Stiffness Test Results of Low Cost Rubber Base Isolator-Strip (LCRBI-S) as Base Isolation in Simple Houses

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ABSTRACT

Indonesia is one of the countries that has a very high seismic area. In the building design standards, several base isolation studies were carried out for residences. The use of base isolation with rubber as the main material and fiber material to strengthen vertical stiffness is applied in the Low Cost Rubber Base Insulator-Strip (LCRBI-S). The use of LCRBI-S with the aim of meeting the criteria of low cost and good performance. In this study uses natural rubber with a hardness of 35 Shore A. The type of fiberglass used as a reinforcing material is Net. Using Chemlok matrix as a fiberglass composite forming. Dimensions LCRBI-S is a square type with a simple housing service load. The stages of testing carried out on the test object include Vertical Stiffness Test end Horizontal Stiffness Test. The results of testing the stiffness value of LCRBI-S samples 1 and 2 are greater than samples 3 and 4, this is because the number of layers of fiberglass reinforcement is more in samples 1 and 2. So to increase the stiffness value of LCRBI-S can be done by increasing the number the reinforcement layer.

KEYWORDS: *Simple house building, Low Cost Rubber Base Insulator-Strip (LCRBI-S), Earthquake zone, Stiffness test.*

Introduction

The need for livable housing increases from year to year in terms of quantity. This needs to be balanced with improving the quality of both the use of materials and existing building construction systems. Considering that Indonesia is one of the countries that has a very high seismicity area [1,2].

In residential buildings, research has been carried out on base isolation in the form of elastomeric insulators, which consist of several layers of rubber and steel or laminated fiber as reinforcement [3,4]. The rubber layer in the isolator has the ability to dampen the horizontal direction during seismic movements because of its low horizontal stiffness so that it can isolate the transmission of earthquake energy from the foundation to the upper structure. Meanwhile, the steel plate or lamina fiber between the rubber layers serves to increase the vertical stiffness of the insulator [5,6]. Some have successfully used laminated fibers to make insulators cheaper [6] and even used recycled rubber from tires or industrial waste [7].

In this research, we use the form of Low Cost Rubber Base Isolator-Strip (LCRBI-S) as an effort to obtain a simple type of home insulator that is optimal both in terms of cost efficiency, construction function, and ease of implementation. The form of the Low Cost Rubber Base Insulator-Strip (LCRBI-S) that will be carried out by the research can be seen in **Figure 1**.

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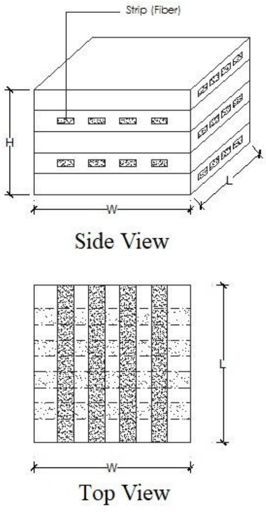


Figure 1. Low Cost Rubber Base Insulator-Strip (LCRBI-S) Plan.

2. Method

A. Creation of LCRBI-S

Details of the material to be used as a constituent of LCRBI-S which consists of 2 types of LCRBI-S, results of material testing.

The rubber used is

Type : CLL (RB 35*)

Tensile Strength : 8.7 Mpa

Elongation at Break : 552 (%)

Hardness : 55 Shore A

(*) Name of manufacturer

Meanwhile Fiberglass

Type : NET

Tensile Strength (Strand) : 1,014.5 Mpa

Strain (Strand) : 3.5 (%)

Tensile Strength (Strand Group) : 1,811.6 Mpa

Strain (Strand Group) : 5.8 (%)

Tensile Strength (Resin Composite, oven 150°C 2 hours) 188.4Mpa

Strain (Resin Composite, oven 150°C 2 hours) 7.6 (%)

Tensile Strength (Chemlok Composite, oven 150°C 2 hours) : 2,695.7Mpa

Strain (Chemlok Composite, oven 150°C 2 hours) : 7 (%)

The procedure for making LCRBI-S with resin matrix composites is;

1. Cutting 1.2 mm thick rubber compound according to the size of the mold, which is 16x16 cm.

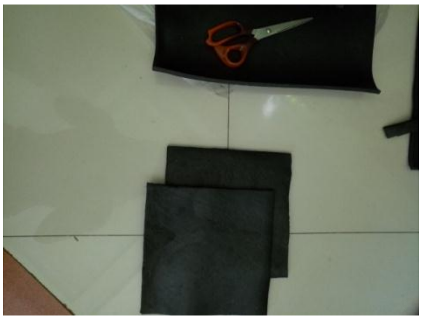


Figure 2. Cutting compound sheet

2. The cut compound sheets are arranged according to the planned rubber layer thickness, namely 5 mm and 10 mm. The layers must be kept clean, including the plastic wrap for the compound to be removed.

