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Retrofitting in the middle of project execution: case study of a public hospital building

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Abstract

Since the publication of the Conseil International du Bâtiment or CIB's Agenda 21, local government has become an agent of change to achieve sustainability in development policy-making, including implementation of building standards. The Indonesian Earthquake-Resistant Building Standard was recently revised after considering sustainability and earthquake damage reduction methods by drawing on lessons learnt from past earthquakes. However, the willingness of building practitioners and local authorities to deal with those changes, particularly on the budget implications of project execution and appropriate procurement mechanisms, has raised a number of issues. Several of these stem from the lack of awareness and consistency in educating practitioners and officials. As a consequence, the implementation of the new standard has been slow and problematic. This paper presents a case study the impact of implementing and retrofitting a new earthquake resistance standard in a public hospital building in the middle of project execution. The research undertook structural simulation and field observation on an eight-storey public hospital building in Indonesia. The research found that the capabilities of contractors and awareness of local authorities of dynamical changes of policy implementation affected the project success. The analysis suggests that empirical guidance by the local authority is required for practical adjustments in governing retrofitting procedures in public building management.

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1. Introduction

The impact of earthquakes on human populations has become an increasingly influencing factor for stakeholder in terms of policy implementation and further preventative action in project planning. However, the biggest challenge lies in public building management and dealing with earthquake-resistant buildings in the middle of project execution could be an extraordinary case. In addition, a strategic building project, such as a public hospital, also needs a carefully considered decision-making process by local authorities. This includes retrofitting of hospital buildings. The adaptability of the government to apply new building standard needs is an important consideration due to unpredictable outcomes, such as attaining adequate resources of material and experts, building project safety during high-risk activities during the retrofitting, and non-technical effects (i.e. social or political impacts afterward).

In the last two decades, the management of hospital buildings has been a notable topic in public building management and also the focus of property management [1,2,3]. Population growth has increased the demand of publicly funded healthcare infrastructure. As the loss of healthcare facilities and services post-earthquake is unavoidable, a consideration of adequate hospitals or healthcare unit services during crisis situations is an emerging research topic [1,4]. At the grass root level, local authorities should take a proactive role in making strategic decisions for policy adaptation amidst the increasing impacts of earthquake.

Hospitals are critical infrastructures during disaster emergencies. They are usually equipped with specific installations for emergency purposes. Generally, a hospital should have beds and sanitary facilities, patient support facilities, storage space and utilities, and fixed or movable equipment [5,6]. Following the provision of World Health Organisation (WHO) to anticipate the large number of injured people after the earthquake events, the physical structure of the hospitals should be resilient and be able to provide vital healthcare services after earthquakes [1]. Attempts have been made to reduce the impacts of earthquake on hospital buildings in Chile, El Salvador, Bangladesh, Turkey and Indonesia [4,7,8,9]. An example from the Mexico earthquake in 1985 demonstrated how safe hospital buildings could be feasibly designed, constructed and properly functioning following the event. Adaptation of hospital buildings to withstand earthquakes were developed and implemented in Japan and in the USA based on large-scale investments to reduce the devastating impacts of the earthquake [6].

This research presents a real case from a hospital building project in West-Java, Indonesia. This paper will be organised into five sections. Section 2 describes the research method. In the section 3, the structural model and brief evaluation of building structure is provided, from columns, beams and foundation. The discussion of engineering adjustment and policy impact will be presented. Section 4 reports the findings and recommendations, which provide a synthesis of the simulation and retrofitting of structural elements. The final section contains concluding remarks.

2. Method

The study utilises a simulation model and observations of a public hospital project site. The structural simulation is conducted using structural analysis programme (SAP) by 3D frame analysis. The data, such as design drawings, field observations and interviews with structural engineers and contractors were collected from the public hospital project. The analysis was also supported by field observations and corroborating evidence through reputable information. Based on ethical issues, the information regarding locations, name and persons involved in the project case or related information that mention the institution of the third parties will be anonymous or implicitly described in this research. This paper will focus on the structural analysis impact of retrofitting buildings in the middle of project execution and highlights the role of local authorities in the execution and policy impact management of public hospital building.

