A STUDY ON PROPERTIES OF FOAM CONCRETE USING MULTI-WALLED CARBON NANOTUBES

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Abstract

The objective of this paper is to study the properties of the foam concrete normally referred as cellular concrete is reinforced with multi-walled carbon nanotubes (MWCNT). Normally foam concrete finds its application in lightweight structural elements, insulating material and partition material in framed structures with low compressive strength, tensile strength and flexural strength. The study aims to improve the properties of foam concrete using multi-walled carbon nanotubes (MWCNT) as a cementitious material and fly ash as a partial replacement of fine aggregate. The density of lightweight concrete ranges from 400 to 1600kg/m3. In this study a trial-and-error method was followed to choose an appropriate density of foam concrete according to field conditions. The method for proper dispersion of nano material MWCNT in foam concrete mixture is also revealed in this study. Casting of three different concrete beams of size 150mmX200mmX1800mm are made. One is normal concrete (B1), second one is conventional foam concrete (B2) and the third one is foam concrete reinforced with MWCNTs (B3). The experimental results are to be compared with analytical results of SAP for validation.

Keywords:-Foam Concrete, nanotubes, multi-walled carbon nanotubes, MWCNT, SAP.

I.INTRODUCTION

Builders throughout the world are paying an increasing attention in the use of foam concrete normally referred as cellular concrete.

1.1 Foam concrete

Foam concrete comprises of cement, sand, water and mechanically generated foam in the form of gel.

Foam is prepared in a special device called foam generator and later mixed by using special mixer. By controlling the dosage of foam, foam concrete of different densities (400-1600 kg/m3) has been casted. Because of the integration of air-pores into the base matrix, the foam concrete gives low self-weight, high workability and excellentinsulatingvalues. Foam concrete is a free flowing, self-levelling; material that does not require compaction. This type of concrete is particularly suitable for high technology special structures where apart from the response to reduce the cost and environmental impact are considered. Althoughfoam concrete possesses a great number of benefits, its compressive strength, tensile strength and flexural strength are low. Attempt have been made to improve the properties of foam concrete by adding nanomaterial multi- walled carbon nanotubes(MWCNT).

Since nanotechnology is gaining popularity in the field of civil engineering and construction which deals with particle at nano-scale (ie) 10^{-9}m. One of the methods recently employed to improve the technical characteristics of concrete is the use of additives consisting of nano dispersive particles.

Concrete can be tailored by the incorporation of nanotubes to control material behavior and add novel properties by the grafting of molecules into cement particles, cement phases, aggregates and additives to provide surface functionality.

Nanosized particles have a high surface area to volume ratio providing the potential for chemical reactivity when it is admixed. Several challenges will need to be solved to realize its full potential, including the proper dispersion of the nano-scale additives, implementation on larger scale and a lowering of the cost benefit ratio.

1.2 Multi-walled carbon nanotubes

Carbon nanotubes are allotropes of carbon with a cylindrical nanostructure. Their name is derived from their long, hollow structure with the walls formed by one-atom-thick sheets of carbon called graphene. These sheets are rolled at specific and discrete angles and the combination of the rolling angle and radius decides the nanotubes properties.

There are three types of carbon nanotubes: i)Single walled carbon nanotubes(SWCNT) ii)Double walled carbon nanotubes(DWCNT) iii)Multi walled carbon nanotubes(MWCNT)

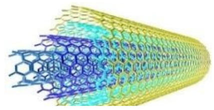


Fig. 1. Multi-walled carbon nanotubes

Multi-walled carbon nanotubes (MWCNT) are with high aspect ratio, very high tensile strength, high surface area to volume ratio and economical. So MWCNT take part in this study. Fig.1 shows the image of MWCNTs.

IIEXPERIMENTAL SETUP

2.1 Introduction

This chapter presents a summary of the experimental work conducted in the present investigation to study the properties of foam concrete reinforced with the nanomaterial multi-walled carbon nanotubes.

2.2 Experimental program

2.2.1 Dispersion of MWCNT

The full potential of employing MWCNTs as reinforcements has been severely limited because of the difficulties associated with dispersion of MWCNTs during processing and poor interfacial interaction between MWCNTs. The incorporation of MWCNTs into a concrete matrix leads to an exceptionally large quantity of particles and high surface area of fillers, resulting in the difficulties that uniform dispersion of these particles. This difficulty can be overcome by the ultrasonication process.

