Micropiles – An Innovative and Economical Solution for Retrofitting of Bridge Foundation

Dipali Paresh Doshi[1] Dr.A.K.Desai[2] and Dr.C.H. Solanki[3]
[1]Applied Mechanics Department, Polytechnic, The M.S.University of Baroda, Vadodara 390002
[2,3]Applied Mechanics Department, SVNIT Surat – 395 007
E-mail: doshidipali2000@yahoo.co.in

Abstract: Pile foundations are generally used for load carrying and transferring system. Piles are transferring the load to hard stratum. Piles are also used to resist loads from the super structures, dynamic loads or uplift loads. Hence Piles are successfully practiced to support bridges, buildings, docks and other heavy structures across the globe.

When soil is not having adequate bearing capacity or when there are boulders or cavities in soil strata or less over head clearance or when surrounding existing structures are there, then use of number of micropiles instead of small number of Piles shall be considered as micropiles have high flexibility and ductility during the seismic conditions. Micropiles are also used as an inclined member. Providing micropiles as solution in such situations are found more reliable and economical.

Before 1950 micropiles were not much used due to their long flushing process. But in 1950's in Italy they have been invented and from that time they are widely used in all over the world. They have gained popularities to provide stability under seismic conditions. Now, various design and simulation tools are available for its design and verifications. Micropiles are often used to strengthen the existing structures among the various ground improvement techniques as it is more economical and can be used easily with latest technology of construction.

In this paper benefit of micropiles for retrofitting of bridge foundation in sandy soil, which was damaged during earthquake are presented. The numerical simulations are done using MIDAS GTS software. This simulation technique is the finite element method. The effect of different type and intensity of earthquakes on this bridge foundation are studied. Micropiles will be designed considering expected stability and economy of retrofitting among various options.

Keywords:Micropiles, retrofitting, bridge foundation, MIDAS GTS, finite element method

1. Introduction

Pile foundations are used to transfer load from super structure to the hard soils or rocks. Pile foundations have became the integral part of the main structure and they transfer load from super structure to deeper soil or rocks with high bearing capacity. It is to be noted that Piles are generally long. Piles are slender member and designed to resist vertical, lateral and uplift load. They are widely applied for support of bridges. Docks, Marine Jetties, Offshore platforms for Oil wells andother structures required to provide support in soft/silky soils. In case ofPiles, the load transmission to deeper soils or rocks is either through friction or end bearing or combination of both.

The modern technologies of retrofitting of structures by micropiling developed by Lizzy, known as a “father of micropiles” in 1950 in Italy after the World War II. There was a challenge to restore the ancient monuments and structures which were damaged during World War II. Micropiles were introduced as they were found beneficial due to their economy and feasibility of construction even in situations when there are boulders or cavities in soil strata or less over head clearance or when surrounding existing structures are there.

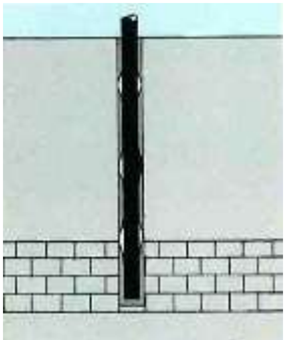

Fig.1 Shallow Bedrock

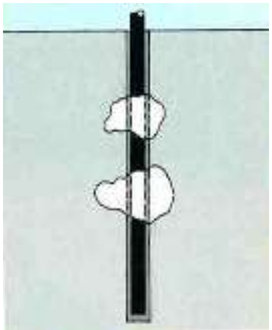

Fig.2 Boulders and cavities

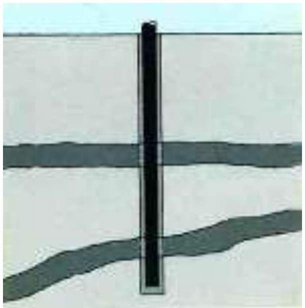

Fig.3 Intermediate Hard Strata

Nowadays micropiles also known as mini piles are accepted due to its smaller size and easy construction. They are in the size of 90 mm to 250mm and reinforcement are placed with neat cement grout. It can be used in any type of soils, boulders and hard materials. Due to its flexibility and ductility they used for retrofitting of old structure and as foundation support for the new structures..Micropiles are used to improve the bearing capacity and reduce the settlement.
Initially micropiles were not used very popularly because of its time consuming drilling and flushing process and also there were not much proven simulation techniques were available to verify stability with micropiles. From 1970 to 1980 the growth of micropiles was very slow. But after 1980, various construction methods are developed for micropiles and the rapid growth of micropile technique was observed and their use become worldwide. In India very few micropile installations were made till end of 19th Century, but after the Bhuj earthquake in 2001, micropile technique was introduced at number of places to strengthen and retrofitting of existing foundations.

