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Prioritization of Seismic Retrofit for RC Existing Buildings in Bangladesh
Part.1 Consideration of repair and retrofitting cost

Keywords
Repair Cost Retrofit cost
Retrofit Scenario Cost Benefit Ratio

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1. Introduction

Developing countries like Bangladesh have a number of vulnerable buildings [1] which needs retrofitting for earthquake preparedness. But due to the limitation of the available budget, it is impossible to retrofit all vulnerable buildings. There is an urgent necessity to utilize the limited budget for an effective retrofit strategy.

The objectives of this study are:

- To develop the retrofit prioritization strategy setting considering direct repair cost and strengthening cost of RC buildings in Bangladesh.
- To find out the parameter for setting appropriate retrofit strategy.
- To find the tendency of retrofitting benefits for different occupancy.

The study is facilitated by the survey of 22 public buildings conducted in 2018.[1]

2. Methodology

The methodology that is adopted in this study is presented in Fig.1

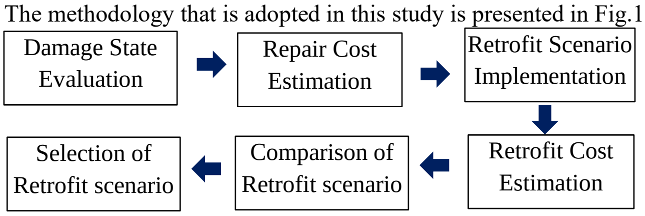

Fig.1: Methodology adopted in this study

2.1 Damage and Repair Cost

The repair cost is based on the damage level as shown in Table 1. The damage level is assumed from the past studies [1] based on the seismic capacity and demand ratio. The corresponding repair cost is assumed as a percentage of the rebuilding cost based on the past study[2] The rebuilding cost is the building replacement cost which includes the new building cost and demolition cost.

Table 1: Assumed Damage State and Repair Cost

Capacity/ Demand	Assumed Damage State	Repair Cost (% of rebuilding cost)
>1.5	Slight	2%
1-1.5	Minor	10%
0.75-1.0	Moderate	20%
0.5-0.75	Severe	50%
<0.5	Collapse	100%

The rebuilding cost is considered \$437/sqm for hospitals, \$375/sqm for schools, \$337/sqm for offices, and \$312/sqm for residential buildings. [3]

2.2 Retrofit Scenario

The retrofit scenario implemented in this study is based on the building retrofitting order in terms of occupancy and in terms of seismic capacity. 2 scenarios are being considered in this study. Table 2 shows the summary of retrofit scenario.

Table 2: Retrofit Scenario summary

Retrofit Scenario	Scenario A		Scenario B		Scenario C	
	Sc A-1	Sc A-2	Sc B-1	Sc B-2	Sc C-1	Sc C-2
Target Damage	Slight	Minor	Slight	Minor	Slight	Minor
Capacity/ Demand	1.5	1.0	1.5	1.0	1.5	1.0

2.2.1 Scenario A

Retrofit scenario A is considered to be retrofitting buildings according to the importance of the buildings. In this study hospital or school building is considered an essential facilities building after that the office buildings and then the residential buildings to be retrofitted.

Scenario A is divided into 2 subcategories:

Scenario A-1: The target damage level is `slight` damage. Therefore the target seismic index is 1.5 times the seismic demand index.

Scenario A-2: The target damage level is `minor` damage. Therefore the target seismic index is 1.0 times the seismic demand index**.**

2.2.2 Scenario B

The retrofit scenario B is based on the retrofitting buildings according to the priority from lowest to highest seismic capacity.

Scenario A is divided into 2 subcategories:

Scenario B-1: The target damage level is `slight` damage. Therefore the target seismic index is 1.5 times the seismic demand index.

Scenario B-2: The target damage level is `minor` damage. Therefore the target seismic index is 1.0 times the seismic demand index**.**

2.2.3 Scenario C

The retrofit scenario C is based on the Cost Benefit Ratio. The priority of the buildings are according to the higher benefit to lower benefit in terms of per unit retrofit cost. In this study only minor damage level is considered for scenario C. In this study the Cost Benefit Ratio more than 10 is considered high, 5 to 10 as medium and less than 5 is considered low in terms of Cost Benefit Ratio.

2.3 Retrofitting Cost

The buildings are considered to be retrofitted before an earthquake to meet the target damage level. The target level is based on the target damage level. In this study, RC wing wall insertion for all buildings have been considered for simplicity. The retrofitting cost has been evaluated based on the difference in seismic capacity. The required strength is given by eq.1

$$\Delta Q = \Delta Is \times W / Fexp \qquad (1)$$

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その１．補修および補強コストを考慮した場合

Where, ΔQ = Strength Required (KN)

$\Delta Is = Is(target) - Is(existing)$; Is_0 = Seismic Demand Index

$Is(target) = 1.5 \times Is_0$ (for scenario A-1/B-1)

$= 1.0 \times Is_0$ (for scenario A-2/B-2)

W = Weight of building (KN)

Fexp = Ductility index expected (considered 1.27 after retrofitting)

The average shear strength of RC wing wall is 1.5 MPa and the thickness is considered 150 mm. The retrofitting cost is considered $270/sqm of retrofitting works after reviewing the cost analysis [4].

