Strengthening method of concrete structure

Wewin Inge¹, Audrey¹, Sofie Nugroho¹, Helen Njo²

¹ Architecture Department, Faculty of Engineering, Universitas Sumatera Utara, Medan, Indonesia
² Civil Engineering, Faculty of Engineering, Universitas Sumatera Utara, Medan, Indonesia

E-mail: wewin_inge@yahoo.com, Audrey23Njo@gmail.com, sofienugroho95@gmail.com and njo_helen@yahoo.com

Abstract. Building extension in Indonesia is not favored, and not many people know the advantages of the method because architects and engineers tend to lack the knowledge and experience. The aim of this paper is to explain a method on how to strengthen a concrete building structure that people can use/learn as a better way to cut potential cost and save time. The strengthening method explained in this paper is steel jacketing, providing a case study of this method in the extension of a restaurant located in Medan, Indonesia. In this study, engineers calculated that the tensile stress of the existing RC column and beam is not strong enough to reinforce the building extension applied load. Therefore, the steel jacketing method can be applied to improve the column and beam strength and ductility. The result of the case study proves that this is one of the best methods for building extension applied in Indonesia.

Keywords: building extension, reinforced concrete structure, strengthening, steel jacketing, welding

1. Introduction

This paper analyses a building extension project on strengthening its structure in Medan city, Indonesia. The project presented is one-storey family restaurant located in the middle of Medan City, using steel jacketing methods on columns and beams for strengthening existing building on building extension. This paper includes report of the loading, combination loading and structural analysis which includes the study of span beam structures, longitudinal beams and columns. The analysis and study of this structure follow the standard technical rules, and follow the rules applicable in Indonesia.

1.1. Background

Medan is currently the third biggest city in Indonesia, and the 4th highest total index of Human Development Index among the other cities which is 85.46 (4th October 2017, Medan City Government of Planning and Development Department). By such increasing index of Medan City, it influences the economic development and economic welfare with criteria such as life expectancy, education and income level. Proven by the increasing amount of new developments, new lifestyles and residences, such as Podomoro City Deli Medan, a 5.2 Ha condominium, apartment, office tower, and a luxurious
shopping mall. It is undeniable that Medan will constantly grow new developments in number for the next few years.

Buildings nowadays are built for many purposes and functions. A building is designed to be able to fulfill its functions including its occupancy. As time passes, the occupancy number increases which results in the demand of building expansion to solve the increase. That is what happened in one of the family restaurant in Medan, North Sumatera, named Wisma Benteng. It is a one storey family restaurant that can also be used for party events. The expansion is made on the main building and will result in the increase of building load, therefore, the building structures that are made of reinforced concrete, should be strengthen to avoid the failure of load bearing and building collapse. There are various methods of reinforced concrete strengthening. The method that will be used depends on the evaluation and conditions of existing structures and some outside factors, and in this case is steel jacketing.

1.2. Purpose and objective

The purpose of this paper is to give some guidelines about one of many methods to strengthen a building structure for building extension that benefit the designers to handle building extension projects using mentioned method, which is steel jacketing. The main focus is to explain thoroughly on how to identify the needs of building extensions that refers to steel jacketing method and how to use that method to strengthen the existing structure from specific factor and cause.

The purpose can be fulfilled by following the guidelines of steel jacketing method on mentioned case study that can be used for building extension. The guidelines written can also be used as a solution or alternative method in different situations and conditions with a thorough consideration of all aspects and contractors, engineers or construction advisors’ consultation.

1.3. Scope and limitations

The main focus of this paper is to describe and explain literally the usage of steel jacketing, a strengthening structure method on building extension in a restaurant at Medan City. Also defines the reason and the low cost using that method on the building based on contractors and clients consideration. The project is chosen by considering the amount of time efficiency and the needs to extend space on the building to fulfill the purpose. The project was carried out with consults from a Civil Engineering Design and Supervision company located in Medan. The main targeted audience commonly is the citizens of Medan city, such as practitioners, contractors, architects, lecturers, students and common citizen. Conditions, regulations and other standards of building are therefore influenced by the Medan City and other cities in Indonesia. The descriptions and results may be applicable to other buildings if the users are aware of the specifications and other considerations.

1.4. Method

This paper is written theoretically and analytically based on a real case study of strengthening structure of a building extension, where the building is horizontally extended. The subject presented in this paper is specified to analyse the method used in the case study based on the contractor and engineer’s decision and judgment. This analysis might not be suitable for other similar extension condition, but still be useful as one of the executed project references.