Ultrasonication is the act of applying ultrasound energy to agitate particles in a solution for various purposes. In the laboratory, it is usually achieved using an ultrasonic bath or an ultrasonic probe also known as sonicator. In this paper sonicator bath is used for

ultrasonication process.

Fig.2Ultrasonication process using bath sonicator

The principle of ultrasonication technique is that when ultrasound propagates via a series of compression, attenuated waves are induced in the molecules of the medium through which it passes. The production of this shock waves promotes the "peeling off" of individual nanoparticles located at the outer part of the nanoparticle bundles results in the separation of individualized nanoparticles from the bundle.

Ultrasonication is an effective method to disperse MWCNTs in liquids having a low viscosity, such as water, acetone and ethanol. In this study polycarboxylate ether, a superplasticizer is used as a liquid medium for dispersing MWCNTs.

2.2.2 Generation of foam

Foam can be generated using a special device named foam generator. There are two types of foaming agents:

A. Protein based foam solution
B. Synthetic foam solution

The unit weight of protein based and synthetic foam solutions are 80g/ltr and 40g/ltr respectively. The protein-based foam solution yields high strength comparing with synthetic foam solution. In this paper, protein-based foam solution is used. The foam solution to water ratio 1:40 was pumped into the foam generator and air pressure of 6 psi was also sent through air nozzle to foam generator. The generator generates the foam in the form of gel.

2.2.3 Materials and Mix Proportions

ASTM Type I Ordinary Portland cement of 53 grade was used for all concrete mixtures. The chemical composition of cement and fly ash used are given in table 1. Class F fly ash conforming to ASTM C618 was used. The complete details of the concrete mixes are presented in table 2. The W/C ratio was kept as 0.3 and S/C ratio as 2.5.

Table 1: Chemical composition of OPC & fly ash

CHEMICAL COMPOSITION (%)		
	OPC	Fly ash
Silicon dioxide(SiO2)	21.6	54.9
Aluminium oxide(Al2O3)	4.13	25.8
Ferric oxide(Fe2O3)	4.57	6.9
Calcium oxide(CaO)	64.44	8.7
Magnesium oxide(MgO)	1.06	1.8
Sodium oxide(Na2O)	0.11	0.3
Potassium oxide(K2O)	0.56	0.1
Sulphur trioxide (SO3)	1.74	0.6
Loss on ignition	0.76	0.2

The trial and error method was followed in finding the target density of foam concrete mix. Initially the target density was kept as 500 kg/m^3 and it has been increased according to field conditions. Finally the target density was kept as $1500kg/m^3$.

Table 2 Composition of mixtures

Series	Mix Number	Composition of mixture (per m3)		
		Cement	Sand	Fly ash
		(kg)	(kg)	(kg)
I	1	492.94	1233.56	0
	2	492.94	986.85	246.71
	3	492.94	740.14	493.42
	4	492.94	493.42	740.14
	5	492.94	246.71	986.85
II	1	492.44	1233.56	0
	2	492.44	986.85	246.71
	3	492.44	740.14	493.42
	4	492.44	493.42	740.14
	5	492.44	246.71	986.85
III	1	491.95	1233.56	0
	2	491.95	986.85	246.71
	3	491.95	740.14	493.42
	4	491.95	493.42	740.14
	5	491.95	246.71	986.85
IV	1	491.46	1233.56	0
	2	491.46	986.85	246.71
	3	491.46	740.14	493.42
	4	491.46	493.42	740.14
	5	491.46	246.71	986.85
V	1	490.96	1233.56	0
	2	490.96	986.85	246.71
	3	490.96	740.14	493.42
	4	490.96	493.42	740.14
	5	490.96	246.71	986.85

Weight of foam = 18.48 kg/m^3

Volume of superplasticizer = 4.8 litres/m^3

Volume of water = 143.23litres/m^3

2.3 Casting of foam concrete specimens

Foam concrete was produced in a laboratory using a paddle mixer by adding the preformed foam to a base mix. The foam concrete produced was divided into five series.

Series I–0.1% weight of cement replaced by MWCNT & series II,III,IV & V – 0.2, 0.3,0.4&0.5% weight of cement replaced by MWCNT respectively.

