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Research Article

PERFORMANCE OF BASALT FIBRE REINFORCED RECYCLED AGGREGATE CONCRETE UNDER PURE TORSION

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ABSTRACT

This paper presents the torsion behaviour of basalt fibre reinforced recycle aggregate concrete. Total ten mixes are taken for experimental work among them, 5 mixes with basalt fibres and other 5 mixes without basalt fibres. The recycled concrete aggregate was used in the mix as replacement to the natural aggregate in the proportion of 0,25,50,75 and 100%. In addition to the torsion behaviour for various mixes, the compressive and split tensile strengths are evaluated. The strength parameters of recycled aggregate concrete (RAC) were compared with natural aggregate concrete(NAC), From the test results it is observed that compressive, split tensile and torsion strengths of RAC are increased up to 50% replacement of recycled aggregate. Due to addition of basalt fibres for RAC mixes, strengths are increased and more effectiveness is observed for 50% RAC mix. Regression model is developed to estimate the torsional shear strength for rectangular beam as function of compressive strength.

INTRODUCTION

Construction and Demolition (C&D) waste constitutes a major portion of total solid waste production in the world and most of it used for landfills. Researches by concrete engineers have clearly suggested the possibility of appropriately treating and reusing such waste as aggregate in new concrete. Recycling is the art of processing the secondary raw material and it is the solution to the problem of an excess of waste material not forgetting the parallel trend of improvement of final quality. The technology today has advanced so far that it is forcing us to think of new concept called sustainability. Preservation of the environment and conservation of the rapidly diminishing natural resources should be the essence of sustainable development. In this concern here in the experimental work has planned to obtain the torsional behaviour for basalt reinforced recycle aggregate concrete. The recycle aggregate (RA) can be treated as second grade material for concrete works and in general it is obtained from demolition of structures/buildings. The specific gravity of demolished concrete is lower than natural aggregate (Yong-Hak Lee *et al*, 2011), the volume of voids and water absorption of recycled concrete is higher than those of normal concrete (Chakradhara Rao *et al*,2011) and it shows variation in workability during fresh concrete stage (Topcu I.B *et al* 1995). The use of recycled aggregate will have better shape, surface texture and bonding with cement concrete. The density of the recycled concrete is more or less equal to natural concrete (Tam W *et al*, 2008). But, the compressive strength of recycled concrete will be less and it is recovered by introducing reinforcement in the form of continuous or discontinuous fibres (Ann K.Y *et al*, 2008). As the replacement ratio of recycled aggregate increases, it will decrease the compressive strength of the concrete (Eguchi K *et al*, 2007). In particular tensile strength behaviour of RAC, it is noticed that the concrete is weak / brittle under tensile loading and the mechanical properties of concrete may be improved by incorporation of randomly oriented short discrete fibres, which prevent or control initiation and propagation or coalescence of cracks. The character and performance of fibre reinforced concrete (FRC) change depending on the properties of concrete and the fibres (material). Due to addition of steel fibres in Reinforced Concrete (RC) members improves the pre cracking

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torsional stiffness, first cracking load of the member under pure torsional loading (T.D.Gunneswar rao, 2005). The addition of fibres exhibited better overall torsional capacity of rectangular and non rectangular beams (Constantin E *et al*, 2009). A special numerical technique, smeared crack approach was used for experimental data (Chrish G *et al*, 2000). The lateral torsional buckling behaviour of pre-tensional concrete beams was found as initial rotation showed higher effect on buckling load than the initial lateral displacement (Jonathan B *et al*, 2012). The strength and fracture characteristics specimens. Industrially prepared SFRC. The torsion test results are showed as, it is good indirect method to determine tensile strength and modules of elasticity of SFRC (M.K.Lee *et al*, 2003). From the past literature it's noticed that no work has been taken place to evaluate the torsional strength capacity for RAC using the basalt fibres hence herein, the work is aimed to evaluate the torsional strength of RAC along with compressive and split tensile strengths

Experimental Program

The following parameters are considered for the experimental programme (Table 1).

