EXPERIMENTAL INVESTIGATION ON DURABILITY PROPERTIES OF SELF COMPACTING CONCRETE BY PARTIAL REPLACEMENT OF FLY ASH AND GGBS IN OPC

M. Jagadeesh, N.R.Gowthami Reddy, T.Naresh Kumar.
***PG Student, AITS, Rajampet-516126, Kadapa District, Andhra Pradesh, India,**
****Assistant Professor, AITS, Rajampet-516126, Kadapa District, Andhra Pradesh, India.**
*****Assistant Professor, AITS, Rajampet-516126, Kadapa District, Andhra Pradesh, India.**

ABSTRACT:
Self-compacting concrete is a fluid mixture suitable for placing in structures with congested reinforcement without vibration. Self-compacting concrete development must ensure a good balance between deformability and stability. Also, compatibility is affected by the characteristics of materials and the mix proportions; it becomes necessary to evolve a procedure for mix design of SCC. The paper presents an experimental procedure for the design of self-compacting concrete mixes. The test results for acceptance characteristics of self-compacting concrete such as slump flow, V-funnel and L-Box are presented. Further, compressive strength at the ages of 28, 56, and 90 days was also determined and results are included here.

Key words: Self-compacting Concrete; Fly Ash; Mix Design; Fresh Properties; Hardened Concrete; Properties; Compressive Strength.

I. INTRODUCTION
One of the basic infrastructural facilities that man needs for good living is shelter. The development of technology in materials and construction has made it possible to build even skyscrapers. However, the increasing cost of conventional construction materials has made it difficult to meet the shelter requirements of the teeming population of developing countries. Fast expansion in the construction industry brought forth with it associated problems.

Self-compacting concrete (SCC) also referred to as "self-consolidating concrete," has newly been one of the most important development in the construction industry. SCC, require no compaction energy and use of vibrators inside entirely filling the formwork yet in the attendance of dense reinforcement has been developed in Japan in the late 1980s, to improve the reliability of concrete and concrete structures. In order to achieve this property, SCC must have good deformability, high segregation resistance, and no blocking around reinforcements without applying any vibration.

SELF COMPACTING CONCRETE
Self-compacting concrete is a form of concrete that is capable of flowing in to the congested interior of form work passing through the reinforcement and filling it in a natural manner, consolidating under the action of its own weight without segregation and bleeding. It is made from almost the same ingredients as that of the conventionally vibrated concrete except that the relative proportions of these ingredients are to be carefully selected to impart self-compacting property to fresh concrete.

Characteristics of Fresh Self- Compacting Concrete
Self-Compacting concrete is characterized by its special properties in fresh state namely flow ability, viscosity, blocking tendency, self-levelling and strength of mixture. These workability parameters are ground into three key properties, namely.

1. **Filling ability or deformability.**
2. **Passing ability.**
3. **Stability.**

II LITERATURE REVIEW
A. Pineaud (2016) the mechanical tests carried out at room temperature, it can be observed that the influences of the volume of cement paste and of the W/B ratio are quite similar for SCC and VC. W/B ratio is the predominant parameter with respect to mechanical properties at room temperature. Comparison of the overall results of the studied SCCs with the values proposed by Euro code 2 shows that, for a given compressive strength, the modulus of elasticity of SCC is significantly lower than the values proposed by Euro code 2.

Suraj N. Shah., Shweta S. Sutar, YogeshBhagwat (2014) carried out an experimental study on to find out the effect of addition of red mud, which is a waste product from the aluminium industries, and foundry waste sand, which is a waste product from foundry, on the properties of self-compacting concrete containing two admixtures and experimentation combinations of admixtures which is taken Super plasticizer &VMA. It can be concluded that maximum compressive strength of self-compacting concrete with the combination of admixtures (SP+VMA) may be obtained by adding 2% foundry waste sand which is a waste material of ferrous industry (foundry).