Figure 3. Preparation of rubber compound layer thickness

3. Cutting fiberglass, using a type of net that has many holes as a bonding medium between rubber compounds. Cutting with dimensions of 14x14 cm, with the hope that 1 cm around the circumference will occur in compound bonding.

(a) (b)

Figure 4. (a) Fiberglass cutting (b) Fiberglass layer on rubber compound layer

4. Making a composite between fiberglass and Eternal 2504 Resin with mepoxe catalyst [8]. The process of making by hand lay up. The ratio of resin to catalyst is 100 : 1. The hardening time is around 30 minutes to become a composite. The dry composite is ready to be used as a reinforcement layer.

Figure 5. Manufacture of fiberglass composites

5. Arrangement of layers between the rubber compound and the fiber composite as a unit to form LCRBI-S. Before placing it on the mold, its weight is weighed as a reference for subsequent production.

Figure 6. Weighing of rubber layers and fiberglass composites

6. The steel plate used as the top and bottom of LCRBI-S is ground on the part affected by the rubber compound so that it is clean from the iron surface with the aim of providing bonding strength of the rubber to the iron plate. Then the part is given chemlock until dry and repeated up to 2 times.

(a) (b)

Figure 7. Preparation of steel plate (a) With grinding (b) Applying Chemlock

7. The process of warming up the LCRBI-S making machine before use takes 2 hours to reach a constant temperature of 150°C. Apart from that, the LCRBI-S mold was tested by applying water droplets until an estimated temperature of 150°C had reached the mold so that it was ready to insert the base isolation material.

Figure 8. Heating the oven machine to a temperature of 150°C

8. Installation of the bottom steel plate on the LCRBI-S mold. In this process, double gloves are used to avoid the hot touch of the mould.
9. The process of arranging rubber and fiberglass compound layers according to the plan on the mold. In this process, rubber and fiberglass compounds are added up to 2.5 cm from the height dimension to obtain LCRBI-S quality which is solid and not hollow.
10. Installation of top steel plate as cover for LCRBI-S.
11. LCRBI-S press process until the surface of the top steel plate touches the top of the 12 cm high mold. This process is characterized by the release of air and rubber from the middle of the four surfaces of the mold.
12. The LCRBI-S oven process is carried out for 2 hours at a constant temperature of 150°C. The rubber compression process ends when the rubber stops coming out of the hole in the middle of the side of the mold.
13. Disassembly of the LCRBI-S mold is carried out waiting for the mold to cool so that the melted resin hardens again.

LCRBI-S uses Chemlock without resin

While the procedure for making LCRBI-S with a chemlock matrix composite is as follows;

1. Cutting 1.2 mm thick rubber compound according to the size of the mold, which is 16x16 cm. The cut compound sheets were arranged according to the planned rubber layer thickness, namely 5 mm and 10 mm. The layers must be kept clean, including the plastic wrap for the compound to be removed. For cutting fiberglass, a Net type is used which has many holes as a bonding medium between rubber compounds. Cutting with dimensions of 14x14 cm, with the hope that 1 cm around the compound will stick together. Composite manufacture between fiberglass and Chemlock. The process of making by hand lay up. The setting time is around 15 minutes to become composite. The dry composite is ready to be used as a reinforcement layer. Arrangement of layers between the rubber compound and the fiber composite as a unit to form LCRBI-S. Before placing it on the mold, its weight is weighed as a reference for subsequent production. The steel plate used as the top and bottom of the base isolation is ground on the part affected by the rubber compound so that it is clean from the iron surface with the aim of providing bonding strength of the rubber to the iron plate. Then the part is given chemlock until dry and repeated up to 2 times. The process of heating the LCRBI-S making machine before use takes 2 hours to get a constant temperature of 150°C. Apart from that, the LCRBI-S mold was tested by applying water droplets until an estimated temperature of 150°C had reached the mold so that it was ready to insert the LCRBI-S material.
2. Installing the bottom steel plate on the LCRBI-S mold. In this process, double gloves are used to

avoid the hot touch of the mould.

