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LIFE CYCLE COST ANALYSIS (LCCA) SIMULATION OF LRB APPLICATION IN EARTHQUAKE-RESISTANT BUILDINGS FOR EVERY EARTHQUAKE EVENT

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Abstract

The technology that can be used to reduce the earthquake loads received by a structure is the base isolation system. There are two basic isolation systems that are commonly used, namely the Lead Rubber Bearing (LRB) system and the High-Damping Rubber Bearing (HDRB) system. The application of LRB in precast concrete building systems has not been widely implemented because LRB is still an imported product and is expensive. For this reason, a study is needed on the calculation of Life Cycle Costs and a comparison of imported prices and local prices. This study calculates LCCA with a 50-year building life plan, planned with 4 conditions. The four requirements are conventional high-rise building construction, precast structures, precast structures with LRB for LRB replacement every 25 years, and precast structures with LRB for LRB replacement every 40 years. The LCCA deviation value will be close to 0 (zero) if an earthquake occurs in the 32nd year for LRB replacement every 40 years, and the 35th year for LRB replacement every 25 years. A comparison of the LRB prices between imported products and Indonesian national products shows that the price of local products is 23% of the price of imported products.

Keywords: Life Cycle Cost Analysis, Simulation, LRB, Buildings, Earthquake, Event.

INTRODUCTION

Indonesia is in an earthquake area (Ring of Fire) where earthquakes can occur at a high frequency. Many buildings collapsed, especially the site buildings which are generally categorized as non-engineered-structures (non-engineered buildings). Non-engineered buildings are buildings that are constructed spontaneously and informally in the traditional way with little or no intervention by qualified architects and engineers in their design. Such buildings generally use stone masonry or adobe masonry, wood or a combination of these traditional locally available materials in the construction of the walls. The walls are reinforced with practically installed beams and columns. The bonds between building elements are not strong and integrated. The building construction is not strong enough to withstand earthquake loads. Because of this, many buildings collapsed and caused casualties.

The high cost of constructing earthquake-resistant buildings and the services of architects and engineers has caused many people to hand over the construction of their houses to people who

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do not have competence in building construction. The collapse of these buildings was partly due to the weak strength of the buildings in overcoming earthquake loads. Earthquake loads arise in the form of ground vibrations which are transmitted from the lower building to the upper building. Rigid joints between the substructure and the upper structure cause severe shocks to the upper structure. These shocks can be minimized by separating the lower and upper structures which are defined as base isolation. One of the base isolation systems is Lead Rubber Bearing (LRB). LRB is a strong support material to withstand vertical loads, but can provide flexibility in lateral deformation. With this capability, the LRB can dissipate earthquake energy, so that the destructive energy can be reduced or eliminated. LRB can also reduce the burden of earthquakes that occur.

The application of LRB in precast concrete building systems has not been widely carried out. The combination of LRB and precast concrete systems is interesting to study because precast concrete has several advantages compared to conventional concrete construction including having good performance, easy and fast implementation, economical, and carrying the concept of environmentally friendly construction.

Issues that need to be addressed include the issue of initial costs and life cycle costs. Based on the initial additional costs required to add to the cost of LRB, this is quite an attractive value in terms of life cycle cost.

LITERATURE REVIEW

According to Ugarelli (2010) in the journal "The Role of Cost Breakdown Structure in Life Cycle Cost Model" in 2015, life cycle cost is a technique that allows a comparative cost assessment to be made over a certain period of time, taking into account the initial capital investment and future operating costs. The cost breakdown structure describes all the costs that arise in each phase of the Life Cycle Cost and its purpose is to identify, determine, and manage all the cost elements that will be taken into account in life cycle costs (Langdon, 2010). Cost breakdown structure helps in estimating life cycle costs

Kelly and Male (1993); Ashworth and Hogg (2007) say that Life Cycle Cost (LCC) evaluates various cost elements, particularly the materials and components used, such as energy, water consumption, and overall asset performance. LCC is composed of initial costs, maintenance and operational costs, change and replacement costs and salvage value.

$$LCC = C + M + O + R - S$$

Purpose

Create a Life Cycle Cost Analysis (LCCA) model for applying the LRB of imported products and the LRB of Indonesian national production in earthquake-resistant buildings.

