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Split Tensile Strength of Self Compacting Concrete with Artificial Lightweight Aggregate

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A B S T R A C T

Earthquake damage to buildings is directly proportionate to the weight of the structure. Self compacting concrete is a type of concrete that can consolidate without the use of vibrator. To minimize damage structures caused by earthquakes, infrastructure development needs lighter materials and superior workmanship. Lightweight aggregate can reduce weight of the structure, SCC with ALWA is a solution to reduce dead load of the structure with ease of execution. The purpose of this study is to see how much the split tensile strength influences the composition of ALWA as coarse aggregate substitute in Normal Concrete and SCC. The proportions of ALWA that substituted into concrete were 0%, 15%, 50% and 100%. There are 24 cylindrical specimens, each measuring 100 mm in diameter and 200 mm in height. The analysis was carried out using ASTM C 496/C 496M. The results of split tensile strength show that the higher variation in the composition of ALWA, the lower split tensile strength produced. The addition of ALWA as a substitute for coarse aggregate in a mixture of normal and SCC concrete was most effective at 15% ALWA with a split tensile strength of normal concrete 2.23 MPa and SCC 2.32 MPa.

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1. Introduction

Concrete with lightweight aggregates is a great way to lower a structure's dead load, whereas self compacting concrete (SCC) is a concrete mixture that does not require the use of compactors or vibrator machines. Because it becomes more cost effective and can minimize processing time, the combination of lightweight aggregate concrete and self compacting concrete delivers advantages in terms of cost and building time [1].

The coarse aggregate in this research was created from a styrofoam and acetone mixture, which was subsequently molded into granules and mortar coated. Artificial lightweight aggregate is one of the main aspects that might affect concrete's tensile strength, which is why researchers are investigating the effect of using artificial lightweight aggregate made of styrofoam on split tensile strength of self compacting concrete.

Styrofoam

Styrofoam has begun to be used in lightweight concrete for structural purposes, such as columns, beams, and plates [2]. Where structural lightweight concrete must not exceed 1840 kg/m3 in weight and must conform to the standards for compressive strength and split tensile strength of lightweight concrete for structural purposes. Building constructions designed to withstand earthquakes should have a minimum compressive strength of 20 MPa [3].

Artificial Lightweight Aggregate (ALWA)

The artificial lightweight aggregate component has a significant impact on the compressive strength of self-compacting mortars. Increased artificial lightweight aggregate content resulted in a decrease in compressive strength. However, at the 3-day, 7-day, 28-day, 56-day, and 90-day mortar ages, decreasing the w/b ratio significantly increased the compressive strength values [4].

The effect of adding styrofoam to lightweight concrete with toluene solvents on compressive strength and modulus elasticity. The concrete used was low-quality concrete K175 with a 1:2:3 cement: sand: gravel ratio and a FAS of 0.5. With toluene solvents, the styrofoam composition varied by 0%, 12%, 14%, 16%, 18%, and 20% from the weight of gravel utilized in this investigation. According to the test findings, the minimum concrete press strength was 16.6 MPa when styrofoam 20% with Toluene solvent was used, and the maximum concrete compressive strength was 23.1 MPa when styrofoam 12 percent with Toluene solvent was added [5].

Split Tensile Strength of Concrete Cylinder

Concrete with a mixture of crumb rubber and tile fragments produces split tensile strength from 1.5 MPa to 2.1 MPa. The relationship between split tensile strength (fct) and compressive strength fc' of concrete with a mixture of crumb rubber is obtained by the equation fct = 0.445 $\sqrt{fc'}$ MPa [6].

