

# Utilization of Iron Sand Waste and Bottom Ash as Alternate Concrete-making Materials

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**Abstract** *Purpose:* This Research to know whether the waste of iron sand and bottom ash can be used as substitute aggregate looks at the percentage of bottom ash and iron sand waste as fine aggregate for concrete production. The use of such waste as a material for making concrete will reduce waste that can pollute the environment. *Methodology:* The planned concrete compressing strength is  $f_c = 20$  Mpa and the materials to be used are cement, water, sand as fine aggregate and gravel as coarse aggregate. This Research used 25 cylindrical concrete specimens with a variety of ages 3, 7, 14, 21, and 28 days. The process is divided into 6 stages: preparation, aggregate testing, planning (mix design), test specimen production, concrete curing and testing specimens. *Results:* The results of this Research stated that bottom ash and iron sand waste could be used as a substitution of fine aggregate for making concrete. Based on several tests, the ratio of iron sand waste and bottom ash which is the closest to the gradation of zone 2 (ideal zone) is the percentage of the iron sand waste mixture of 40% - 60% bottom ash that enters zone 2 (rather rough). Suggestions for further Research are to use coarse aggregate whose size varies and use admixture in concrete mixtures. *Applications/Originality/Value:* Expectations from this Research can provide benefits, among others, can reduce the environmental impact of waste to the surrounding community and provide information for the dive the world community, especially the construction of the benefits and usefulness of iron sand waste and bottom ash as a building material.

**Keywords** Iron Sand Waste, Bottom Ash, Concrete, Compressive Strength

## 1. Introduction

The need for concrete for construction is increasing, and at the same time as natural aggregates are decreasing in

various regions, which creates an urgent need to consider substitute materials for aggregates in concrete. This great need led researchers to look for alternative materials by using waste materials, by-products and recyclables. (Ravindrarajah & Tam, 1987); (Dayalan & Beulah, 2014).

Fly ash and bottom ash are waste from power plants that use coal as an energy source. Such waste that continues to accumulate can result in environmental pollution (Darwis, Soelarso, & Hidayat, 2015). Coal ash obtained from the bottom of the furnace commonly referred to as coal bottom ash (CBA). This ash is heavier and more difficult to be carried by exhaust gases compared to fly ash, as discussed by Bajara et al. (2013), Menéndez et al. (2014) and Singh et al. (2013).

Industrial waste such as iron sand waste for steel production can be dangerous for the environment. Stockpiling this material near the production site can cause soil and groundwater contamination (Ghannam, Najm, & Vasconez, 2016). In Karangkandri Village, Cilacap, Central Java, there is an iron sand mining industry which is now inactive, but iron sand waste remains. The processing of iron sand waste in Karangkandri Village has not been fully utilized, and in Karangkandri Village, iron sand waste is only used as rice fill material.

Being around coal ash dumps can increase the probability of getting cancer and other diseases. The waste can also affect the quality of drinking water from wells, where humans can get cancer because they drink water that has been contaminated with arsenic (EPA. 2007).

Coal waste and iron sand waste generated from day to day always increase. If this much waste is not treated, it will cause problems, and one of which is environmental pollution. Utilization of waste is one of the ideal alternatives to overcome the problem of waste (Ramzi et al. 2016). Because it can ease the cost of disposal and reduce adverse effects on the environment, nevertheless, the strategy should be paid attention to in terms of the utilization of environment and energy to use available materials efficiently (Alzaed, 2014).

## 2. Literature Review

There have been several previous studies that used material substitutes in concrete production. Research is to find out whether ceramic waste can be used as a substitute for aggregate. The results obtained are the use of ceramic waste for the manufacture of concrete turned out to be quite effective and efficient (Ramadevi, 2017).

Research by replacing fine aggregate, which generally uses normal sand with GGBS (impact heater granulated slag). The substitution of the fine total by GGBS is in the scope of 0% (without GGBS), 5%, 10% and 15%. Concrete blends were blended totally, tried and discover the compressive, flexural and split rigidity are contrasted and the customary cement (Manhas & Moohmend, 2018). (Please rephrase the sentence)

Research by using iron sand as a substitute for cement against the compressive strength and tensile strength of concrete is done. Iron sand containing  $\text{Fe}_2\text{O}_3$ ,  $\text{SiO}_2$ ,  $\text{MgO}$  and 80-100 mesh concrete sizes has the potential to be used as a substitute for cement in the production of high-performance concrete as discussed by Lufti (2012).

