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Influence of Quality of Recycled Fine Aggregate on Properties of Concrete

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Synopsis

Today, the river sand isn't gathered because of the destruction of the environment. So recycled aggregates hopes to use for concrete. But properties of concrete with recycled aggregate are decreased by qualities of one. Then the concrete properties need to be estimated by some indexes including the aggregate qualities. In this study, when 6 sorts of fine aggregate were used, we investigated influences of qualities of fine aggregate on properties of fresh and hardened concrete. As the result, it was found that, for the case of same mix proportions, the air content was decreased with increase of the total surface area of fine aggregate and the slump was decreased for the reason. And if total water content was made water content added to the amount of absorbed water of all aggregates, concrete strengths were correlated with cement content to total water content ratio. It will be able to use as a index for controlling concrete strengths.

KEYWORDS: recycled fine aggregate, water absorption, total surface area, total water, cement to total water ratio

1. Introduction

River sand is good quality for concrete. But, today, the river sand isn't gathered because of the destruction of the environment. So by-product aggregates, like blast-furnace slag aggregate and recycled aggregate, hopes to use for concrete except for sea sand and pit sand. Original materials, produced place and procedure change qualities of the by-product aggregates. Therefore, the designers need to make some test concretes again and again if the by-product aggregate is used as concrete material. It is same in case of using recycled aggregate and the reason is one of factors preventing concrete recycle. Now, concrete standard specifications are shift from specification code to performance-based code. So, It has to be clearly properties of concrete is related to by qualities of aggregate. In this study, because we get fundamental data for mix design using recycled fine aggregate, relationships between properties of concrete and qualities of recycled fine aggregate were investigated.

2. Test Procedures

2.1 Used Material

Properties of materials using in this study are shown in Table 1 and 2. Fine aggregates using in this study are 6 sorts including 3sorts of ordinary fine aggregates and 3 sorts of recycled fine aggregates. NS-I is a river sand from Ibi river in Japan, NS-C is another river sand from Fujian Province in China and NS-L is a crushed limestone sand. 3 sort of recycled fine aggregate are RS-P made at plant for recycled aggregate, RS-HA and RS-HB broken 2 kinds of

Table 1 Used material except for fine aggregate

Kinds of material	Used material	Note
Cement	Ordinary portland cement	Density:3.15g/cm^3
Coarse aggregate	Crushed stone produced in Takatsuki city	Density: 2.67 g/cm^3 Water absorption: 0.87% Solid content: 59.8%
Air entraining and water-redusing admixture	Lignin sulfonic acid	Delayed type
Air entraining admixture	Conversionly alkyl carboxylic acid	-

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Table 2 Fine aggregate used this study

Grouping	Mark	Producing place and broken building	Density of oven-dry condition (g/cm^3)	Water absorption (%)	Solid content as an index of particle shape (%)	BET specific surface area (m^2/g)
Ordinary fine aggregate	NS-I	Ibi river in Japan	2.52	2.39	58.6	1.83
	NS-C	Fujian Province in China	2.55	1.65	59.7	0.82
	NS-L	Crushed limestone sand	2.64	1.24	55.3	0.74
Recycled fine aggreagte	RS-P	Plant for recycled aggregate	2.13	8.97	56.8	4.08
	RS-HA	Building built in 1932	2.18	8.10	55.8	4.91
	RS-HB	Building built in 1957	1.99	11.40	59.2	4.42

Table 3 Mix proportions (1 m^3) for the case of using NS-I and crushed stone (standard mix proportions)

Water / cement	0.4	0.5	0.6
Sand / total aggregate by volume (%)	41.2	43.2	45.2
Water (kg /m^3)	173	163	163
Cement (kg /m^3)	433	326	272
Fine aggregate (kg /m^3)	680	762	817
Coarse aggregate (kg /m^3)	1004	1037	1025
Air entraining and water-redusing admixture (g /m^3)	1083	815	680
Air entraining admixture is adds (g /m^3)	15.2	11.4	9.52

buildings. Average concrete compressive strength of one building built in 1932 was 28.2 N/mm^2 and that of another building in 1957 was 32.9 N/mm^2. Some concrete masses from those buildings were broken by a jaw crasher and a cone crusher. Then 0.15 – 2.5mm of particle range were picked up as recycle fine aggregate.