Table 1 Variables for Experimental work

Sl.No	Factors for the experimental work		
1	% of Recycle Aggregate Variation	0,25,50,75 and 100%	
2	Dosage of Basalt fibre	4 Kg/m^3	
3	Total number of mixes	10	
4	Mix Ratio as per ACI 211.1-91code (Cement: Fine Aggregate :Natural Aggregate: Recycle Aggregate)	1:2.60:2.96:0.00 for 0%RAC mix 1:2.69:2.20:0.73 for 25%RAC mix 1:2.76:1.42:1.42 for 50%RAC mix 1:2.8:0.70:2.10 for 75%RAC mix 1:2.80:0.00:2.79 for 100%RAC mix	Water cement ratio for all mixes is 0.57
5	Strength evaluation	Compression, Split tensile and Torsional strengths	
6	Type of specimens cast	Cubes(30Nos)-150x150x150mm Cylinders (30Nos)-150mm dia and 300mm height Beams (30Nos)-150x150x1500mm. Reinforcement for beam is 10mm dia 2 No's at top and two numbers at bottom. Shear Stirrups-8mm dia at 150mm centre to centre distance.	
7	Strength evaluation day for all mixes	28 th day from the date of casting	

Materials

The following materials were used for the present experimental work.

Cement

Ordinary Portland cement conforming to IS 8112:1989 was used. The specific gravity of the cement was noticed as 3.12.

Fine Aggregate

Locally available river sand passing through 4.75 mm I.S .Sieve is used. The specific gravity of the sand is found to be 2.75 and it was conformed to zone II.

Natural Coarse Aggregate

Crushed granite aggregate available from local sources has been used. To obtain a reasonably good grading, 50% of the aggregate passing through 20 mm I.S. sieve and retained on 12.5mm I.S. Sieve and 50% of the aggregate passing through 12.5mm I.S. Sieve and retained on 10 mm I.S. Sieve is used in preparation of NAC and RA. The specific gravity of the combined aggregate is 2.70.

Recycled concrete aggregate

The recycled concrete aggregate was obtained from demolished cement concrete pavement. The generated waste material was is not able to use as it is, as coarse aggregate in the concrete. So there is a need to develop as graded aggregate to use in concrete. To convert the waste as coarse aggregate the waste material was transported to crusher unit and made as 20 and 12.5 mm aggregate. Two different sizes were obtained from the waste material, so as to use the material effectively. To obtain a reasonably good grading, 50% of the aggregate passing through 20 mm I.S. sieve and retained on 12.5mm I.S. Sieve and 50% of the aggregate passing through 12.5mm I.S. Sieve and retained on 10 mm I.S. Sieve is used. The specific gravity of combined aggregate was observed as2.56.

Water

Potable water was used for mixing and curing.

Basalt Fibers

The used basalt fiber can be viewed in below figure 1. The properties are presented in Table 2, which were obtained from the supplier.

Figure 1 Basalt Fiber

Table 2 Physical properties of Basalt Fibers

Sl. No	Property	Units	Value
1	Equivalent length	mm	50
2	Filament diameter	Micro meter	9-15
3	Specific gravity	No units	2.8
4	Tensile strength	MPa	3000-4840
5	Young's modulus	GPa	79.3-93
6	Ultimate elongation	%	3.1

Casting and Curing

The cubes were cast in steel moulds with inner dimensions of 150 x 150 x 150mm, the cylinders were cast in steel moulds with inner dimensions as 150mm diameter and 300mm height and beams were cast in wooden moulds with inner dimensions as 150x150x1500mm. All the materials are weighed as per mix design and kept aside separately. The cement, sand, coarse aggregate and recycled concrete aggregate were mixed thoroughly till to reach uniformity to the concrete mix. The fibers are added to concrete ingredients in dry state. After achieving uniform mix then the water is added to the mix and mixed with hand operation till to get homogenous mix. For all test specimens, moulds were kept on table vibrator and the concrete was poured into the moulds and the compaction was adopted by mechanical vibrator. The specimens are de-moulded after twenty four hours and were exposed to water bath for 28 days in curing pond. After curing the specimens in water for a period of 28 days, the specimens were taken out and allowed to dry under shade. Three cubes, three cylinders and three beams were cast for each mix.