3. Result and discussion

3.1. Structural model

The hospital building structure consists of two building blocks. Each block has eight storeys, which are separated by dilatations. The dilatations support the gravity load (dead load and live load) and seismic loads. Thus, whenever

the soil settlement influences one side of the building, the building's settlement will not influence the strength of the other side of the building structure. There are homogenous columns within the hospital structure, with dimensions of $70 \times 70 \text{ cm}^2$, from the first floor to the eighth floor. However, the perimeter portal has a dimension of $60 \times 40 \text{ cm}^2$ from the bottom to the top floor. The main beams of the structure have a dimension of $70 \times 35 \text{ cm}^2$ and a length of 8 m. The construction of the building is supported by pile foundations, which are $40 \times 40 \text{ cm}^2$ and $30 \times 30 \text{ cm}^2$ and located at a depth of 24 in firm soil layers.

a. Standard of structural analysis

The structural analysis was conducted with reference to Indonesian Buildings Standards, as follows: Loading Standard for Housing and Buildings [10], Standard of Reinforced Building Construction Calculation [11], Design Standard of Earthquake-Resistant Buildings [12], Standard of Calculation for Steel Building Construction [12] and Design Standard of Earthquake-Resistant Buildings and Non-Buildings [13].

b. Standard Quality of Material

The quality of material used for the structural analysis is as follows: concrete material used $f'c = 30 \text{ MPa}$ and reinforcing used $fy = 400 \text{ MPa}$.

c. Loading for Structure

The service load on the buildings' frame consists of Dead Load, Live Load and Seismic Load. The Dead Load (D) is calculated through the concrete structure's elements, which consist of their self-weight of slab, beam and column. Loads from floors, ceilings and finishing loads are determined at about 125 kg/m^2 . The Live Load (L) caused by occupation activities for hospital buildings standard is 250 kg/m^2 . The Seismic Load (Ex or Ey) refers to Design Standard of Earthquake Resistant Buildings and Non-Buildings [13]. In regard to the dynamic analysis of the earthquake, a simulation was carried out using the Dynamic Analysis Methods using Spectrum Response from SNI 2012. Load Combination (Combo) for structural analysis consists of four combos:

$$\text{Combo 1 : } U = 1.2D + 1.6L \quad (1)$$

$$\text{Combo 2 : } U = 1.4D \quad (2)$$

$$\text{Combo 3 : } U = 1.2D + 1.0L + 100\%Ex + 30\%Ey \quad (3)$$

$$\text{Combo 4 : } U = 1.2D + 1.0L + 30\%Ex + 100\%Ey \quad (4)$$

Where, D= dead load, L= live load, Ex = seismic load on direction X, Ey = seismic load for direction Y.


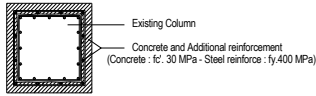
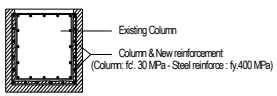

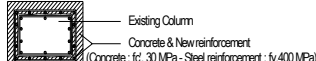
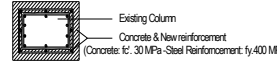
Evaluation of the strength of the concrete structure of the public hospital building was calculated based on the Standard Calculation of Concrete Structures for Buildings [11]. The design method for concrete structure employed LRFD (Load Resistance Factor Design), whereby the safety factor used was in the form of the Load Factor and Strength Reduction Factor of Material.