Tensile strength testing is conducted based on ASTM C 496/C 496M – 11 [7]. A compression testing machine (CTM) is used in this test. The P compressive load is applied evenly across the whole height of the cylinder using a concrete cylinder test object with diameter of 100 mm and height of 200 mm, that is set in an elongated direction above the CTM test equipment. If the tensile strength of the test object is surpassed, it will be broken in half from end to end. The following equation is used to compute the magnitude of the tensile strength:

$$\text{ft} = \frac{2P}{\pi LD} \tag{1}$$

In eq:
ft = split tensile strength (MPa)
P = maximum load (N)
L = length of cylindrical test object (mm)

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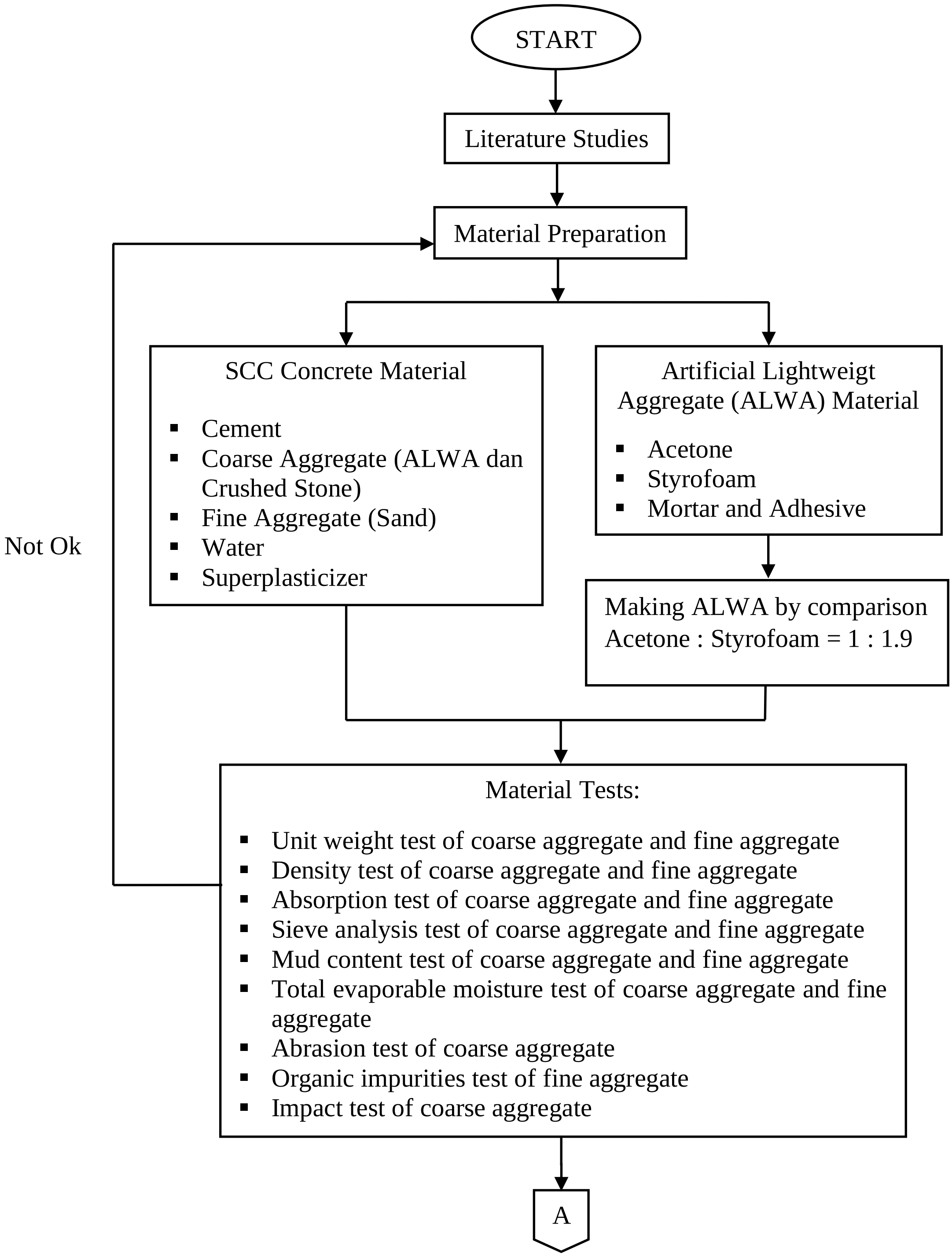
D = diameter of the cylinder test object (mm)

