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Analysis of The Substitution of Coconut Shell Ash and Glass Powder in Cement Mixtures with Sikafume Additives on The Compressive Strength of Concrete

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ABSTRACT

This research uses coconut shell ash and glass powder to replace part of the cement aims to find out the compressive strength value of concrete and also the value of water absorption. The use of coconut shell ash as much as 5%, 7% and 9% and glass powder as much as 10% of the weight of cement. And also use additive Sikafume as much as 5% of the weight of concrete. For Normal Concrete, the compressive strength value is 12.39 MPa and the water absorption value is 1%. For the compressive strength value of concrete variation BAS1 with 5% ATK is equal to 11.44 MPa and 1.35% absorption, BAS2 with 7% ATK of 10.32 MPa 1.38% absorption, BAS3 with 9% ATK of 7.50 MPa and 1.38% absorption, BAS4 with 5% ATK with 5% Sikafume of 10.32 MPa and 1.22% absorption, BAS5 with 7% ATK with 5% Sikafume of 10.32 MPa and 1.24% absorption, BAS6 with 9% ATK with 5% Sikafume of 8.82 MPa and 1.37% absorption. The optimal concrete compressive strength value is in the BAS1 variation od 11.44 MPa and the optimal water absorption is in the BAS4 variation of 1.22%. from the results of tis study, it can be seen that the more coconut shell ash used, the lower the compressive strength of concrete and the more water absorbed. This is because coconut shell ash in fine form reacts with free lime $Ca(OH)_2$ and water into a solid mass that is insoluble in water, namely CSH and CAH.

Keywords: Coconut Shell Ash, Glass Powder, Compressive Strength, Absorption, Additives.

Introduction

Portland cement, water, fine aggregate, and coarse aggregate are the primary constituents of concrete. In order to decrease the waste of glass and coconut shells, as well as the financial impact of using cement exclusively in the concrete mixture, glass powder and coconut shell ash are added to the cement mixture.

So far, broken glass has been considered household waste or garbage and is rarely used. Glass is a clear and transparent solid material that is usually fragile and is obtained from broken glass that is no longer used. The glass in question can be interpreted as a material that has a high silica chemical content and has a specific gravity of 2560 kg/m3 and is made of 75% silicon dioxide (SiO2), (Na2O), (CaO) and several additional substances [1]. While

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glass powder is glass that is ground by pounding and then sifted with a sieve.

Indonesia is known as a country rich in natural resources that can be utilized. Indonesia's natural wealth is filled with various types of plants, one of which is coconut, where the fruit is usually used for food and the shell is used for burning. Based on data from the Indonesian Ministry of Agriculture, coconut productivity in Indonesia was 2,920,665 in 2015 [2].

Thus, the purpose of this study is to ascertain whether glass powder and coconut shell ash may be combined to create concrete that is resistant to absorption. and whether adding glass powder and coconut shell ash to concrete can improve its compressive strength.

When it comes to building construction, the components of concrete—hydraulic cement, also known as Portland cement, water, coarse and fine aggregate, and additives—play a crucial role. [3], often with admixture or additive added if needed. With age, the concrete will also harden until after 28 days, it reaches the design strength (fc).

To create a solid, sturdy, and stable mass, concrete is made of Portland cement or another hydraulic cement, fine and coarse aggregate, water, and optional additives. As a construction material, concrete has advantages. The advantages of concrete include [4]:

a. Can be easily formed according to construction needs.
b. Able to bear heavy loads.
c. Resistant to high temperatures.
d. Low maintenance costs.

On the other hand, concrete also has disadvantages. The disadvantages of concrete include:

a. The shape that has been made is difficult to change.
b. The implementation of work requires high precision.
c. Heavy.
d. High sound reflection power.

Concrete content can be classified into three general categories [5], namely:

a. Lightweight Concrete.
   Lightweight concrete weighs 1800 kg/m3. In this concrete, there are many aggregates that are applied, for example synthetic aggregates that are processed or formed so that their mechanical characteristics change.
b. Normal Concrete.
   Concrete weighs 2200 – 2500 kg/m3 and contains sand, natural gravel and crushed stone as aggregate.
c. Heavy Concrete (Heavy Weight Concrete).
   This concrete is always used as protection against radiation weighing >3200 kg/m3.