Pacheco Torgal.F et al. (2011) determined the effect of Metakaolin and Fly ash on strength and durability of concrete. The durability was found by three methods namely water absorption, oxygen permeability and concrete resistivity. They reported that partial replacement of Portland cement by 30% Fly ash leads to serious decrease in early age compressive strength than the reference mix made with 100% Portland cement. The use of hybrid of them at 15% Fly ash and 15% Metakaolin based mixtures resulted in minor strength loss

Bartle Person (2001) approved out an investigational and numerical study on mechanical properties, such as strength, elastic modulus, creep and shrinkage of self-compacting concrete and the correspondence properties of normal compacting concrete. The revise incorporated mix proportions of preserved or air-cured sampling with water binder ratio (w/b) varying between 0.24 and 0.80. Fifty percent of the mixes be Self-Compacting Concrete and period was Normal Compacting Concrete. The age at load of the concretes in the creep study various between 2 and 90 days. Strength and relative wetness were also originated. The results indicate that elastic modulus, creep and shrinkage of SCC do not differ significantly from the equal properties of Normal Concrete.

Nan Su et al (2001)planned a new mix design method for self-compacting concrete. First, the amount of aggregates necessary was resolute, and the paste of binder was then full into the voids of aggregates to make certain that the concrete thus obtain has flow ability, self-compacting ability and other required SCC properties. The amount of aggregates, binders and mixing water, as well as type and amount of super plasticizer to be used are the main factors influence the properties of SCC. Slump flow, V-funnel, L-flow, U-box and compressive strength tests were approved out to observe the act of SCC, and the results indicate that the anticipated method could be used to make effectively SCC of high quality.

III: MATERIALS AND METHODOLOGY

Cement

A cement is a binder, a substance used in construction that sets, hardens and adheres to other materials, binding them together. Cement is seldom used solely, but is used to bind sand and gravel (aggregate) together. In this project we hired Commercially available 53 grade ordinary Portland cement manufactured by Ultra Tech Cement with Specific Gravity of 3.2 and Fineness Modulus of 225m^2/kg used in all concrete mixes.

Coarse Aggregate

Aggregates are primarily naturally occurring, inert granular materials such as sand, gravel, or crushed stone. But, technology is broadening to include the make use of recycled materials and man-made products. In this investigation used 12mm size aggregates are used for Self-Compacting Concrete.

Fine Aggregate

Fine Aggregate can be natural or manufactured sand, but it have to be of uniform grading. The particle fineness than 150um sieve are considered as fines. To achieve a balance between deformability or fluidity and stability, the total content of fineness has to be high, usually about 520 to 560kg/m^3

FLY ASH

Fly ash conforming to the requirements of IS 3812 manufacturing from Rayalaseema Thermal Power Project (RTPP) in dharmal village near to Proddtur Kadapa district. The specific gravity of fly ash is 2.2 and specific surface area of fly ash 280m^2/kg was used as supplementary cementitious material in concrete mixtures. 85% of particles are passed through 45um sieve. In this investigation Class F fly ash is used in Self Compacting Concrete.

Chemical composition (%) of Fly ash

Compound	Content %Wt.
Sio_2	58
Al_2O_3	22.5
Fe_2O_3	5.75
TiO_2	5.6
Cao	2.12
MgO	1.6
SO_3	1.77
Na_2O	0.89
LOI	6.02

GGBS

Ground Granulated Blast Furnace Slag (GGBS) is a byproduct of Iron industry and which is obtained from during the manufacture of iron. The molten slag is a secondary product of sintering of the raw materials and this is quenched under high pressure of water jets, which results as granulates. The GGBS is obtained when the granulated slag is ground to a very fine powder with a specific surface area of 400-600m2/kg.

Chemical Composition (%) of GGBS

Compound	Content %wt.
Cao	36.5
SiO_2	38.1
Al_2O_3	12.4
MgO	10.9
K_2O	0.6

Super Plasticizer Admixture

For self-compacting concrete, the best Super plasticizer is anadmixture based in Polycarboxilates, do not guide by the brand of the admixtures because each producer has the personal name, the composition must be based in ethers of Polycarboxilates, the last generation of chemical superplastizicer admixtures.

