Strengthening Technique of Reinforce Concrete Structure: Bangladesh Perspective

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Abstract. *Problem Statement:* Strengthening of existing building is significant issue when need to carry additional load. Section Enlargement, RC jacketing and retrofitting by FRP are common strengthening methods used by practical engineers in Bangladesh to increase the load carrying capacity of an existing building. The aim of the study was to determine the most effective and economical strengthening methods among the mentioned methods in perspective of Bangladesh for one storey vertical extension. *Approach:* Methodology of the study included, making plan and beam-column layout, capacity assessment, determination of allowable bearing capacity of soil, structural analysis and cost analysis. The actual compressive strength of concrete was determined by core test. *Results:* After the analyses, results show that the column and foundation merely carry the load from super structure. But, the column and foundation is not capable of carrying extra load from additional storey as the design vertical load for four storeys will exceeds the load carrying capacity of the element and hence, strengthening is required for column and foundation which will prone to damage after vertical extension. *Conclusions:* Finally, strengthening of column by RCC jacketing and strengthening of foundation by foundation enlargement were selected by cost analysis and engineering point of view.

Keywords: Strengthening Technique, RC Jacketing, FRP Strengthening, Section Enlargement, Cost Analysis.

1 INTRODUCTION

In developing countries like Bangladesh, most of the buildings are mainly low-rise buildings. With the rapid development of construction, land becomes more and more scarce. As a result, in developing countries construction of new building are quite expensive. Besides this, after several major seismic events and building collapse that occurred in the recent past, such as the Rana Plaza, in Savar, Dhaka (2013) and many other buildings throughout the country (specially in Dhaka), the structural engineering community and building owners began to question the effectiveness of building codes to protect property. However, there are other reasons for poor performance of old buildings such as less quality of concrete, inadequate attention during design and construction, unskilled labour, improper code practice and improper soil classification tests before construction.

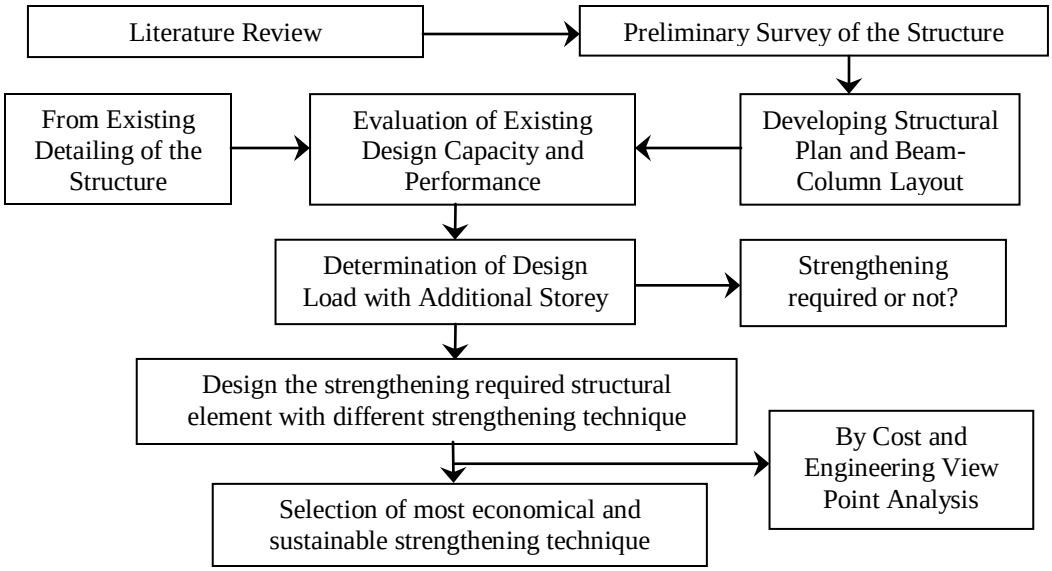
The purpose of strengthening is to rectify the observed defects and bring the building to reasonable architectural shape so that all services start functioning. This enables the use of building for intended purpose. Repairs do not improve structural strength or stability. In fact a repaired building may be deceptive. It may hide the structural defects. Outwardly it may appear good. It may suffer from structural weakness such weakness may cause collapse during future anticipated loads. The performance of the structure expected according to the BNBC code .The RC jacketing of column should be done with minimum requirements which

are the most important factor for the success of RC Jacketing of column. The procedure for the FRP strengthening also should be correct with proper code practice.