2.2 Methods of Tests

For qualities of fine aggregate, density in oven-dry condition, water absorption, fineness modulus and solid content as an index of particle shape were investigated through JIS A 1109, 1102, 1104 and 5505. And specific surface area was measured by BET adsorption process with nitrogen gas.

Mix proportions of concrete were made in case of W/C = 40, 50 and 60 %. The standard mix proportions, shown as Table 3, were decided with NS-I and crushed stone. The targets of air contain and slump of that concrete were 5 $\pm$ 1% and 12 $\pm$ 2cm. In case of using a different fine aggregate, content of fine aggregate was replaced by the other aggregate in volume and 18 sorts of mix proportions were drew up. In the beginning, changes of air content and slump were investigated on 18 mix proportions at same mix proportion. Next, properties of flesh concrete were adjusted the target condition by changing amount of chemical admixture. On the adjusted concrete, strengths of hardened concrete at 28 ages were investigated. Time of mixing before throwing water was 30 seconds and after throwing it, materials of concrete were mixed for 150 seconds by gravity type mixer. Also, percentage of surface moisture of recycled fine aggregate keep about 3%.

3. Relationships between Qualities of Fine Aggregate and Properties of Flesh Concrete

Figure 1 and 2 show relationships between the water absorption of fine aggregate and properties of flesh concrete. The air contain and the slump were increased with increasing W/C. Further, the higher the water absorptions was, the lower the properties of flesh concrete were. But, for large scattering, it is difficult to expect

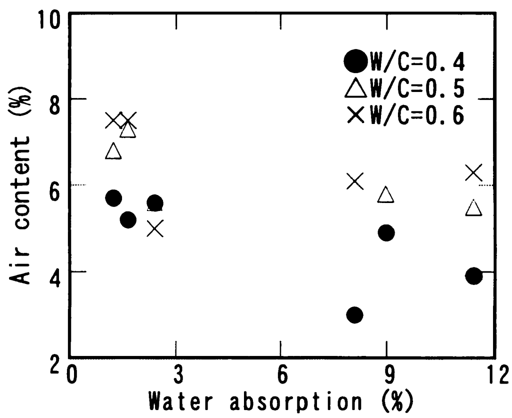

Figure 1 Relationship between air content and water absorption.

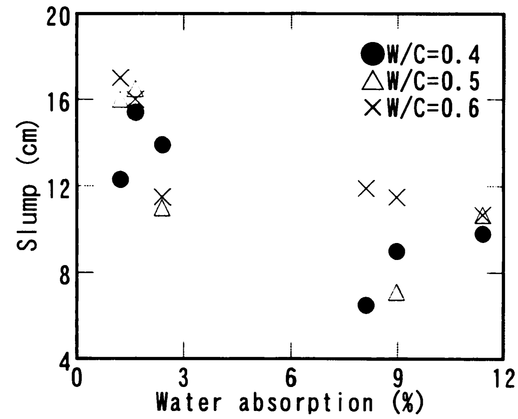

Figure 2 Relationship between slump and water absorption.

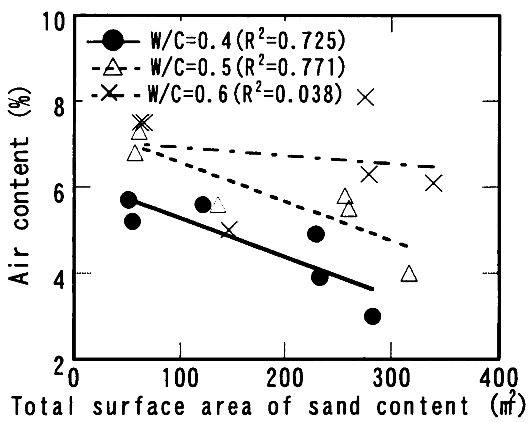

Figure 3 Relationship between slump and total surface area of sand content.