This paper approach is aimed to describe a particular case study that uses a method for storey extension and strengthening the structure. The case study is derived from the report of a building project itself. By explaining the executed method along with literature studies, accompanied by direct investigation through the process; direct interview with the contractors and engineers are included as part of the discussion and judgment of method choosing decisions; and therefore concluded with desired project completion.

2. General approaches for strengthening structure considerations

The chapter below is about the factors that need to be considered between the existing building extension and other aspects.
3. Causes of deficiencies
Concrete structures can become deficient during their service life and require repair or strengthening. Some of them are needed as a result of construction or design errors, functional changes, design code updates, lack of maintenance, change in structural system, increased traffic volumes, blasts and explosions, damage accumulated over time or caused by accidental overloading, fires, or earthquakes [1].

While complete replacement of a deficient/deteriorated structure is a desirable option, strengthening/repair is often more economical and hence this aspect of civil engineering infrastructure renewal has received considerable attention over the past few years throughout the world [2].

In this Wisma Benteng restaurant case, the reason of the building extension is the increasing traffic volumes, thus requiring additional area. The building is horizontally extended to the sides and front of the building. Moreover, the owner demands to have the most economic construction with short amount of time to complete, which later are completed for only 3.5 months.

In addition, the strengthening method must be applied to the construction due to the overloaded existing building structure to hold the extension by calculation, which will be explained later.

4. Factors affecting selection of strengthening method
Strengthening a building structure for extension purpose do have several confusing methods. Not only the methods themselves, but also the requirements and factors that are needed to be considered. When selecting strengthening methods and materials, outside constraints must be considered such as [3]:

• Limited access to work areas.
• Operating time schedule (when owner will allow work to take place),
• Budget & financial limitations.
• Required useful life of structure (The strengthening program should be consistent with objective of owner. For example, the minimum strengthening should be done if the structure is to be demolished in a few years).
• Environmental aspects and implications of weather.
• Effect of strengthening on loading mechanism for other adjacent structural members.
• Architectural requirements.

Comparing the aspects with the current study case, Wisma Benteng restaurant is indeed in need of additional access to work areas, has limitations in financial and operating time, requires useful life of structural, and better architectural requirements such as better interior design. Therefore, the restaurant had renovation for several months to imply for better prospects.

5. Strengthening techniques
Structure strengthening techniques and purpose vary. Most strengthening systems are composed of a composite strengthening system. The composite strengthening could be achieved by section enlargement, external posttensioning, externally bonded steel elements, advanced fiber-reinforced polymer (FRP) composites, textile reinforced concrete (TRC), near-surface mounted (NSM) system, or a combination of these techniques. It should be tailored to serve the intended use for the designed service life of the structure without interfering with its functionality [4].

Strengthening structure techniques have many categorized methods. The technique used in Wisma Benteng restaurant is steel jacketing traditional strengthening technique. Below are the specific categories Wisma Benteng restaurant has used to strengthen its structures.

5.1. Steel jacket
This technique is chosen when increasing the cross sectional area of the column is not permitted. The steel jacket is manufactured in two shell pieces and welded in the field around the column. However, this method requires difficult welding work and, in a long term, the potential problem of corrosion remains unsolved. Steel jacketing has been proven to be an effective technique to enhance the seismic
performance of old bridge columns [5]. The method is applied on the Wisma Benteng restaurant extension on the main structural columns as shown in Figure (5a-5c).

![Welding Process](image)

**Figure 1.** (a) welding process, (b) (c) welding process before attaching to the column, (d) after welding process

The main structural columns that have been strengthened with steel jacketing method are inside the building, which are not exposed to the outside environment. Therefore, they do not have any contact with any rain from outside the building Figure (5e). The strengthened columns were wrapped with plywood and other materials for interior aesthetic.
5.2. Flexural strengthening of beams
Steel jacketing on structural beams are also applied on strengthening the structure of Wisma Benteng restaurant extension. Steel plates with at least 5mm thickness are welded to prevent distortion during blasting operation and holding the extended roof load (caused by extended building horizontally so the roof are expanded to cover all additional area). Figure (5.2) (a).