3.2. Evaluation of structure

a. Upper structural element: column

The strength of the structural column is examined by calculating the stress ratio of the existing columns. The stress ratio is the ratio between the stresses that occur in the column due to the combination of service loading on the structure with a column capacity based on the amount of reinforcement strength that is applied. Column structures are stated as being quite strong if the value of the stress ratio is less than or equal to one ($R \leq 1$). From the structural analysis, the study obtained that the stress ratio for permanent load combination (Combo 1 and 2, Dead Load or Dead Load + Live Load) has a value of less than one. The maximum value of the stress ratio revealed from the permanent load combination is 0.86. Nevertheless, a stress ratio greater than one on the temporary load (Combo 3 & 4, Dead Load + Live Load + Earthquake Load) was applied on the structure. This means that the retrofitting should be executed on particular existing columns that have stress ratios greater than one. Regarding the retrofitting of

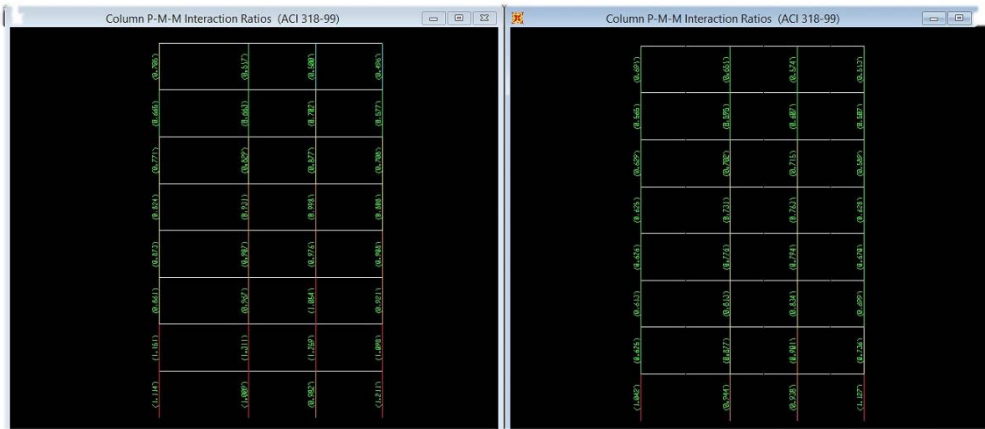
structural columns, any column with a stress ratio value greater than one ($R > 1$) needs to be strengthened to support the service load on the system of the structure. Thus, retrofitting should be undertaken by enlarging the column dimension, both by resizing geometrics of the concrete body and by additional reinforcement, which is termed the ‘Jacketing Method’. The section details of the retrofitting column are shown in Figure 1.

Difference	Existing column (SNI-03-1726-2002)	Retrofitting Column (SNI-03-1726-2012)	
Column reinforcement			
Type of column	K1	K1PA	K1PB
Dimension (in mm)	700x700	850x850	850x800
Reinforcement	16D22	16D22+12D22	16D22+16D22
Stirrups	D10-100	D10-150	D10-150
Column reinforcement			
Type of column	K4	K4PA	K4PB
Dimension (in mm)	600x400	750x550	750x550
Reinforcement	10D19	10D19+14D19	10D19+8D19
Stirrups	D10-100	D10-150	D10-150

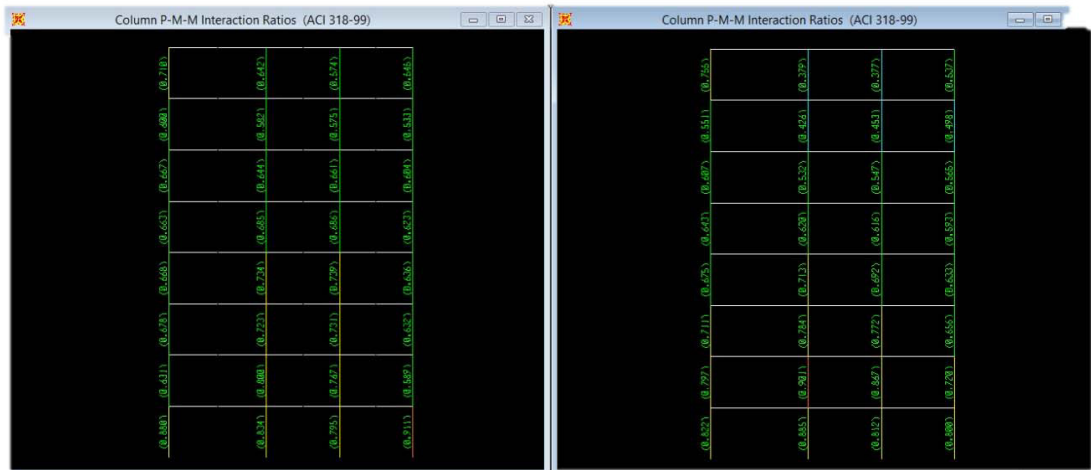
Note: K1= column type 1 ;K4= column type 2; K1PA,B= retrofitting column type 1, mode A or B ;K4PA,B= retrofitting column type 2, mode A or B; D = deformed steel reinforcement (Source: As Built Drawing case building project, 2014)

