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SEISMIC VULNERABILITY ASSESSMENT OF AN EXISTING RC BUILDING IN BANGLADESH

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ABSTRACT

As in past decades, Bangladesh has experienced quite a few earthquakes in many regions, especially in the Sylhet region. So, it has become necessary to assess the seismic capacity of the existing buildings. In addition, the building design code of Bangladesh has been upgraded recently with modified seismic demands. Therefore, this is also important to check the adequacy of the existing RC buildings' capacities with the changed seismic demand. There is no established guideline in Bangladesh to assess the seismic capacity of the existing buildings. However, the Public Works Department of Bangladesh has adopted the Japanese seismic evaluation method and suggested it as CNCRP manual. Therefore, the Japanese seismic evaluation procedure has been utilized in this study to assess the seismic vulnerability of an existing RC building.

The main objective of the study is to investigate the vulnerability of an existing RC building in Bangladesh by comparing seismic capacity and seismic demand of the building of interest. The seismic capacity of the existing RC building, known as seismic index, has been evaluated by applying the detailed evaluation procedure of Japanese seismic evaluation manual. In the detailed evaluation procedure, the failure mechanism of the RC building is considered as story collapse at ground floor level where the columns would fail by flexure or shear based on the column design, and the beams are considered to be strong enough. The seismic index has been calculated based on both strength and ductility of ground floor columns for both of the principal horizontal directions. On the other hand, the seismic demand index has been determined as per BNBC 2020 using the method suggested by the CNCRP manual.

The values of seismic capacity indices for two principal horizontal directions were found to be 0.37 and 0.40. As the minimum value governs, the seismic capacity of the building is considered to be 0.37. On the other hand, the seismic demand index for this particular building was found to be 0.22. As the seismic capacity index has a greater value than the seismic demand index. The building can be considered as not vulnerable.

Keywords: *RC building, seismic assessment, seismic vulnerability.*

1. INTRODUCTION

Seismic capacity assessment is a very important aspect for structural engineers because of the observed catastrophic failure of existing RC buildings in recent earthquakes e.g. Nepal EQ 2015. Bangladesh is located in a high-risk zone for an earthquake. To minimize the loss of properties, and major casualties, it is necessary to evaluate the seismic vulnerability of an existing building. Seismic evaluation is a systematic process of evaluating deficiency using performance-based principles of an existing building to resist earthquakes. According to investigations of previous and contemporary earthquake damage, it has been shown that Building structures in Bangladesh are prone to severe damage during moderate and significant ground motion (Islam et al., 2016). To understand the effect of an earthquake on an existing building, a suitable method of assessment should be applied to estimate the vulnerability of the buildings under seismicity.

There are several established guidelines to assess a buildings seismic vulnerability such as the Rapid Visual Screening (RVS) method (FEMA P-154), Handbook for the seismic evaluation of building (ASCE 31-03) and the Japanese Seismic Evaluation Standard (JBDPA 2001). The Rapid Visual Screening (RVS) method (FEMA P-154) evaluates an existing building based on a visual investigation of the building and gives a performance score. The visual inspection should contain the building information such as the number of stories and shapes, identifying the occupancy, the type of soil and geologic hazards, the irregularities of the building, gravity loading system, earthquake force resistance system and building materials. The basic performance score is assigned depending on the structural load resisting system (e.g. RC frame system, braced frame system, moment-resisting frame system, flexible diaphragm system, rigid diaphragm system) and the basic performance score needs to be modified using penalty factors due to the height of the building, structural irregularities (i.e. story and plan irregularities), building age, and soil type. Seismic evaluation by ASCE 31-03 refers to a three-tier screening procedure with consideration of ground shaking and, to a lesser extent, other seismic hazards. In this method, the evaluation of the buildings is done according to their Life Safety or Immediate Occupancy Performance Levels. The goal of the first-tier evaluation is to identify the building that meets the basic constructive parameters and to identify potential deficiencies using the corresponding checklists (e.g. structural checklist, foundation checklist, the nonstructural checklist). If certain parts of the building do not fulfil the first-tier checklist standards, the second-tier evaluation can be done on individual elements or the entire building using one of the seismic evaluating procedures (e.g. linear static procedure, linear dynamic procedure etc.). If there is any doubt that the first and second tiers are too conservative for a realistic review and that a more comprehensive study is required, the third tier of evaluation is used by comprehensive investigation (nonlinear analysis) and it can be done for the entire structure or for individual parts that did not fulfil the second-tier standards. Seismic evaluation of buildings by the Japanese Standard (JBDPA 2001) consists of three different levels of evaluation. The first level screening procedure is more conservative where cross-sectional area and concrete strength of vertical members are required to evaluate the seismic index. The second level screening procedure is more detailed than the first level and requires structural drawing along with material properties. In the second level screening procedure, it is assumed that the strength of the beam is greater than that of a column so that failure would be story collapse. The ultimate strength and plastic deformation capacity of vertical members are evaluated based on the cross-sectional area, reinforcement detail, and material strength which yields to the evaluation of the seismic index. In the third level screening procedure, building characteristics are examined in greater detail than in the second level screening procedure with the consideration of both the strength of columns and beams along with walls by the numerical analysis software. The second level evaluation of the Japanese Standard (JBDPA 2001) has been adopted by the Public Works Department of Bangladesh in an improvised manner and is known as the CNCRP Manual (CNCRP 2015). From the above discussion, it is clear that the second level evaluation by JBDPA 2001 considers both lateral strength and ductility (i.e. deformability) to evaluate the seismic index and therefore, this method is utilized in this study.