RESEARCH METHOD

This study calculates LCCA with a 50-year building life plan, planned with 4 conditions. The four conditions are conventional high-rise building construction, precast structures, precast

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structures with LRB for LRB replacement every 25 years, and precast structures with LRB for LRB replacement every 40 years.

It is assumed that an earthquake occurs once in 50 years where the probability of an earthquake can occur in the 1st, 2nd, 3rd year, and so on (simulated if it occurs in the 1st to 50th years). Comparison of each LCCA value in the life cycle cost (LCCA) model in all conditions. The pattern of occurrence was analyzed from the life cycle cost (LCCA) graph in all conditions.

FINDINGS AND DISCUSSION

In this research on Implementation of LRB for Local Products and Imported Products in Earthquake Resistant Buildings, the assumptions for calculating Life Cycle Cost Analysis are:

- The life of the building is designed to be 50 years
- Earthquake events occur once in 50 years with moderate damage
- The possibility of an earthquake occurring in the 1st, 2nd, 3rd year, etc. (simulated if it occurs in the 1st to 50th year)
- For Operational and Maintenance costs in concrete buildings is 0% and the amount is i = 8%. (with inflation of 3%/year and interest rate of 5%/year)
- Building revenue/revenue ranges from 30-33% per year

Building investment costs for:

- Conventional building investment costs 100%
- The investment cost of precast buildings is 75% compared to Conventional
- Investment costs for Precast + LRB buildings are 78.66% compared to Conventional

The cost of repairs due to the earthquake for the damage that occurs is:

- Conventional at 35% Investment (requires 1 year to repair)
- Precast of 35% Investment
- The combination of the precast system with LRB (0%) has no improvement

There are 2 alternatives regarding the base material of LRB rubber (natural or a combination of natural + synthetic):

1. Natural rubber material, no repairs after the earthquake and there is a replacement LRB costs every 25 years
2. Natural + Synthetic rubber material, no repairs after the earthquake and there is a replacement LRB costs every 40 years

LCCA for Conventional, Precast and Precast + LRB (replacement of LRB every 25 years and 40 years), as shown in Figure 1.

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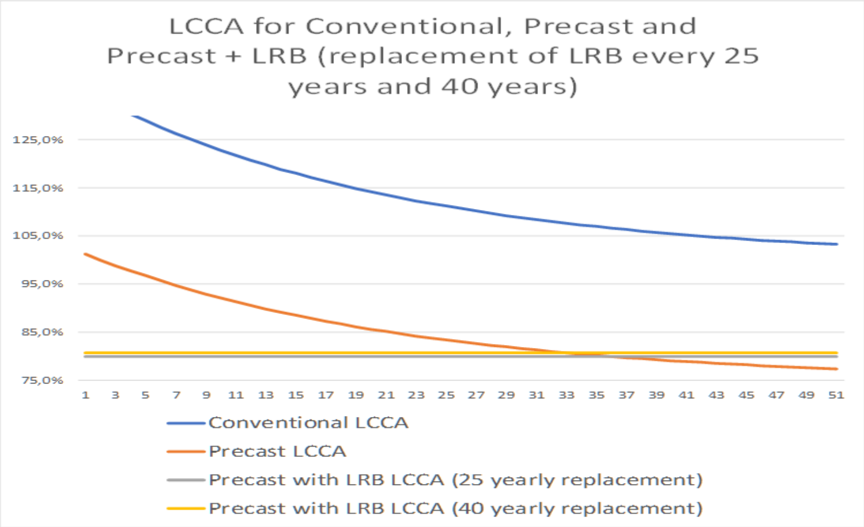

Figure 1: LCCA for Conventional, Precast and Precast + LRB (replacement of LRB every 25 years and 40 years)

Deviation from LCCA Precast and Precast + LRB (replacement of LRB every 25 years and 40 years) against Conventional, it can be seen that with increasing time (getting closer to the 50th year), the deviation value is getting smaller for the three systems, namely Precast and Precast + LRB (Replacement of LRB every 25 years and 40 years) against Conventional.