The mixing sequence consisted of combining the binder material with water and mixing it until a homogenous base mix was achieved. After that the dispersed MWCNTs were added to the basemix. The required weight of the foam was generated and added immediately to the base mix and mixed for a minimum duration until there was no physical sign of the foam on the surface and the foam was uniformly distributed throughout the mix.

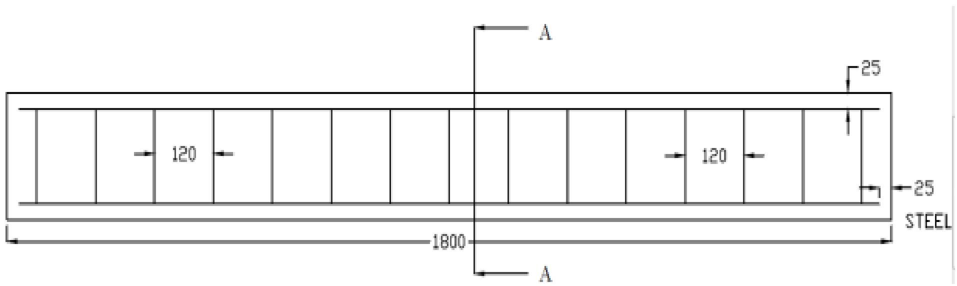
A number of standard test specimens of different sizes were chosen for investigating the various parameters. Cubes 150 x 150 x 150 mm size were used for testing the compressive strength. Cylinders 150mm dia and 300mm height were used for finding split tensile strength and young's modulus. Prisms 100 x 100 x 400mm were used for finding the flexural strength of the foam concrete.

2.4 Casting of beams

Three different beams: one was normal concrete of characteristic compressive strength equivalent to that of foam concrete, other was conventional foam concrete and the third one was foam concrete reinforced with MWCNTs.

2.4.1 Reinforcement details

Fig.3 shows the reinforcement details of beam of size 150mm x 200mm x1800mm.



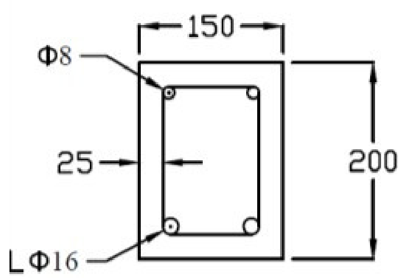


Fig.3a Longitudinal Section

ALL DIMENSIONS ARE IN mm

Fig.3b Cross Section

Fig.3 Reinforcement details of beam

Clear cover & reinforcement details:

1. Clear cover on all the four sides = 25mm
2. Main bars diameter = 2nos. of 16mm ϕ
3. Anchor bars dia = 2nos. of 8mm ϕ
4. Stirrups = 2 legged stirrups of 8mmϕ
5. No. of stirrups = 15nos.@120mm spacing

2.4.2 Mix design for normal concrete

Normal concrete beam specimen was casted by using M15 grade. As per IS 10262:2009 the mix design was carried out and the mix proportions were tabulated in table 3.

Table 3:Mix proportion of M15 normal concrete

Materials	Weight	Unit
Cement	394	kg/m^3
Fineaggregate	743.09	kg/m^3
Coarse aggregate	1114.63	kg/m^3
Water content	197	kg/m^3
Watercementratio=0.5		

3. RESULTS AND DISCUSSION

3.1 Introduction

The foam concrete specimens were tested after28 days from casting and their results are as follows:

3.2 Compressive strength

The effect of MWCNTs on the compressive strength of foam concrete was shown in fig.4. For given foam volume MWCNTs greatly improves the strength. However for a foam concrete with 0.4 & 0.5 % weight of cement replaced by MWCNTs, its strength get reduced because of accumulation of nano particle in the given superplasticizer.

If the percentage of fly ash in foam concrete mix is increased its compressive strength also get increased upto an optimum value. After that the strength gets decreased due to the breakage of air pores in the base matrix.