Research by using Bottom Ash as an additional ingredient in the manufacture of concrete with seawater immersion, then revealed the concrete is stronger. In essence, this study aims to determine the effect of a mixture of species of cement paste with bottom ash to the compressive strength of concrete with a variety of mix percentage of 0%, 10%, 20%, 25%, with the immersion of seawater on the duration of 7, 14, and 28 days. The results of this study are derived from following factors. Levels mix Bottom Ash and seawater soaking time on the concrete cylinders showed that the addition of Bottom Ash as a cement substitute as much as 10% had elevated concrete strength of regular concrete (Bottom Ash content 0%) of 1.95 MPa for immersion 7 days, 3.87 MPa to soak 14 days, 0.5 MPa for 28 days immersion. And compressive strength in the bath 14 days and 28 days decreased the strength of concrete, which is not significant, as discussed by Arinata, Hidayat, & Wibowo (2014).

This Research replaced sand with WFS (waste foundry sand) and then analyzed the strength and durability of concrete. The results of the test have shown that using WFS as a substitute for fine aggregate increased the strength and durability of the concrete (Ramesh, Lokeswari, & Ravitheja, 2018).

The Research used ground Low-Density Poly Propylene (LDPP) bags as a substitute for fine aggregate in the manufacture of concrete. Replacement with the proportion

of 5%, 10%, 15% and 20% of fine aggregate. The test result is that a mixture with a portion of 10% of LDPP gets better strength, stress and flexibility than conventional concrete (Sreenath & Harishankar, 2016).

According to Alzaed (2014), the effect of iron filing on concrete can increase the compressive strength of concrete. Several formulas are used in Research to find the percentage of iron in making concrete. The result of the study is that the compressive strength of concrete increases by 17% when 30% of iron is added to the concrete mixture. At the same time, the tensile strength of concrete has only a slight effect if the percentage of iron filling in the concrete mix reaches more than 10%. The tensile strength of concrete is increased by 13% when adding 10% iron filling to the concrete mixture.

A Research using Bottom Ash as an additional mixture in the manufacture of concrete with seawater immersion then tested the strength of the concrete. Basically, it is to determine the effect of a mixture of cement paste species with bottom ash on the compressive strength value of concrete with a variation of the mixture percentage of 0%, 10%, 20%, 25%, with seawater immersion. The results of this Research obtained by a factor of mixed bottom ash content and seawater immersion time in a concrete cylinder showed that the addition of bottom ash as a substitute for cement by 10% has an increase in the strength of concrete than standard concrete (bottom ash 0% content) as much as 1.95 MPa for immersion 7 days, 3.87 MPa for 14-day immersion, 0.5 MPa for 28-day immersion. And for compressive strength at 14 days and 28 days immersion did not significantly decrease the strength of concrete as discussed Arinata, Hidayat, & Wibowo (2014).

## 3. Materials

### Cement

This study uses OPC (Ordinary Portland Cement) Type I that probably is the most familiar around you because it is most widely used by the wider community and circulating in the market. This type is commonly used for general building construction that does not require specific requirements for heat hydration and initial press force. The uses of Portland Type I Cement include building construction for residential houses, terraced buildings, and highways, which is suitable for use in soil and water containing sulphate 0, 0% – 0, 10%. Below is a cement type resistant table (U.S. Bureau of Reclamation, 1981):

**Table 1.** Attack on Concrete by Soils and Waters Containing Various Sulfate Concentration

Relative Degree of Sulfate Attack	Percentage Water-Soluble Sulfate (as SO <sub>4</sub> ) in Soil Samples	Sulfate (as SO <sub>4</sub> ) in Water Samples, Ppm	Cement Type
Negligible	0.00 to 0.10	0 to 150	I
Positive	0.10 to 0.20	150 to 1500	II
Severe	0.20 to 2.00	1500 to 10000	V
Very Severe	2.00 or more	10000 or more	V + pozzolan

### Iron Sand

Iron sand is sand deposition containing iron particles (magnetite) found along the coast. In the processing of iron sand in the industrial world will produce iron powder waste or iron sand waste (Ghannam, Najm, & Vasconez, 2016). In this Research used iron sand waste is from Karangandri village, Cilacap, Indonesia.

