PRESENT STATUS OF APPLICATION OF STRENGTHENING AND REPAIRING TECHNIQUES FOR COLUMN JACKETING AND ITS OUTLOOK IN BANGLADESH

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ABSTRACT
With better understanding of seismic demand on structures and with our recent experiences with large earthquakes near urban centers, the need of seismic retrofitting is well acknowledged especially in the ready-made garments sector in Bangladesh. This paper summarizes and reviews the use of the industrial structures strengthened and repaired with column jacketing in Bangladesh with respect to realistic case studies. According to different codes and engineering practices retrofit measures may vary considerably. The paper will be introducing and evaluating retrofit measures using column jacketing based on FEM modeling and in perspective to existing seismic conditions. Seismic analysis has conducted based on nonlinear time history analysis using SAP2000 a product of Computer and Structure Inc. in basic frame and retrofitted frame. The study results are discussed in detail both in diagrams and with a simple formula. Based on the suggested procedure, seismic retrofitting has been carried out by using the ACI-562 guideline.

Keywords: Retrofit; ACI-562; SAP2000; column jacketing; Bangladesh

INTRODUCTION
The massive 7.9 magnitude earthquake in Nepal (2016) and its climbing death toll have raised the heavyweight cautionary signal for Bangladesh and the surrounding's about colossal earthquake. So now a day detailed engineering assessment and retrofitting measures are a vital issue in this Asian zone. Retrofitting is the modification of existing structures to make them more resistant to earthquake by optimizing the strength, ductility and earthquake loads (O. R. Chowdhury et al, 2015). Earthquake load is generated from the site seismicity, mass of the structures, important of buildings, degree of seismic resistant etc. Due to variety of structural condition of building, it is hard to develop typical rules for retrofitting. Each building has different approaches depending upon the structural deficiencies. Hence engineers are needed to prepare and design the retrofitting approaches. In the design of retrofitting approach, the engineers must comply with the building codes. The results generated by adopting retrofitting techniques must fulfil the minimum requirements on the building codes such as deformation, detailing strength etc. In view of this, the paper will be assessing a case study of an existing six storied industrial building. This building is used mainly for light factory operations including operational offices, dining, and sewing, cutting, finishing and finished goods storage. A plan view of this building has shown in Fig. 1.

METHODOLOGY
This paper presents seismic retrofits technique suitable for improving the local and global response performance of existing reinforced concrete industrial buildings that was designed for mainly gravity load and situated in low to moderate seismic zone of Bangladesh. Retrofit schemes are developed to focus on redistributing damage throughout the structure providing a control of story deformations. This is achieved by retrofitting using column jacketing method, thereby a low-cost solution with minimal structural disturbance. A six-storied industrial building has been used as a case study for this research. Several visits were made to check and collect data to assess building stability through scanning, rebar

Fig. 1: Plan View of a 6 Storied Industrial Building

testing and core cutting on rcc column, beam and slab of different levels of the building. To assess and analyse data, followed the code of BNBC, the guide line of Accord, Alliance and National Tripartite Plan of Action (NTPA) on structural integrity, using ACI-562 code to evaluate concrete strength from core test results. Finite element software ETABS (a product of Computer and Structure Inc.) was used to analyse different types of load calculation and developed a 3D model of existing building structure and based on the evaluation a retrofit model was also developed.

Geotechnical Investigation

From soil report it has found the structure is built on soft soil (SD Type, SPT < 15) in zone 2 (moderate seismic intensity zone) of Bangladesh Seismic map.

Strength Assessment of Concrete

To assess the strength of the concrete, core test has conducted on January 2016. According to the core test result of the concrete strength varies between 1580 psi and 3700 psi. Considering all these, concrete strength value of 1683 psi was found as per ACI-562 and this value was considered in the analysis.

Test of Collected Steel Sample

Rebar samples collected from the building showed 63 ksi yield strength according to laboratory test results. To be in accordance with real-time scenario 60 ksi yield strength was considered for the assessment.

Scanning of Structural Member

To verify the reinforcement in the existing columns, beams and slabs, Ferro scanning was performed. Reinforcements were scanned at twenty locations at different floor levels. Three locations are at level 1 (two beams and one column), five locations are at level 2 (four columns and one slab), seven locations are at level 3 (four columns, one slab and two beams) and another five locations are at level 6 (four columns one slab).

STRUCTURAL ANALYSIS

Structural Model

Finite element analysis has been performed for this building based on as-built structural and architectural layout. The building has beam supported slab system (level-1, 2, 3) and edge supported

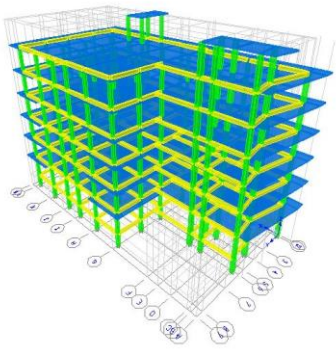

Fig. 2: 3D Finite Element Model of the 6 Storied Building

slab system (level-4, 5, 6). Beams and columns were modeled with appropriate frame elements. The slab was modeled with shell elements. Fig. 2 shows the 3D model of the building.

Boundary Condition

For this 6-storied industrial building with pile foundation, it is reasonable to assume that the bases of columns are fully restrained in all directions both translational and rotational. Thus, all the nodes at the bottom of each column were rendered fully restrained against all sort of displacement in the node.