Fig. 1. Reinforcement from Existing Column and Retrofitting Column

After the jacketing of a particular column with $R > 1$, the post-stress ratio of the structure is re-examined to detect the new performance reliability. The results after jacketing show that the value of the stress ratio of reinforced columns is less than one ($R < 1$). This indicates that the columns are strengthened and are able to bear the load combinations (Combo 1 to 4) applied to the structure (see the example column of Portal 1 and 7 in Figure 2 (a) and (b)).



(a)



(b)

Fig. 2. Stressed Ratio Column of Portal 1 and 7 (a) before retrofitting (b) after retrofitting

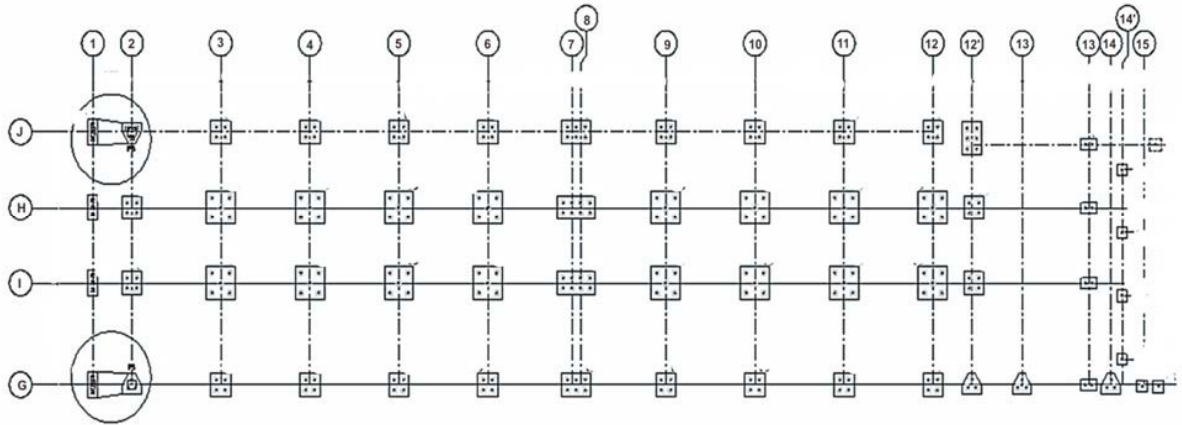
b. Upper structural element: beam

Overall performance of structural beams is reliable to support the building loads, but the beams on the roof level still need strengthening from torque-moment. Therefore, the reinforcement increased from 2D13 to 6D13 (additional reinforcement is about 111 kilograms). Unfortunately, those beams which need strengthening have not been executed yet on the field.