1.1 Installation of Micropile

Micropile is widely used in the construction field because of the low vibration and no noise. Micropiles are widely used in housing area, school, hospital or any location where driving of piles are not allowed due to restriction of noise of pile driving process. The installation procedure for micropile is almost similar to bored piling but it’s using drilling process.

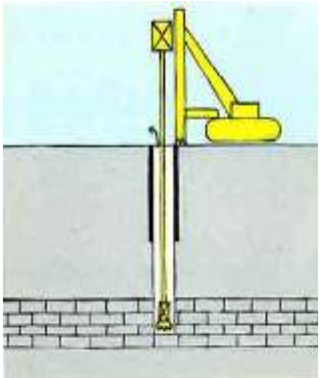

Fig.4 Drilling and flushing

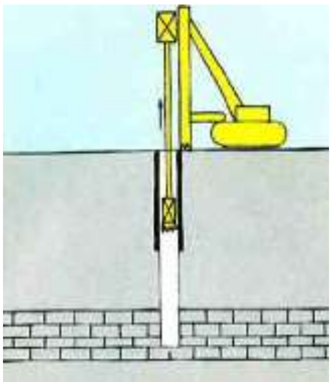

Fig.5 Withdrawing Drilling String

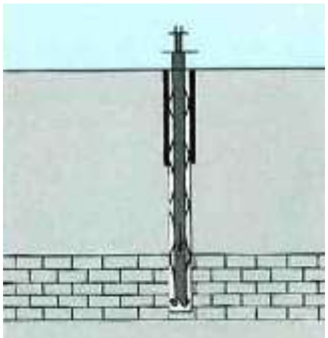

Fig.6 Inserting Steel reinforcement

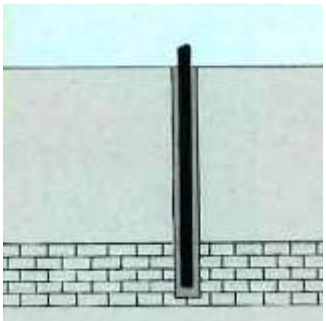

Fig.7 Completed Micropile

1.1 Research work done:

Mary Beth D Hueste et al [2] used micropiles as a one of the common retrofit techniques around the perimeter of the existing pile foundation of bridge, increased the stiffness of the foundation. Shahrour et al [5] conducted a 3-D FEM analysis of micropiles using PECPLAS and studied effect of soil-micropile structure interaction considering the superstructure as a single degree-of-freedom system. Ousta and Shahrour [4] performed similar analysis like Shahrour but on saturated soils.

Alsaleh H. and Shahrour I. [1] studied the behavior of micropile group under seismic loading. Numerical analysis was carried out by finite difference program using FLAC 3D. They found that the nonlinearities of the soil and micropile-soil interface both have significant effect on the seismic response of the micropiles group as well as that of structure. Turan and Naggar M. [6] have studied the use of micropile in the seismically active area to resist lateral load with 3D FE model. Pile cap flexibility and surcharge loads on the soil surface have a significant effect on the lateral response of a micropile supported foundation.

Wang Z et al. [7] studied effect of micropiles on soil reinforcement under static and dynamic loading by using PLAXIS 2D and found that micropile treated soil greatly reduces the settlement of the embankment.

Nath et.al. [3] have verified the resistance of pile cap subjected to lateral loads using a finite element software program PLAXIS 2D. In this research work the bridge which is damaged during earthquakes of different intensities located in sandy soil is retrofitted with micropiles of different diameters. The numerical analysis is done using MIDAS GTS software. Graphs of lateral force and bending moments of different diameters of micropiles with different PGA values of earthquakes studied.