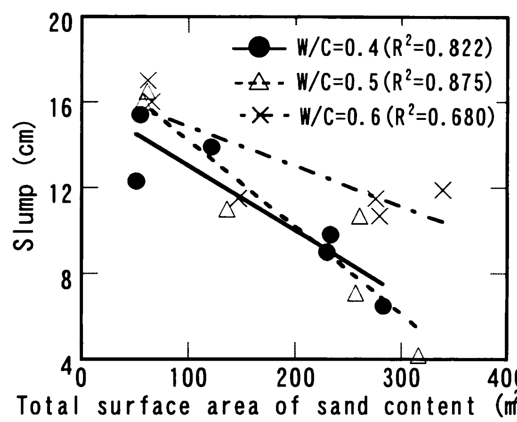

Figure4 Relationship between air content and total surface area of sand content.

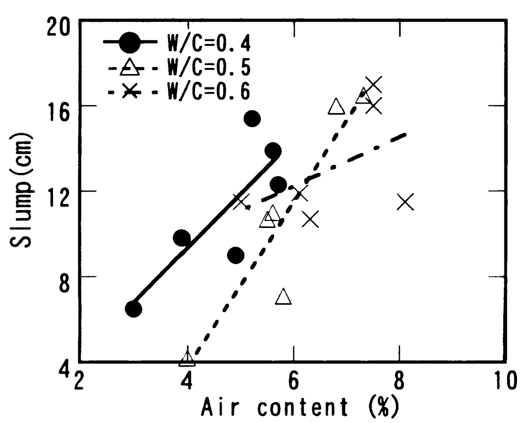

Figure 5 Relationship between slump and air

conditions of fresh concrete through the water absorption. Here, the high water absorption of fine aggregates were recycled fine aggregates.

Recycled fine aggregate has larger surface area and worse shape of particles than ordinary sand. There seem to be parts of the cause that properties of fresh concrete with recycled fine aggregate were lower than those with ordinary sand. Then, total surface area of fine aggregate in 1 m^3 of concrete was calculated by BET surface area and content of fine aggregate. Relationships between the total surface area and the properties of fresh concrete were shown as Figure 3 and 4. While a regression line of those indexes was calculated by the least-squares method. In those figures, the regression line and the coefficient of determination were shown due to investigate influence of the all surface area on fresh concrete. And also, same information was shown in some figures after

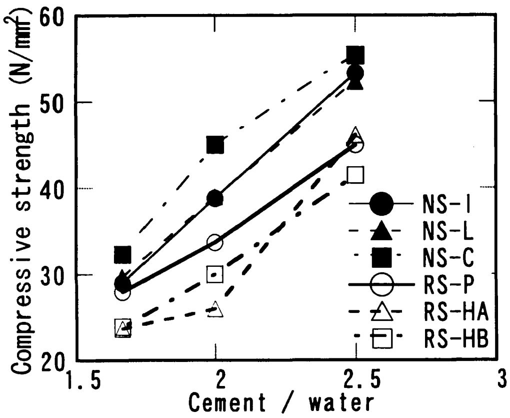

Figure 6 Relationship between C/W and compressive strength of concrete.

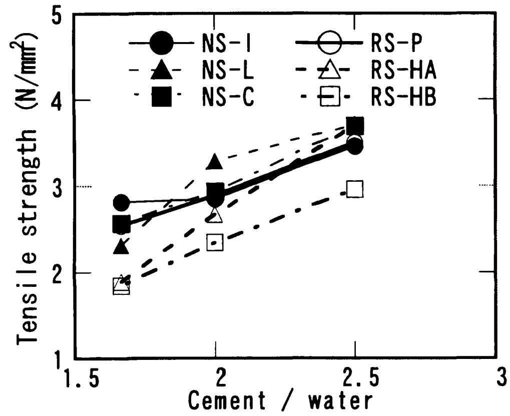

Figure 7 Relationship between C/W and tensile strength of concrete.

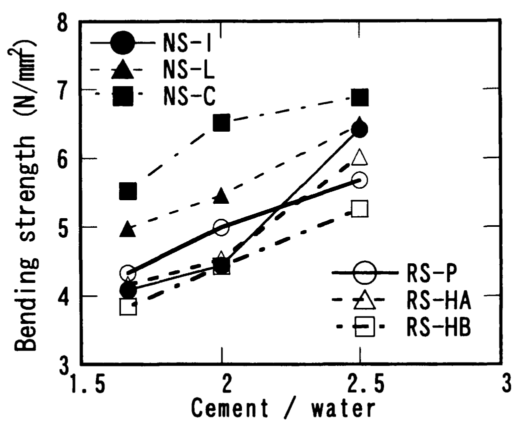

Figure 8 Relationship between C/W and bending strength of concrete.

this figure. As the result, the air content and the slump were decreased with the increase of the all surface area, but the tendencies of the relationships were not changed by W/C.