MIX PROPORTIONING OF SCC

In designing the SCC mix, it is most useful to consider the relative proportions of the key components by volume rather than by mass. The following key proportions for the mixes listed below:

1. Air content (by volume)
2. Coarse aggregate content (by volume)
3. Paste content (by volume)
4. Binder (cementitious) content (by weight)
5. Replacement of mineral admixture by percentage binder weight
6. Water/ binder ratio (by weight)
7. Volume of fine aggregate/ volume of mortar
8. SP dosage by percentage cementitious (binder) weight
9. VMA dosage by percentage cementitious (binder) weight

MIX DESIGN PROCEDURE FOR SELF COMPACTING CONCRETE

The design procedure adopted for preparation of self-compacting concrete with the application of fly ash and GGBS. Self-compacting concrete mix design for M30 grade as per **"EUROPEAN GUIDE LINES"**

In designing the mix it is most useful to consider the relative proportions of the keycomponents by volume rather than by mass.

- ✓ Water / Powder ratio by volume of 0.80 to 1.10
- ✓ Total powder content – 160 to 240 liters (400 – 600 Kg) per cubic meter.
- ✓ Coarse aggregate content normally 28 to 35 percent by volume of the mix.
- ✓ Water cement ratio is selected based on requirements in EN 206. Typically watercontent does not exceed 200 liter/m^3.
- ✓ The sand content balances the volume of the other constituents.

MIX	MIX ID
NORMAL CONCRETE	A1
10% FLY ASH AND 0% GGBS	A2
10% FLY ASH AND 5% GGBS	A3

10% FLY ASH AND 10% GGBS	A4
10% FLY ASH AND 15% GGBS	A5

Batching and Mixing

Batching is process of measuring the quantities of concrete either by volume or by mass for preparation of concrete mix. In this weight batching method is adopted to measure the quantities of fine aggregate, cement, coarse aggregate, fly ash and GGBS and super plasticizer. For mix proportion for design were measured by using weighing balance. The ingredients of concrete in the required quantities were enhanced into the capacity laboratory concrete mixer. After through mixing i.e., having achieved uniform colour, workable consistency to concrete, the concrete was shipped into tray for casting specimens.

Casting and Curing of Specimens

IS standard 150mm×150mm ×150mm for cubes, 150mm ×300mm for cylinders, and 700mm×150mm×150mm for beams for casting specimens the concrete has been placed in the standard metallic moulds in three layers and compacted with tamping rod by giving 25 blows. Before placing the concrete in moulds a thin coat of oil was applied for the walls of the moulds inside for easy removal. Then moulds were placed on needle vibrator for 10 r 15 seconds after finishing smoothly on the top surface of specimens.

IV EXPERIMENTAL INVESTIGATION

COMPRESSIVE STRENGTH TEST

TEST PROCEDURES FOR SELF-COMPACTING CONCRETE (SCC):

This section describes the various tests generally performed on self-consolidating concrete (SCC). The physical characteristics of SCC as determined using these tests are critical for ensuring quality structures that are safe, durable and economical.

Workability Tests for SCC

In this investigation workability tests are followed by

1. **Slump Flow Test with T_{500}**
2. **L-Box Test**
3. **V-funnel and T_5**
4. **J-Ring Test**

COMPRESSIVE STRENGTH TEST

Concrete cubes ofsizes150mm×150mm×150mm were tested for crushing strength. Compressive strength depends on loads of factor such as w/c ratio, cement strength, excellence of concrete material and excellence control during manufacture of concrete.

These cubes are tested by compression testing machine after 7 days, 14 days or 28 days curing. The sample is placed centrally on the base plate of machine and the load have to be apply gradually at the rate of 140 kg/cm2 per minute till the specimen fails. Load at the failure separated by area of sample gives the compressive strength of concrete. The sample to increased load breaks down and no greater load greater load can be constant. The maximum load applied to specimen shall then be recorded and any unusual value noted at the time of failure brought out in the report.

The cube compressive strength, then f_c=P/A N/mm^2

Where P is an ultimate load in N, A is a cross sectional area of cube in mm$^{2.}$

Fig. Compressive Strength Test

SPLIT TENSILE STRENGTH OF CONCRETE

The following tests are conducted for the calculation of compressive strength

- ACID RESISTANCE TEST
- SULPHATE ATTACK TEST
- ALKALINITY TEST
- RCPT (RAPID CHLORIDE PERMEABILITY TEST)

Acid Attack Test

The concrete cube specimens of various concrete mixtures of size 150 mm were cast and after 28 days of water curing, the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for 90 days after 28 days of curing. Hydrochloric acid (HCL) with pH of about 2 at 5% weight of water was added to water in which the concrete cubes were stored.