### Bottom Ash

Bottom ash is ash which is produced when coal combustion settles (Kumari & Thandavamoorthy, 2017). Coal ash requires proper management so as not to cause environmental pollution and. This coal ash requires a spacious and safe shelter with a high handling cost.

### Coarse Aggregate

This study uses coarse aggregate from the Klawing river in Purbalingga with a size of no more than 20 mm.

### Water

The function of water in a concrete mixture is to help chemical reactions that cause the binding process and as a lubricant between the aggregate and cement mixture so that it is easy to work on.

## 4. Methodology

This research was conducted in a laboratory to make 25 cylindrical concrete samples with a size of 15 x 30 cm, and there are several steps done, such as:

### Preparation

This stage prepares the materials used in this research, such as:

- Ordinary Portland Cement Type I
- Iron sand waste from Karangandri village, Cilacap, Indonesia
- Coarse aggregate from the Klawing river, Purbalingga, Indonesia
- Bottom Ash from a thermal power station in Jepara, Indonesia

### Aggregate Testing

This test method is based on SNI 03-1968-1990 (Fine and Coarse Aggregates, Sieve Analysis Test Method), SNI 03-1970-1990 (Aggregate Fine Test Methods specific gravity and Water Absorption) and SNI 2417: 2008 (About How to Test Aggregate Wear with Los Angeles Abrasion Machines).

### Planning (Mix Design)

Calculations to determine the proportion of each aggregate in each condition, the value of the slump plan and the number of test objects is made that is as many as 25 pieces consisting of 5 test pieces for each age plan 3, 7, 14, 21, and 28 days.

### Test Specimens Production (Mixing Process)

After knowing the proportions, the materials are weighed according to their needs to be stirred in a concrete mixer for 3-5 minutes, then whether the slump value is in accordance with the plan slump value is tested, then the concrete mould is mixed in a 15 cm x 30 cm cylinder, and when filled the cylinder is divided into three layers and each layer is pounded with iron 25 times with Ø16 mm iron, the mould is filled to be full until it is flattened.

### Concrete Curing

Wait for the concrete mixture on the cylinder mold for 24 hours, and then remove the mould. After that, the sample totally immersed in water. Five groups with every 5 samples were then taken from the water at the age of planned (3, 7, 14, 21, and 28 days) for the concrete compressive strength test.

### Testing Specimens

Concrete compressive strength testing is done at the age of 3, 7, 14, 21, and 28 days for each concrete specimen. The equation used:

$$f_c' = \frac{P}{A} \quad (1)$$

where:

$f_c'$  = Compressive strength (MPa)

P = Maximum load (N)

A = Area of the press (mm<sup>2</sup>)

## 5. Result and Discussion

### Material Testing

#### Fine Aggregate Testing

The percentage gradation of the mixture of iron sand and bottom ash waste used is included in the Zone 2 sand gradation (ideal sand gradation). Based on the test results, the percentage included in zone 2 is the percentage of iron sand waste 40% - 60% bottom ash.

The test results of the specific gravity test for iron sand waste is 3.20. These results indicate that iron sand waste aggregate is included in the heavy aggregate. The bottom ash density test result is 2.12, and it shows that the bottom ash density is a mild aggregate. The results of the specific gravity test percentage of iron sand waste is 40% - 60% with bottom ash 2.58. These results indicate that the percentage of weight is included in the normal aggregate.

Fine aggregates for building materials (except Special Aggregates, for example, light aggregates and so on) good fine aggregates do not have a mud content of more than 5% (General regulations on building materials in Indonesia - 1982, article 11 page 17). If the mud content exceeds 5%, it must be washed first. Based on the results of testing the level of iron sand waste sludge obtained value of 1.80% while the bottom ash sludge testing results obtained amount of 0.76%.

#### Coarse Aggregate Testing

Coarse aggregate tests performed include the coarse aggregate specific gravity and rough aggregate wear. Coarse aggregate gradation is not carried out because the coarse aggregate (gravel) used is a maximum size of 20mm originating from the Klawing River, Purbalingga, Indonesia.