The purpose of this study is to assess the seismic vulnerability of an existing RC building in Bangladesh by comparing the seismic capacity index, I_s and seismic demand index, I_{so} considering the second level evaluation procedure prescribed by JBDPA (2001).

2. SEISMIC ASSESSMENT OF EXISTING RC BUILDING

Seismic assessment requires to evaluate both lateral capacity of a building structure and expected seismic demand for that building. These two evaluation aspects are described in the following sub-sections.

2.1 Seismic Capacity Assessment

The second level evaluation by JBDPA (2001) is a detailed procedure to assess the lateral capacity of a building that needs structural drawing of the existing building. This lateral capacity is evaluated considering story collapse mechanism as shown in Figure-1, where beams are considered strong enough and columns are considered to be susceptible to collapse. The columns may fail by shear or flexure depending on the design of the RC columns. In second level evaluation, RC columns are firstly divided into two categories a) shear column and b) flexural column. Based on the types of columns, strength index (*C*-index) and ductility index (*F*-index) of each column are needed to be determined. To evaluate the seismic capacity of a building which is referred as seismic capacity index (I_s) and expressed by equation (1). The basic seismic index (E_0) is a function of strength index, *C*, and ductility index, *F*.

$$I_s = E_0.S_D.T \quad (1)$$

where, I_S = Seismic index of structure, E_0 = Basic seismic index of structure, S_D = Irregularity Index, and *T* = Time index.

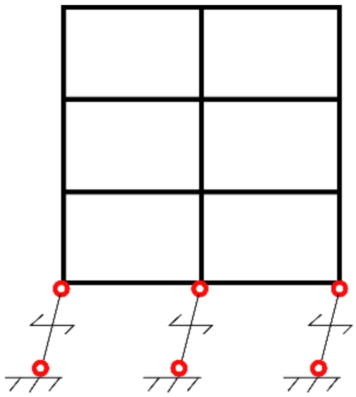

Figure 1: Story collapse mechanism. (JBDPA 2016)

2.2 Strength and Ductility Evaluation

Strength and ductility evaluation consists of two different types of indices 1. Strength Index, *C* and 2. Ductility Index, *F*. These indices are later used to determine the basic seismic index E_0. The basic seismic index is later used to determine the seismic capacity index, I_S.