Testing

Compaction factor test

The compaction factor test apparatus consists of two hoppers, each in the shape of frustum of a cone and one cylinder. The upper hopper is filled with concrete this being placed gently so that no work is done on the concrete at this stage to produce compaction. The second hopper is smaller than the upper one and is therefore filled to overflowing. The concrete is allowed to fall in to the lower hopper by opening the trap door and then into the cylindrical mould placed at the bottom. Excess concrete across the top of the cylindrical mould is cut and the net weight of the concrete in cylinder is determined. This gives the weight of partially compacted concrete. Then the cylindrical mould is filled with concrete and compaction was done by tamping rod. The fully compacted weight is then determined and compaction factor (C.F) is calculated by using the standard formula (refer any standard text book of Concrete Technology).

Cube compressive strength test

Compression test on cubes is conducted with 2000kN capacity compression testing machine. The machine has a least count of 1kN. The cube was placed in the compression-testing machine and the load on the cube is applied at a constant rate till to failure of the specimen and the corresponding load is noted as ultimate load. Then cube compressive strength of the concrete mix is then computed by using standard formula (this test has been carried out on cube specimens at 28 days).

Split tensile strength

The cylinder is placed on the bottom compression plate of the testing machine and is aligned such that the center lines marked on the ends of the specimen are vertical. Then the top compression plate is brought into contact at the top of the cylinder. The load is applied at uniform rate, until the cylinder fails and same load is taken in to account as ultimate load. From this load, the splitting tensile strength is calculated for each specimen by standard formula.

Torsion test

All the beams were tested under pure-torsion. To achieve the pure torsion, torque arms were fitted for the specimens and the beam was placed on two roller supports which create ease to rotate in vertical plane. Two deflection meters (LVDT) are fixed to measure the deflection for each successive load. I-section is placed on torque arms to develop pure torsion moment. All precautionary measures are taken as the orientation of the centre of the beam exactly below the point of application of load. Maintaining initially the specimens horizontally without any rotation was taken during experimentation. Load was applied at regular intervals of increments up to failure. For each increment of load, the beam was examined for cracks with magnifying glass and the deflections were noted. The load at which the first crack appeared was noted and also the propagation cracks were marked on the beams. The test was carried up to final failure and the final load is taken as ultimate load .Torsion test set up as shown in Figure 2(a) and tested beam can be viewed in Figure 2(b).

Figure 2 a Torsion test setup

Figure 2 b Tested beam for torsion

DISCUSSION OF TEST RESULTS

Workability

The workability of different mixes has been measured by Compaction factor test. The values of compaction factors results are presented in Table 3.From this it is observed that the compaction factor decreases with increase in the % of recycled concrete aggregate in the concrete mix. The decreases of workability may be due to higher water absorption of recycled concrete aggregate than the normal aggregate. From the same table it can be also noticed that as the % of fibers increase the workability is decreases when compared to concrete without fibers. In the presence of the basalt fibers in recycled concrete aggregate concrete the workability is decreases. This may be due to effect fibers, generally the fibres gives dimensional stablity to the mixes, same was happened for these mixes. In the table the NAC indicates the mix with natural aggregate and

RAC following with number indicates ,the mix with recycle aggregate ,the number represents the replacement of Natural aggregate with recycle aggregate.The prefix of 'F' letter for mixes indicates the mix with basalt fibres.This same nomenculture was used in the subsequent sections.

Table 3 Workability

Sl.No	Nomenclature	Fibre (kg/m^3)	Compaction Factor (CF)
1.	NAC		0.78
2.	RAC 25		0.71
3.	RAC 50	0	0.66
4.	RAC 75		0.62
5.	RAC 100		0.58
6	FNAC-0		0.72
7	FRAC-25		0.68
8	FRAC -50	4	0.62
9	FRAC-75		0.57
10	FRAC-100		0.51

Compressive strength

The compressive strengths results are presented in Table 4, from this; it can be observed that the 28 days compressive strength increases with the increase in the percentage of recycled up to 50%. For 25, 50 recycled concrete aggregate there is a increase in compressive strength about 4.59%, 11.2% and for 75,100% recycled aggregate there is a decrease in compressive strength about 0.9, 4.2% respectively over reference concrete. From the same table it also observed that, for fiber added mixes, the compressive strength increases at every % of recycled concrete aggregate. From a law of rule of mixtures the strength enhancement is expected for the mixes with addition of fibers.