Coconut shell is a part of the coconut fruit that functions to cover the flesh of the coconut fruit, where this coconut shell is waste around us that is rarely used in concrete work but is more often used as cooking fuel. Coconut shells are still not widely utilized compared to other parts of the fruit. Although a small part has been used as charcoal and coconut flour. Coconut shells are included in the hardwood group, which chemically has a composition that is almost similar to wood [6].

Figure 1. Coconut Shell Ash [6]

Asahan Regency is one of the plantation centers in North Sumatra. Important commodities produced by plantations in Asahan Regency are rubber, palm oil, cocoa and coconut. Coconut production in Asahan in 2020 reached 23,260.86 tons with a planted area of 22,070.66 hectares. Silau Laut, Sei Kepayang, Tanjung Balai and Sei Kepayang

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Timur Districts are the largest coconut producers in Asahan [7].

The chemical content contained in coconut shell ash is as follows:

Table 1. Coconut shell content [8]

Chemical composition	(%)
Cellulose	26,60
Pentosan	27,70
Lignin	29,40
Ash	0,60
Extractive Solvent	4,20
Uronate Anhydrous	3,50
Nitrogen	0,11
Water	8,00

Glass is a clear and transparent solid material that is usually easily broken and obtained from broken glass that is no longer used. The glass in question can be interpreted as a material that has a high silica chemical content and has a specific gravity of 2560 kg/m3 and is made of 75% silicon dioxide (SiO2), (Na2O), (CaO) and several additional substances [1]. While glass powder is glass that is smoothed by pounding and then sifted with a sieve. The following table displays glass powder's chemical composition:

Table 2. Chemical composition of glass powder [9]

Chemical composition	(%)
SiO_2	72.20
Al_2O_3	1.54
Fe_2O_3	0.48
CaO	11.42
MgO	0.79
Na_2O	12.85
K_2O	0.43
SO_3	0.09
LOI	0.36

Sikafume is a fine pozzolan material, where the silica composition is mostly produced from the remains of silicon production and silicon iron alloys. Sikafume is a material that contains more than 85% SiO2 and is a very fine material that is round in shape and has a diameter of 1/100 of the cement diameter [10]. There are several advantages in using sikafume in concrete mixtures. These advantages can be seen from two conditions, including:

A. When the concrete is in the binding process:
   1. Facilitates work (workability).
   2. Reduces water and concrete seepage (bleeding).
   3. Provides a long setting time.
B. When the concrete is in hard condition:
   1. Increases tensile strength.
   2. Increases flexural strength.
   3. Reduces shrinkage and creep.
   4. Increases resistance to sulfate and aggressive environments.
   5. As chloride penetration.
   6. Lower permeability.
   7. High wear resistance.

The physical advantage of using sikafume is that the fine particle shape can fill the very tight empty cavities between the aggregate particles and the cement mixture which is a weakness for concrete is the reason for the wall effect that prevents the cement from uniting with the aggregate surface [10].

The use of low sikafume (below 5% of the weight of cement) cannot produce stronger concrete because sikafume particles cannot fill empty cavities and also cannot cover the surface of coarse aggregate. However, the use of good sikafume must also be limited, no more than 10% of the weight of cement used [11].

There is a small discrepancy between the water content of the concrete's inner and its surface. Furthermore, a high absorption of water on the concrete surface will weaken the concrete cover. Concrete's internal structure and surface (cover) both affect its compressive strength. We find that the amount of water absorbed cannot be used to determine the compressive strength [12].

Concrete curing is the final stage of concrete making. The concrete surface must be assumed to be always wet from the time the concrete begins to harden until the curing process is complete (approximately 28 days). The concrete surface must remain moist so that the water in the concrete does not come out, this is to ensure that the cement curing process (reaction between cement and water) takes place perfectly. If it does not happen perfectly, hot air will evaporate the water vapor on the

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surface of the fresh concrete, so that the water in the concrete flows out so that the new concrete does not have enough water for the hydration process, and cracks will appear on the concrete surface [13].