2.2.1 Strength Index, *C*

The individual strength index, *C* of a member is computed considering the ultimate lateral load carrying capacity of the RC columns using the equation (2) – (9). Similarly strength index for the shear walls can also be calculated using the guidelines of JBDPA (2001)

$$C = \frac{Q_u}{\sum W} \quad (2)$$

$$Qu = \min(Qmu \ \ and \ Qsu) \quad (3)$$

$$Q_{mu} = \frac{M_u}{h} \quad (4)$$

$$Q_{su} = \left\{\frac{0.053p_t^{0.23}(18+F_c)}{\frac{M}{Q*d_e}+.12} + 0.85*\left(p_{we}*\sigma_{wy}\right)^{\frac{1}{2}} + 0.1\sigma_{0e}\right\} * b_e * j_e \quad (5)$$

$$p_{we} * \sigma_{wy} = p_w \sigma_{wy} \left(\frac{b}{b_e}\right) + p_{sh}\sigma_{sh}(t + b_e) \quad (6)$$

$$p_{te} = \frac{a_t}{b_e * d_e} \quad (7)$$

$$j_e = \frac{7d_e}{8} \quad (8)$$

$$\sigma_{0e} = N/(b_e * j_e) \quad (9)$$

where, C = Strength Index, Q_u = Ultimate lateral load-carrying capacity of the vertical members in the story concerned, $\sum W$ = The weight of the building including live load for seismic calculation supported by the story concerned, M_u = Ultimate moment capacity. p_w = Shear reinforcement ratio, σ_{wy}=yield strength of shear reinforcement, d_e = Distance between tensile reinforcing bar center and extreme fiber of the wing wall in compressive size (mm), p_{sh} =Horizontal shear reinforcement. σ_{sy} = yield strength of bars,

2.2.2 Ductility Index, *F*

The deformation capacity of vertical members are referred as *F*-index in second level evaluation of JBDPA (2001). The ductility index, *F* of a vertical structural member depends on the yield and ultimate deformation capacity of vertical members and the vertical member types i.e. shear column, flexural column, shear wall etc. and can be computed according to the classification shown in the Table-1.

Table 1: Determination of the value of Ductility Index, *F* for different conditions (JBDPA 2001).

Vertical member		F index	Criteria
Structural Wall	Shear wall	1	-
	Flexural wall	1	${}_wQ_{su} / {}_wQ_{mu} = 1.0$
		2	${}_wQ_{su} / {}_wQ_{mu} \geq 1.3$
		$1<F<2$	$1.0< {}_wQ_{su}/{}_wQ_{mu} <1.3$
Structural Column	Shear column	$F = 1 + 0.27 * \frac{R_{su} - R_{250}}{R_y - R_{250}}$	-
	Flexural column	$F = 1 + 0.27 * \frac{R_{mu} - R_{250}}{R_y - R_{250}}$	$R_{mn} < R_y$
		$F = \frac{\sqrt{\frac{2R_{mu}}{R_y} - 1}}{0.75 * \left(1 + \frac{.05R_{mu}}{R_y}\right)} \leq 3.2$	$R_{mn} \geq R_y$
	Extremely Brittle Column	0.8	-

${}_wQ_{su}$= Ultimate shear strength of wall, ${}_wQ_{mu}$ = Shear force at the flexural strength of the wall, R_y = Yield deformation in terms of inter-story drift angle = 1/150, R_{250} = Standard inter-story drift angle = 1/250, R_{su} = Inter-story drift angle at the ultimate deformation capacity in shear failure, R_{mu} = Inter-story drift angle at the ultimate deformation capacity in flexural failure

2.3 Basic Seismic Index of Structure (E0)

Generally, a building structure consists of several vertical load bearing members i.e. columns and shear walls and they will fail at different deformation levels, based on the strength and ductility capacity of individual vertical member, under the seismic load. Therefore, a concerned story of a building can fail in a ductile or brittle manner based on the types of vertical members' deformation capacity. The basic seismic index of structure (E_0) depends on the ductile or brittle failure mechanism of a story and can be determined as follows:

Ductility-dominant basic seismic index of structure

Figure-2 shows an idealized relationship of strength index (*C*) and ductility index (*F*) of a building where all members are ductile i.e. capacity degradation is not much. To calculate the value of basic seismic index, E_0 the structural members are classified according to their ductility index *F*. The members are divided into groups and the groups are formed in the order of smaller value of the ductility index, *F* (Figure-2) i.e. F_1, F_2, F_3 etc. Any grouping can be adopted to get the maximum E_0 value. The value of E_0 can be calculated using the equation (10)

$$E_0 = \sqrt{(C_1F_1)^2 + (C_2F_2)^2 + (C_3F_3)^2} \tag{10}$$

where, C_1, C_2, C_3 = Strength index, *C* of 1st ,2nd ,3rd group respectively. F_1, F_2, F_3 = Ductility index, *F* of 1st ,2nd ,3rd group respectively