3. The process of arranging the rubber and fiberglass compound layers according to the plan on the mold. In this process the rubber and fiberglass compound is increased by 2.5 cm from the dimensional height to obtain a quality base isolation that is solid and not hollow.
4. Installation of the top steel plate as a cover for the LCRBI-S.
5. Press the LCRBI-S until the surface of the top steel plate touches the top of the 12 cm high mold. This process is characterized by the release of air and rubber from the middle of the four surfaces of the mold.
6. The LCRBI-S oven process is carried out for 2 hours at a constant temperature of 150°C. The rubber compression process ends when the rubber stops coming out of the hole in the middle of the side of the mold.
7. Disassembly of the LCRBI-S mold can be done immediately without waiting for the mold to cool.

The results of the LCRBI-S molding process can be seen in Figure 9. LCRBI-S using the Eternal 2504 resin composite could not be tested because 2 of the 3 LCRBI-S samples were imperfect. This is due to the Eternal 2504 resin melting during the oven process at a temperature of 150°C at the same time as the pressing process. Returning to normal temperature does not make the composite bond perfectly with the rubber material [9,11] so that the LCRBI-S results show that some of the layers have come off. This is different when the Eternal 2504 resin composite with fiberglass is baked in an oven at 150°C for 2 full hours which does not melt.

(a) (b)

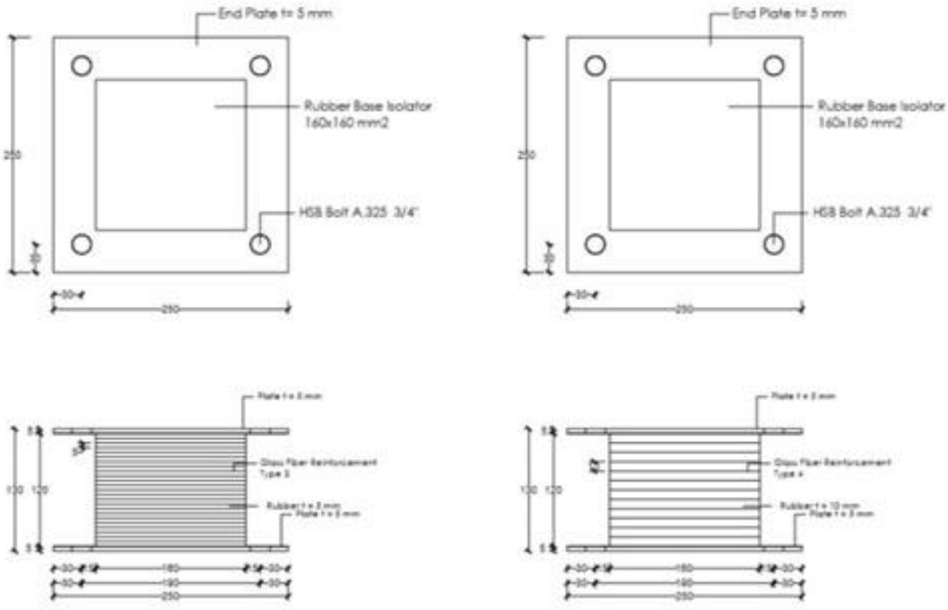
Figure 9. LCRBI-S with fiberglass reinforcement and Eternal 2504 resin (a) Sample 1, (b) Sample 2

Meanwhile, LCRBI-S is a result of fiberglass composite with chemlok, perfect bonding can occur (**Figure 10**).

Figure 10. LCRBI-S with fiberglass and Chemlock reinforcement

B. LCRBI-S Testing Process

Tests were carried out on 4 square LRCBI-S samples with differences in the number of layers and composition of reinforcement type.



(a) (b)

Figure 11. Dimensions of square LCRBI-S with different number of layers of reinforcement and thickness of rubber, (a) Sample 1 and sample 2, (b) Sample 3 and sample 4

The LCRBI-S test method uses the requirements of BS EN 15129-2009 to determine the horizontal stiffness value of base isolation and BS-EN-1337-3-2005 to determine the vertical stiffness value of base isolation.