Concrete performance can be tested by the concrete strength value, and the concrete compressive strength is the ability of concrete to withstand the load per unit surface area. The concrete compressive strength will increase as the concrete age increases until the age of 28 days, but after that the increase will decrease [14].

Because the concrete compressive strength value is higher than the concrete tensile strength value, the concrete compressive strength value is considered as a rough determinant of concrete quality. Concrete can also be classified according to its compressive strength. The types of concrete are as follows:

Table 3. Concrete Compressive Strength Value [13]

Types of Concrete	Compressive strength (MPa)
Simple Concrete	10
Normal Concrete (Ordinary Concrete)	15 – 30
Prestressed Concrete	30 – 40
High Compressive Strength Concrete	40 – 80
Very High Compressive Strength Concrete	> 80

Concrete's compressive strength is determined by several elements, in addition to the ratio of water cement factor and its compaction level, other important factors are as follows [15]:

a. Type of semen and its quality.
b. Type and surface area of aggregate.
c. Concrete treatment.
d. Age of concrete.

Methods

Time and Place of Research

The study was carried out between March - August of 2024. The research activities took place at the Laboratory of the University of Muhammadiyah North Sumatra (S 3°36'53.632" E 98°40'34.583") Jl. Kapten Muchtar Basri No. 3, Glugur Darat II, Kec. Medan Tim., Medan City, North Sumatra 20238 which is a place for making concrete test objects, checking the aggregate base for concrete test object making materials, and curing concrete.

Tools and Materials

The instruments employed in this study were a compressive strength machine, as well as 21 concrete test objects. The materials used in this research were coconut shell ash, glass powder and additional materials in the form of sikafume.

Technique for Gathering Data

For this investigation, primary and secondary data sources are needed. Primary data come from firsthand observations made in the field, while secondary data come from earlier research. The essential main data include of:

a. Fine aggregate and coarse aggregate sieve analysis
b. The specific gravities and absorption of the fine and coarse aggregates
c. The amount of water in coarse and fine aggregate
d. Unit weight of fine aggregate and coarse aggregate
e. Mud content of fine aggregate and coarse aggregate
f. Mix design
g. Slump testing
h. Water absorption in concrete

Research Procedure

Preparation of sample making materials

Coarse and fine aggregate are used to create the samples. The materials will undergo testing beginning with aggregate absorption, specific gravity, and sieve analysis, aggregate water content, aggregate unit weight, aggregate mud content, mix design, slump test, and water absorption on concrete. while coconut shell ash is obtained from the process of burning coconut shells purchased from coconut milk sellers. The coconut shells are dried first and then cleaned from the flesh and fibers that are still attached to the shell. after drying, the shells are then burned until they become ash. the burning process takes about 10 hours. while glass powder is obtained from glass waste fragments that are carefully ground until smooth. then sieved using sieve no. 200.

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Determination of test objects / samples

The percentages of glass powder and coconut shell ash are calculated using data from multiple earlier investigations. The concrete's compressive strength will decrease if more than 10% coconut shell ash is used [16]. The concrete's compressive strength will also decrease if more than 10% glass powder is used [1].

Table 4. Concrete Compressive Strength Values in Previous Research [17]

Age	Coconut Shell Ash	Compressive Strength (MPa)
28 days	0%	22.71
	3%	17.39
	5%	20.99
	7%	14.57

Table 5. Concrete Compressive Strength Values in Previous Research [16]

Age	Coconut Shell Ash	Compressive Strength (MPa)
28 days	2.5%	21.01
	5%	20.33
	7.5%	20.27
	10%	20.82

Table 6. Concrete Compressive Strength Values in Previous Research [18]

Age	Coconut Shell Ash	Compressive Strength (MPa)
28 days	6%	26.25
	9.6%	31.25
	13%	18.75
	16%	17.5
	19%	16.25

Table 7. Concrete Compressive Strength Values in Previous Research [1]

Age	Glass Powder	Compressive Strength (MPa)
28 days	2.5%	20.28
	5%	20.37
	7.5%	20.56
	10%	21.41
	12.5%	18.49
	15%	16.69

Therefore the researcher determines the percentage of coconut shell ash to vary between 5%, 7%, and 9% and a fixed percentage of glass powder of 10%. the samples in this study were 21 samples aged 28 days.