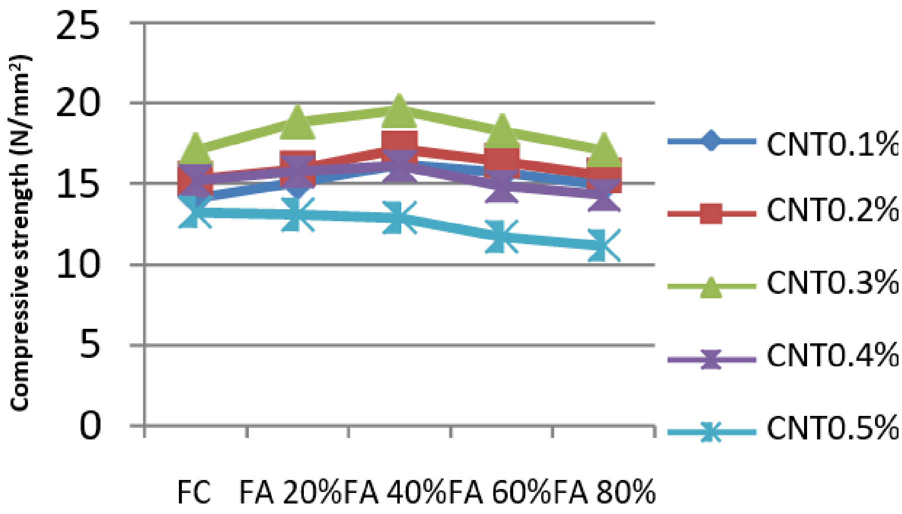


Fig.4 Compressive strength of foam concrete specimens

3.3 Split tensile strength

The split tensile strength also shows the similar variation corresponding to the compressive strength.

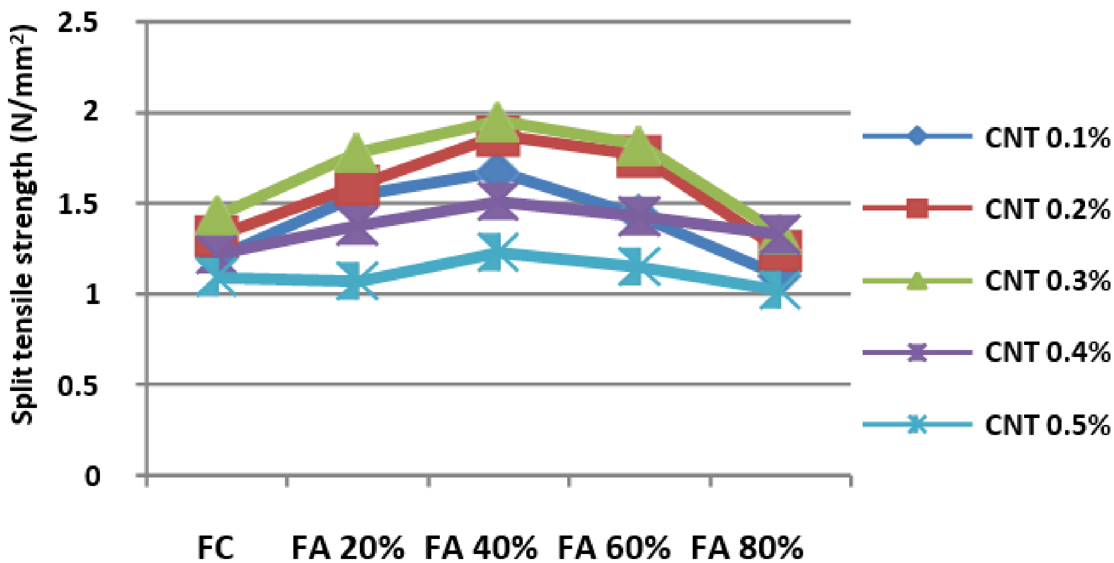


Fig.5 Split tensile strength of foam concrete

The fig.5 shows that the optimum value of split tensile strength was attained by 0.3% weight of cement replaced by MWCNT.

3.4 Young's modulus

The modulus of elasticity of the study material foam concrete reinforced with multi-walled carbon nanotubes (MWCNT) is more when compared with the conventional foam concrete.

The fig.6 shows the young's modulus of the foam concrete with fly ash as partial replacement of fine aggregate.

