configurations in both plan and elevation. The RC columns used to transfer vertical and horizontal loads. The columns and beams sections are provided previously in Fig. 1. These sections are designed according to gravity loads only without considering seismic force. Table 3 presents the reinforcement of columns.

Table 3: Columns Reinforcement Ratios

Columns	**Section**	**Reinforcement**	**Actual Reinforcement Ratio, A_s%**
C1	30X70	12 Φ16	1.15%
C2	30X80	14 Φ 16	1.17%
C3	30X100	16 Φ 16	1.07%
C4	30X120	20 Φ 16	1.12%
C5	45X110	24 Φ 18	1.23%

5. Design Response Spectrum Curve

For the two considered codes, Fig. 4 shows the design response spectrum curve.

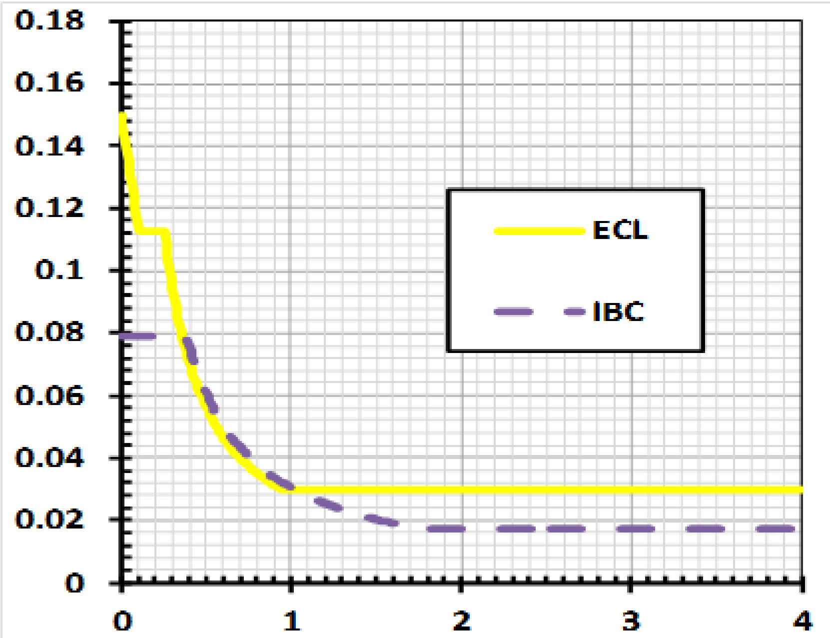


Fig. 4: Design Response Spectrum curve

6. Numerical Results

Table 4 gives the results of static and dynamic base shear force. In addition, it gives the static and dynamic story drift results for each of ECL and IBC.

Table 4: Base Shear Forces and Story Drift

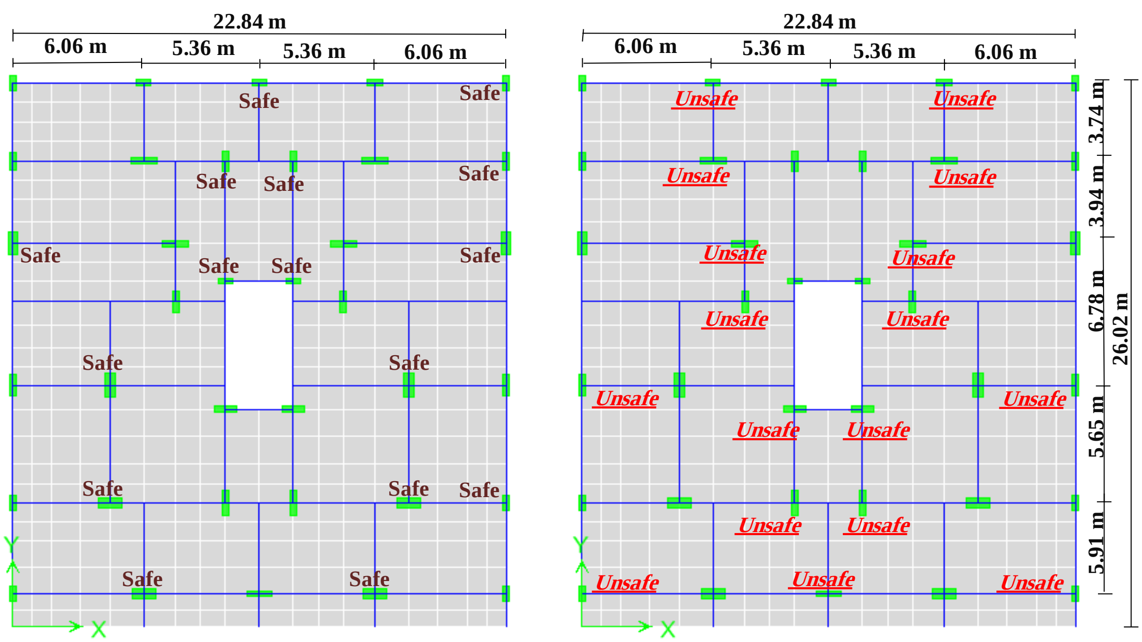
Item	ECL	IBC
Static base shear force (ton)	284.2	206
Dynamic base shear force (ton)	241.6	175
Story static drift	0.0081 (un safe)	0.016
Story dynamic drift	0.0068 (un safe)	0.01
Allowable story drift	0.005	0.02