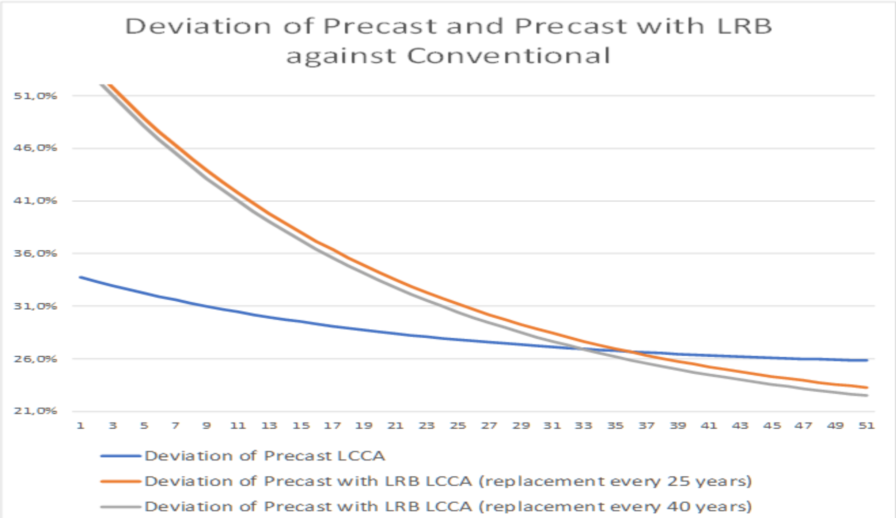

Figure 2: Deviation of Precast and Precast + LRB against Conventional

LCCA Comparison of Precast and Precast + LRB (replacement of LRB every 25 years and 40 years) for Earthquake events from the 1st to the 35th year, the smallest LCCA value is the Precast System + LRB for (Replacement of LRB once every 25 years). For Earthquake events above the 35th year, the smallest LCCA value is the Precast System.

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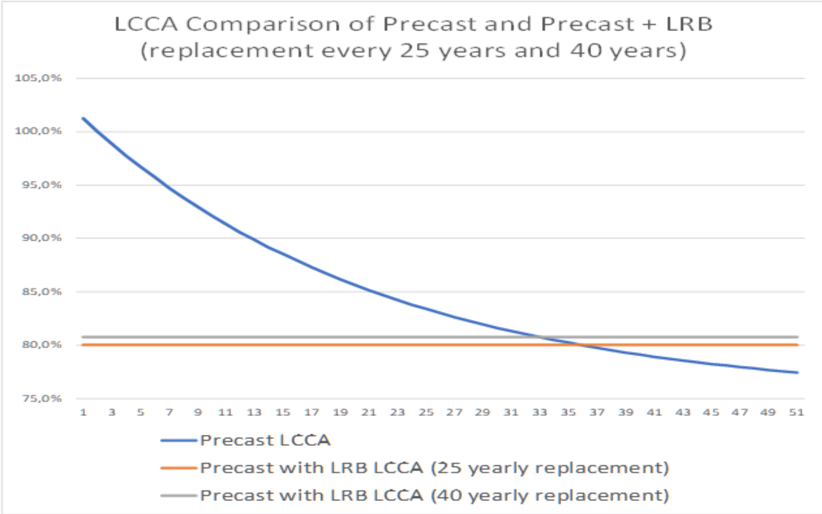

Figure 3: LCCA Comparison of Precast and Precast + LRB (replacement every 25 years and 40 years)

Deviation of Precast + LRB (replacement of LRB every 25 yrs and 40 yrs) against Precast, it can be seen that as time goes on (getting closer to the 50th year) the deviation value gets smaller for the Precast + LRB system (LRB replacement every 25 years and 40 years) against Precast. In fact, the deviation reaches minus for earthquake occurrences over 35 years