Table 4 Compressive strength

Sl.No	Nomenclature	Fibre (kg/m^3)	Average Stress(N/mm^2)
1.	NAC		33.26
2.	RAC-25		34.80
3.	RAC-50	0	36.88
4.	RAC-75		31.55
5.	RAC-100		30.44
6	FNAC-0		36.88
7	FRAC-25		37.11
8	FRAC-50	4	38.22
9	FRAC-75		35.77
10	FRAC-100		32.88

Spilt tensile strength

The 28 days split tensile strength of recycled aggregate concrete mixes are presented in Table 5. From this it is observed that, the split tensile strength increases with the increase in the percentage of recycled aggregate up to 50% and for other mixes the strengths are decreased. For 25, 50% of recycled there is increase in split tensile strength by 4%, 7.4% over the reference concrete. For 75% and 100%, the split tensile strength has decreased by 7.74% and 9.04 %respectively over reference concrete (NAC-0). From the Table 5 it is also observed that as the % of volume fraction of fibres increases the split tensile strength increases at every % of recycled concrete aggregate. The fibres are act as crack arresters and those may take more time to failure and also takes more loads to failure.

Table 5 Split tensile strength

Sl.No	Nomenclature	Fibre (kg/m^3)	Average Stress(N/mm^2)
1.	NAC		2.24
2.	RAC-25		2.36
3.	RAC-50	0	2.40
4.	RAC-75		2.16
5.	RAC-100		2.08
6	FNAC-0		2.39
7	FRAC-25		2.41
8	FRAC-50	4	2.47
9	FRAC-75		2.35
10	FRAC-100		2.23

Torsional Strength

The torsion strength results for recycled aggregate concrete mixes are presented in Table 6. From this it is observed that, the torsional strength increases with the increase in the percentage of recycled aggregate up to 50% and later for various % of RAC mixes it was decreased when compared with natural aggregate concrete (NAC-0). For 75% and 100%, the torsional strength has decreased by 2%. For 25, 50% of RAC there is increase in torsional strength by 7.69% and 12.82% over the Natural 56% and 5.98% respectively over granite aggregate concrete (NAC-0). For fibre incorporation mixes the torsional strengths are increased for all mixes of recycle aggregate concrete, but the trend is similar to RAC mixes without fibres. Among the FRAC mixes the mix with 25 and 50% shown higher torsional strengths when compared to other two mixes of 75 and 100%. The % of increase in torsion strength for 25 and 50% RAC mixes is about 2.32 and 9.30% respectively when compared with FRAC-0 mix. The enhancement of strength for 50% RAC mix may be due to better bond (surface texture) between the RA and NA and the arrangement of aggregates in the mass of concrete.

Table 6 Torsion moment

Sl.No.	Nomenclature	Fiber in (kg/m^3)	Torque at First Crack (kN-m)	Ultimate Torque (kN-m)
1	NA C		3.97	5.85
2	RAC-25		4.22	6.30
3	RAC-50	0	4.55	6.60
4	RAC-75		3.99	5.70
5	RAC-100		3.68	5.50
6	FNAC-0		4.25	6.45
7	FRAC-25		4.42	6.60
8	FRAC-50	4	4.79	7.05
9	FRAC-75		4.09	6.30
10	FRAC-100		3.90	6.00

Torsion and angle of twist

The behaviour of torsion verses angle of twist for various mixes (with and without fibres) are depicted in figure 3 and 4. All the beams exhibited linear torque-rotation behaviour at initial state there after they shown non linearity and some clinks are observed at different places, these may due to a little experimental error. The torque-rotation relationship of beams with fibres showed considerable improvement compared to conventionally reinforced beams. The concrete with fibres showed greater rotational capacity over conventional concrete.