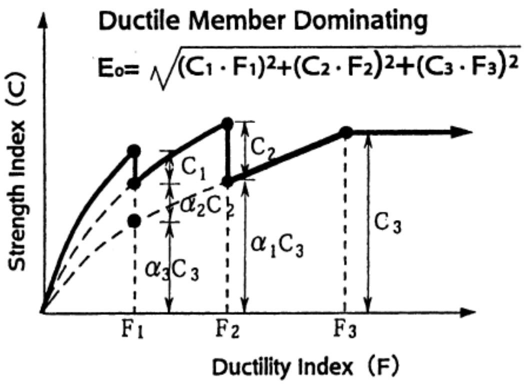

Figure 2: Basic seismic index of ductility-dominant structure (Fukuyama et al., 2000)

Strength-dominant basic seismic index of structure

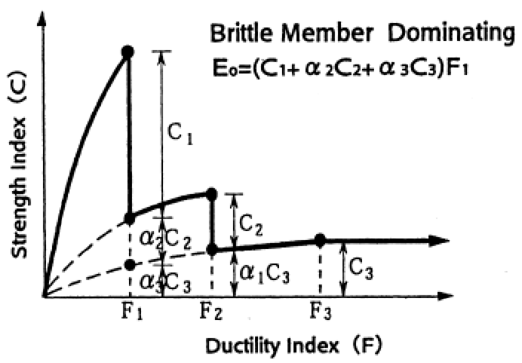

Figure 3: Basic seismic index of strength-dominant structure (Fukuyama et al., 2000)

Figure-3 shows an idealized relationship of strength index (*C*) and ductility index (*F*) of a building where some members are brittle i.e. large capacity degradation at lower deformation.The ductility index F_1 (for the first group) is selected as the cumulative point of strength. The contribution of the strength indices for the members with a higher ductility indices than the first group is considered only. It will be selected in a way that the calculated value of E_0 will be maximum. In the higher groups, effective strength factor α is calculated while the effects of yield deformations and clear height of the vertical members on the basis of the relationship between the drift angle and the story shear force are considered. Seismic index E_0 for strength dominating structures can be calculated by the equation (11)

$$E_0 = \frac{n+1}{n+i} * \left(C_1 + \sum_j \alpha_j C_j\right) * F_1 \tag{11}$$

where, αj= Effective strength factor in the j-th group at the ultimate deformation R_1 correlating to the first group which is considered as per Table-2, C = strength index of the member. F = Ductility index of the member.

All the members can not reach their individual strength capacity in a certain drift level. Some can reach their maximum capacity but others can show a certain percentage of their total strength so there is a factor which can actually calibrate their contribution at a certain drift. As the equation suggests there is a term α which is called "effective strength factor". This factor helps to divide the columns to various groups according to their contribution of strength at various drift levels. It can be calculated as par JBDPA (2001) using Table-2

Table 2: Effective strength factors.

Cumulative point of groups $F_1 \geq 1.0$ (Drift angle $R_1 \geq R_{250} = 1/250$)			
Groups	F_1	$1.0 < F_1 < 1.27$	$1.27 \leq F_1$
	R_1	$R_{250} < R_1 < R_{150}$	$R_{150} \leq R_1$
	Shear ($R_{SU} = R_{250}$)	0	0
	Shear ($R_1 < R_{su}$)	α_s	0
	Flexural ($R_{my} < R_1$)	1	1
	Flexural ($R_1 < R_{my}$)	α_m	1

here, α_s = Effective strength factor for a shear member, $\alpha_s = Q_{F1}/Q_{SU} = \alpha_m * (Q_{mu}/Q_{SU})$, α_m = Effective strength factor for flexural column, $\alpha_m = Q_{F1}/Q_{mu} = 0.3+0.7 * (R_1/R_{my})$

2.4 Seismic Demand Index, IS0

The seismic demand index of a structure is necessary to evaluate the strength demand of the structure to resist seismic loading. This varies according to different parameters such as the location of the building, building structural type, soil characteristics, building height etc. The seismic demand index (I_{S0}) can provide a numerical value which is comparable to the seismic capacity index which can be very helpful to decide if the building is vulnerable or not. The seismic demand index, I_{S0} can be computed using the equations (12) – (14) as suggested by CNCRP (2015). The seismic zone factors, Z and other building parameters should be calculated as per BNBC (2020).