Sulphate Attack Test

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na_2SO_4) and 5% of magnesium sulphate ($MgSO_4$) by weight of water and those which are not immersed in sulphate water. The concrete cubes of 150mm size after 28days of water curing and dried for one day were immersed in 5% Na_2SO_4 and 5% $MgSO_4$ added water for 90days. The concentration of sulphate water was maintained throughout the period.

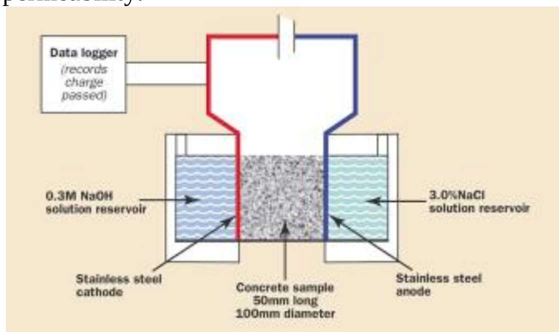
Alkaline Attack Test

To determine the resistance of various concrete mixtures to alkaline attack, the residual compressive strength of concrete mixtures of cubes immersed in alkaline water having 5% of sodium hydroxide (NaOH) by weight of water was found. The concrete cubes which were cured in water for 28 days were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. Then the cubes were immersed in alkaline water continuously for 90 days.

RCPT (RAPID CHLORIDE PERMEABILITY TEST)

Corrosion of reinforcing steel due to chloride ingress is one of the most common environmental attacks that lead to the deterioration of concrete structures. Corrosion-related damage to bridge deck overlays, parking garages, marine structures, and manufacturing plants results in millions of dollars spent annually on repairs. This durability problem has received widespread attention in recent years because of its frequent occurrence and the associated high cost of repairs. Chlorides penetrate crack-free concrete by a variety of mechanisms: capillary absorption, hydrostatic pressure, diffusion, and evaporative transport. Of these, diffusion is predominant.

The rapid chloride permeability test meets these goals. RCPT has had results that correlate well with results from the classical 90-day salt ponding test. Standardized testing procedures are in AASHTO T 277 or ASTM C 1202. The RCPT is performed by monitoring the amount of electrical current that passes through a sample 50 mm thick by 100 mm in diameter in 6 hours (see schematic). This sample is typically cut as a slice of a core or cylinder. A voltage of 60V DC is maintained across the ends of the sample throughout the test. One lead is immersed in a 2.4 salt (NaCl) solution and the other in a0.3 M sodium hydroxide (NaOH) solution. Based on the charge that passes through the sample, a qualitative rating is made of the concrete's permeability.



The RCPT setup is simple and provides results relatively quickly.

V RESULTS

This part explains the mechanical strength properties like compressive strength, split tensile strength, flexural strength, non- destructive test (rebound hammer) and young's modulus test of concrete mixture with fly ash and ground granulated blast furnace slag and discussion are presented.

FRESH PROPERTIES OF SCC

FRESH PROPERTIES OF SCC

Table: Fresh properties of self-compacting concrete

PERCENTAGE REPLACEMENT OF FLY ASH AND GGBS	SLUMP FLOW IN mm	SLUMP FLOW IN sec (T_{50cm})	V-FUNNEL in sec	L-BOX (H_2/H_1)
10% & 0%	670	5	10	0.9
10% & 5%	650	7	9	0.83
10% & 10%	630	7	12	0.8
10% & 15%	625	7	8	0.79

Observations:

From the table, it has been observed that fresh properties of SCC such as such as Slump flow and T_{50cm} slump flow, V-Funnel test, L-box test for replacement to cement by Fly ash and GGBS is within their limits.

COMPRESSIVE STRENGTH RESULTS

The Compressive strength results for various replacement levels of fly ash and GGBS by Cement such as 0%, 5%, 10% & 15% are tabulated below in table.