Table 8. Sampling Determination

Code	Coconut Shell Ash (%)	Glass Powder (%)	Sikafume (%)	Sample
BN	0	0	0	3
BAS1	5	10	0	3
BAS2	7	10	0	3
BAS3	9	10	0	3
BAS4	5	10	5	3
BAS5	7	10	5	3
BAS6	9	10	5	3

Mix design

The concrete mix design in this study is referred to based on SNI 7656: 2012 and concrete books [3].

Curing concrete

After the sample is made, the sample is treated by soaking the sample for 28 days. The purpose of this soaking is so that the concrete surface must remain moist so that the water in the concrete does not come out, this is to ensure that the cement curing process (reaction between cement and water) takes place perfectly. If it does not happen perfectly, hot air will evaporate the water vapor on the surface of the fresh concrete, so that the water in the concrete flows out so that the new concrete does not have enough water for the hydration process, and cracks will appear on the concrete surface [13].

Test of Compressive Strength

Testing for compressive strength of concrete is done using the SNI-applied standards [19]. A 1500 kN capacity compression test apparatus is used for the testing. Before testing, the test object is first weighed and given a capping on both surfaces so that it can be placed upright on the testing tool then the compressive load is given evenly in a perpendicular direction from above along the entire length of the test object. The number of test samples is planned to be 21 samples.

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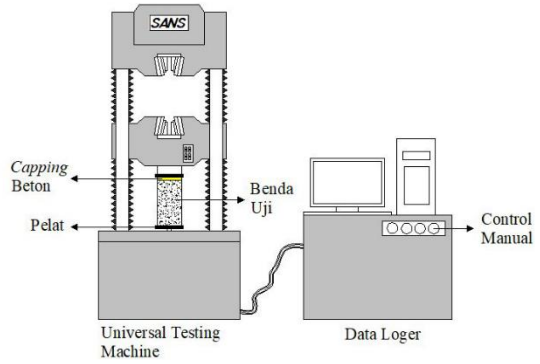

Figure 2. Compressive Strength Machine [20]

Results and Discussions

Slump Test

To find out how workable a combination of regular fresh concrete and concrete with fiber added is, slump testing is done. In order to do a slump test, three layers of freshly mixed concrete are inserted into the Abrams cone (each material taken must represent the combination). Every layer is around one-third the height of the cone and has 25 punctures or prods. Each layer must have the prodded stick or prodded stick reach the bottom. Once the Abrams cone has been filled with new concrete, level its top and allow it to sit for ten seconds. After that, lift the Abrams cone perpendicularly until the fresh concrete is released from the cone, measure the difference in the height of the Abrams cone and the height of the mixture. The value obtained is the Slump value. Table 5 shows the Slump value for each concrete mixture with various variations. Such as the planned Slump value in the Mix Design is 25 - 50 mm

Table 9. Slump Value

No	Concrete Variations	Slump Value (mm)
1	BN	55
2	BAS1	40
3	BAS2	35
4	BAS3	35
5	BAS4	65
6	BAS5	65
7	BAS6	55