2. Research Method

In this research, the specimens used for split tensile strength tests were the concrete cylinders with the diameter of 100 mm and the height of 200 mm as many. Twelve cylinders of normal concrete and twelve cylinders of SCC were prepared and they were cured until 28 days of age before the tests. The fresh concrete test for normal concrete is the slump test, whereas for SCC, it consists of the flow, T500 slump time, V-funnel, and L-box tests. Testings of split tensile of concrete were performed based on the ASTM C 496/C 496M – 11 using a Compression Testing Machine [7]. For each composition, i.e. 0%, 15%, 50%, and 100% ALWA replacement, used three cylinder specimens to provide the representative average values.

Research Flow

The following are stages of the research carried out from beginning to end which are described in **Figure 1.**



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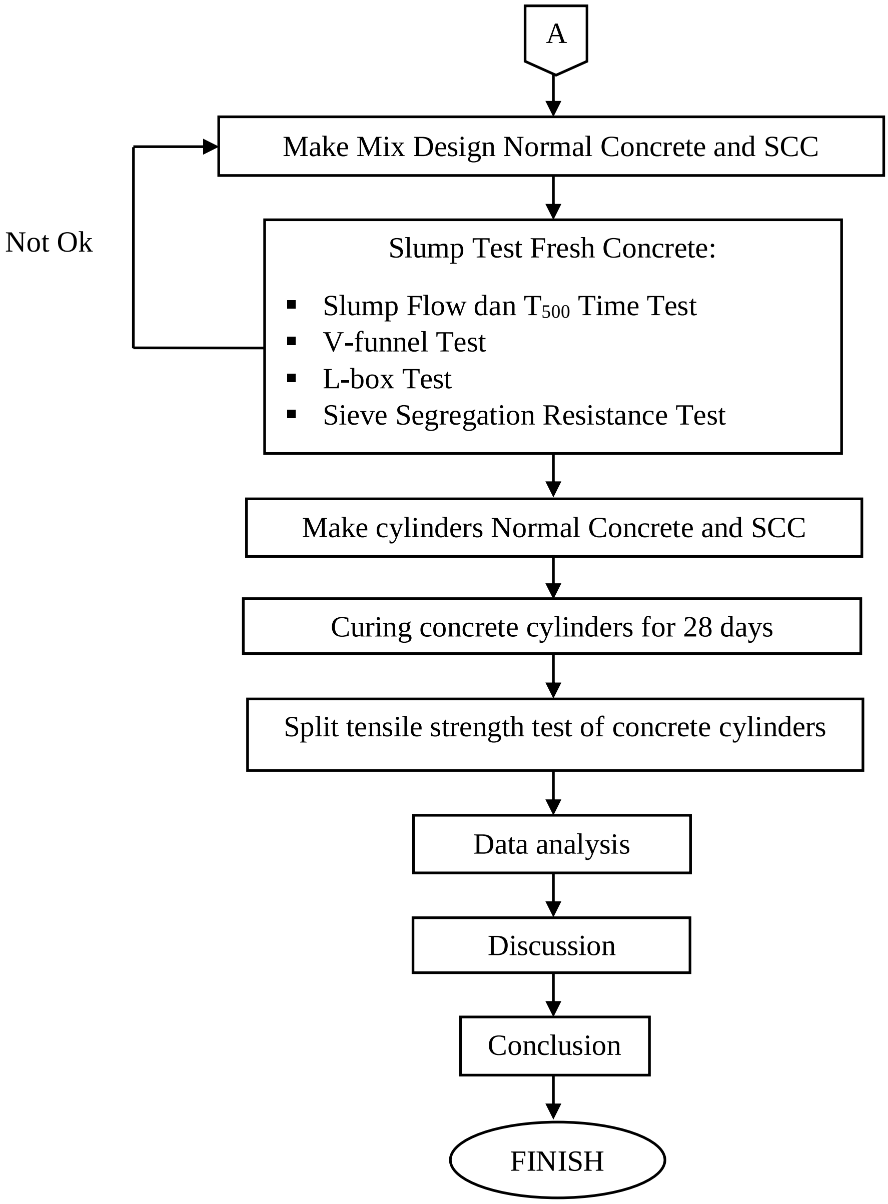