2. Numerical Analysis

In the current research work the bridge foundation built on the piles of diameter 1.2 m in loose sand is damaged after different PGA earthquakes are taken. The micropiles used for the numerical analyses were in the range of 100 mm 150mm and 200mm. The foundation is taken is 50 m X 50 m .In FEM model the bottom of the foundation is considered as a fixed boundary and the sides are having only vertical movement prepared in MIDAS GTS software. The structural piles and micropiles were assumed to rest on dense coarse send at a depth of 13 m. The soil properties of sand for the analyses as shown in Table 1 and the time history of the earthquakes are shown in Table 2.

Table 1 Soil Properties ϕ soil (loose + dense sand) taken for the bridge Foundation

Soil Type	Unsaturated Unit Weight kN/m^3	Saturated Unit Weight kN/m^3	Cohesion kN/m^2	Friction Angle (Degrees)	Young's modulus kN/m^2	Poison's Ratio
Loose Sand	18	18.5	1	25	13000	0.3
Dense Sand	20	21	1	35	30000	0.3

Table 2 Time history of the earthquakes

Earthquakes	**Peak ground Acceleration**	**Time (Sec)**
Koyna(1967)	0.65g	7.02
El centro(1940)	0.3569g	53.72
Kobe(1995)	0.7509g	40.00

3. Result and Discussion

Below Figures 8(a), 8(b) & 8(c) show that the lateral force reduced in the bridge foundation retrofitted with micropiles in El Centro earthquake. This reduction in lateral force in 200 mm diameter micropiles are more as compare to 100 mm and 150 mm diameter micropiles. The upper portion of the foundation is loose sand. So during earthquake it reduces its shear strength and offering less soil resistance. So upto 9 m depth the reduction is significant.