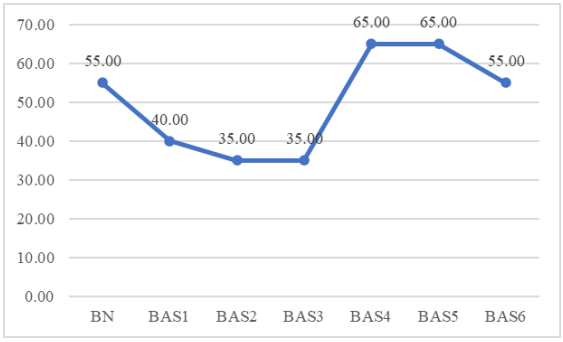

Figure 3. Average Slump Value Graph

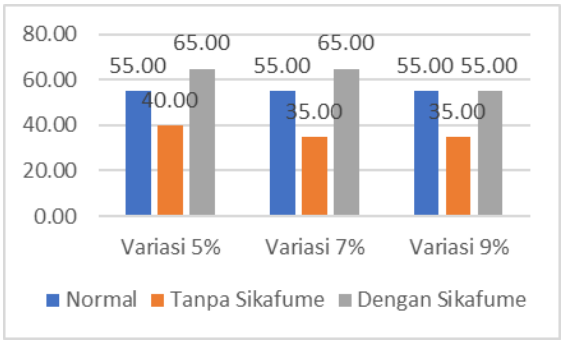

Figure 4. Slump Value Graph

The graph above shows that when concrete containing a mixture of glass powder and coconut shell ash is mixed with regular concrete, the slump value decreases. The higher the percentage of coconut shell ash used, the lower the slump value. Meanwhile, for the concrete mixture with the addition of Sikafume, the Slump value increased by 10 cm from normal concrete. By adding Sikafume to the concrete being mixed, an increase in workability is seen and is directly proportional to the increase in the Slump value. It can be seen that fresh concrete is very easy to mix and compact. From the slump test for all variations of concrete made, concrete with the addition of sikafume has a higher slump value than normal concrete, so it is certain that sikafume can increase the workability of concrete.

Testing the Compressive Strength of Concrete

Using a compression testing machine equipped with 21 cylindrical test objects of 30 cm in height and 15 cm in diameter, the compressive strength of the concrete was tested after 28 days of curing.

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Table 10. Average Concrete Compressive Strength Value

No	Concrete Variations	Average Compressive Strength Value (MPa)
1	BN	12.39
2	BAS1	11.44
3	BAS2	10.32
4	BAS3	7.50
5	BAS4	10.32
6	BAS5	10.15
7	BAS6	8.82

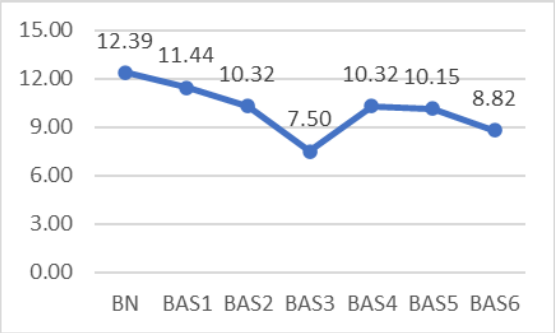

Figure 5. Average Concrete Compressive Strength Value Graph

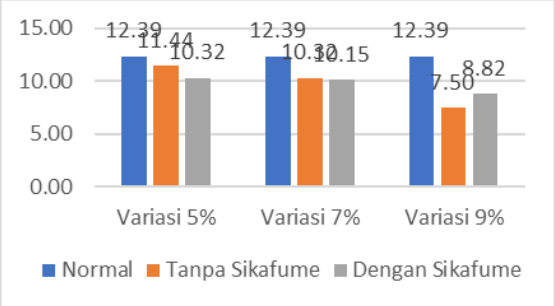

Figure 6. Compressive Strength Value Graph

It is evident that the variation concrete's compressive strength value is lower than that of the regular concrete. When coconut shell ash was utilized in the BAS1, BAS2, and BAS3 variant concrete, the compressive strength value produced with a fixed proportion of glass powder decreased with the percentage of coconut shell ash used. However, the compressive strength of concrete in this variation also decreased as the percentage of coconut shell ash and glass powder used increased with a fixed percentage. The BAS6 variation used additional materials in the form of Sikafume, but the increase in concrete's compressive strength value did not surpass that of normal concrete.According to earlier research, adding a maximum of 9% Coconut Shell Ash to concrete without also adding a mixture of Glass Powder would raise the concrete's compressive strength value. Similarly, adding less than 10% Glass Powder to concrete without adding a mixture of Coconut Shell Ash would do the same.

However, because it was thought that an alkali-silica interaction happened, the compressive strength value of concrete fell in the study's results. When more than 75 microns of glass powder are employed, the alkali-silica reaction takes place. To avoid alkali-silica reactions, glass powder with a particle size of less than 75 microns can be used in place of cement [21].