Figure 1. Research Flow

3. Description and Technical

3.1 Materials

A. Cement

The selected cement is well sealed with no visible clumping, and the package is undamaged. The grain material is smooth with no visible clumping. The cement used in this study is Portland Cement type I produced by PT. Gresik cement.

B. Coarse Aggregate

1. Artificial Lightweight Aggregate (ALWA)

In this study, the artificial light aggregate (ALWA) used is based on styrofoam, acetone, and mortar. The ratio of the mixture of acetone and styrofoam is 1:1.9. After the alwa granules so then coated with mortar with a ratio of sand : cement : water : adhesive is 1 : 1 : 0.25 : 0.025. For the display of Artificial Lightweight Aggregate (ALWA) that has been coated by mortar can be seen in **Figure 2.**

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(a) pre-coated (b) post-coated

Source: Varia Usaha Beton Laboratory

Figure 2. Artificial Lightweight Aggregate Coated by Mortar

2. Crushed Stone

Crushed stone is the coarse aggregate used in the construction of this concrete. Natural aggregate such as crushed stone is one type of aggregate. The crushed stone used in this study is derived from Paserpan.

C. Fine Aggregates

Fine aggregate is natural sand produced by the stone crushing industry as a natural disintegration of rock or sand with the greatest grain size of 5 mm. The fine aggregate used in this study is sand that comes from Lumajang.

D. Water

The water was not tested in a laboratory, but it appeared to be clean enough to be utilized as a concrete building ingredient. The water used comes from the Varia Usaha Beton Laboratory's network of clean water sources.

E. Superplasticizer

Superplasticizer can improve the quality of concrete due to reduced water usage so that the cement water factor becomes lower with increased slump. The superplasticizer mixture used is viscoflow type derived from PT. Sika Indonesia.

3.2 Specimens Object

The specimens object in this study was a cylinder with a diameter of 100 mm and a height of 200 mm that was utilized to measure split tensile strength. Three regular concrete specimens and SCC were used for each mixture of 0%, 15%, 50%, and 100% ALWA content, for a total of 24 test specimens. The number of test specimens can be seen in **Table 1.**

Table 1. Number of Test Specimens

ALWA	Split Tensile	
(%)	Normal Concrete (C)	Self Compacting Concrete (SCC)
0	3	3
15	3	3
50	3	3
100	3	3
Total	12	12

Source: Research Data

with:

C0 = normal concrete without ALWA
C15 = normal concrete with ALWA 15%
C50 = normal concrete with ALWA 50%
C100 = normal concrete with ALWA 100%
SCC0 = self compacting concrete without ALWA

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SCC15 = self compacting concrete with ALWA 15%
SCC50 = self compacting concrete with ALWA 50%
SCC100 = self compacting concrete with ALWA 100%

4. Results and Discussions

Impact Test of Crushed Stone and Artificial Lightweigt Aggregate

The impact value of this crushed stone has met the requirements of British Standard 812-112 where the impact value should not be more than 30%. The results of the impact test of crushed stones can be seen in the table below.

Table 2. Impact Result Data in Crushed Stone

No.	Check	Symbol	Unit	Test 1	Test 2	Average
1.	Sample weight before test	M_1	(gr)	647	655	651
2.	Sample weight after test	M_2	(gr)	75	73	74
3.	Aggregate Impact Value	(M_2/M_1) x 100	(%)	11.6	11.1	11.4

Source: Analysis Result

From **Table 2.** can be seen the samples used in this test were aggregates that passed 14 mm and held 10 mm. From the test results obtained crushed stone impact value of 11.4%. For impact result data in Artificial Lightweight Aggregate (ALWA) using Styrofoam shown in the table below.