It is possibility that the air content influences the slump. Then, Figure 5 illustrated the influence. The slump was generally linear increased as the air content increased. In other studies [1) 2)], it is found that water content decreases by 2 - 4% due to keep the same slump as the air content increases by 1% and that the slump increases by 3 cm with 3% increase of the water content. It is, inevitably, seemed that the slump increases by 3 cm as the air content increases by 1%. In this study, the slump increased by about 2.5 –3.3 cm as the air content increased by 1% for W/C = 40 and 50%.

As a result of fresh concrete test, it is found that the air content of concrete with the recycled fine aggregate is decreased due to large surface area of the aggregate. The slump of concrete is decreased for the reason. It is thought that the chemical admixture need be increased for keeping properties of fresh concrete.

4. Relationship between Qualities of Fine Aggregate and Properties of Hardened Concrete

4.1 Influence of Absorption and W/C on Properties of Hardened Concrete

Figure 6, 7 and 8 show influence of cement to water ratio on concrete strengths. All concrete strengths were increased with increase of C/W and decreased more when the water absorption increased. The decreasing rates of concrete strengths were almost same in spite of qualities of fine aggregate. This is that the water absorption and C/W largely influence the concrete strength.

4.2 Introduction of Total Water Content and Cement to Total Water Ratio

Recycled fine aggregate has higher water absorption and larger surface area than ordinary fine aggregate. Those qualities were thought to influence properties of concrete. The water absorption of recycled fine aggregate is higher than 10% in some case. Today, the designers control concrete strength at mix design by water to cement ratio. The water don't contain amount of water absorbed into aggregate because it is thought that it doesn't have

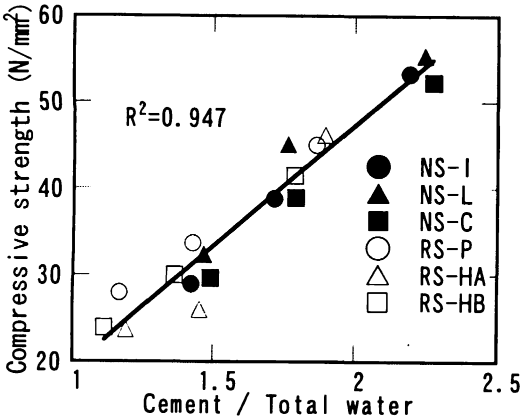

Figure 9 Relationship between C/TW and compressive strength of concrete.

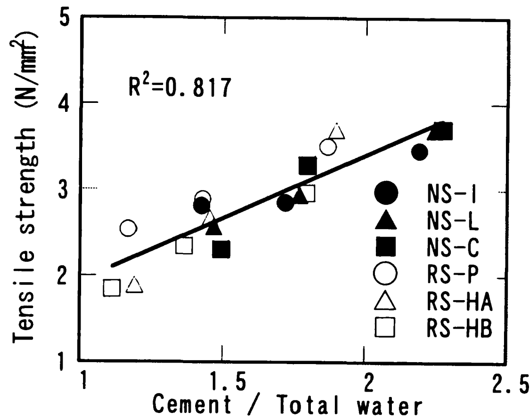

Figure 10 Relationship between C/TW and tensile strength of concrete.

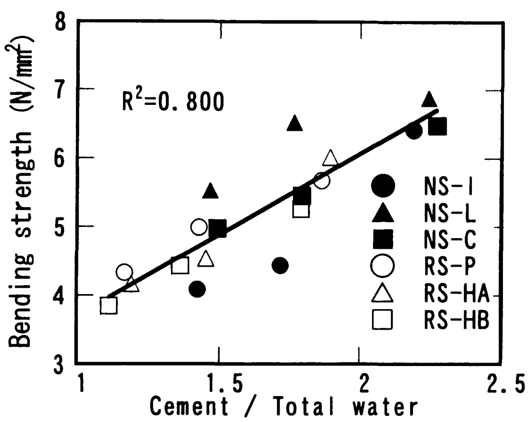

Figure 11 Relationship between C/TW and bending strength of concrete.

influence the concrete strength. But, if recycled fine aggregate of the water absorption has 9 % such as RS-P, recycled fine aggregate of absorbed water has about 50kg/m^3. It is difficult to ignore this amount. Then we introduced some ideas as follows.