Vertical Testing (Axial Force)

In vertical testing the sample will be tested in the vertical direction with load control. The samples were loaded with vertical forces up to 50 kN. The concept of setting up testing equipment is in accordance with **Figure 12**.

Figure 12. Axial Test

Combination Testing (Axial Force and Lateral Force)

Horizontal tests were carried out under constant axial load and horizontal displacement control. Initially, the samples were subjected to a constant vertical load of up to 50kN. At the same time, the vertical load is held constant and then the specimen is deformed in cyclic shear with three fully reversed cycles at specified strain levels of 25%, 50% and 75% (based on a rubber thickness of 120 mm). The loading set up of the horizontal test is illustrated in **Figure 13**.

(a) (b)

Figure 13. Lateral Test (a) Sample of test object, and (b) Process of setting the test object

(a) b)

Figure 14. Lateral Test (a) axial loading, and (b) lateral loading

3. Results and Discussion

The test results from this study were in the form of displacements from sample 1, sample 2, sample 3, and sample 4 for both vertical and horizontal loads.

Vertical Test Results (Axial Force)

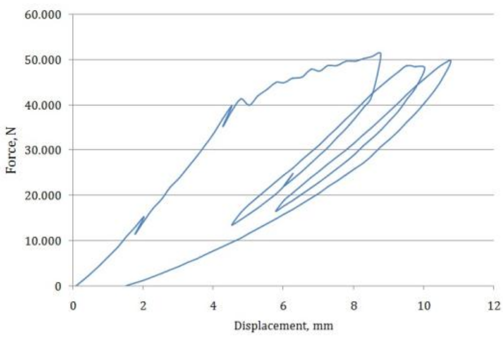


Figure 15. Vertical Test Output (Force-Displacement) Sample 1.

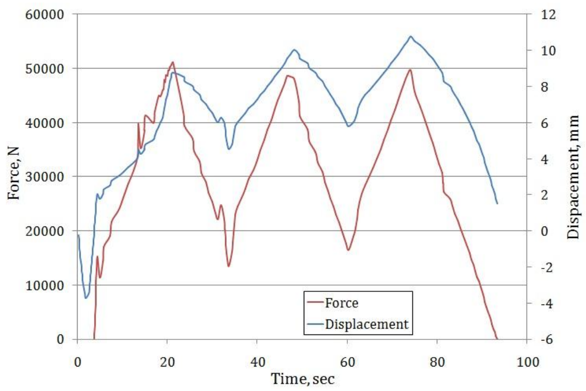


Figure 16. Vertical Test Output (Force-Time-Displacement) Sample 1.

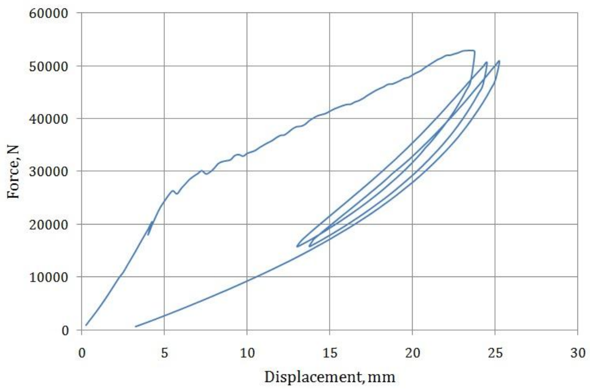


Figure 17. Vertical Test Output (Force-Displacement) Sample 3.

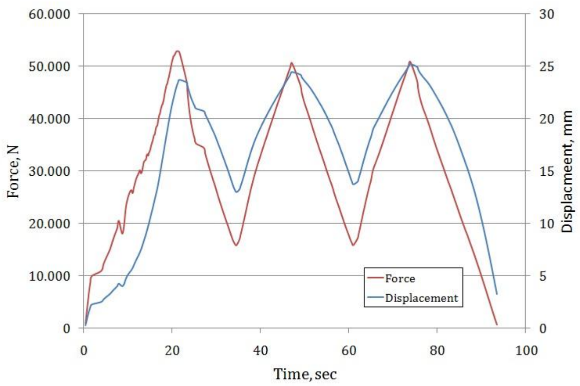


Figure 18. Vertical Test Output (Force-Time-Displacement) Sample 3.

