IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

ISO 3297:2007 Certified ⵣ Impact Factor 8.066 ⵣ Peer-reviewed / Refereed journal ⵣ Vol. 10, Issue 9, September 2023

DOI: 10.17148/IARJSET.2023.10914

# Experimental Study on Uplift Capacity of Short Finned Piles in Sand Stabilized by Geo-jute

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**Abstract:** The current research focuses on evaluating the uplift potential of piles with fins, which is crucial for constructing foundations for basin structure, electricity pylons, and other structures that need to withstand uplift loads. Various factors were examined, including the number of fins, the ratio of fin length to pile length (Lf/Lp), fin width, fin shape, and insertion of fins within the pile. These tests encompassed different fin position, entrenchment depth, enumerate of fins, and fin breadth. All the test results demonstrated that uplift resistance of finned piles increases with a higher Lf/Lp ratio. Moreover, for a fixed Lf/Lp ratio , the uplift-resistance of piles fabricated in sand improved as the sand's relative density increased. The number of fins exhibited a significant positive impact on the uplift resistance of finned piles. Increasing the fin width also resulted in an enhanced uplift capacity. The relative density of sand was found to have a substantial influence on the usefulness of finned piles. Rectangular-shaped fins were more resourceful than triangular fins. Positioning the fins at the pile head provided sufficient resistance to deformation. Overall, the findings specified that the uplift capacity of finned piles can be enlarged by increasing the Lf/Lp ratio (0.4), adopting a fin breadth of 1.0 times the pile dia (Dp), using wider fins, employing rectangular-shaped fins instead of triangular ones, and positioning the pile head fins.

**Keywords:** Uplift resistance, Relative Density, Fins, Deformation.

## I. INTRODUCTION

Foundations serve the essential purpose of transferring the load from the super-structure to subsoil, preventing subsidence of the structures. These impact load could either compressive or tension-based, encompassing the structure's self-weight and imposed loads. In some cases, a loading acting on the foundation might even become tensile. Additionally, lateral wind loads can influence the imposed loads, leading to potential over-turning moments that necessitate the inclusion of foundations. To counteract over-turning moments and ensure stability, foundations come in two types: shallow and deep, depending on site conditions and the magnitude of the loads. Deep foundations, such as pile foundations and well foundations, are viable options. Among these, pile foundations tend to be more economical than well foundations. When compared to shallow sub-structures, deep sub-structures require greater depth. However, constructing deep foundations can be a challenging and labor-intensive process. The deep sub structure is further classified into: Pile sub structure, Pier sub structure, Cassion or Well sub structure.

A pile is a slender structural member installed in the ground to transfer structural loads into the soil. Piles can be installed through casting in-situ or using pre-cast methods. The construction process involves excavation and sinking the piles to the required depth. Interestingly, pile foundations have been in use for over 12,000 years, with the Romans and Vitruvius being early adopters of this technique. Pile foundations are particularly useful when the distribution of loads from the structure is unpredictable. They are also recommended in situations where the subsoil is loosely packed or has a high void ratio. Additionally, when encountering hard core laminations at considerable depths, pile foundations become the preferred choice. In cases where shallow foundations are unsuitable, deep foundations like piles, piers, or well foundations are commonly employed. The versatility of pile foundations allows them to be used in various soil types and for different types of structures, making them an economical choice in many instances.

## II. EXPERIMENTAL WORK

### A. Experimental Setup

A pile along with an embedment length of 290 mm and shapes of triangle and rectangle fins of varied widths constructed of aluminium sheets with a thickness of 2 mm was employed in this experimental inquiry. Removable screws were cast-off in each pile section to secure fins at an angle of 180 degrees. They were arranged at the pile's top, center, and bottom. At a 45° angle, the pile was inserted vertically inside the sand bed**.** subsequently dial gauges were mounted on the tip of the head of pile and adjusted to ensure no tensile displacement ensued.