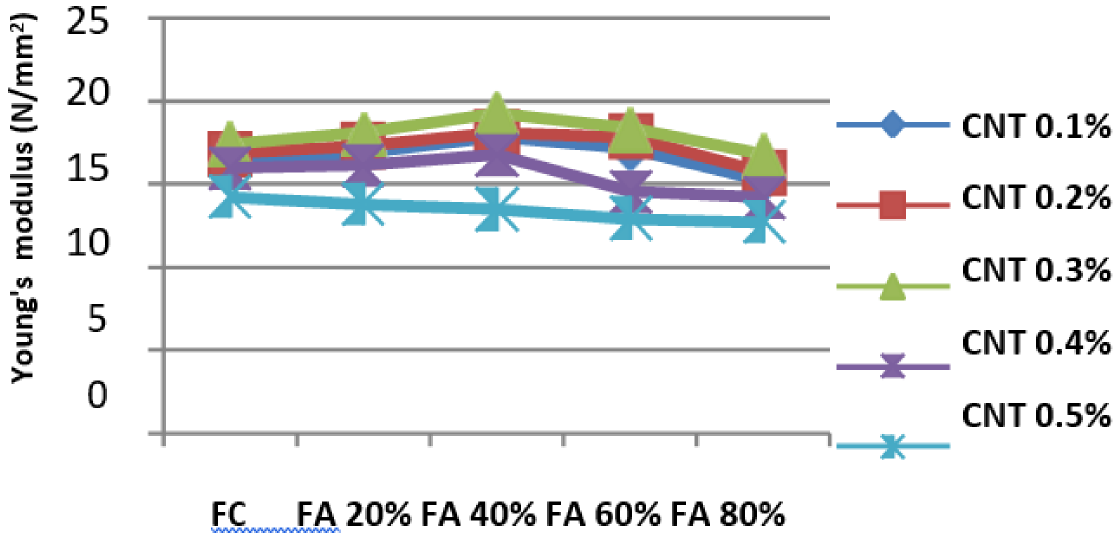


Fig.6 Modulus of elasticity of foam concrete specimens

3.5 Flexural strength

The foam concrete prisms of size 100mmx100mmx400mm were casted and tested. The flexural strength of foam concrete reinforced with MWCNTs is more compared with conventional foam concrete. Due to the presence of air-pores in the base matrix the specimen is more brittle compared with normal concrete.The fig.7 shows the variation of flexural strength of different foam concrete mixes.

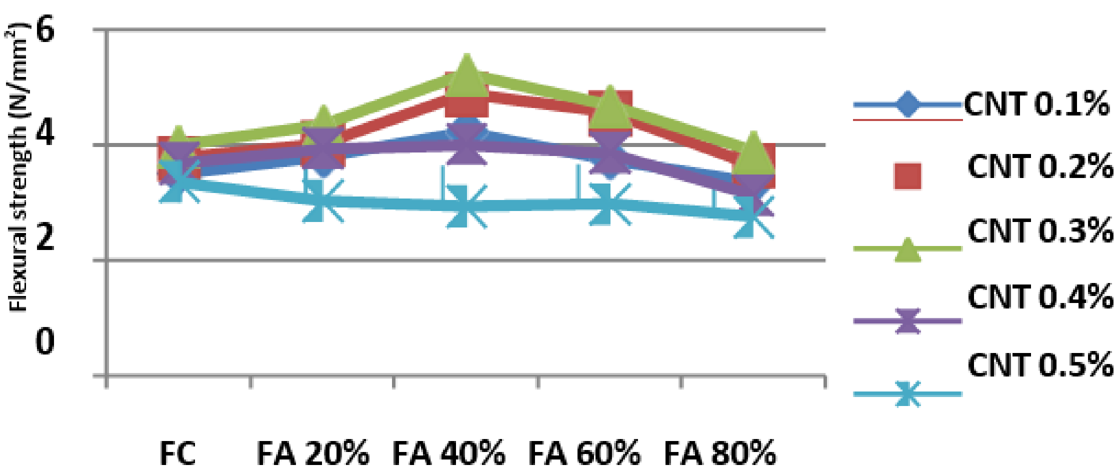


Fig.7 Flexural strength of foam concrete specimens

4. ANALYTICAL PROGRAM

The optimum values of compressive strength, young's modulus and fresh density of the foam concrete reinforced with MWCNTs were noted and it can be taken into account for modeling the beam of size 150mmX200mmX1800mm. Table4 gives the material properties of normal concrete, conventional foam concrete and foam concrete reinforced with MWCNT. And also Fig.8 shows the image of modelled beam with above said properties.