Figure 2. (e) steel-jacketed column wrapped with secondary skin for interior purpose

Figure 3. (a) flexual strengthening beam
There are three ways to strengthen beams by adding new steel profiles to different directions, such as above, beneath or at the sides of the old concrete beam, Statens råd för byggnadsforskning (1978). Figure below are three different ways to perform the strengthening profiles on beams. The strengthening structure in Wisma Benteng Restaurant is using the profiles beneath the existing beam as shown above Figure (5.2)(b). The original beam is in this way still loaded, but the steel profile helps to carry additional load. [6]

![Blocks above supports](image)

(i)  (ii)  (iii)

**Figure 4.** (b) Different ways to strengthen beams with steel profiles i) above, ii) beneath and iii) on the sides of the original beam, after Statens råd för byggnadsforskning (1978).

Investigations into the performance of the structures strengthened by this technique started in the 1960s. This method had been used to strengthen both buildings and bridges in countries such as Belgium, France, Japan, Poland, South Africa, Switzerland and United Kingdom [7].

There are some disadvantages associated with the column jacketing technique. They are: (i) in some cases the presence of beams may require most of the new longitudinal bars in jacket to be bundled into the corners of the jacket, (ii) because of the presence of the existing column, it is difficult to provide cross ties for the new longitudinal bars which are not at the corners of the jacket, and (iii) because of the lack of guidelines, this type of jacketing columns is based mostly on engineering judgment.[8]

Many civil structural elements, like reinforced concrete beams are often required to be upgraded or strengthened due to increased load requirements. Strengthening is becoming both environmentally and economically more preferable replacement, particularly if rapid, effective, and simple strengthening methods are available [9]. Wisma Benteng restaurant did cooperate due to the same circumstances on the extension project with affordable price and quickest way to complete.

**5.3. Strengthen of foundations**

Other consideration that need to be pay attention to is the part of the building that transfer the load to the earth, the foundation. In this case, to ensure the load is transferred well to the earth, a new foundation is added on each strengthened column. The footing around column is being excavated with the dimension 1.5x1.5x1.5m from the floor. A 1x1x1.5m brick foundation is constructed as the new foundation. In addition, a wall of brick is made around the hole and it is then filled with concrete.
6. Strengthening Structure Calculations and Analysis
Report below is the calculation and analysis of Wisma Benteng Restaurant renovation [10].

6.1. Project data summary
1. Project data
   1.1. Project name : Wisma Benteng Building Renovation
   1.2. Location : Jalan Kapten Maulana Lubis Medan
2. Structure Material Data
   2.1. Structure Type : Frame structure from steel construction
2.2. Steel Profile Quality: $f_y$ (tensile melt) = 2400 kg/cm²
2.3. Concrete Column Quality $f'_c$ : 228 kg/cm²
2.4. Concrete Ring Beam Quality $f'_c$ : 210 kg/cm²
2.5. Steel Concrete Quality : $f_y$ (tensile melt) = 2400 kg/cm²

3. Steel Construction Building Structures Data (21m span). Figure (6.1)

3.1. Column : IWF 200x100x5.5x8
3.2. Concrete Column : Dimension 25x30 cm
3.3. Rafter : IWF 250x125x6x9
               IWF 150x75x5x7
3.4 Building Span : 21 meter
3.5. Side Span : 5 meter
3.6 Building Height : 5 meter
3.7 Span Distance Max : 5 meter

![Figure 7. 21 meter span](image)

4. Ring Beam Data. Figure

4.1. Concrete Column : Dimension 25x30 cm
4.2. Ring Beam : Dimension 20x35 cm
4.3. Column Distance : 5 meter

![Figure 8. Ring beam](image)

6.2. Loading and loading combination

1. Loading

1.1. Dead Load (DL) (For Ceiling Weight + Hangers + Lamp 50kg/m²)

| Load                              | Calculation          | Value   |
|-----------------------------------|----------------------|---------|
| Galvalume Roof Load              | $= 5 \times 5 \text{ kg/m}^2$ | $= 25 \text{ kg/m}$ |
| Roof Collar Beam Load            | $= 5 \times 6.76 \text{ kg/m}$     | $= 33.80 \text{ kg/m}$ |
| Wind Bond Load, Plate etc. Estimate |                        | $= 2.00 \text{ kg/m}$ |
| Ceiling Load, hangers and lamp   | $= 5 \times 50$         | $= 250 \text{ kg/m}$ |

Total $= 310.8 \text{ kg/m}$
Taken 315 kg/m

1.2. Dead Load (DL) (For Ceiling Weight + Hangers + Lamp 20kg/m2)
   Profile Self-load programmed calculated
   - Galvalume Roof Load = 5 x 5 kg/m2 = 25 kg/m
   - Roof Collar Beam Load = 5 x 6.76 = 33.80 kg/m
   - Wind Bond Load, Plate etc. Estimate = 2.00 kg/m
   - Ceiling Load, hangers and lamp = 5 x 50 = 100 kg/m
   Total = 160.8 kg/m