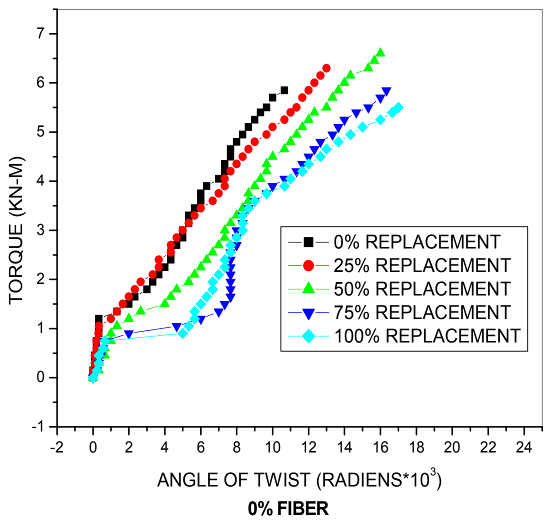

Figure 3 Torque vs. Angle of twist (0% fibre)

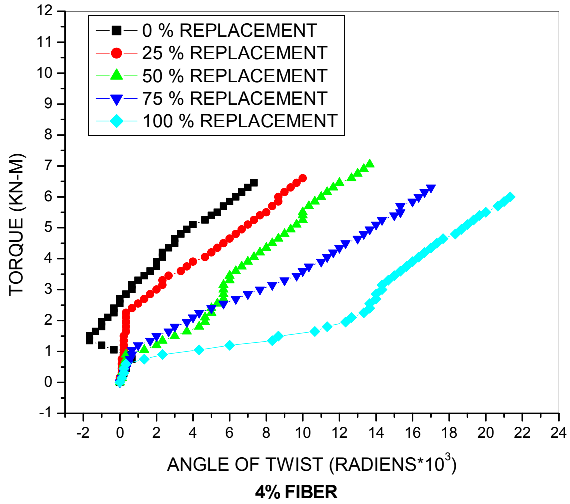

Figure 4 Torque vs. Angle of Twist (4% fibre)

Shear stress

Due to application torsion moment for the structural member, the shear stresses are induced in the cross section with different intensities at various locations. The maximum shear stress may occur at the surface of the member. In the present experimental work, the rectangular beam was taken to evaluate the torsion capacity for each mix of RAC. The maximum shear stress was found for various RAC mixes using standard formula (Refer any text of Theory of Elasticity and Plasticity).

Shear stress= $3T_u/x^2y$.

Where T_u is ultimate torque
x and y are the cross dimensions of beam

The obtained shear stress results for recycled aggregate concrete mixes are presented in Table 7. From this it is observed that, the shear stress increases with the increase in the percentage of recycled aggregate up to 50% and for later % of RAC mixes it was decreased. For 25, 50% of recycled there is increase in shear stress by 7.69% and 12.80% over the Natural aggregate concrete (NAC-0). For 75% and 100%, the shear stress has decreased by 2.56% and 5.98% respectively over granite aggregate concrete (NAC-0). For fibre incorporation mixes the shear stresses are increased for all mixes of recycle aggregate concrete. Among the FRAC mixes the mix with 25 and 50% shown higher shear stress compared to other two mixes of 75 and 100%. The % of increase in shear stress for 25 and 50% RAC mixes is about 2.32 and 9.30% respectively when compared with FRAC-0 mix.

Table 7 Shear stress

Sl.No.	Nomenclature	Fiber in (kg/m³)	Experimental Shear Stress Value(N/mm²)
1	NA C		5.20
2	RAC-25		5.60
3	RAC-50	0	5.86
4	RAC-75		5.20
5	RAC-100		4.93
6	FNAC-0		5.73
7	FRAC-25		5.86
8	FRAC -50	4	6.26
9	FRAC -75		5.60
10	FRAC-100		5.31

Regression Model to Estimate Shear Stress

The following regression models are established to estimate the torsional shear strength of concrete and the models are tested with experimental results. In general, strength parameters (flexure, shear, split tensile strength etc) are related to cube compressive strength. Hence here in also the authors would like to develop regression models to estimate the torsional shear strength as function of cube compressive strength. With this intension the models are developed and furnished below. The performance of regression models are presented in Table 8. From this table it is noticed that, the experimental values are varying about ±10%. From the results it is noticed that the proposed models are made good agreement with the experimental results.

f_{ck}=33.277+0.0135296(R) +0.57306(BF)---------Eq (1)
Where
f_{ck}=compressive strength in MPa,
R=% replacement of recycled concrete aggregate
BF= Basalt fibre in kg/m³.