DOI: 10.17148/IARJSET.2023.10914

Finally, the substance fractured as a result of its own weight. Consequently, the head of pile was stressed using a mannual hand jack set directly on the proving ring. connected to jack of one side to the loading frame, while the other was free. The dial gauge's uplift deformation registered for each load increment, and this data were utilized to generate load-deformation graphs**.**

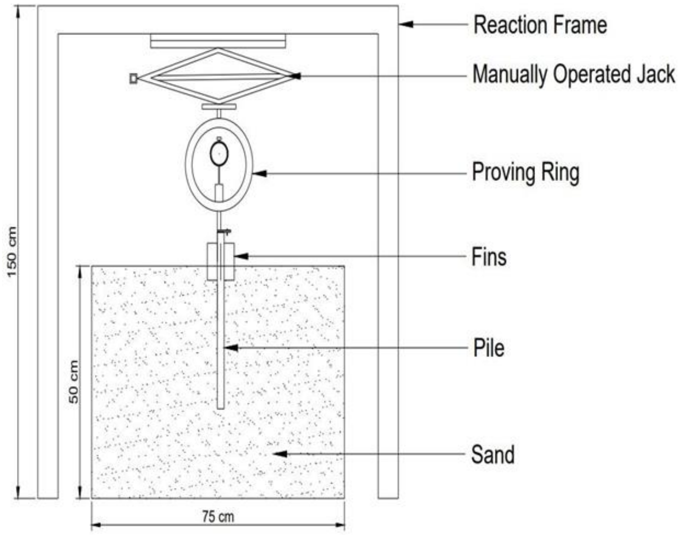


**Fig. 1: A schematic diagram of Setup of Experiment**

**Fig. 2: Laboratory test setup**

B. Test Materials

1. Model Tank

Experiments are conducted in tank which is made up of iron ore. The dimension of model tank is 75cm length, 75cm width 50cm depth. The model tank as been equipped with iron frame like structure it is attached with steel jack similar to telescope jack from which load generated through laboriously.

2. Sand

Sand that are extorted form the river sand is dried out in the normal temperature. The various laboratory test are examined. The specific gravity of soil particles will be determined utilizing a Pycnometer test. Specific gravity was formerly taken as a mean of 2.42 from all three measurements. The water content of soil particles is determined.

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**Table 1: Properties of Sand**

| PROPERTIES | VALUES |
|---|---|
| Type of Sand | Sand |
| Specific Gravity (G) | 2.42 |
| Water Content, WC(%) | 7.5 |
| Grain Size : D10, D30, D60 (mm) | 05., 0.32, 0.37 |
| Uniformity Coefficient, $C_u$ | 1.4 |
| Coefficient of Curvature, $C_c$ | 0.29 |
| Clasification (IS 1498-1970) | SP |
| Maximum dry weight, $Y_{max}$ (KN/m$^3$) | 18.85 |
| Minimum dry weight, $Y_{min}$ (KN/m$^3$) | 14.37 |
| Maximum void Ratio, $e_{max}$ | 0.507 |
| Minimum void Ratio, emin | 0.783 |
| Relative Density(%) | 1.6 |
| Cohesion (c) | 0 |
| Angle of internal friction (ø) | 37 |

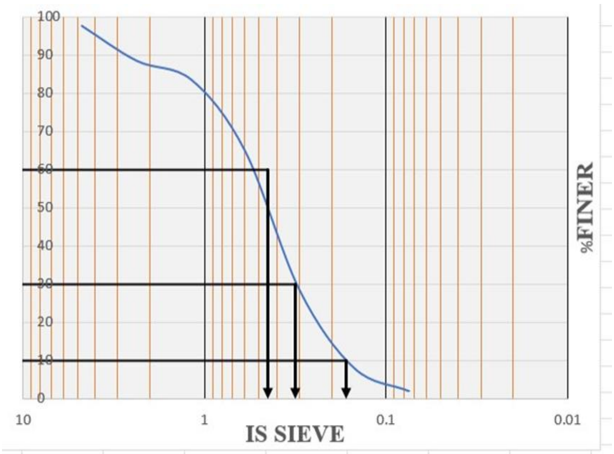


**Fig. 3: Grain size analysis curve**

3. Model Pile

The model piles in this contemporary examine have been constructed using aluminium pipes. These piles have a consistent outside diameter of 21mm and a thickness of 2mm for all trials. The original lengths (Lp) of the piles were set at 290mm, resulting in an L/D ratio of 28.6, indicating short piles. During the investigation, two different formats of fins were used. Fins were created from aluminium sheets with a thickness of 2.0mm, forming rectangular and triangular shapes with various proportions. The fins were then welded in either a 90° or 180° orientation and positioned at the pile head.

  

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

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**Fig. 4: A smooth aluminium pile**

**Table 2 : Dimensions of Pile**

| Type of Materials | Aluminium pile |
|---|---|
| Diameter of pile in mm | 20 mm |
| Length of pile in mm | 290 mm |

4. Fins

The fins can be strategically positioned at various points along the pile's length, such as the pile head, mid-length, or tip. Additionally, they can come in various shapes, counting rectangular fins, triangular fins and some helical configurations. The application of fins in pile design is a common practice in geotechnical engineering, as it helps optimize the pile's performance in specific soil conditions and under different loading scenarios.