The aim of the study is to determine the capacity of existing structural element and identify the weak column and foundation for one storey vertical extension and strengthening the structural element if required. Strengthening of RC column and foundation then compared with respect of cost analysis and engineering view point analysis. However, there are many technical factors including serviceability, strength, durability and non-technical factors such as constructability, aesthetics and cost were considered when selecting a strengthening system.

2 METHODOLOGY

2.1 Analysis Strategy



2.2 Existing Building

The case study building is shown in figure 1 which was designed according to the code of Pakistan. The plan area of the existing building is 204 ft. by 113 ft. Size of reinforced concrete column and foundation (columnar) is 10 in. by 14 in. and 8 ft. by 8 ft. The building is in the earthquake zone 3 according to BNBC.

- Total Area of the Building → 23052 square-ft.
- Number of columns (12 inch X 25 inch, Brick Column) → 34 Nos
- Number of columns (10 inch X 12 inch, RCC Column) → 50 Nos
- Number of columns (12 inch X 25 inch, Show Column) → 34 Nos
- Number of Beams (10 inch X 29 inch, T - Beam) → 46 Nos (Each Floor)
- Number of Beams (10 inch X 14 inch, T - Beam) → 9 Nos (Each Floor)
- Number of rooms (Ground Floor) → 10 Nos
- Number of rooms (First Floor) → 26 Nos
- Number of rooms (Second Floor) → 13 Nos
- Number of Toilets (Ground Floor) → 1 Nos
- Number of Toilets (First Floor) → 3 Nos
- Number of Toilets (Second Floor) → 2 Nos

- Staircase dimension → 11ft X 16ft
- C/C distance between columns (Longitudinal) → 12ft
- C/C distance between columns (Transverse) → 10 ft
- C/C distance between beams (Longitudinal) → 12ft
- C/C distance between beams (Transverse) → 10 ft

Fig. 1. Existing building.

Existing slabs and beams have no structural crack, but some non-structural crack. So, additional strengthening technique is not required for the slabs and beam of the existing building. And if vertical extension is done, load will pass slab to beam and then column. Hence, existing slab and beam will not be affected with the additional load. But, before the strengthening technique applied the existing non-structural damages of slabs and beams should be minimized by taking proper action.