The relation between torsional shear stress and compressive stress is given by
τ=0.8396+0.132799(f_{ck})---------Eq (2)
Where τ=shear stress MPa.
The above equations are subjected to constraints of
$0 \le R \le 100$
$0 \le BF \le 4$
From the table 8, it can be observed that, the shear stress increases with increase of volume fraction of fibre. The shear stress of fibre reinforced concrete beam with 4kg/m³ of basalt fibres are enhanced by 5.79% when compared to conventionally R.C beams without fibres.

Table 8 Performance of Regression Model

Sl.No.	Nomenclature	Analytical Shear Stress Value(N/mm²)	Fiber in (kg/m³)	Experimental Shear Stress Value(N/mm²)	Experimental /Analytical
1	NA C	5.25		5.20	0.99
2	RAC-25	5.29		5.60	1.06
3	RAC-50	5.33	0	5.86	1.09
4	RAC-75	5.38		5.20	0.99
5	RAC-100	5.42		4.93	0.91
6	FNAC-0	5.55		5.73	1.03
7	FRAC-25	5.59		5.86	1.05
8	FRAC-50	5.64	4	6.26	1.11
9	FRAC-75	5.68		5.60	0.98
10	FRAC-100	5.73		5.31	0.93

CONCLUSIONS

The following conclusions are drawn based on the experimental work conducted in this investigation:

- The workability for recycled concrete aggregate is decreases with compared with normal aggregate concrete.
- The compressive strengths were increases with the increase of recycled concrete aggregate up to 50% in the concrete mix.
- The split tensile strengths were increases for recycled concrete aggregate concrete upto 50% when compared with granite aggregate concrete.
- The torsional strength was increases for recycled concrete aggregate concrete upto 50%.
- The incorporation of recycled aggregate up to 50% is beneficial for the concrete works.
- Addition of fibres to recycled aggregate concrete results, increase of torsion strength and rotation capacity.
- For 25, 50% of recycled there is increase in torsional strength by 7.69% and 12.82% over the Natural aggregate concrete (NAC-0).
- The % of increase in torsion strength for 25 and 50% RAC mixes is about 2.32 and 9.30% respectively when compared with FRAC-0 mix.
- There is an increase in torque with addition of fibres at respective % of replacement recycled concrete aggregate.
- Regression model was proposed in the article to estimate torsional shear strength.

References

Ann K.Y, Moon H.Y, Kim Y.B, Ryou J, (2008). *Durability of recycled aggregate concrete using pozzolanic materials*, Waste Management, 28: 993-999.

Chakradhara Rao M, S. K. Bhattacharyya, and S. V. Barai, (2011). *Influence of field recycled coarse aggregate on properties of concrete*, *Materials and Structures*, vol. 44:205-220.

Chrish G. Karayannis, (2000). Smeared crack analysis for plane concrete in torsion, *Journal of structural Engineering.* 638 - 645.

Constantin E., Chalioris, Chris G.Karayannis,(2009). *Effectiveness of the steel fibres on the torsional behaviour of flanged concrete beams*, cement & concrete composites, 31:331-341.

Eguchi K., Teranishi K., Nakagome A., Kishimoto H., Shinozaki K., Narikawa M, (2007). Application of recycled coarse aggregates by mixture to concrete production, Construction and Building Materials, 21:1542 - 1551.

Jonathan B.Hurff, Lawrence F.Kahn,(2012). Lateral torsional buckling of structural concrete beams, *Journal of structural Engineering*.1138-1148.

M.K.Lee, B.I.G.Baar,(2003). Strength and fractural properties of industrial prepared steel fibre reinforced concrete, Cement and Concrete Composites, 25: 321 - 332.

Tam W.Y .Vivian, Wang K, Tam C.M,(2008). Assessing relationships among properties of demolished concrete, recycled aggregate and recycled aggregate concrete using regression analysis, *Journal of Hazardous Materials,* 152 :703-714.

T.D. Gunneswar rao, (2005). Analytical model for the torsional response of steel fibre reinforced concrete member under pure torsion. 27:493-501.

Topcu I.B., (1995). *Using waste concrete as aggregate*, Cement and Concrete Research, 25:1385 - 1390.

Yong-Hak Lee and Won-Jin Sung and Kee-Won Seong, (2011). Torsional stiffness of pre stressing tendon, in double-t beams, *Journal of Engineering Mechanics*, Vol. 137, No. 1:61-72.

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