**Fig 5 : Attachable rectangular 2 fins**

**Fig 6 : Attachable triangular 4 fins**

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**Fig 7 : Attachable rectangular 4 fins**

5. Geosynthetics

Coir Geotextile is been exploited for this project because it is made of 100% natural fiber collected from coconut husk, adds organic material to the soil, has a high tear strength, and is simple to install, maintain, and patch. The thickness of geotextiles shall be measured using a standard thickness gauge in accordance with IS: 13162 (1992). The mass per unit area shall be calculated in accordance with IS: 14716 (1999). When any sort of reinforcement is implanted in the soil, the most crucial criterion to determine is the tensile strength of the material utilized. ASTM D 4595 (1994) has been used to find out the tensile characteristics of coir geotextiles.

**Fig 8 : Geojute in model tank**

C. Sand Bed Preparation

To establish a uniform density across the bed, sand was falling down from the sky at a regulated discharge rate and constant height of fall, so that the sand was evenly distributed. The relative density attained during the experiments might be tracked by collecting samples in tiny cans of a given capacity and distributing them around the test tank. Loose density circumstances were represented by the 35 percent range of the relative density created by the rainfall techniques used in this study. The average unit weight is 14.9 kilonewtons per cubic metre. The maximum and minimum densities were met in line with IS: 2720 (PART 14)- 1983.

There was no indication of particle segregation during the sand raining experiment, and the uniformity tests showed that the relative densities obtained from each of the three samples were independent of the cans' placements. The sand's internal friction angle was calculated to be 36°. Dry tamping and maintaining the sample's relative density at 35% yielded this result in a direct shear test.


**Fig. 9 : Sand bed prepared and leveled**

DOI: 10.17148/IARJSET.2023.10914

1. Calibration of Height of Fall

The calibration of fall height is a crucial process that involves determining the relationship between the height from which sand is poured (fall height) and the resulting density of the sand in a container. This calibration is necessary to consistently achieve the desired dry density of the sand during experiments and tests.

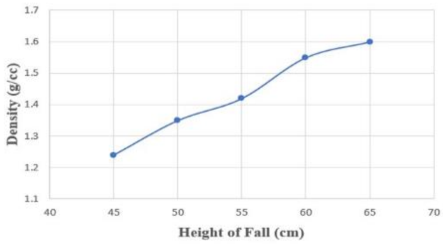


**Fig. 10 : Calibration curve**

2. Rainfall technique

The sand was continuously added to the container using a Raining mesh to maintain a consistent height of sixty millimeters. The sand was poured from a height of 800mm above the bottom of the tank. Piles were inserted into the sand to a height of 290mm. This sand pouring method is commonly referred to as "fall of sand by technique of rainfall." For the unsecured example, this sand pouring technique occasioned in a preset dry density of 1.6g/cc. The density of the sand in the steel ampule was noted for every test.

**Fig. 11: Pouring of sand to the model tank by using a mesh**

## III. EXPERIMENTAL PROCEDURE

- The intended experimental program is to investigate the load carrying uplift capacity of the finned pile of dia 290 millimeter. It comprises of an iron test tank model that is 750 mm long, 750 mm wide, and 500 mm tall. A 20-millimeter-diameter pile with a 30-millimeter-to-length ratio has been added to the tank.
- Mark the experimental tank for ever 10cm vertically geo jute are placed and sand are pored for every layer.
- Sand that has been cured in the sun or the oven is pumped into the tank using the rainfall method. This process involved pouring the sand through a 4.75 millimeters mesh. For the next sand filling, the mesh was kept at a consistent height. To achieve the predetermined density goals, this was done. The tank's bottom must have at least 600 millimeters of sand before it might be deemed finished.
- Model tank is completely jam-packed by sand unto the appropriate height from the bottom, it is slammed inside the sand layer. The simple pile without any fins has an embedment length of 290 millimeters with the aim of maintain its verticality.
- The 290 millimeters long finned pile has been rotated clockwise and impelled inside the sandy layer. A screw has been used to raise and expansion of pile. The threaded end position of screw is connected to the pile and a proof ring with a strain control. This proving ring has a hand-operated loading jack attached to it. The response frame holds up the jack.
- In sequence to measure displacement, a travel dial gauge with an accuracy of 0.01 mm is permanently calibrated to suit for a plate of aluminum involved to the pile head. The mass of the process increased gradually throughout. Throughout the stabilization of the pile's deformation, Each capacity escalation was sustained constant at the exact value.
- The loading is only stopped for maximal deformation when it achieves its maximum value; after that, it either starts to drop or remains constant.
- The layout of pile's with fins uses different Lf/Lp ratios while maintaining the same embedment length.