Combination Test Results (Axial Force and Lateral Force)

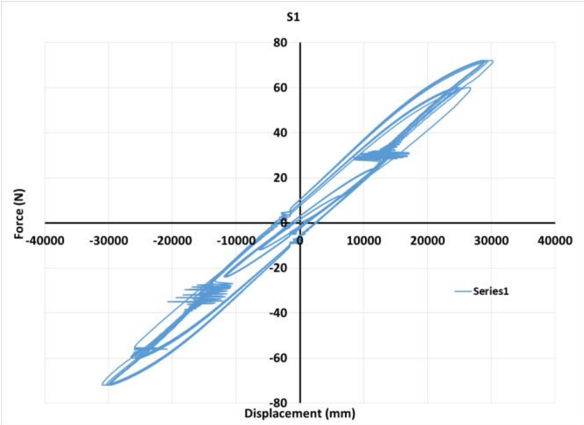


Figure 19. Lateral Test Output (Force-Displacement) for sample 1

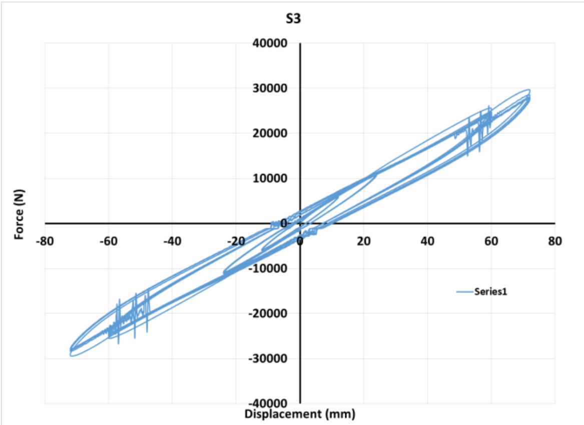


Figure 20. Output of Lateral Test (Force-Displacement) sample 3

Stiffness Results from Vertical Testing

Table 1. Vertical Stiffness of Sample 1

No	Load Control (N)	Kv min (N/mm)	Kv max (N/mm)	Kv average (N/mm)
1	10,000	2,872.99	9,241.65	6,057.32
2	20,000	3,846.65	10,170.76	5,337.04
3	30,000	4,590.86	10,879.62	6,345.38
4	50,000	-	-	8,138.19
5	51,167(Max.)	-	-	7,743.22

Table 2. Vertical Stiffness of Sample 3

No	Load Control (N)	Kv min (N/mm)	Kv max (N/mm)	Kv average (N/mm)
1	10,000	1,160.29	5,897.19	2,774.15
2	20,000	1,613.44	6,416.49	2,505.35
3	30,000	1,923.99	5,572.56	2,995.31
4	50,000	2,662.44	3,184.48	2,849.35
5	52,954(Max.)	-	-	2,995.88

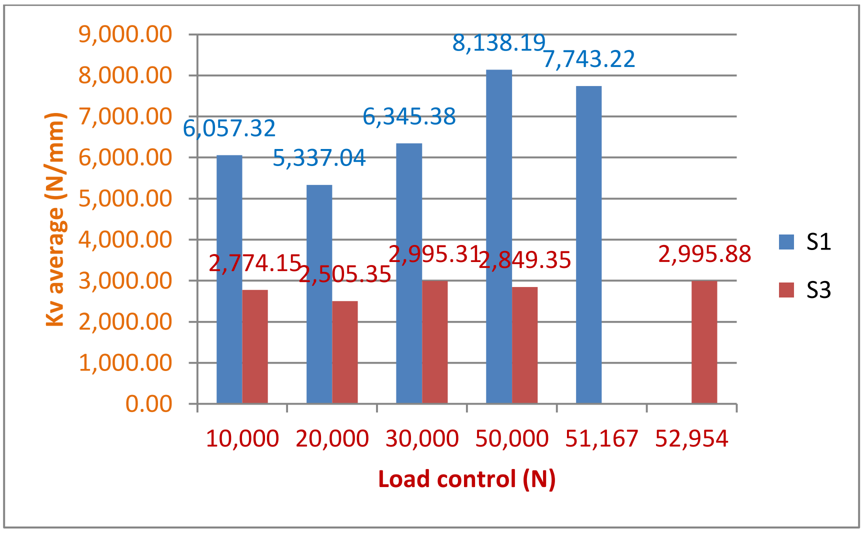


Figure 21. Comparison graph of average Kv based on load control for Sample 1 and Sample 3

Figure 21 shows that Sample 1 obtained a much greater average vertical stiffness for each load control carried out. At a control load of 50,000 N, Sample 1 produced an average Kv of 8,138.19 N/mm, while Sample 3 had a value of 2,849.35.