Table 4 Properties of concrete

	Normal Concrete	Normal Foam Concrete	Foam Concrete with MWCNT
Compressive strength (N/mm²)	15	14.01	19.61
Young's modulus (N/mm²)	19364.91	18714.97	22141.59
Poisson's ratio	0.2	0.2	0.2
Density kg/m³	2500	1500	1500

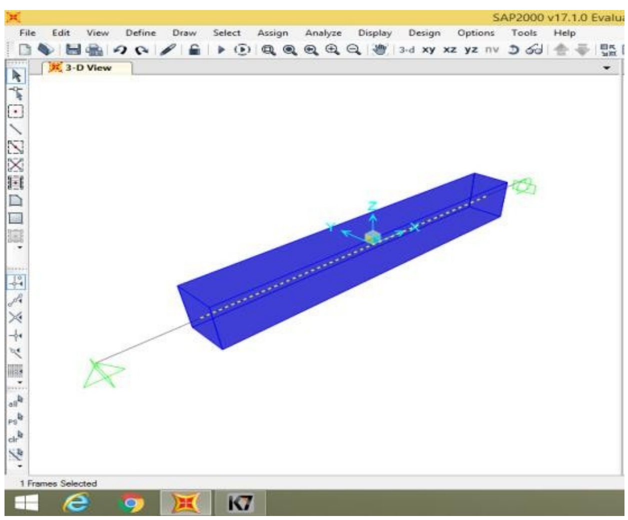


Fig.8 Beam modelled using SAP 2000

Loading and boundary conditions

The boundary conditions were given as simply supported and two point loading was given. The loading was given in an incremental manner and the maximum deflection at the midpoint for each and every load was noted. Graph was plotted between load vs deflection.

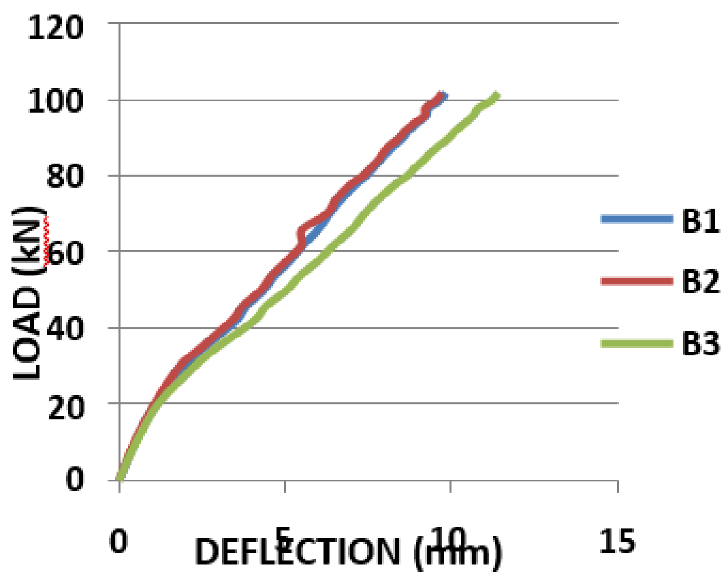


Fig.9 Graph between load vs deflection

5. CONCLUTIONS

The following conclusion can be stated based on the investigation on foam concrete reinforced with MWCNT

1. Introduction of nanomaterial MWCNT in the base matrix of foam concrete mix increases the compressive strength, split tensile strength, young's modulus and flexural strength. 0.3% replacement of MWCNT by weight of cement with 40% replacement of fly ash for fine aggregate gives the optimum value of the compressive strength, split tensile strength, young's modulus and flexural strength.
2. If the percentage of MWCNT gets increased the accumulation of nanomaterial occurs due to improper dispersion of that nanomaterial in the present liquid medium superplasticizer leads to reduction in the strength of test specimens.
3. If the percentage of fly ash get increased in the base matrix, the breakage of air-pores occurs leads to shrinkage.
4. When comparing this foam concrete reinforced with MWCNT with normal concrete of equivalent grade, the foam concrete yields high strength. The main disadvantage was the foam concrete was brittle in nature.
5. Analytical result shows that foam concrete with MWCNTs shows minimum deflection comparing with normal concrete

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