$$I_{S0} = (2/3)\, Z * I * C_S \tag{12}$$

$$C_S = \frac{1.25S}{T^{\frac{2}{3}}} \leq 2.75 \tag{13}$$

$$T = C_t * h_n^{\frac{3}{4}} \tag{14}$$

where, Z = Zone co-efficient, I = Structural importance factor, C_s = Normalized acceleration response spectrum, which is a function of structural period and soil type, T = Fundamental period of vibration in seconds, S = Site coefficient , h_n = Height above ground level in meter.

3. BUILDING STRUCTURAL DETAILS

An existing four storied RC building was selected which is located in Khulna, Bangladesh. The four storied building is regular in shape and was constructed in 2015 according to BNBC 2006. According to cross section there were four types of columns designated as $C_1 – C_4$ as shown in Figure 4. These columns, 31 in total, were classified into 29 column types according to their tributary area are designated as Col_1 – Col_{29}. Among them the maximum cross section of the columns was 600 sq. inch and the minimum was 240 sq. inch. The yield strength of the steel used as main and shear reinforcement was 415 MPa and the cylinder strength of the concrete was 24 MPa. For main reinforcement 25 mm, 20mm and 16 mm bars were used. Again 10 mm bars were used at an interval of 4/8/4 inch c/c for shear reinforcement. 2.14% to 2.35% of steel was used in each of the columns as main rebars. Figure-4 shows the placement of columns and shear walls of that building.

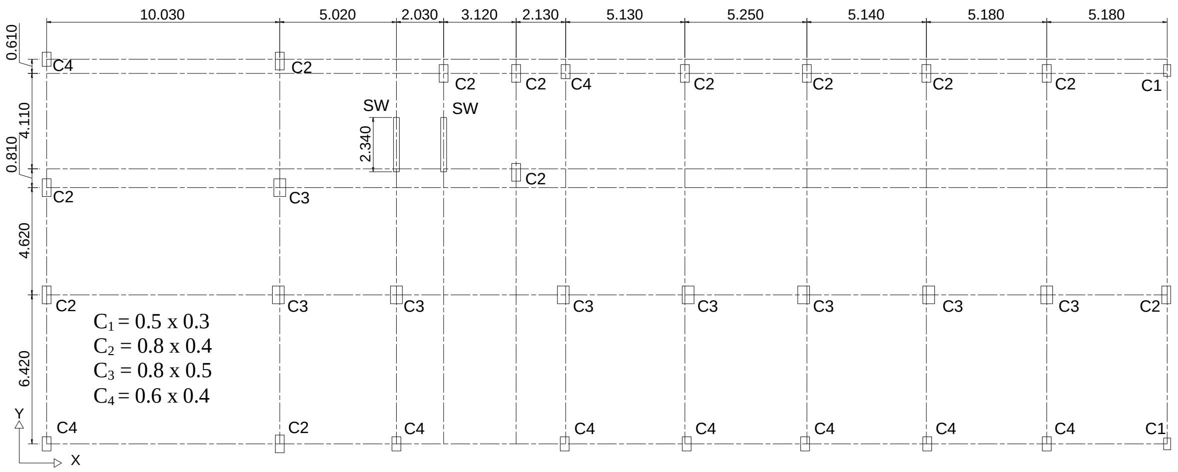

Figure 4: Column layout of the building (all dimensions are in meter).

4. ANALYSIS AND RESULT

Considering the structural characteristics of the building, it was assessed thoroughly using the Japanese second level evaluation procedure as per the guidelines of JBDPA (2001). During this assessment procedure each of the structural members were assessed individually and classified into groups according to their strength contribution in different drift levels, from which the seismic capacity index, I_S was calculated. The seismic demand index I_{so} was calculated according to BNBC (2020) using the suitable values corresponding to seismic zone and structural features of the building.