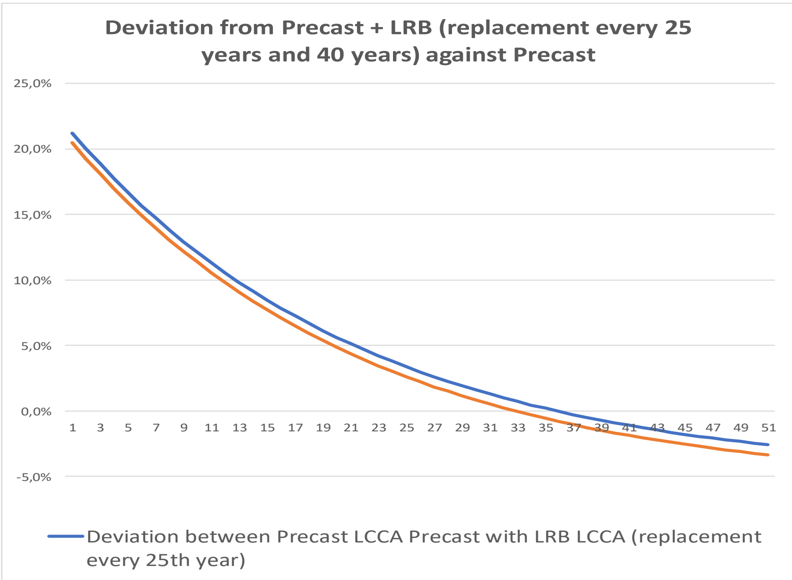

Figure 4: Deviation from Precast + LRB (replacement of LRB every 25 yrs and 40 yrs) against Precast

Price comparison LRB imported products and Indonesian National products, it can be seen that the price of local products is 23% of the price of imported products.

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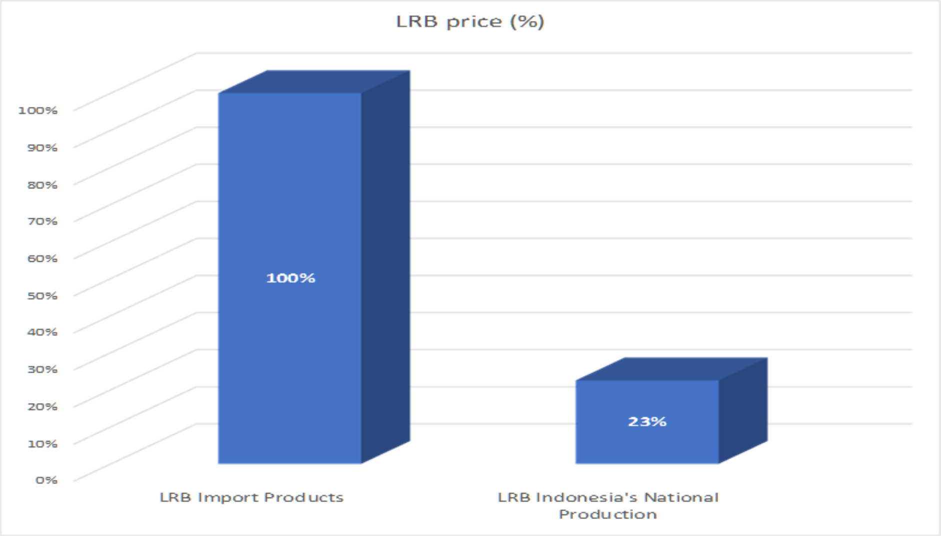

Figure 5: LRB price (%)

CONCLUSION

1. The LCCA comparison between the three systems is that Conventional LCCA is bigger than Precast LCCA and Precast + LRB LCCA
2. In the beginning, Precast LCCA is bigger than Precast + LRB LCCA, and at some point, it will experience the opposite
3. From the deviation of conventional LCCA to LCCA Precast and LCCA from the combination of precast with LRB based on simulations of each earthquake event (from year 1 to 50), it can be seen that each earthquake event affects LCCA deviation in both systems.
4. The earlier the earthquake occurs, the greater the value of the LCCA deviation in the three systems. This means that the use of a combination of precast with LRB will be very profitable or efficient if an earthquake occurs at the beginning of the year.
5. The LCCA deviation value will be close to 0 (zero) if the earthquake occurs in the 32nd year for LRB replacement every 40 years, and the 35th year for LRB replacement every 25 years.
6. If the earthquake occurs over that year (the 32nd or 35th year) or even if no earthquake occurs at all during the life of the building (50 years), the deviation value or efficiency is negative, which means that the LCCA combination of precast + LRB is greater than the precast system but still below the Conventional LCCA value
7. A comparison of LRB prices between imported products and Indonesian national products shows that Indonesian national product prices are cheaper, whereas local product prices are 23% of imported product prices.

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LIMITATION & FURTHER RESEARCH

Calculation of LCCA on high-rise buildings with conventional structures, precast structures, precast structures with LRB (for LRB replacement every 25 years, and replacement every 40 years). The LCC calculation is done by simulating every earthquake that occurs once in a period of 50 years where the possibility of an earthquake can occur in the 1st, 2nd, 3rd year and so on (simulated if it occurs in the 1st to 50th year).

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