Stiffness Results from Lateral Testing

Table 3. Horizontal Stiffness of Sample 1 and Sample 2

No	Strain Level	Diplacement(Δx) (mm)	Kh min (N/mm)	Kh max (N/mm)	Kh average (N/mm)
1	10%	12	108.77	692.29	441.12
2	20%	24	252.76	557.91	420.23
3	50%	60	410.32	443.72	425.47
4	60%	72	398.99	429.47	413.50

Table 4. Horizontal Stiffness of Sample 3 and Sample 4

No	Strain Level	Diplacement(Δx) (mm)	Kh min (N/mm)	Kh max (N/mm)	Kh average (N/mm)
1	10%	12	151.48	608.29	426.39
2	20%	24	263.28	514.21	389.22
3	50%	60	403.29	425.15	413.59
4	60%	72	384.67	411.56	394.86

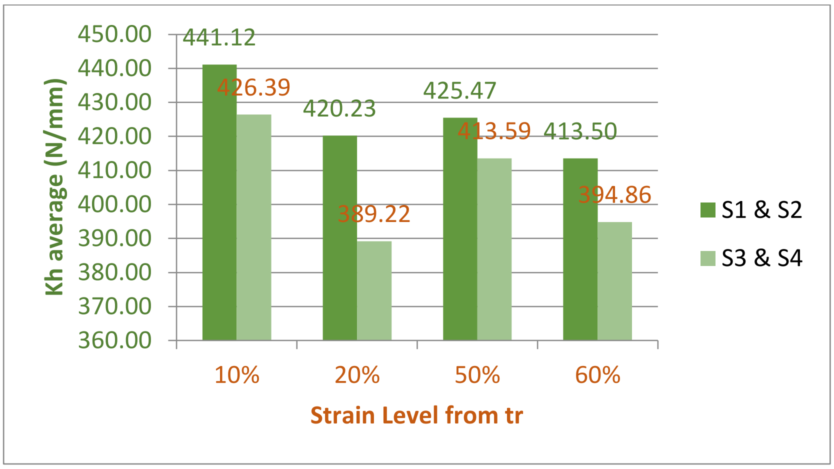


Figure 22. Comparison graph of average Kh based on strain level and rubber thickness

Based on **Figure 22**, Sample 1 and Sample 2 have a larger average Kh at each strain level review. At a strain level of 10%, Sample 1 and Sample 2 produce an average stiffness of 441.12 N/mm compared to Sample 3 and Sample 4 at a value of 426.39 N/mm.

4. Conclusion

This research produces several conclusions about Low Cost Rubber Base Isolator-Strip (LCRBI-S), Base isolation in simple houses, including;

1. Vertical test results on the LCRBI-S sample show that sample 1 has a much greater average vertical stiffness at each load control carried out. At a load control of 50,000 N, Sample 1 produces an average Kv of 8,138.19 N/mm, while Sample 3 has a value of 2,849.35 N/mm. The results of the lateral test on the LCRBI-S sample, Sample 1 and Sample 2 had a higher average Kh at each strain level review. At a strain level of 10%, Sample 1 and Sample 2 produce an average stiffness of 441.12 N/mm compared to Sample 3 and Sample 4 at a value of 426.39 N/mm. So it was found that samples 1 and 2 had a vertical stiffness value of 15 times the horizontal stiffness value and samples 3 and 4 had a vertical stiffness value of 7 times the horizontal stiffness value.
2. The stiffness value of LCRBI-S samples 1 and 2 is greater than samples 3 and 4, this is because the number of layers of fiberglass reinforcement is greater in samples 1 and 2. So to increase the stiffness value of LCRBI-S it can be done by increasing the number the reinforcement layer.
3. LCRBI-S is worth testing on simple house buildings with further research to test performance with structural analysis support programs.

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