4.1 Computation of individual member strength (*C*-index) and ductility (*F*-index)

Table 3: Calculation of strength index, C

Column	N (KN)	M_u (KN-m)	Q_{mu} (KN)	ρ_t (%)	ρ_w (%)	$M/(Q.d)$	Q_{su} (KN)	Q (KN)	Column type	Total weight (KN)	C
Col_1	1094.5	693	325	0.905	0.002	3.00	362	325	Flexural	49036	0.007
Col_6	2696.7	1633	765	0.923	0.003	3.00	729	729	Shear		0.015
SW	-	3510	822.49	-	-	-	973.7	822.5	Flexural		0.016

N = Normal force, M_u = Moment capacity

The lateral strength (Q_u) and deformation capacity (R) of each vertical members have been computed using the structural drawing and the material properties to attain corresponding strength (C) and ductility index (F). The strength index (C) computation of representative columns C1 and C6 (2 out of 29 columns classified by tributary area) and shear wall, SW is presented in Table-3. In addition, the deformation capacity (e.g. ${}_CR_{max}$, ${}_CR_{my}$, ${}_CR_{mp}$, R_y) and ductility index (F) of representative columns C1 and C6 (2 out of 29 columns classified by tributary area) and shear wall, S_w is presented in Table-4.

Table 4: Calculation of Ductility Index, F

Column Id	${}_CR_{max}$	${}_CR_{my}$	${}_CR_{mp}$	R_y	${}_CQ_{su}/{}_CQ_{mu}$	R_{my}	F
Col_1	1/100	1/150	0.001	1/150	1.11	1/150	1.75
Col_6	1/100	1/150	-	1/150	0.95	1/150	1.22
SW	-	-	-	-	1.18		1.61

4.2 Seismic Capacity Evaluation

From the detailed analysis, the vertical members were divided into two groups (F = 1.27 & F = 1.75) for X-direction (long direction) as shown in Table-5. A graph was constructed (Figure-5) from these obtained analysis results for the determination of the seismic capacity index, $\boldsymbol{I_s}$ of the building for X-direction. According to the Figure-5, it's clear that at F = 1.27 most of the columns fail as a result a substantial strength reduction takes place. So, to calculate the capacity the values corresponding to F=1.27 can be taken into accounts. So, E_0 = 0.37 and as S_D = 1.0 and T = 1.0, I_S = 0.37.

Similarly, the columns of the Y-axis was divided into one group (F=1.75) as shown in Table-6. Another graph corresponding the strength index C and ductility index, F was constructed from the values from Table-6 which is shown in Figure-6. As shown in the Figure-6 at F = 1.75 the building witnesses a sudden change in strength, the values corresponding to F = 1.75 was taken into consideration to evaluate the seismic capacity index along Y-direction. The value of I_S for Y-direction is found to be 0.40 and was calculated using the similar procedure. As the value of I_S for the X-direction (I_S = 0.37) is the lowest, the seismic capacity index can be taken as 0.37.

Table 5: Strength and Ductility index, group classification for members in X direction (long direction)

Column ID	First Group			Second Group		
	α	C	F	α	C	F
Col_1	0.83	0.0066	1.75	1	0.0066	1.75
Col_2	1.00	0.0215	1.27	0	0.0215	1.27
Col_3	1.00	0.0110	1.27	0	0.0110	1.27
Col_4	0.83	0.0137	1.75	1	0.0137	1.75
Col_5	1.00	0.0107	1.27	0	0.0107	1.27
Col_6	1.00	0.0149	1.22	0	0.0149	1.22
Col_7	1.00	0.0150	1.22	0	0.0150	1.22
Col_8	1.00	0.0105	1.27	0	0.0105	1.27
Col_9	1.00	0.0138	1.22	0	0.0138	1.22
Col_{10}	0.83	0.0092	1.75	1	0.0092	1.75
Col_{11}	0.83	0.0072	1.75	1	0.0072	1.75
Col_{12}	0.83	0.0086	1.75	1	0.0086	1.75
Col_{13}	0.83	0.0069	1.75	1	0.0069	1.75
Col_{14}	1.00	0.0144	1.22	0	0.0144	1.22
Col_{15}	0.83	0.0069	1.75	1	0.0069	1.75
Col_{16}	1.00	0.0114	1.27	0	0.0114	1.27
Col_{17}	1.00	0.0143	1.22	0	0.0143	1.22
Col_{18}	0.83	0.0063	1.75	1	0.0063	1.75