2.2 Plan and Beam-Column Layout

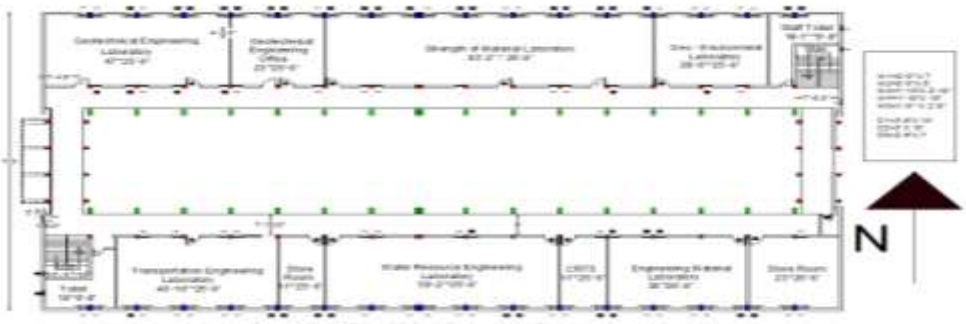


Fig. 2. Ground floor plan

Fig. 3. First floor plan

Fig. 4. Second floor plan

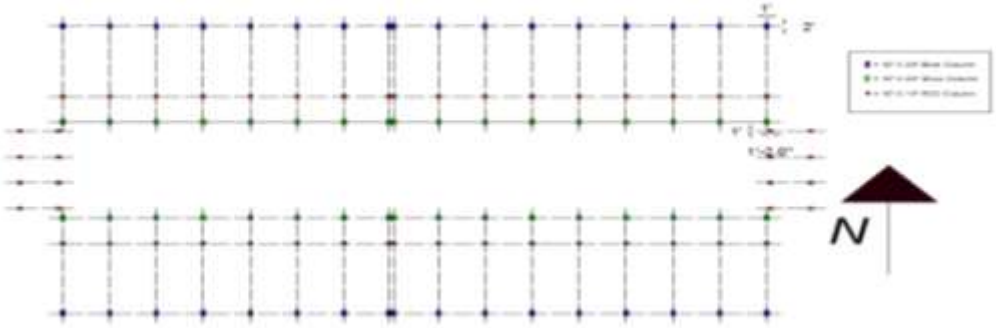


Fig. 5. Beam-Column layout

The detailing of the beam, column and foundation were identified from the existing detailing made at 1969 by chief engineer, East Pakistan. Used yield strength of steel was 40 ksi and compressive strength of concrete was 2.5 ksi. The actual compressive strength of concrete was determined by core test.

Table 1. Material strength properties

Material Properties	Description
Yield Strength of used Reinforcement	40 ksi
Compressive Strength of used Concrete	3 ksi
Actual Compressive Strength of Concrete	2 ksi
Allowable Bearing Capacity of Soil	1.91 ksf

2.3 Existing Column and Foundation

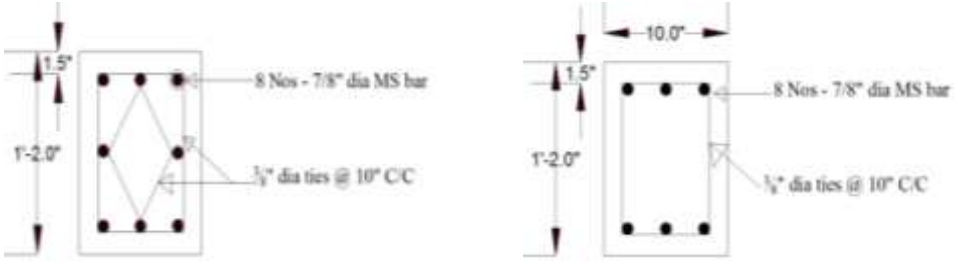


Fig. 6. Ground floor & first floor RC column section

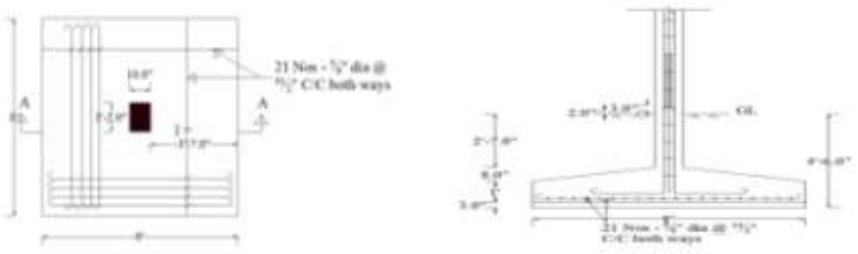


Figure 7. Plan & cross-section of the existing foundation

2.4 Modeling Approach

Analytical analyses were done with the proper code according to Nilson A. H. (2010) and BNBC (2012) to find out the existing capacity of the structural element and future anticipated load. A numerical analysis was also done with ETABS to find out the accurate result with the analytical one. ACI-318-99 was followed during the concrete frame analysis with ETABS. All lateral loads (Wind and Earthquake) were modified according to BNBC (2012) which was mainly followed in Bangladesh by practical engineers. All the dimension and material properties of slab, beam and column were entered and assigned to the program.

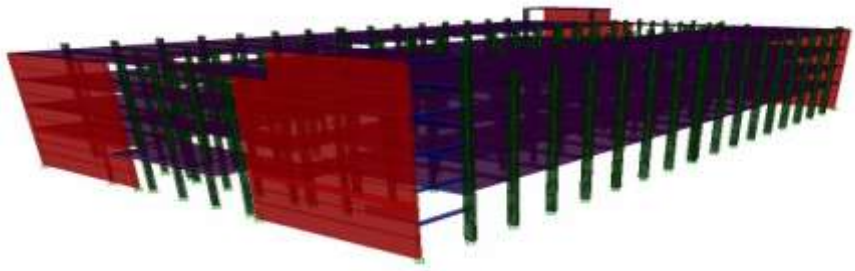


Fig. 8. Remodel of the existing structure

3 RESULTS AND DISCUSSION

The capacity and analysis of the structure are given to the Table 2:

Table 2. Analysis of structural element

Structural Element	Size	Capacity (Kips)	Load (Kips) from		Additional Load ((Kips)	Strengthening Required?
			Existing Structure	After adding storey		
GF Column	10*14 Sq. in	124	121	163	39	Yes
1st Floor Column	10*14 Sq. in	96	81	122	26	Yes
Foundation	8*8 Sq. ft.	122	121	163	41	Yes

After analysis of structural element (which is reflected by Table 2), it is seen that, the structural element can carry the present load coming from super structure where foundation is in critical state. But after adding storey, the vertical load coming from super structure exceeds

the capacity of the element. As the design load exceeds the capacity, so strengthening must be required for adding one storey.

ETABS analysis showed that, the reaction of RCC column is 160 Kips which is approximately similar to analytical analysis. ETABS analysis also showed that, vertical load due earthquake and wind was very low for this 4 storied building as the structure is in the earthquake zone 3 and only have 4 storey after vertical extension. So, wind and earthquake effect can be ignored in this analysis.

Total cost of strengthening method per column (140in^2) to carry additional load is given to the Table 3:

Table 3. Cost analysis of different strengthening methods

Strengthening Method	**Total Cost in TK for (140 in^2) RCC Column**
RC Jacketing	35000
FRP	230000

Table 3 shows that, total cost is lower for strengthening the column by RC jacketing. For FRP strengthening the material needed (epoxy resin, primer and FRP sheet) for strengthening is quite high. Besides this, the installation cost is also high for FRP strengthening. Due to this, the cost needed per column is much greater than RC jacketing.

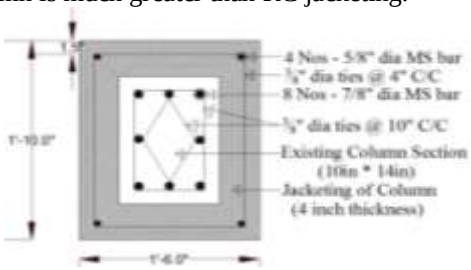


Fig. 9. RC jacketing of RCC column

This will provide additional capacity to all floor columns.

For foundation strengthening, enlargement of the foundation is easy to handle and mostly used in Bangladesh.

Required area of foundation

= 175 / 1.91 = 175/1.91= 91.623 sq. ft

Required size of foundation = 10 ft * 10 ft

So, additional 1 ft. need to be added at each side of the existing foundation and No. 7 MS bar need to be provided @ 9" C/C at the enlarged portion (all sides) to carry additional 41 Kips.

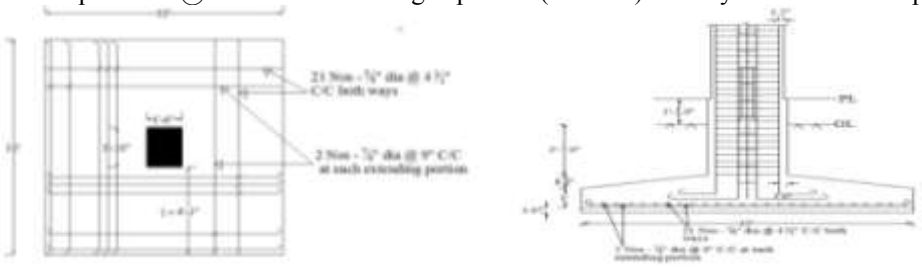


Fig. 10. Plan & cross-section of enlarged foundation

4 CONCLUSION

- Results showed that however both the RC jacketing and FRP are able to strengthen the column and increase the capacity of the column to carry additional load, but column jacketing is much more suitable and economical in respect of Bangladesh.
- For the foundation strengthening, the enlargement of foundation is mostly used and easy to handle for isolated foundation.
- Therefore, based on the above discussion it might be concluded column jacketing and foundation enlargement are the most economic strengthening method for column and foundation for adding additional storey to the existing civil engineering building.

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