2.4 Cost Benefit Ratio (*CBR*)

The retrofitting of buildings gives the cost that will be recovered in terms of the direct repair cost. The total cost is defined by the sum of repair cost and retrofitting cost. The recovery cost (Δ_{rec}) is loss that will be recovered after retrofitting buildings.

The Cost Benefit Ratio (*CBR*) can be defined as the ratio of cost recovery and retrofit cost (Ret_{cost}) given by eq.2

$$Cost\ Benefit\ Ratio\ (CBR) = \frac{\Delta_{rec}}{Ret_{cost}} \qquad (2)$$

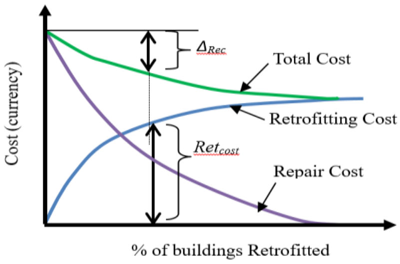

Fig.2: Concept of Cost Benefit Ratio

3. Application on Surveyed Buildings

The 22 surveyed buildings in Dhaka city (Zone Factor, Z=0.2)[5] of Bangladesh are selected as a case study. The buildings are RC frames with masonry infill. The seismic demand index is considered to be 0.3 for Dhaka city[5]. The buildings are evaluated based on past studies and manuals [1,4]. The building's seismic capacity is considered as the minimum seismic capacity in longitudinal and transverse directions of a building. Fig3 shows The building's number of story and floor area per story in sqm are shown in the parenthesis.

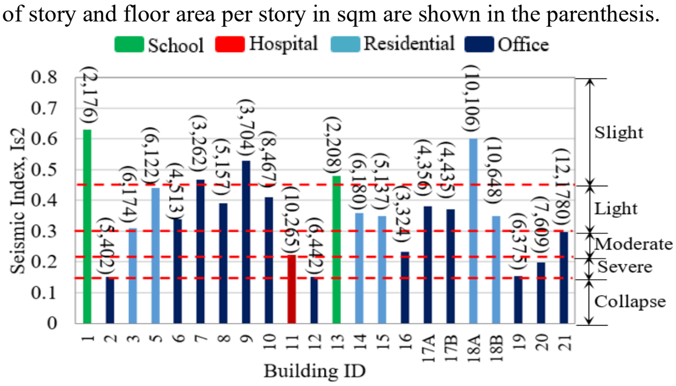

Fig.3: Building's Seismic Capacity, Damage level and in parenthesis (Number of strory, Floor area in sqm)

4. Comparison of the retrofit Scenarios

The cost benefit ratio comparison is shown in Fig.4.The Cost Benefit Ratio is higher for essential facilities buildings compared to other buildings and damage states distribution shows that the more severe the damage the higher the Cost Benefit Ratio.

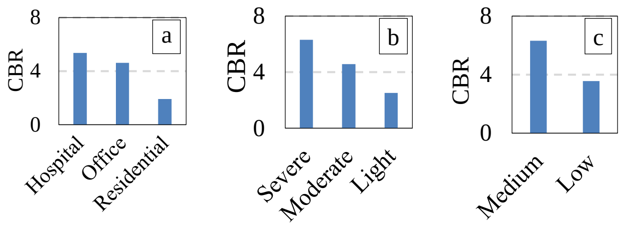

Fig. 4: Cost Benefit Ratio: a) Occupancy wise (Scenario A-1) b) Damage state-wise (Scenario B-1) c) Cost Benefit Ratio-wise (Scenario C-1)

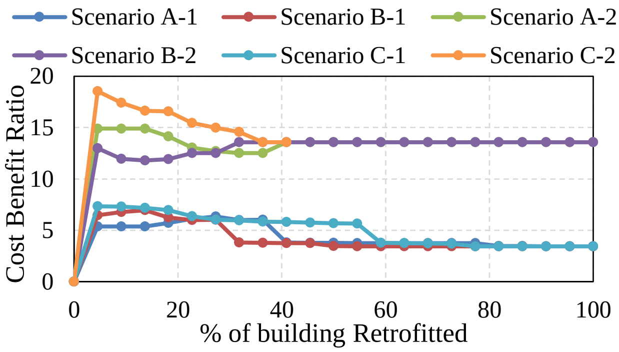

Fig. 5: Cost Benefit Ratio Comparison

Fig. 5 shows that the scenarios A2 and B2 have a higher cost-benefit ratio. But the best scenario will be the cost-benefit ratio should be higher initially than it should be in decreasing. Therefore, sorting in terms of cost benefit ratio the scenario C1 and C2 is introduced which gives higher cost benefit ratio initially then the cost benefit ratio is in descending order. Therefore the higher benefit is provided initially in investing money for retrofitting as budget is limited.

5. Conclusion:

The methodology for retrofit prioritization strategy has been proposed in this study. The following are the concluding remarks:

- A cost-benefit ratio was proposed in this study which shows the cost-effectiveness based on several retrofitting strategies.
- The retrofitting with Cost Benefit Ratio wise scenario gives the most effective retrofit scenario.
- Based on the sample of study, it was shown that prioritizing of retrofitting hospitals and potentially severely damaged buildings would give the higher cost benefit ratio.

Limitations of this study are:

- A small sample on a definite area has been selected.
- Damage criteria and repair cost have been assumed based on past study.
- Indirect loss and human loss are not considered.

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