6.1 Column Results

Table 5 demonstrates the straining actions as result for applying seismic force on this building. For each of ECL and IBC, Fig(s.) (5, 6) illustrate the columns safety (safe or unsafe) under seismic force respectively. For ECL, seventeen columns are unsafe under seismic loads while, four columns are unsafe under seismic loads if IBC is utilized. Figure 7 shows the required A_s% relative to the actual A_s% for ECL and IBC. Finally, Fig. 8 shows the required columns sections for safe seismic force.

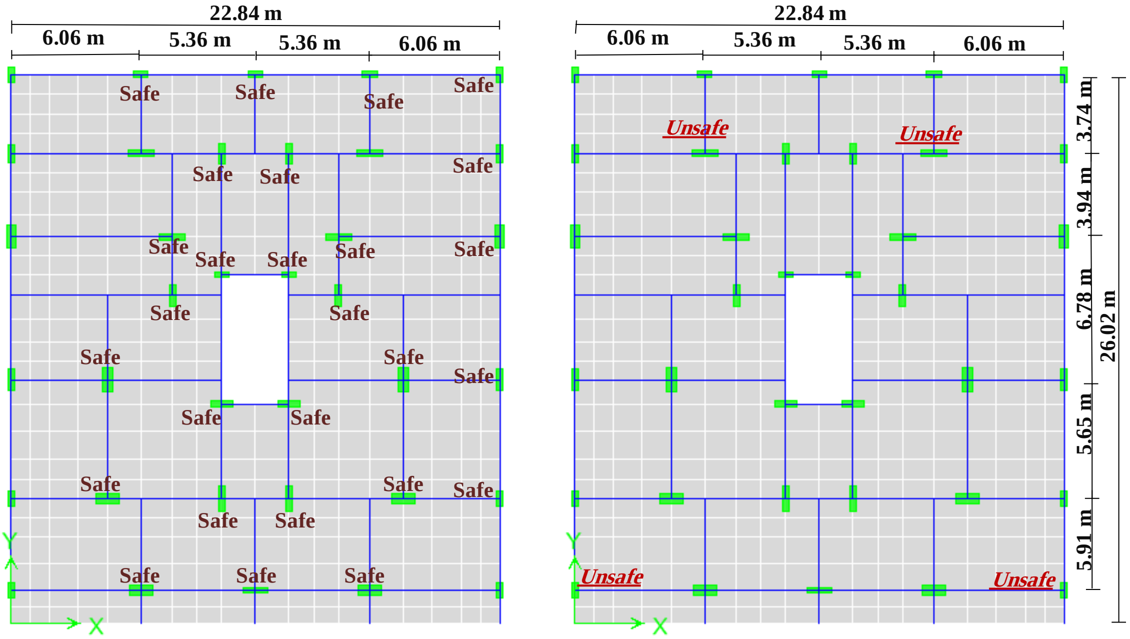
Table 5: Column Straining Actions

Column	ECL				IBC				Case
	N	Q	M_x	M_y	N	Q	M_x	M_y	
	(ton)		(t.m)		(ton)		(t.m)		
C1x	171	7	1	23	182	5	2	16	UDLSPECX
C1y	212	5	19	2	208	4	14	3	UDLSPECY
C2	166	9	31	3	181	7	22	4	UDLSPECY
C3x	253	**11**	1	48	258	**8**	1	32	UDLSPECX
C3y	272	**11**	47	4	280	**8**	32	4	UDLSPECY
C4x	292	**21**	1	90	313	**16**	1	63	UDLSPECX
C4y	268	**16**	75	2	290	**12**	51	2	UDLSPECY
C5x	351	22	2	103	388	17	1	72	UDLSPECX
C5y	408	19	93	1	447	15	64	1	UDLSPECY