RESULTS

After finite element analysis, a several number of columns of the structure were found to be inadequate. Design Load to Structural Element Capacity of Column (D/C Ratio) for columns in Level-1 are shown in Table-1. Inadequate columns are to be considered as those with D/C ratio greater than 1 and marked in red in the table. Concrete column jacketing has been applied by encasing existing columns in concrete jacket with longitudinal and transverse reinforcement as shown in fig-3. The columns have an increased size and added reinforcement so that their flexural capacity becomes greater than that of the joining beams. For the columns at the ground floor level, the added column reinforcement was anchored into the pile cap as foundation has defined as fixed. Transverse reinforcement has added to the potential plastic hinge regions in base columns to provide adequate rotational ductility and enhance shear capacity. The concrete used for this retrofit technique is a high-performance material that has the

Table 1: D/C Ratio of Level-1 Columns

Grid Line	A	B	C	D	E	F	G	H	I	J	K	L
1							2.18	1.91	2.37	2.34	2.33	
1C												O/S
2	1.61			1.75		1.66						
3							2.66	1.98	2.06	2.01	2.42	2.24
4			1.71			1.67						
5							2.95	2.01	1.99	1.97	2.02	2.11
6		1.36				1.64						
7							1.88	1.95	1.96	1.97	1.95	1.95
8							2.55	2.02	1.90	1.92	2.01	1.89
	N	O	P	Q	R	S	T	U	V	W	X	Y
1A							2.51	2.58				
1B	1.65			2.23		1.87						

characteristic properties of low shrinkage, high strength (f'_c = 6 ksi), and superior bond adhesion by epoxy coating to existing concrete members.

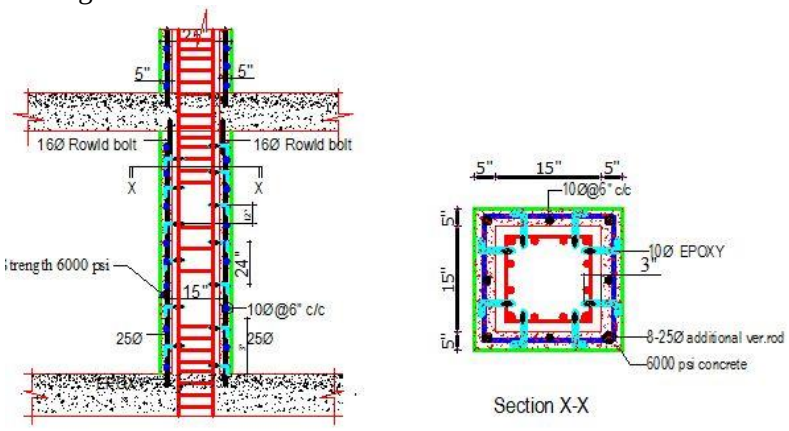

Fig. 3 : Concrete Column Jacketing Technique

Another finite element model has been developed to investigate the structure Load/Capacity ratio after retrofitting. After retrofitting the design load to structural element capacity are as follows in Table 2.

Table 2: D/C Ratio for Level-1 Columns after Retrofitting

Grid Line	A	B	C	D	E	F	G	H	I	J	K	L
1							0.44	0.38	0.39	0.36	0.33	
1C												0.32
2	0.42			0.21		0.41						
3							0.42	0.35	0.34	0.33	0.34	0.33
4			0.48			0.47						
5							0.44	0.35	0.24	0.24	0.27	0.31
6		0.43				0.43						
7							0.39	0.27	0.23	0.23	0.24	0.24
8							0.37	0.25	0.19	0.19	0.24	0.25
	N	O	P	Q	R	S	T	U	V	W	X	Y
1A							0.89	0.91				
1B	0.81			0.96		0.82						

Column jacketing method was incorporated in the structural retrofit model using SD section design process in the ETABS finite element software. The column sections were increased by 5 inches on each side by reinforced concrete jacketing method (Teran & Ruiz, 1992).

Time History Analysis

The retrofit solutions outlined in the previous section provide local retrofit measure for frame structures. However, the global effectiveness of this retrofit measure in a structure is not completely obvious. Application of this certain types of retrofit measure may not be beneficial to overall structural performance. Global verification of integrating the local retrofit measures throughout the structure is most effectively evaluated by using inelastic dynamic analysis programs. In this study, nonlinear time history analysis was performed using SAP2000 (a product of CSI Inc.) implemented by Modak-Sotelino Generalized algorithm (Sukomol & Elisa, 2002) in pre-retrofit frame and retrofitted frame. It has seen that, in retrofitted frame story drift was decreased in a significant manner with respect to the original sub assemblage. Story drift data has shown in fig 4.

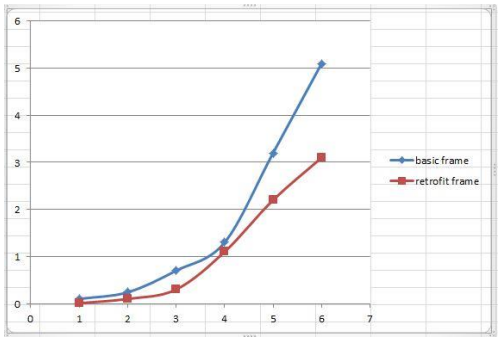

Fig. 4: Story Drift in Pre-Retrofit Frame and Retrofit Frame

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CONCLUSIONS

Based on the present study, the following conclusions can be drawn:

- Concrete jacketing of columns and encasing the joint region in a reinforced fillet is an effective but the most labour-intensive strengthening method due to difficulties in placing additional joint transverse reinforcement.
- Retrofitting by column jacketing decrease storey drift in a large extent.
- It is important to obtain accurate as-built information and analytical data to perform a seismic evaluation of the existing structure and to select the appropriate retrofitting strategy
- Further research should be conducted to improve the selection of appropriate retrofit techniques using criteria based on performance, economy and constructability

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