The results of specific gravity tests obtained at 2.74 are categorized as average aggregate. Based on SNI 03-2417-1991 (Aggregate Wear Test Method with Los Angeles Abrasion Machine) the good value of aggregate wear to be used is <40%. From the testing of coarse aggregate wear by using a Los Angeles machine, the wear value is 32.25%. Therefore the coarse aggregate derived from Klawing River, and Purbalingga is a suitable

aggregate in concrete manufacture.

#### Aggregate Testing Result Data

Table 2 shows the data of aggregate test results, including data on gradation test results, specific gravity, sludge content for fine aggregate while rough aggregate is tested for specific gravity and gravel wear.

Based on the gradation test results, the percentage of fine aggregate entering zone 2 (ideal zone) is the percentage of iron sand waste 40% - 60% bottom ash.

**Table 2.** Aggregate Testing Result Data

Test	Fine Aggregate		Coarse Aggregate
	Iron Sand Waste	Bottom Ash	Gravel
Gradation	Zona 4	Zona 2	Max. 20 Mm
Specific gravity	3,2	2,12	2,74
Sludge levels	1,80%	0,76%	-
Gravel wear	-	-	32,25%

#### Slump Test

In testing the slump, the test has been performed 2 times. The results of the slump test can be seen in Table 3.

**Table 3.** Slump Test Result

Slump Test Result			
Mix 1	Mix 2	Average	Information
3 cylinder	2 cylinder		To Be Tested on Concrete Age (days)
(cm)	(cm)	(cm)	
8	8	8	3
8	8	8	7
10	10	10	14
8	8	8	21
8	8	8	28

Based on the results of the slump test obtained ranged from 8 cm - 10 cm, while in the planning of concrete mix (mix design)  $10 \pm 2$  cm, the value of the slump test has met the plan.

#### Concrete Compressive Strength

This test is carried out in 3, 7, 14, 21, and 28 days for each concrete specimen. Concrete compressive strength test results can be seen in table 4.

**Table 4.** Concrete Compressive Strength Test Results (3 days)

No.	Test Object Code	Weight (gram)	Maximum load (P)		Area of Press (A) (mm)	Compressive strength (MPa)	Estimated compressive strength at 28 days (MPa)
			(Kg)	(N)			
1	SP1.3	12.270	19.000	186.390	17662,5	10,55	22,94
2	SP2.3	12.370	22.000	215.820	17662,5	12,22	26,56
3	SP3.3	12.200	21.400	209.934	17662,5	11,89	25,84
<b>Average Compressive Strength</b>						<b>11,55</b>	<b>25,11</b>

Note : cylinder conversion age 28 days from age 3 days (divided) = 0.46

**Table 5.** Concrete Compressive Strength Test Results (7 days)

No.	Test Object Code	Weight (gram)	Maximum load (P)		Area of Press (A) (mm)	Compressive strength (MPa)	Estimated compressive strength at 28 days (MPa)
			(Kg)	(N)			
1	SP1.7	12.340	32.000	313.920	17662,5	17,77	25,39
2	SP2.7	12.250	33.000	323.730	17662,5	18,33	26,18
3	SP3.7	12.190	32.000	313.920	17662,5	17,77	25,39
<b>Average Compressive Strength</b>						<b>17,96</b>	<b>25,65</b>

Note : cylinder conversion age 28 days from age 7 days (divided) = 0.70

**Table 6.** Concrete Compressive Strength Test Results (14 days)

No.	Test Object Code	Weight (gram)	Maximum load (P)		Area of Press (A) (mm)	Compressive strength (MPa)	Estimated compressive strength at 28 days (MPa)
			(Kg)	(N)			
1	SP1.14	12.220	37.000	362.970	17662,5	20,55	23,35
2	SP2.14	12.360	43.400	425.754	17662,5	24,10	27,39
3	SP3.14	12.280	39.000	382.590	17662,5	21,66	24,61
<b>Average Compressive Strength</b>						<b>22,11</b>	<b>25,12</b>