Water Absorption in Concrete

Water absorption in concrete is the increase in weight of a test object due to water seeping into the pores or cavities in the test object, but does not include water retained on the outer surface of the test object, expressed as a percentage of its dry weight [22].

Table 11. Water Absorption Value in Concrete

No	Concrete Variations	Average Water Absorption in Concrete (%)
1	BN	1.00
2	BAS1	1.35
3	BAS2	1.38
4	BAS3	1.44
5	BAS4	1.22
6	BAS5	1.24
7	BAS6	1.37

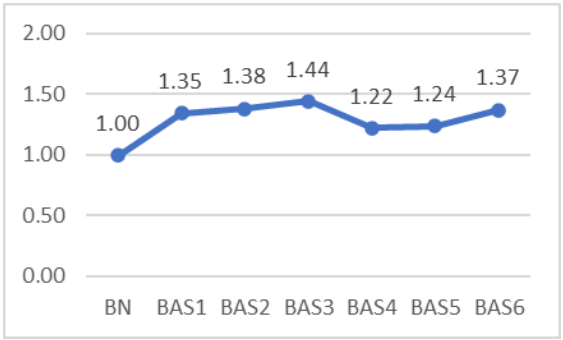

Figure 7. Average Water Absorption Value

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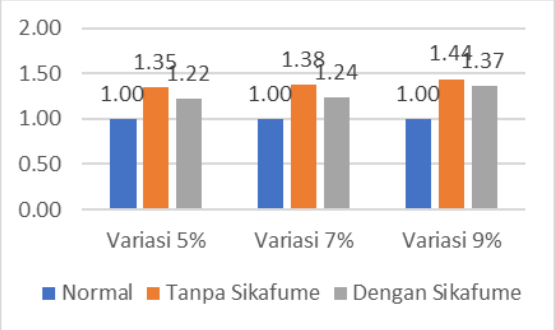

Figure 8. Water Absorption Value Graph on Concrete

From the graph above, it can be seen that by adding coconut shell ash to the concrete mixture with a composition of 5%, 7%, and 9% of the weight of the cement used, water absorption increased compared to normal concrete. However, the absorption value decreased when the fresh concrete mixture was added with an additive in the form of Sikafume. The more coconut shell ash mixture used in the concrete mixture, the water absorption capacity increased. This is because coconut shell ash in fine form reacts with free lime $Ca(OH)_2$ and water into a solid mass that is insoluble in water, namely CSH and CAH [17].

Conclusions

The following conclusions may be made based on the testing and data processing results from the investigation of the impact of partial cement placement utilizing glass powder and coconut shell ash with sikafume material on the compressive strength of concrete:

1. A mixture of Coconut Shell Ash and Glass Powder can be a material for making cement that is resistant to absorption, this is indicated by the absorption value obtained of no more than 10%. The optimal air absorption value occurs in the BAS4 variation with 5% Coconut Shell Ash + 10% Glass Powder + 5% Sikafume.
2. Adding 5%, 7%, and 9% of a mixture of Coconut Shell Ash, 10% Glass Powder, and 5% Sikafume additives does not raise the concrete's compressive strength value. The compressive strength value obtained decreases with increasing amounts of Coconut Shell Ash combined with glass powder. This is due to the fact that finely ground coconut shell ash combines with air and free lime Ca(OH)2 to create CSH and CAH, two solid masses that are air-soluble. additionally the alkali-silica reaction's beginning. When glass powder with a size larger than 75 microns is utilized, the alkali-silica reaction takes place.
3. The BAS1 concrete variation, which contains 10% glass powder and 5% coconut shell ash, has the perfect percentage for concrete's compressive strength value, 11.44 MPa.

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Author Contributions

The author contributed as a researcher, data processor, and made test objects with a mixture of coconut shell ash and glass powder to determine whether the materials used were able to make concrete resistant to immersion and to determine the resulting compressive strength value.

Conflicts of Interest

In order to graduate from the Program Studi Teknik Sipil, Fakultas Teknik, Universitas Muhammadiyah Sumatera Utara, one must complete this research. The author participates in the planning, data collection, analysis, and publication of the study's findings.

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