Table 3. Impact Result Data in ALWA

No.	Check	Symbol	Unit	Test 1	Test 2	Average
1.	Sample weight before test	M_1	(gr)	454	463	458.5
2.	Sample weight after test	M_2	(gr)	112	112	112
3.	Aggregate Impact Value	(M_2/M_1) x 100	(%)	24.7	24.2	24.4

Source: Analysis Result

From **Table 3.** the test results obtained an ALWA impact value of 24.4%. This ALWA impact value meets the requirements of British Standard 812-112 where the impact value must be less than 30%.

Split Tensile Strength Test

The split tensile strength value is obtained by testing the compressive on the cylinder laterally up to its maximum strength. The results of all test objects of split tensile strength on concrete can be seen in the table below:

Table 4. Split Tensile Strength Test Result Data in Normal Concrete.

No.	Specimen	Specimen Height (mm)	Specimen Diameter (mm)	Maximum Load (kN)	Split Tensile Strength (MPa)
1.	C0-1			77	2.45
2.	C0-2	200	100	79	2.51
3.	C0-3			79	2.51
1.	C15-1			68	2.16
2.	C15-2	200	100	70	2.23
3.	C15-3			72	2.29
1.	C50-1			69	2.20
2.	C50-2	200	100	66	2.10
3.	C50-3			58	1.85
1.	C100-1			38	1.21
2.	C100-2	200	100	39	1.24
3.	C100-3			46	1.46

Source: Analysis Result

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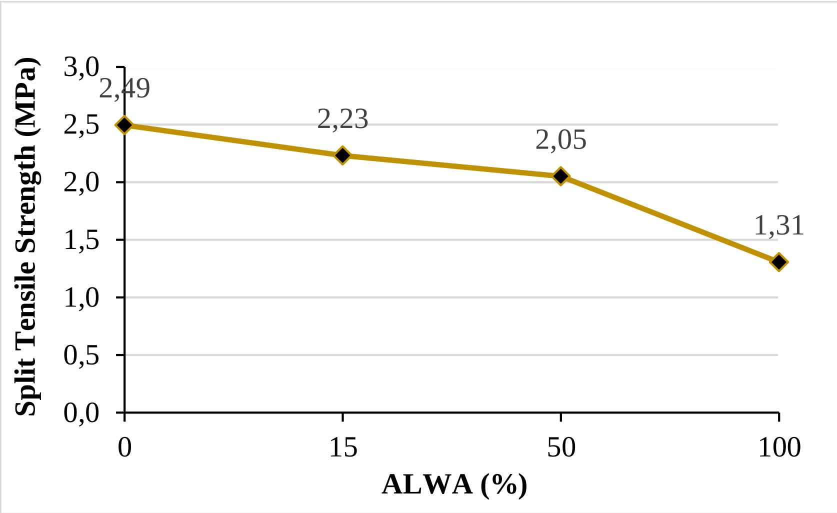
The relationship between average value splite tensile strength normal concrete and the percentage ALWA replacement can be seen in **Figure 3**.



Source: Analysis Result

Figure 3. Graph of The Relationship between Average Value Splite Tensile Strength Normal Concrete and the percentage ALWA replacement

Figure 3. indicates that the highest strength of the split tensile occurs in ALWA level 0% with a split tensile value of 2.49 MPa. At the addition of 15% ALWA can reduce the split tensile strength 0.26 MPa or 10.64%. The all test objects split tensile strength result on Self Compacting Concrete can be seen in the table below:

Table 5. Split Tensile Strength Test Result Data in Self Compacting Concrete.