1.3. Live Load (LL)
   - Rainwater on roof = 20 kg/m2
   - Load per meter length for: LL = 20 x 5 = 100 kg/m

1.4. Wind Load (WL)
   - Wind pressure taken 25 kg/m2
   - W1 = (0.02'alfa’ – 0.4) x 25 x 5 = -10 kg/m (wind suction)
   - W2 = -0.4 x 25 x 5 = -50 kg/m (wind suction)
   - W3 = -0.9 x 25 x 5 = -112.5 kg/m (windward)
   - W4 = -0.4 x 25 x 5 = -70 kg/m (leeward)

2. Loading Combination
   To earn most determined combination, some combinations in analysis and structure design are used:
   1. U = 1.4 DL
   2. U = 1.2 DL + 1.6 LL
   3. U = 1.2 DL + 1.6 LL + 0.8 WL
   4. U = 1.2 DL + 1.6 LL – 0.8 WL
   5. U = 1.2 DL + 0.5 LL + 1.3 WL
   6. U = 1.2 DL + 0.5 LL – 1.3 WL
   7. U = 0.9 DL + 1.3 WL
   8. U = 0.9 DL – 1.3 WL

   Where: DL = Dead Load
           LL = Live Load
           WL = Wind Load

6.3. Structural analysis
   1. Structural Analysis on Portal Frame Length 21 meter (plafond weight 50 kg/m2). Figure (6.3)(a-c)
   From result of the structural analysis, the stress ratios of the portal frame are:
Figure 9. (a) 21 meter Portal Frame Length

Obtained:
Maximum stress ratio of the rafter is 0.959 (safe).

Figure 10. (b) 21 meter Portal Frame Length

Obtained:
The reinforcement amount of concrete column size 25x30 cm (existing) are 12.777 cm².
The reinforcement amount of existing concrete column (6diameter14 + 2diameter12) are 11.02 m².
Thus, the amount of the required concrete column reinforcement are still lacking 1.757 cm².

The lack of required reinforced steel is equalized with the installation of steel plate thickness 6 mm with jacketing system:

Figure 11. (c) 21 meter Portal Frame Length section

Note: Jacketing with steel plate 6 mm.
Existing concrete column.
2. Structural Analysis on Ring Beam Size 20x35 cm

From result of the structural analysis, the stress ratio of the ring beams are: Figure (6.4)(a-b)

![Figure 12. (a) Stress ratio of ring beams](image)

Obtained:
The reinforcement amount of concrete ring beam size 25x30 cm (existing) are 4.282 cm². The reinforcement amount of existing concrete ring beam (2diameter14) are 3.08 m². Thus, the amount of the required concrete ring beam reinforcement are still lacking 1.202 cm².

The lack of required reinforced concrete is equalized with the installation of steel plate with 6 mm thickness with jacketing system:

![Figure 13. (b) Stress ratio of ring beams section](image)

Note: Jacketing with steel plate 6 mm. Existing concrete ring beam.

6.4. Report conclusion

From the calculation of analysing Wisma Benteng renovation structure by using computer structure analysing program, it can be concluded that:

A. For 21 meters portal span.
   1. If the ceiling's load 50kg/m² IWF 250x125x6x9 rafter is safe.
   2. Concrete column in dimension 25x30 is not safe.
   3. Concrete column is strengthened by steel jacketing using steel plate with 6mm of thickness.

B. For 20x35 cm ring beam
   1. Ring beam in dimension 25x30cm is not safe.
   2. Ring beam is strengthened by steel jacketing using steel plate with 6mm of thickness.

C. If there is a hollow space during jacketing process, it should be filled with grout cement.
D. Between the steel plate and the existing column/ring beam concrete, a shear connector will be used.

E. For the ring beam, WF 150x75x5x7 also can be used.

**Conclusions**

There are many methods to strengthen existing building structures for building extension. One of the most traditional ways to strengthen RC structure is steel jacketing method. The project, discussed in this paper, uses the same method and is proven a success. The corrosion problem on using steel jacketing method, as stated in this paper, is resolved considering the position of the structures are inside the building, not directly exposed to outside environment and the climate.

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This publication is the result of research and design of a building that has a historical role in the Medan city so that the study conducted focuses on the study of integrated theory of design decisions.

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