To begin with, we calculated the amount of water absorbed into fine and coarse aggregate contents from the mix proportions. Next, we added the water content to the amount of absorbed water and got amount of total water in concrete. Amount of total water in 1 m^3 of concrete were called as total water content (TW) and total water content was defined as the following formula. Then, a ratio between cement content and total water content were called cement to total water ratio (C/TW).

$$TW = W + s \times Ds \times ws + g \times Dg \times wg$$

Where *TW* is the total water content, *W* is the water content, *s* is the volume of content of fine aggregate, *Ds* is the density of fine aggregate in the oven-dry condition, *ws* is the water absorption of fine aggregate, *g* is the volume of content of coarse aggregate, *Dg* is the density of coarse aggregate in the oven-dry condition and *wg* is the water absorption of coarse aggregate.

Figure 9, 10 and 11 show relationships between C/TW and each of concrete strengths. When C/TW of each concrete were same value, in the case of all strength tests, the strengths of the concrete were same value in spite of used fine aggregate. the coefficients of the determination were high. This means that the amount of water absorbed into fine aggregate has influence on concrete strengths. In other words, when recycled fine aggregate of high water absorption is used as concrete material, as a control index of the concrete strengths C/TW will be better than C/W.

5. Influence of Moisture Content of Fine Aggregate on Concrete Strength

Table 4 Mix proportions for the study of adjusting total water in concrete
(Aimed slump and air is 12cm and 5 %)

Sorts of fine aggregate	NS-I		RS-P		RS-HB		
Condition of fine aggregate	Saturated	Dry	Saturated	Dry	Saturated	Dry	Dry
Cement / total water	1.72	1.78	1.42	1.55	1.36	1.46	1.72
Sand / total aggregate by volume (%)	43.2	43.2	43.2	43.2	43.2	43.2	43.1
Water (kg /m^3)	163	172	163	196	163	223	212
Cement (kg /m^3)	326	326	326	326	326	326	326
Fine aggregate (kg /m^3)	762	744	697	644	656	588	584
Coarse aggregate (kg /m^3)	1037	1037	1037	1037	1037	1037	1034
Air entraining and water-redusing admixture (kg /m^3)	0.815	0.815	1.222	0.815	0.815	1.223	2.196*
Air entraining admixture is adds (g /m^3)	11.41	11.41	3.26	3.26	11.41	16.3	10.98
Air content (%)	5.6	6.0	5.5	5.4	5.5	5.2	4.2
Slump (cm)	11.0	11.9	12.0	13.8	11.0	12.6	11.0
Temperature (°C)	27.4	21.0	23.8	20.4	22.3	25.4	24.4
Added water (x absorbed water)	-	0.60	-	0.65	-	0.75	-

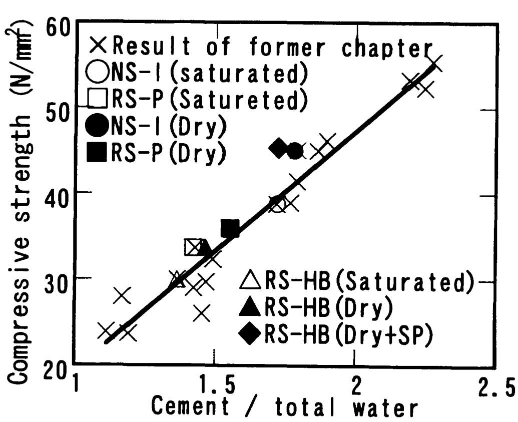

Figure 12 Influence of adjusting total water on compressive strength of concrete.