- ❖ Compressive strength of the cubes when they are tested under the following parameters are given below

1. ACID RESISTANCE TEST
2. SULPHATE ATTACK TEST
3. ALKALINITY TEST
4. RCPT (RAPID CHLORIDE PERMEABILITY TEST).

NOTE:

Before going to the test for the casted specimen, we should workout with the weights of the specimens before and after the curing, by the way we can clearly notice which mix proportion will sustain the chemical, acid curing.

TEST RESULTS IN NORMAL CURING

Table COMPRESSION TEST RESULT @NORMAL CURING.

Mix Designation	Compressive strength N/mm²
	28 days
A1	33.0
A2	33.8
A3	36.3
A4	41.6
A5	32.4

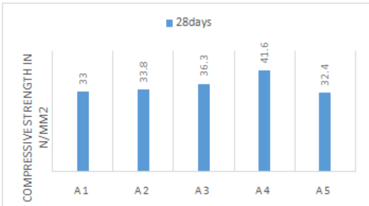


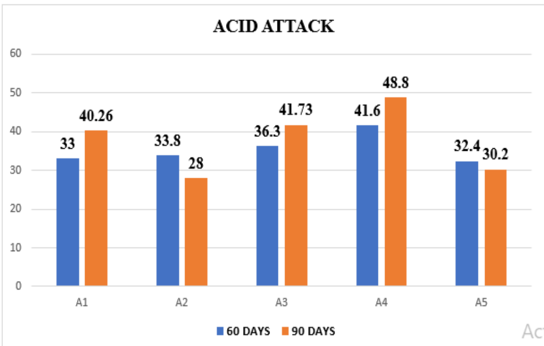
Fig.6.2: Compressive Strength test results (Acid Attack @ 60DAYS)

As we observed the compressive strength is 28 days strength of SCC at acid attack for (30days normal curing + 30days acid curing) i.e. Total 60 days as 10%FA &0%GGBS, from the graph we can clearly make a forward step towards the increase in compressive strength when the replacement of 10% flyash and 10% GGBS is done at acid curing in 60 days compared to all the remaining mixes.

TEST RESULTS IN ACID ATTACK:

Table COMPRESSION TEST RESULT @ ACID ATTACK

Mix Designation	Compressive strength N/mm²	
	60 days	90 days
A1	33.0	40.26
A2	33.8	28.0
A3	36.3	41.73
A4	41.6	48.8
A5	32.4	30.2



Compressive Strength test results (Acid Attack)TEST RESULTS IN SULPHATE ATTACK

As we observed the compressive test at age 60 days and 90 days strength of SCC at acid attackfor (30 days normal curing + 30 days acid curing), (30 days normal curing + 60 days acid curing) i.e. Total 60 &90 days as 10% FA & 0% GGBS, from the graph we can clearly make a forward step towards the increase in compressive strength when the replacement of 10% flyash and 10% GGBS is done at acid curing in 60 days compared to all the remaining mixes.

Table COMPRESSION TEST RESULT @ SULPHATE ATTACK

Mix Designation	Compressive strength N/mm²	
	60 days	90 days
A1	37.4	35.53
A2	38.26	37.4
A3	31.56	40.2
A4	43.73	41.36
A5	32.50	30.5

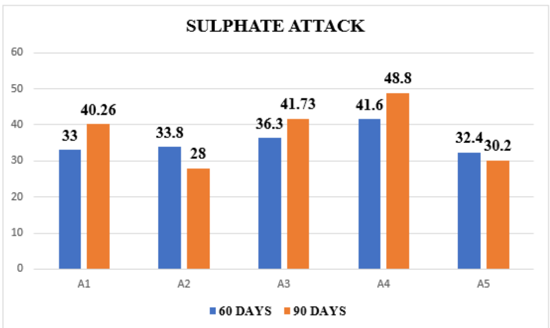


Fig.: Compressive Strength test results (Sulphate attack)

As we observed the compressive test at the age of 60 & 90 days strength SCC at acid attackfor (30 days normal curing + 30 days sulphate curing), (30 days normal curing + 60 days sulphate curing) i.e. from fig: 6.3 we can notice in the sulphate attack the compressive strength the cube with 0% to 15% increase in fly ash and GGBS, increment was done in 10% Fly ash and 10% GGBS.