Note : cylinder conversion age 28 days from age 14 days (divided) = 0.88

**Table 7.** Concrete Compressive Strength Test Results (21 days).

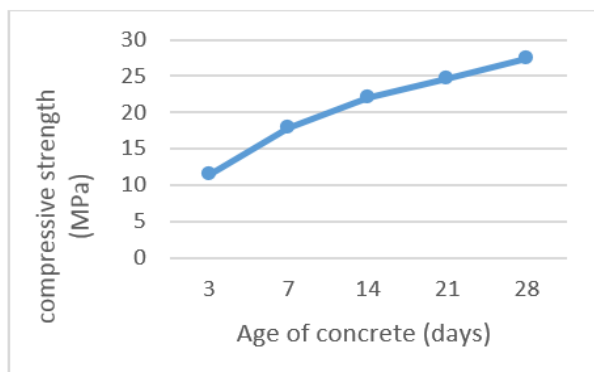
No.	Test Object Code	Weight (gram)	Maximum load (P)		Area of Press (A) (mm)	Compressive strength (MPa)	Estimated compressive strength at 28 days (MPa)
			(Kg)	(N)			
1	SP1.21	12.370	45.000	441.450	17662,5	24,99	26,04
2	SP2.21	12.400	45.000	441.450	17662,5	24,99	26,04
3	SP3.21	12.330	43.000	421.830	17662,5	23,88	24,88
<b>Average Compressive Strength</b>						<b>24,62</b>	<b>25,65</b>

Note : cylinder conversion age 28 days from age 21 days (divided) = 0.96

**Table 8.** Concrete Compressive Strength Test Results (28 days)

No.	Test Object Code	Weight (gram)	Maximum load (P)		Area of Press (A) (mm)	Compressive strength (MPa)
			(Kg)	(N)		
1	SP1.28	12.330	52.500	515.025	17662,5	29,16
2	SP2.28	12.370	48.000	470.880	17662,5	26,66
2	SP3.28	12.400	48.000	470.880	17662,5	26,66
<b>Average Compressive Strength</b>						<b>27,49</b>

The test results above are then made a graph of the results of the compressive strength test, as in Figure 1.



**Figure 1.** Graph of concrete compressive strength at various ages

Based on figure 1, the more concrete the age of the concrete, the more reliable the strength will be. At the age of 3 days, the concrete compressive strength reached 12.37 MPa, age 7 days increased 54.49% to 19.11 MPa, at 14 days increased 29.62% to 24.77 MPa, age 21 increased 1.57% to 25.16 MPa, and age 28 increased 5.29% to 26.49 MPa. It can be concluded that the results of the compressive strength test of the average age of 28 reached the characteristic compressive strength of  $f'_c$  20 Mpa but did not reach the plan compressive strength of 32 MPa  $f'_{cr}$ . One factor why the average compressive strength has not yet reached the plan compressive strength of 32 MPa  $f'_{cr}$  is

the fine aggregate gradation of the percentage of iron sand waste 40% - 60% bottom ash does not fully enter zone 2 (ideal zone).



**Figure 2.** Broken Concrete Generated Pattern

The characteristic of a good concrete that can be seen from the pattern of broken concrete is a good breaking pattern that is broken diagonally / not broken into pieces. From the results of the concrete compressive strength test in the Laboratory, the pattern of rupture produced by tilting / not broken into pieces as in figure 2. Concrete with good quality-tested will sound with a quite loud explosion. Strength test that is made a loud explosion.

### Concrete Specific Gravity

The specific density of concrete at 3, 7, 14, 21, 28 days are as follows:

**Table 9.** Calculation Result of Average Concrete Specific Gravity (3 days)

No.	Test Object Code	Weight		Volume	Concrete Specific Gravity (kg/m <sup>3</sup> )
		gram	kg		
1	SP1.3	12.270	12,27	0,0053	2.315
2	SP2.3	12.370	12,37	0,0053	2.334
3	SP3.3	12.200	12,2	0,0053	2.302
4	SP4.3	12.250	12,25	0,0053	2.311
5	SP5.3	12.130	12,13	0,0053	2.289
<b>Average Specific Gravity</b>					<b>2.310</b>

**Table 10.** Calculation Result of Average Concrete Specific Gravity (7 days)

No.	Test Object Code	Weight		Volume	Concrete Specific Gravity (kg/m <sup>3</sup> )
		gram	kg		
1	SP1.7	12.180	12,18	0,0053	2.298
2	SP2.7	12.340	12,34	0,0053	2.328
3	SP3.7	12.250	12,25	0,0053	2.311
4	SP4.7	12.190	12,19	0,0053	2.300
5	SP5.7	12.370	12,37	0,0053	2.334
<b>Average Specific Gravity</b>					<b>2.314</b>