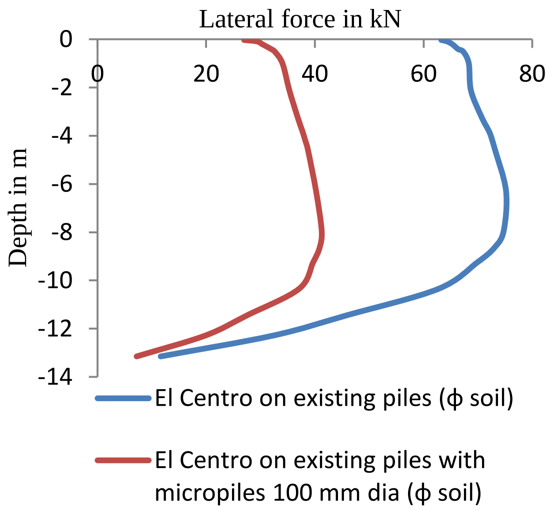

Fig. 8 (a)Lateral force in kN in El Centro for ϕ soil

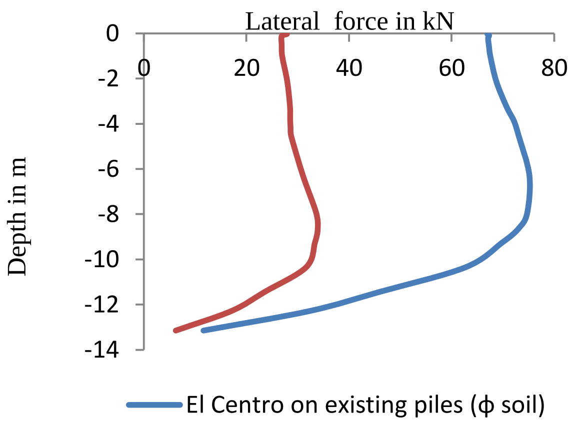

Fig. 8(b) force in kN in El Centro for ϕ soil

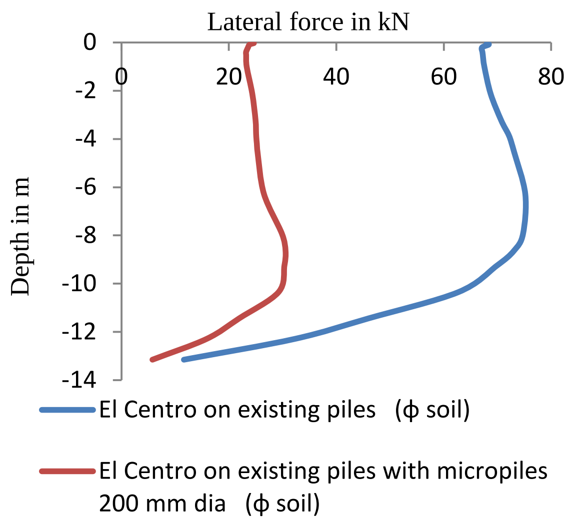

Fig. 8 (c)Lateral force in kN in El Centro for ϕ soil

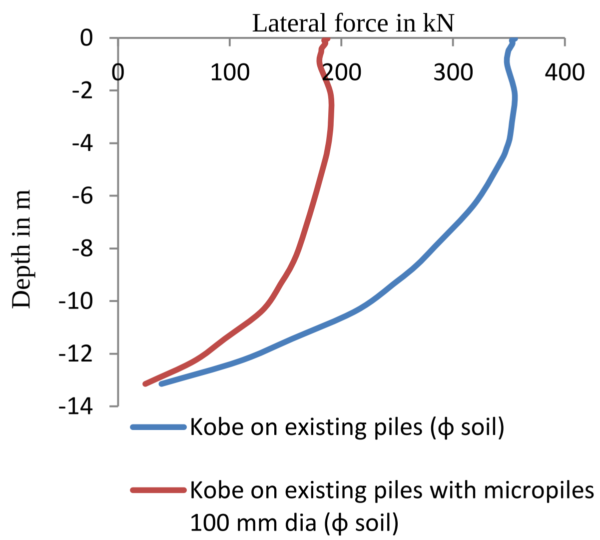

Figure 9 (a) Lateral force in kN in Kobe for ϕ soil

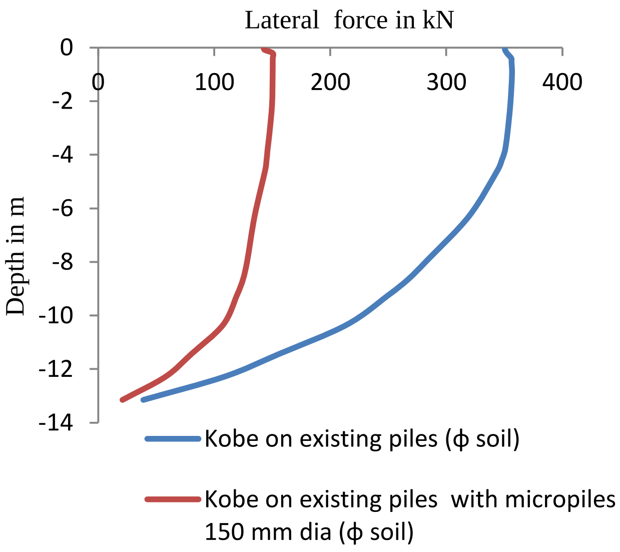

Figure 9 (b) Lateral force in kN in Kobe for ϕ soil

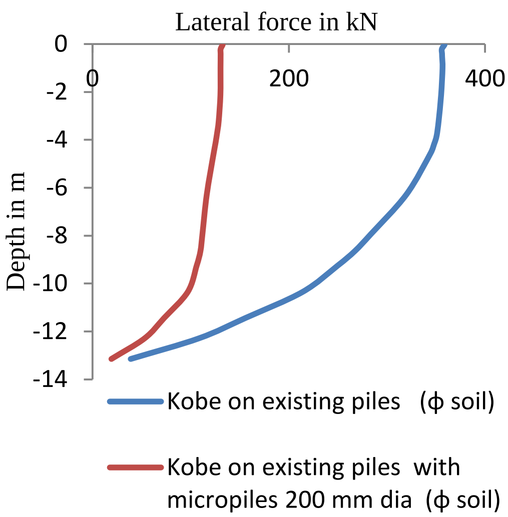

Figure 9 (c) Lateral force in kN in Kobe for ϕ soil

Figure 9(a) to 9(c) show that as compare to El Centro earthquake the reduction in lateral force is more in Kobe earthquake because the PGA of Kobe is high as well as the time duration is also more. As we increase the diameter of the micropile the reduction in lateral force is also more. So in high intensity earthquake for retrofitting of bridge foundation micropile of 200 mm diameter reduces the lateral force significantly.