Column ID	First Group			Second Group		
	α	*C*	*F*	*α*	*C*	*F*
Col_{19}	1.00	0.0142	1.22	0	0.0142	1.22
Col_{20}	0.83	0.0062	1.75	1	0.0062	1.75
Col_{21}	1.00	0.0099	1.27	0	0.0099	1.27

Table 5 (continued): Strength and Ductility index, group classification for members in X direction (long direction)

Column ID	First Group			Second Group		
	α	*C*	*F*	*α*	*C*	*F*
Col_{22}	1.00	0.0142	1.22	0	0.0142	1.22
Col_{23}	0.83	0.0062	1.75	1	0.0062	1.75
Col_{24}	1.00	0.0100	1.27	0	0.0100	1.27
Col_{25}	1.00	0.0143	1.22	0	0.0143	1.22
Col_{26}	0.83	0.0063	1.75	1	0.0063	1.75
Col_{27}	0.83	0.0040	1.75	1	0.0040	1.75
Col_{28}	1.00	0.0105	1.27	0	0.0105	1.27
Col_{29}	0.83	0.0035	1.75	1	0.0035	1.75
SW	-	-	-	-	-	-

Table 6: Strength and Ductility index, group classification for members in Y direction (short direction)

Column ID	*α*	*C*	*F*
Col_{1}	1	0.0044	1.75
Col_{2}	1	0.0131	1.75
Col_{3}	1	0.0067	1.75
Col_{4}	1	0.0090	1.75
Col_{5}	1	0.0065	1.75
Col_{6}	1	0.0120	1.75
Col_{7}	1	0.0120	1.75
Col_{8}	1	0.0064	1.75
Col_{9}	1	0.0112	1.75
Col_{10}	1	0.0058	1.75
Col_{11}	1	0.0048	1.75
Col_{12}	1	0.0055	1.75
Col_{13}	1	0.0046	1.75
Col_{14}	1	0.0117	1.75
Col_{15}	1	0.0045	1.75
Col_{16}	1	0.0069	1.58
Col_{17}	1	0.0116	1.75
Col_{18}	1	0.0041	1.75
Col_{19}	1	0.0116	1.75
Col_{20}	1	0.0041	1.75
Col_{21}	1	0.0062	1.75
Col_{22}	1	0.0115	1.75
Col_{23}	1	0.0041	1.75
Col_{24}	1	0.0062	1.75
Col_{25}	1	0.0116	1.75
Col_{26}	1	0.0041	1.75
Col_{27}	1	0.0027	1.75
Col_{28}	1	0.0064	1.75
Col_{29}	1	0.0024	1.75
SW	1	0.0168	1.61

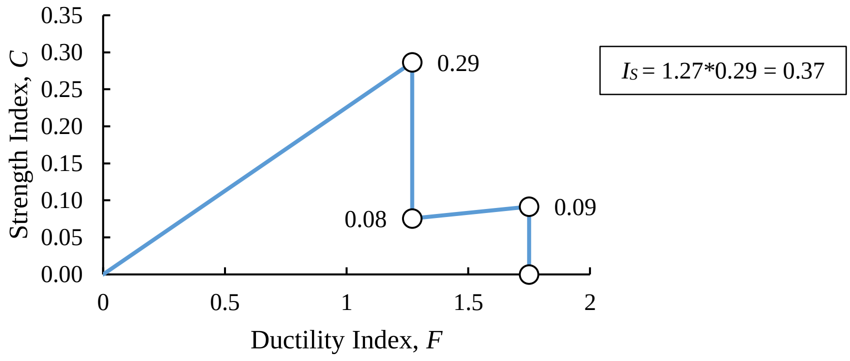

Figure 5: Seismic capacity along X-direction (long direction).

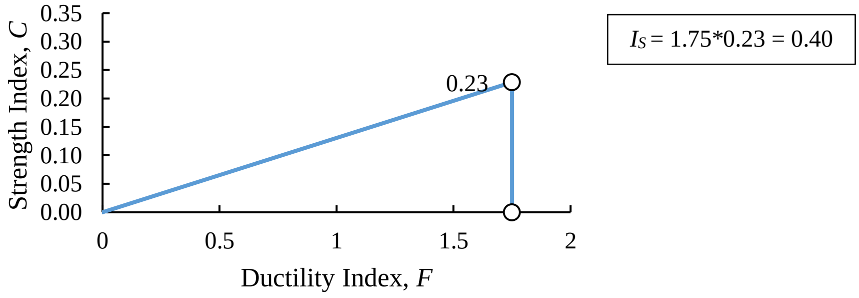

Figure 6: Seismic capacity along Y-direction (short direction).