TEST RESULTS IN ALKALINITY TEST

Table. COMPRESSION TEST RESULT @ ALKALINITY TEST

Mix Designation	Compressive strength N/mm²	
	60 days	90 days
A1	37.93	41.53
A2	42.6	45.96
A3	29.23	33.26
A4	38.06	39.83
A5	28.42	29.82

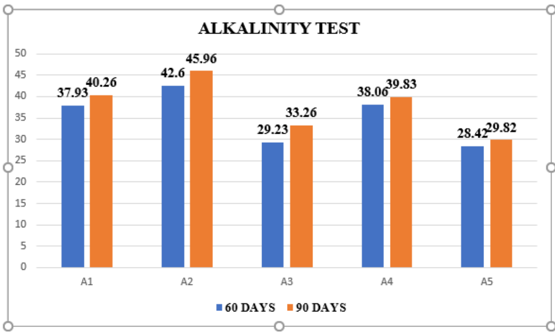


Fig.: Compressive Strength test results (ALKALINITY TEST)

The inference from the graph is the compressive strength at 60 & 90 days strength in SCC at alkalinity for (30 days normal curing + 30 days chemical curing), (30 days normal curing + 60 days chemical curing) i.e. Total 60 & 90 days from the graph we can notice in that with the alkalinity attack the compressive strength the cube with 10% Fly ash to 0% GGBS increase initially and decrement of strength taken place.

RCPT test values:

Table.: RCPT VALUES @28 DAYS & 60 DAYS.

MIX PROPORTIONS	CHARGE PASSED (COULOMBS)	
	28DAYS	60 DAYS
A1	1652.5	1286.7
A2	1435.4	1058.5
`A3	1173.6	953.55
A4	1058.7	735.89
A5	1175.6	985.3

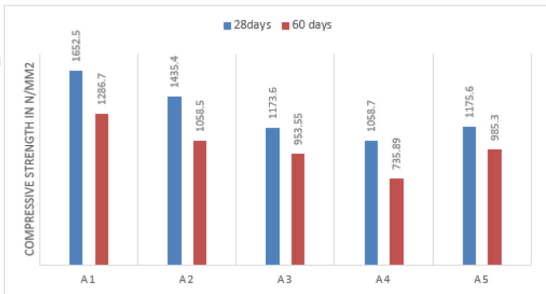


Fig.: RCPT test results

From the graph we can prove that, the chloride permeability is more in case of Normal concrete then it is decreased while adding GGBS 5%, 10% to the concrete for 60 days of curing. The chloride permeability of concrete with 10%FLY ASH + 10% GGBS is less while compared with the all proportions for 90 days.

VI. CONCLUSION

CONCLUSION:

The latest trend in concrete research is to use industrial by-products in preparing the concrete mixes. The addition of GGBS and FA as mineral additives in SCC is a step that would gainfully employ these two otherwise waste products whose disposal is an issue in itself. In this work, SCC prepared using these industrial by-products are evaluated in terms of self-compact ability, compressive strength, and durability study, the following conclusion may be drawn:

- ❖ According to our study, addition of FA to the concrete, can improve the fresh concrete properties.
- ❖ SCC mix which incorporates GGBS requires high dosage of super plasticizer to produce acceptable workability.
- ❖ The results shown that the use of FA and GGBS in concrete offsets the effect of GGBS has increasing the dosage of admixture in concrete to achieve fresh concrete properties.
- ❖ From this project we can conclude that the mix proportion 10% fly ash & 10% GGBS withstands all the strengths and we got optimum results for the above mix
- ❖ Replacing cement with FA reduces the strength of SCC mix when compared with GGBS and Normal SCC mix
- ❖ The combined replacement of FA and GGBS cement shows increases in strength by increase in percentage replacement.
- ❖ SCC mix which incorporates of powder material comprising of 80% ordinary Portland cement, 10% Fly ash and 10% GGBS gives optimum values.

SCOPE OF FUTURE WORK

- ❖ Fly ash can replace a significant part of the necessary filler when used into a self-compacting concrete composition.
- ❖ The elimination of vibrating equipment improves the environment protection near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration.
- ❖ The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction. Based on these facts it can be concluded that SCC will have a bright future.

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