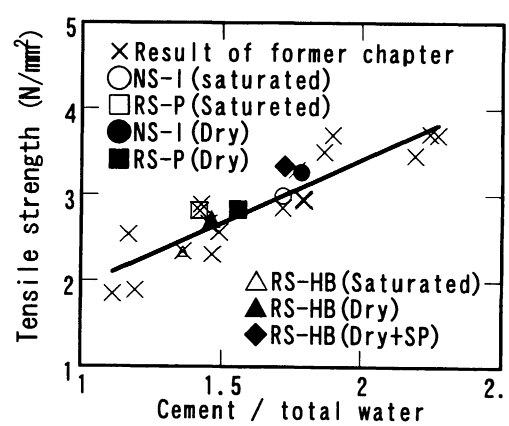

Figure 13 Influence of adjusting total water on tensile strength of concrete.

5.1 Test procedure

As the result of the former chapter, the total water content influences the concrete strength. In other wards, if the cement content is same, it is possible that the concrete strength increases with decrease of total water content. It will be adjusted a moisture content of fine aggregate to decrease total water content. it is expected that the concrete strengths are improved through the methods. The past papers[3] reported that it is effective on concrete strengths to use coarse aggregates at air-dry condition. Then, we made concrete with some fine aggregates of oven-dry condition, but added an amount of water absorbed into those fine aggregates so as to keep 12 cm of slump just after mixing. Also, we used superplasticizer for a sharp cut of total water content and C/TW of concrete with RS-HB was same one with NS-I in saturated surface-dry condition. In this experiment, the polycarboxylate based superplasticizer, NS-I, RS-P and RS-HB is used in addition to Table 1. Some mix proportions were shown in Table 4 and a method of mixing is same in a former chapter. However, a coarse aggregate used in this experiment is saturated surface-dry condition.

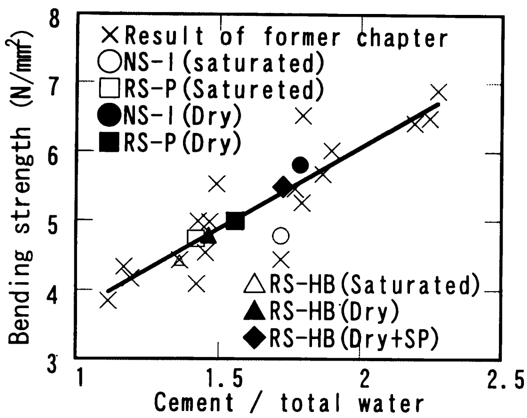

Figure 14 Influence of adjusting total water on bending strength of concrete.

5.2 Results and Discussions

When concrete with fine aggregate in oven-dry conditions had the aimed slump value, the added water was 60% of water absorbed into, 65% in case of RS-P and 75% in case of RS-HB due to get a aimed slump. For this reason, each of C/TW is 0.06 (NS-I), 0.13(RS-P) and 0.1(RS-HB) more than one in saturated surface-dry condition. And, the superplasticizer was used 0.6% of cement content to get C/TW like the concrete with NS-I.

3 results of concrete strength tests are shown as Figure 12, 13 and 14. The compressive, tensile and bending strengths, in case of controlled TW, were plotted above the lines of the results as Figure 9, 10 and 11. The concrete strengths in oven- dry condition increased by 10% more than in saturated surface-dry condition. Then, in case of using superplasticizer, concrete strengths were equal to or higher than those with NS-I in saturated surface-dry condition. Here, increase of concrete strength seems to be due to absorb water into fine aggregate. But it was found that C/TW could control the concrete strengths by no consideration of amount of absorbed water.

As the result, when recycled fine aggregate of high water absorption was used, using in oven-dry condition of one and adjusting properties of flesh concrete have some effects of improvement of concrete strength with one. Furthermore it is some possibility that concrete with recycled fine aggregate gets same strengths of hardened concrete with ordinary fine aggregate, if the superplasticizer is used to control the same C/TW of recycled concrete as one of ordinary concrete, the strengths of each concretes will be same approximately.

6. Conclusion

(1) In case of same mix proportions, air content and slump of flesh concrete are decreased with increase of all surface area of fine aggregate in concrete.
(2) Compressive, tensile and bending strength of concrete with recycled fine aggregate correlate closely with a mass ratio between a cement content and a sum of water content and amount of water absorbed into recycled fine aggregate.
(3) When recycled fine aggregate with high absorption is used, using recycled fine aggregate in oven-dry condition or a superplasticizer prevent a lowering of concrete strengths

7. Reference

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