**Table 11.** Calculation Result of Average Concrete Specific Gravity (14 days)

No.	Test Object Code	Weight		Volume	Concrete Specific Gravity (kg/m <sup>3</sup> )
		gram	kg		
1	SP1.14	12.060	12,06	0,0053	2.275
2	SP2.14	12.220	12,22	0,0053	2.306
3	SP3.14	12.360	12,36	0,0053	2.332
4	SP4.14	12.280	12,28	0,0053	2.317
5	SP5.14	12.280	12,28	0,0053	2.317
<b>Average Specific Gravity</b>					<b>2.309</b>

**Table 12.** Calculation Result of Average Concrete Specific Gravity (21 days)

No.	Test Object Code	Weight		Volume	Concrete Specific Gravity (kg/m <sup>3</sup> )
		gram	kg		
1	SP1.21	12.330	12,33	0,0053	2.326
2	SP2.21	12.370	12,37	0,0053	2.334
3	SP3.21	12.400	12,4	0,0053	2.340
4	SP4.21	12.330	12,33	0,0053	2.326
5	SP5.21	12.220	12,22	0,0053	2.306
<b>Average Specific Gravity</b>					<b>2.326</b>

**Table 13.** Calculation Result of Average Concrete Specific Gravity (28 days)

No.	Test Object Code	Weight		Volume	Concrete Specific Gravity (kg/m <sup>3</sup> )
		gram	kg		
1	SP1.28	12.240	12,24	0,0053	2.309
2	SP2.28	12.300	12,3	0,0053	2.321
3	SP3.28	12.310	12,31	0,0053	2.323
4	SP4.28	12.650	12,65	0,0053	2.387
5	SP5.28	12.350	12,35	0,0053	2.330
<b>Average Specific Gravity</b>					<b>2.334</b>

Based on SNI 03-2834-2000 (Procedure for Normal Concrete Plan) normal concrete density ranges between 2200 to 2500 kg / m<sup>3</sup>, from the calculation of the average density of concrete age of 3, 7, 14, 21, 28 days served in Table 8 through Table 12 directing that the resulting concrete into normal concrete and an average specific gravity density concrete planned approach that is 2,383 kg / m<sup>3</sup>.

## 6. Conclusions

Based on the results of Research that has been done, it can be concluded that:

- Based on the results of grading tests, specific gravity, sludge content and compressive strength values generated that the waste of bottom ash and iron sand waste can be used as fine aggregate for making concrete.
- Fine aggregate gradation is ideal for concrete mixes ie zone 2 (ideal zone). Based on several tests, the ratio of

iron sand waste and bottom ash which is the closest to the gradation of zone 2 (ideal zone) is the percentage of the iron sand waste mixture of 40% - 60% bottom ash that enters zone 2 (rather rough).

- Based on the results of the slump test obtained ranging from 8 cm - 10 cm, whereas in the design of concrete mix (mix design) 10 ± 2 cm, the value of the slum test has met the plan.
- The results of the calculation of concrete density obtained are close to the planned specific gravity of 2,383 kg/m<sup>3</sup> and the specific gravity of this concrete is included in the normal concrete category which has a volume weight between 2200 kg/m<sup>3</sup> to 2500 kg/m<sup>3</sup>
- The compressive strength of the average age of 28 days reached the characteristic compressive strength of f'c 20 Mpa but did not reach the compressive strength of the plan that is f'cr 32 MPa.

The results of this study stated that bottom ash and iron sand waste could be used as a substitution of fine aggregate in the manufacture of concrete. The percentage of fine

aggregate used is the percentage of iron sand waste 40% - 60% bottom ash. The specific gravity concrete, including normal concrete density.

## 7. Suggestions

Suggestions that researcher can tell about this Research are:

- For a coarse aggregate a varied size of 0.5 cm up to 4 cm material is used in order to obtain a better quality of concrete.
- Further Research needs to be done on the gradation of the percentage of iron sand and bottom ash that is completely (perfect) in zone 2 (ideal zone) .
- Further Research needs to be done by adding admixture to concrete mixtures by using iron sand waste and bottom ash so that the compressive strength of concrete is higher.

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