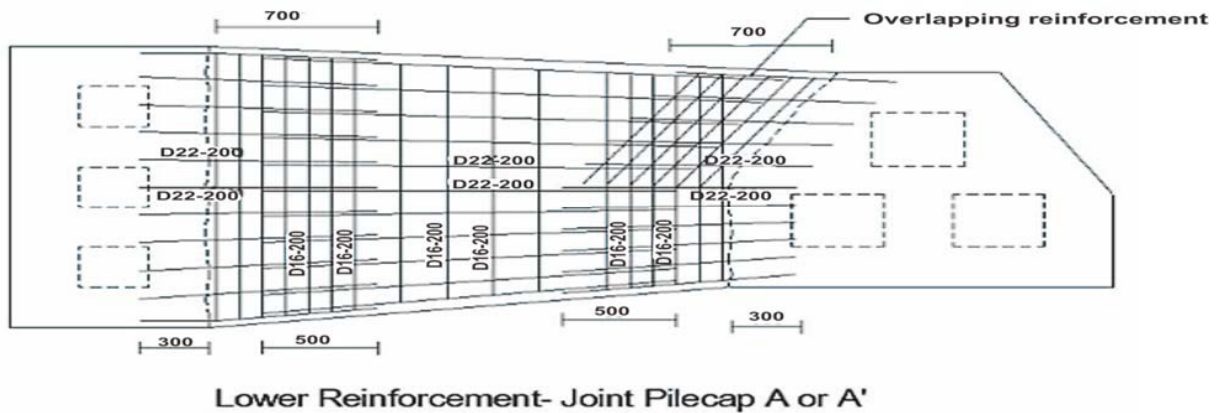
c. Sub-structural element: Foundations

c.1. Analysis of bearing capacity of pile foundations

The soil report on the building location shows that the allowed bearing capacity of one pile foundation (dimension 40 × 40 cm) is 120 tons. The allowable bearing capacity (Pall) of piles to support the load caused by a Permanent Load Combination was applied from the upper structure. However, based on the Indonesian Loading Standard of Buildings, the Pall tolerance can be raised by up to 30% for cases of temporary load combinations. Therefore, the Pall becomes 1.3 x 120 = 156 tons. From the structural analysis on the case Permanent Load Combination 1 (D + L), the maximum service load on the pile foundation is 103 tons (i.e., less than Pall = 120 tonnes). Meanwhile, due to temporary load combination (Combo 2 to 3), the bearing capacity is 168.8 tons (i.e., greater than Pall = 156 tons). This means that the foundation is only reliable for the permanent load combo; otherwise, for the service load or occupied load, the foundation still needs retrofitting to increase the load capacity. The node of foundation retrofitting exists only in two locations (J-1,2 and G-1,2) and the layout foundation retrofitting is shown in Figure 3.



(a)



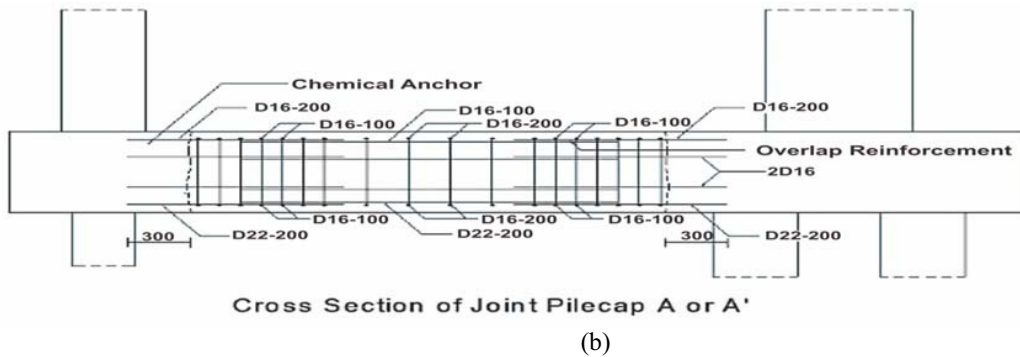


Fig. 3. Layout retrofitting foundations: (a) layout, (b) reinforcement

c.2. Foundations retrofitting

The best solution for strengthening the foundation is through the addition of a bore pile, with a diameter of 30 cm and 15 m depth, around the existing pile and the enlargement of the pile cap. If the first solution is not possible, another solution will need to combine the adjacent existing pile cap from the opposite node (See Fig. 2.) to be able to work together to accommodate the service load. During an earthquake, subsoil of composite pile cap needs to be fixed with grouting (cement + sand) to increase its carrying capacity.