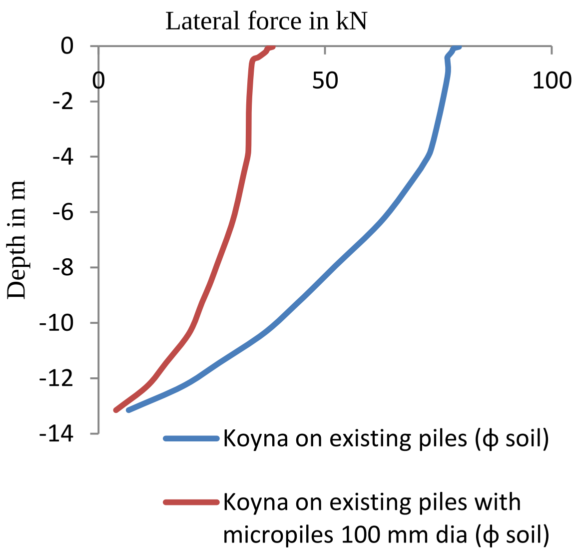

Fig.10 (a) Lateral force in kN in Koyna for ϕ soil

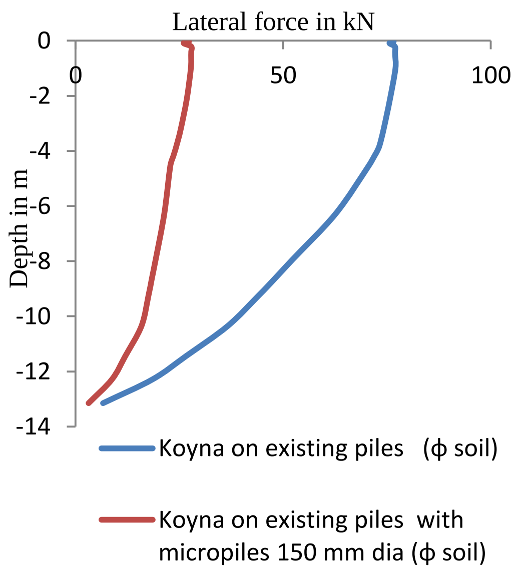

Fig.10 (b) Lateral force in kN in Koyna for ϕ soil

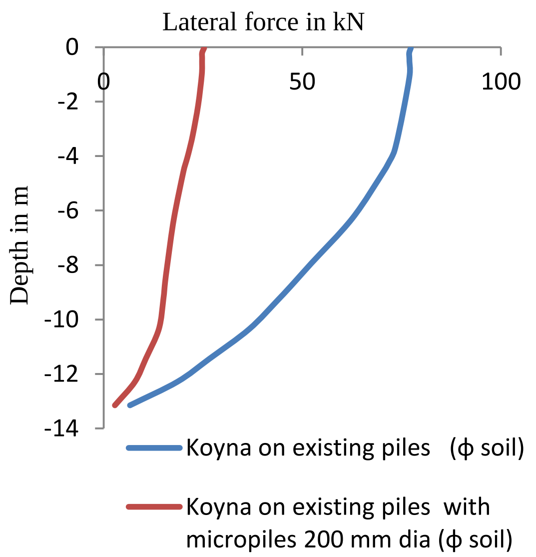

Fig.10(c)) Lateral force in kN in Koyna for ϕ soil

Fig 10 (a) to Fig.10 (c) shows that for Koyna, earthquake hawas of more intensity but for short duration, whichhas damaged the bridge but after retrofitting with micropiles the lateral force reduction is more.

In all type of soil after certain depth the reduction is almost negligible, because at higher depths, densification take place because of the construction of micropiles. In micropiles, We inject pressurized cement grout, which strengthen the soil and improve its bearing capacity and thus settlement of structure also reduces.