a.Nineteen Safe Columns b. Seventeen Unsafe Columns

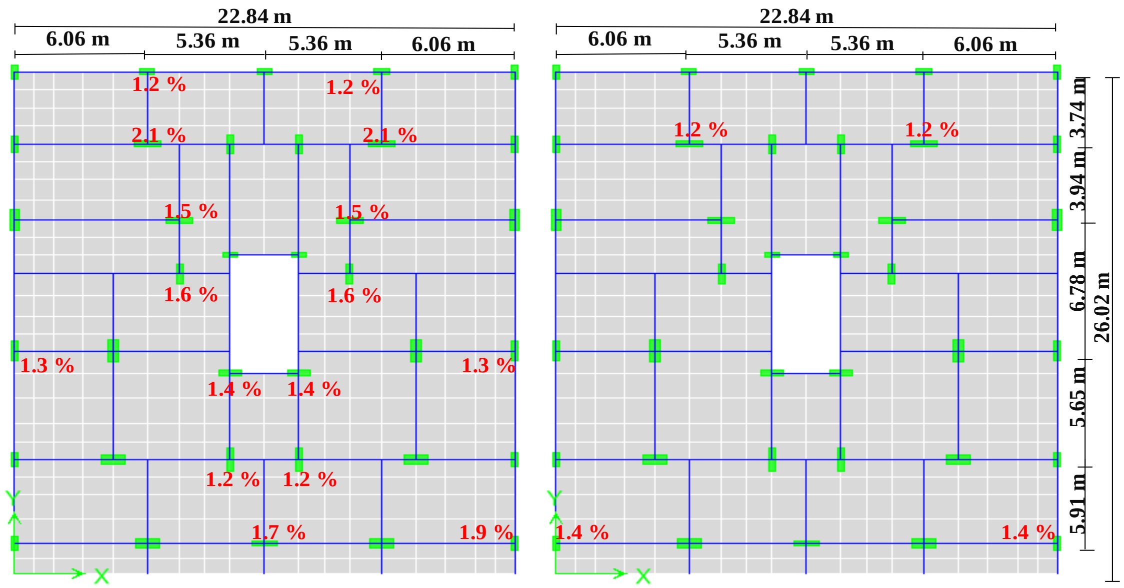
Fig. 5: ECL Columns Status under Seismic Forces



a.Thirty Two Safe Columns

b. Four Unsafe Columns

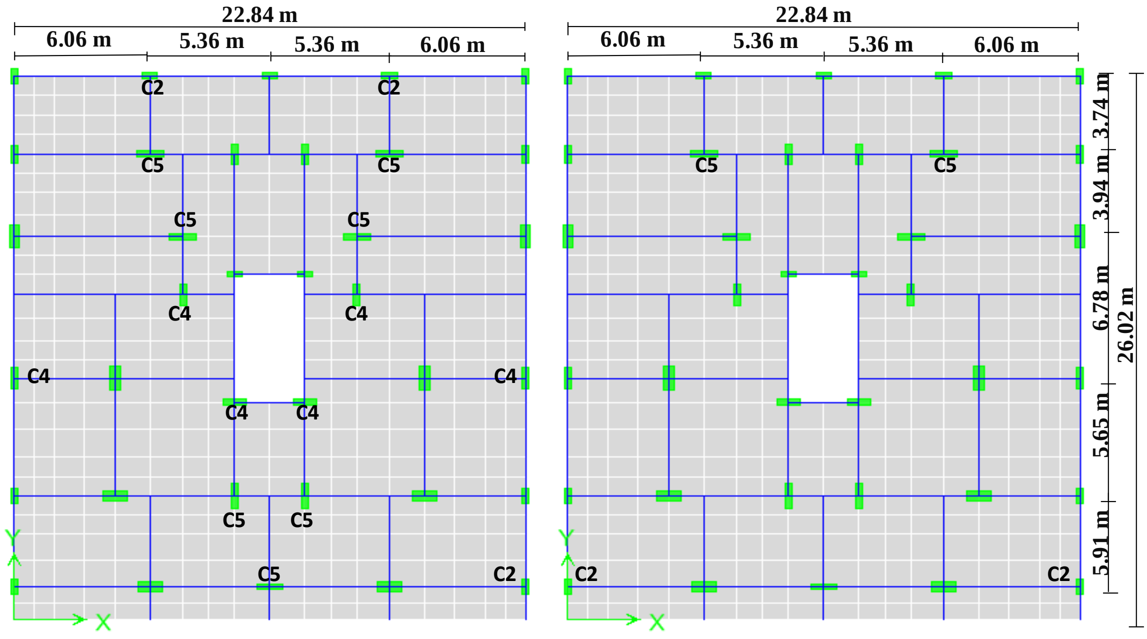
Fig. 6: IBC Columns Status under Seismic Forces



a.ECL

b. IBC

Fig. 7: % Required Increment in Reinforcement Ratio for Unsafe Columns



a. ECL b. IBC

Fig. 8: Required Safe Columns Sections under Seismic Force

6. Conclusions

This paper presents study for old building designed for gravity loads only without considering seismic forces. This study considered two codes (ECL and IBC), applied RS for seismic analysis, and employed method B for *T* estimation. The structural system consists of solid slab with 14 cm thickness supported by 36 vertical columns. The results showed the following:

- For **ECL**, 47% of columns are unsafe under seismic forces. The static and the dynamic story drift are unsafe with ratio about 1.49%. Increment percentage in reinforcement ratio for retrofitting columns reaches up to 2.1% from actual reinforcement.
- For **IBC**, 11% of columns are unsafe under seismic forces. The static and the dynamic story drift are safe. Increment percentage in reinforcement ratio for retrofitting columns reaches up to 1.4% from actual reinforcement.
- According to **ECL** and **IBC**, these old buildings must be retrofitted in the nearest time whereas this retrofitting is major for **ECL** and minor for **IBC**.

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