3.3. Engineering adjustment and policy impact

According to the structural simulation of hospital building, three elements are important. The most consideration is given to the structural elements: columns and foundations. Then, the engineering adjustment summary can be seen in Table 1.

Table 1. Summary of Structural Analysis

Structural Element	Retrofitting Action	Additional material			Comments
		Concrete volume (m ³)	Reinforcement (kg)	others	
Beam (L retrofits =160 m)	Generally a serious treatment on the system structure was not required, except the ring-balk on the roof level that needs strengthening against torque-moment.	N/A	111	N/A	Not constructed yet when the retrofitting was recommended
Column	Retrofitting 30 columns (L retrofits = 4.2 m × 30 columns)	23.0	4805	N/A	Excluded installation works
Foundation (two Nodes)	Combine two pile caps and increase capacity by grouting of the subsoil.	8.4	234	Grouting + chemical rebars	Grouting: 6 node, @12 m + chemical technology for joining pilecaps
Total		31.4	5039		

Note: D = deform type of rebar, N/A = not applicable; Estimated for structural cost around IDR 100 million (< 10% of total cost = 700 billion)

The implication of engineering recommendations affects a large number of reinforcement materials and a few concrete materials. The total concrete volume is 31.4 m³, and reinforcement about 5039 kg of rebar (consisting of 111 kg for retrofitting roof-beams or ring-balk), 4805 kg for retrofitting columns and 234 kg for retrofitting foundations). Based on the structural analysis, the most reinforcement material is required by structural columns, particularly on the first floor.

Table 1 shows that most elements of the previous design of the hospital are still adequate. A new crucial element is introduced by new earthquake standards that require retrofitting, for instance, in the first floor column and at specific locations with a large service load (i.e., Intensive Care Unit and equipment or storage rooms). However, a higher risk element of the project surrounds the stakeholder’s decision for foundation retrofitting. Considering the project location, the stakeholders decided to increase capacity of two foundation nodes (node J,1-2 and G,1-2) as recommended by structural engineer by grouting the subsoil.

Here, the cost implication is considered a constraint in executing policy implementation. Somehow, local authorities have smoothly accommodated the engineering adjustments and cost implications. Such dialogue between the contractor and structural engineer should focus on reliable and feasible attempts to address retrofit actions, even on a case-by-case, day-by-day basis. In addition, the process of the application of new standards of earthquake-resistant buildings and intensive communication relies on the commitment among stakeholders. This case study confirms that a harmonious role in public building management enables environmental changes to be accommodated.

4. Findings

The structural analysis suggests that retrofitting action is required on some elements of hospital building (see Table 1). The structural simulation and field observation identify some implications of implementing the new earthquake-resistance standard:

4.1. Potential dispute between contractor and local authority

Retrofitting of structures in the middle of construction works leads to potential dispute between the contractor and the local authority. The contractor will be focused on the content of contract documents while the local authority will be concerned with compliance to the national regulations and new building standards. Considering the safety factors of hospital building, the local authority has a great deal of interest in the long term impact of the compliance to new standards rather than cost impact at the moment. However, a conflict of interests amongst stakeholders will probably emerge in the middle of project execution. Contractors won the project based on clear tasks detailed in the previous contract document. Thus, every single amendment of the design will affect many aspects, including: incurring additional costs; re-scheduling project completion and investment in hospital operation; a new contract dealing with specialist contractors for retrofitting; local political issues, such as labourers, experts in local building industries, legitimacy of the local authority and local budgetary issues. In summary, many aspects can be a trigger for dispute between the contractor and the local authority; however, at the same time the project management shifts to more complex issues. On one hand compliance the new building standard is mandatory, while on the other hand the consequences of project risk increases and leads to delay, threatens the project safety and has economic impacts for internal or external parties.