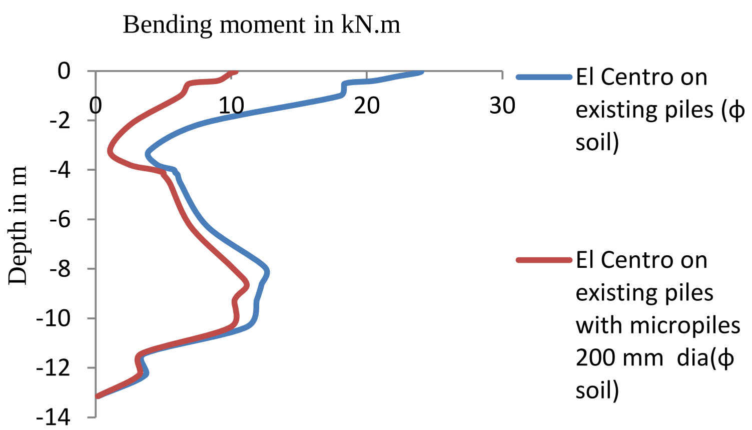

Fig.11 Bending moment in kN. m in El Centro in ϕ soil

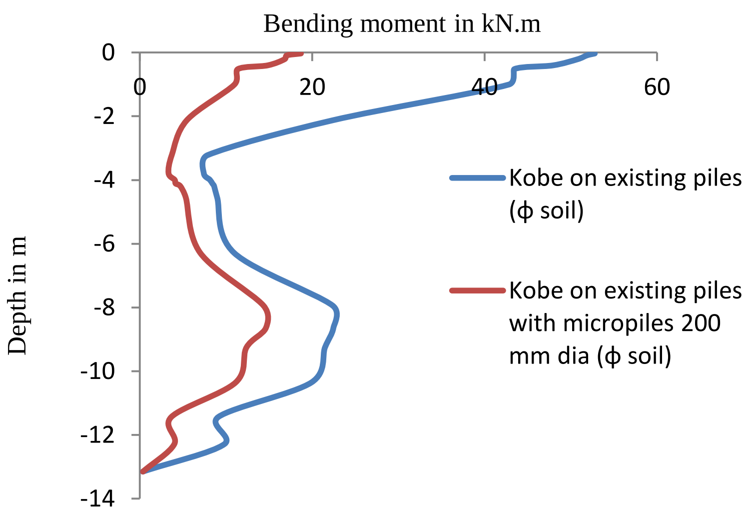

Fig.12 Bending moment in kN. m in Kobe in ϕ soil

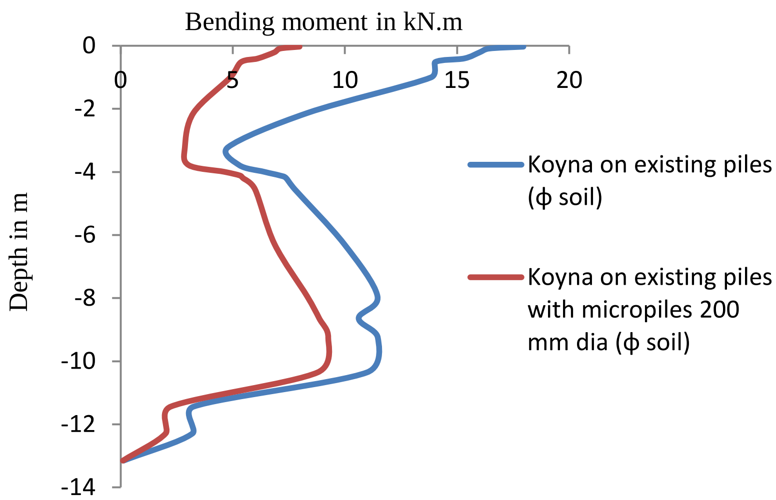

Fig.13 Bending moment in kN. m in Koyna in ϕ soil

From Fig. 11 to 13, it is seen that with micropiles, the reduction in bending moment is also significant. The reduction at the junction of pile cap is alomost 55 to 60% but in the middle at the junction of loose and dense sand the reduction is not more because at the time of construction of micropiles the densification of soil has taken place.

4. Conclusion

The micropile having diameter of 200mm shows 68%percentage reduction in lateral force, while 150mm dia shows 63% and 100mm diameter shows 54%. So, the diameter of micropiles can be selected based on the access availability, economy and criticality of the structure. If the soil is elasto-plastic in nature than it improves the response of the micropile group under the earthquake force.Micropiles are used due to its ductility and flexibility and are beneficial to take lateral load and reduce settlement. Micropiles can be drawn inside soil, even at places where access is restricted. Also it will require less head clearance as compared to big diameter piles. Micropiles can be drawn in any type of ground condition. It will create comparatively very less vibrations. In loose sands, saturated condition is assumed as during earthquake it loses its shear strength and liquefaction occurs and hence the lateral force reduction is significant.

5. References

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