4.3 Seismic Demand Evaluation

The seismic demand index, I_{S0} was calculated as 0.22 using the equation (8) – (10) as per the guidelines of CNCRP 2015. The zone coefficient and other building parameters are considered as per BNBC 2020 as presented in Table-7.

Table 7: Seismic demand index calculation.

Z	***I***	***T***	C_t	***S***	C_s	I_{S0}
0.12	1	0.53	0.073	1.5	2.75	0.22

4.4 Comparison between Seismic Capacity and Demand

The relationship of strength index (*C*) and ductility index (*F*) along with the demand curve for both directions of the building are shown in in Figure 7 and Figure 8. The seismic capacity index I_s is taken as 0.37 as it's the smaller value among the two principal directions and the demand index was found to be 0.22. Comparing to these values it's clear that this building has a greater capacity comparing to the seismic demand. So, this building can be considered as not vulnerable.

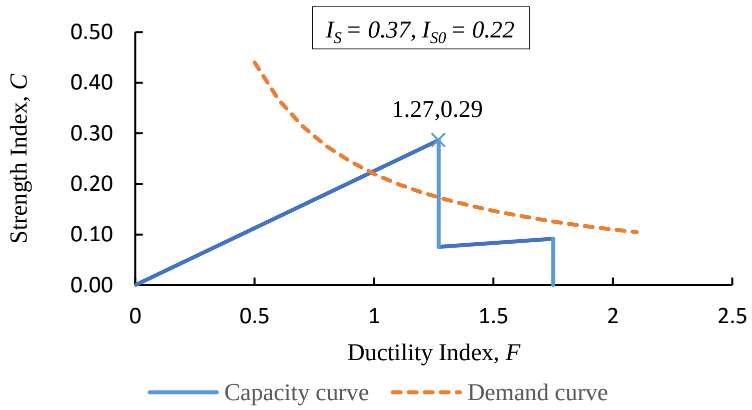

Figure 7: Demand and capacity comparison for X-direction (long direction).

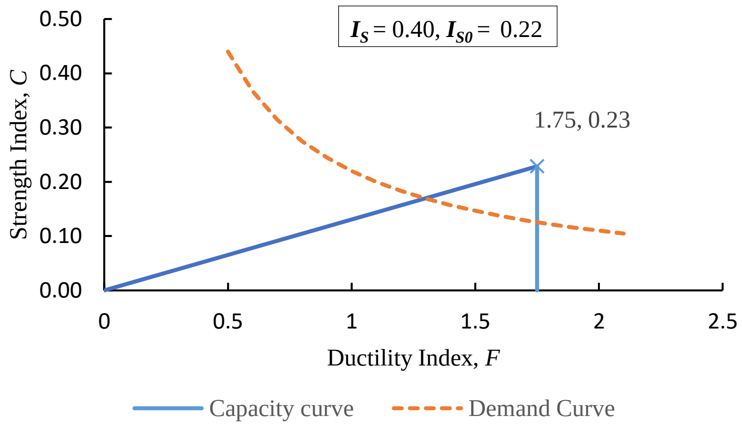

Figure 8: Demand and capacity comparison for Y-direction (short direction).

5. CONCLUSION:

The main purpose of this study was to evaluate the vulnerability of an existing RC building under seismic loading. For this very reason two main parameters, seismic capacity and demand indices were computed with the detailed evaluation procedure of JBDPA 2001 and CNCRP 2015, respectively. The values of seismic capacity indices for two principal horizontal directions were found to be 0.37 and 0.40. The minimum value of seismic indices was considered as the seismic capacity index I_S (= 0.37). On the other hand, the seismic demand index, I_{S0} for this particular building was found to be 0.22. The building can be considered as not vulnerable, as the seismic capacity index has a higher value than the seismic demand index.

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