4.2. Cost-implication of retrofitting activities

Reviewing the design of the hospital building leads to retrofitting actions that have cost implications. Based on calculations by the structural engineer, the impact cost of retrofitting works is still less than 10% of the procurement cost. Nevertheless, problems emerge from the capability of contractors to overcome the retrofitting works in terms of the costs not included by local authorities in the procurement (i.e., e-catalogue or unit price). In other words, the real cost implication of retrofitting lies on the unpredictable cost and uncountable cost (i.e., delay of completion, risk value by investment or operational costs) resulting from the reviewed design. The critical issue of additional-cost might be considered, particularly in accommodating cases through the current procurement system. Basically, the project amendments due to retrofit of the building should consider the broader issues of the local construction industry. Cost-implication from retrofitting activities could be categorised as new phenomena in local building practices that can be adapted into the procurement system of non-standard building cases.

4.3. Administrative impacts of project procurement

Another impact of the implementation of new earthquake-resistant standards is about administrative documents. Almost all changes to the project design involve technical and non-technical documents. The technical documents changed are: design drawings, shop drawings, unit prices and procurement documents (i.e., specification material and works, time schedules and progress reports of hospital project). The non-technical documents include: contract

documents, payment documents and local policy in public building (i.e., legitimacy of review design, minutes of meetings between key stakeholders).

4.4. *The policy impact post implementation of the new building standard*

The public building project at the local authority level still lacks “human resources skills and expertise capacity, adequate material resources”, and only focuses on “local budgetary allocation” [14: 241]. In addition, the national reform and leadership at a national level are still internal barriers for the construction development sector [14, 15]. The implementation of new building standards has a greater impact on the discussion of public policy. Unfortunately, most public building stakeholders, in the context of the Indonesian building industry, they are lack of consideration due to the impact of increasing earthquake magnitude in building structure. The collaboration of multidisciplinary parties creates a learning process and successfully demonstrates adaptability through the policy implementation via retrofitting of the hospital building.

The important aspect of the lesson learnt from this case study is the process of communication among local authorities as a client (owner), engineers as experts to provide objective knowledge and contractors as an executor. Stewart [16] argued that sometimes the decision process of local choice could be carried out far from the project goals. Moreover, Stewart stated that the local government exists in contradictory situations between local priorities and legislation and regulation. However, the ‘winning spirit of the project success’ is effective communication toward project completion. The project risk perspective successfully produces reconciliation among local authorities, contractors and engineers. Finally, for retrofitting to be a success, the greatest challenges revolve around the readiness of local authorities to prepare the operational instrument for future procurement and the empirical guidance for practical adjustments in governing retrofitting procedures in public building management.

5. Conclusion

Retrofitting in the middle of a project is a risky activity, which requires outstanding capabilities of key stakeholders. A hospital building project could be representative of non-standard building in the construction industry and unavailable standard code for building retrofitting, whether in national level and local construction industry. Thus, this research provides a new insight of relevant practical guidance for building stakeholders and local authorities. The adaptation of the new earthquake-resistant standards requires local authorities to be more proactive toward compliance issues of national standards and local needs. The engagement among public building stakeholders in retrofitting the structure of a hospital building in the middle of project execution involves many aspects, including: project costs, administrative project documents for payments and procurement, engineering adjustment documents from engineers, project management teams and third parties involved in the retrofitting actions.

Complex situations arise during the decision-making surrounding the retrofitting process, which pose challenges for the contractor who needs to execute the project in a dynamic environment. This case study demonstrates the potential for conflicts of interest, time management issues and benefit of effective communication under the high pressure of project goals, through structural simulation and retrofitting procedures. A significant number of retrofitting actions are recommended in this public building project. Successful retrofitting relies on the proactive role of local authorities to provide a favourable environment between the contractors and engineers involved.

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