No.	Specimen	Specimen Height (mm)	Specimen Diameter (mm)	Maximum Load (kN)	Split Tensile Strength (MPa)
1.	SCC0-1			85	2.71
2.	SCC0-2	200	100	109	3.47
3.	SCC0-3			79	2.51
1.	SCC15-1			73	2.32
2.	SCC15-2	200	100	70	2.23
3.	SCC15-3			76	2.42
1.	SCC50-1			70	2.23
2.	SCC50-2	200	100	67	2.13
3.	SCC50-3			69	2.20
1.	SCC100-1			57	1.81
2.	SCC100-2	200	100	61	1.94
3.	SCC100-3			58	1.85

Source: Analysis Result

From the **Table 5.** it can be seen that in addition to 15% ALWA can reduce the split tensile strength 0.58 MPa or 19.78%. The higher amount of ALWA substituted into self compacting concrete, the lower split tensile strength value. For a graph the relationship between average value splite tensile strength self compacting concrete and the percentage ALWA replacement can be seen in figure below.

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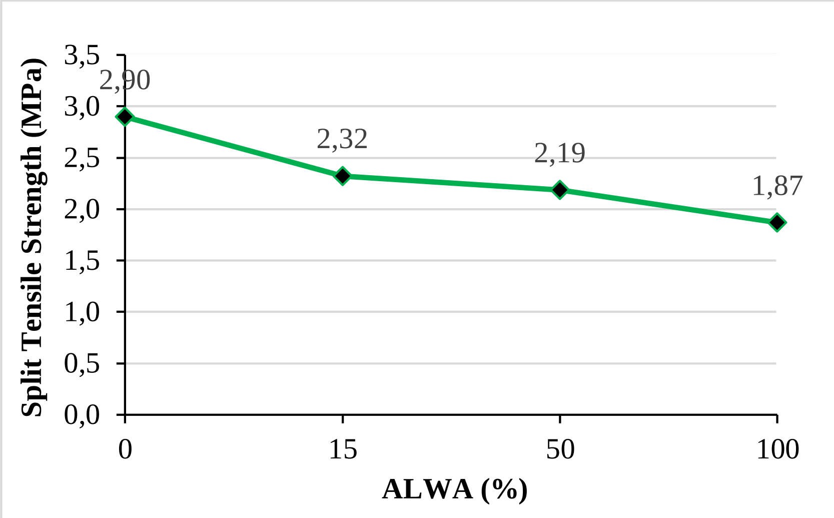

Source: Analysis Result

Figure 4. Graph of The Relationship between Average Value Splite Tensile Strength Self Compacting Concrete and the percentage ALWA replacement

From **Figure 4.** can be seen each addition of ALWA by 0%, 15%, 50%, and 100% results in a significant loss in split tensile strength. Split tensile strength produced 2.90 MPa, 2.32 MPa, 2.19 MPa, and 1.87 MPa in that sequence. This decrease occurs because ALWA's smooth and watertight surface causes poor adhesion to the paste, resulting in ALWA not cracking when the cylinder is split, as seen in the following figure.

C100-1 SCC100-1

Source: Varia Usaha Beton Laboratory

Figure 5. Visual Viewed ALWA after Split Tensile Test

Figure 5. shows the surface of the C100-1 and SCC100-1 test specimen sides after splitting. The most of the ALWA that was substituted into concrete did not shatter but only detached from the concrete, as shown in the image. Unlike crushed stone used in concrete, crushed stone will break after the cylinder is broken.

5. Conclusion and Suggestion
5.1 Conclusion

From the results of study, the followings conclusions can be drawn:

1. Split tensile strength on normal concrete and SCC decreases along with the increase in the amount of ALWA used. The replacement of coarse aggregates on normal concrete and SCC produces the highest split tensile strength at the addition of

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ALWA 15% with the split tensile of normal concrete in 2.23 MPa and at SCC in 2.32 MPa.

2. The higher amount of ALWA, the lower volume weight and split tensile strength in the normal concrete and SCC.

5.2 Suggestion

Based on the research that has been done, the advice that can be obtained for the next researcher is as follows:

1. More research is needed to find out ALWA characteristic frame and shrink test.
2. Water catchment testing is necessary against ALWA coating.

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