  

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- The maximum strain might calculated after plotting the load due to uplift vs. deformation charts. The Lf/Lp ratios, along with the number, shape, placement, and size of fins, determine the pile's ultimate uplift load capability, with a extreme load of that amount.
- To regulate the results, various finned pile parameters are compared to a straightforward vertical pile.

## IV. RESULTS AND DISCUSSIONS

This chapter focuses on analyzing the uplift load-displacement responses of different mixes of finned piles. The study compares behavioral of vertical plain piles with vertical finned piles, where the embedment length remains constant, but different fin parameters are used in the experiments. The chapter includes a figure that illustrates the relationship between the amount of deformation experienced and the net ultimate load. Comprehensive graphical representations of the free sand situation have been thoroughly explored in this study.

➢ REGULAR PILE ACTION SUBJECT TO UPLIFT LOAD

The initial part of the study focused on evaluating the overall effectiveness of a standard pile with a measurement of 290mm when subjected to tension loads. This served as a crucial referral point for making comparisons in the ensuing experiments. The figure below illustrates outcome obtained from experiment conducted on a typical pile that had been hitherto interred in dirt. These findings suggest that the structure has the ability to withstand the maximum tension force concerning deformation.

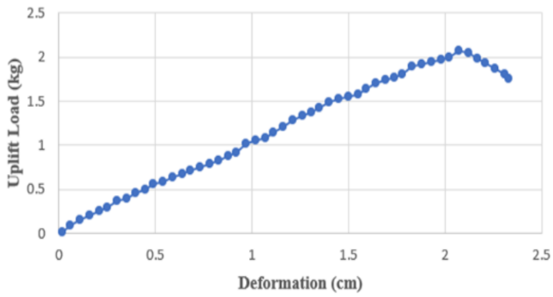


**Fig 12 : Regular pile action subject to uplift load**

➢ IMPACT OF THE NUMBER OF FINS ON THE PILE

With the intention to examine the relationship between the sum of fins and uplift resistance, the study organized the piles into four-finned and two-finned arrangements. Annotations were made with differing fin settings, such as Lf/Lp ratios of 0.2, 0.3, and 0.4, and the spot of the fins on the piles, including both two-finned and four-finned configurations. The objective was to investigate how the number of fins affects the uplift resistance.

The results showed that piles with four fins exhibited superior behavior compared to piles with two fins, as depicted in the Figure below. The addition of fins at the top of the piles increased their stiffness, which had a stronger impact on their performance. The four-finned pile demonstrated enhanced uplift resistance due to the increased influence of the fins on its behavior. Moreover, the orientation of the fins played a role in this improvement, as the diagonally-finned configuration replaced the straight-finned and star-finned arrangements. This change resulted in more of the surrounding sand being engaged, leading to increased resistance against uplift forces.

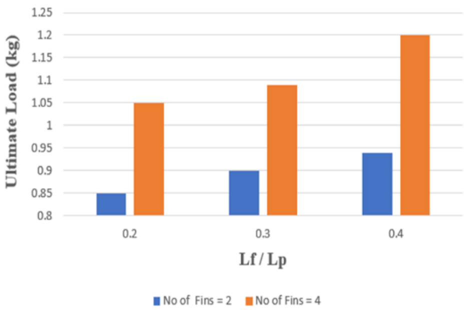


**Fig 13 : Impact of the number of fins on the pile**

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➢ Lf/Lp RATIO EFFECT ON LOAD CARRYING UPLIFT CAPACITY

To inspect the stimulus of fin length on the behavioural of tension-loaded finned piles, researchers conducted mannequin assessments using a rectangular under fin configuration with four fins placed at 90 degrees. The study examined various Lf/Lp ratios, ranging from 0.1 to 0.5, to understand their impingement on the pile final uplift resistance, as depicted in the figure. The results revealed that as the Lf/Lp ratio increased, the ultimate uplift stress of the piles also increased. However, the figure clearly showed that the growth in the piles resistance to the final uplift stress was significant only up to an Lf/Lp ratio of 0.5. Beyond this ratio, the resistance to lateral displacement decreased. Founded on these findings, an Lf/Lp ratio of 0.5 was identified as the most suitable for achieving the best uplift resistance. At this particular length ratio, the piles met both strength and serviceability requirements effectively. Consequently, this optimal Lf/Lp ratio will be employed in the subsequent model tests.

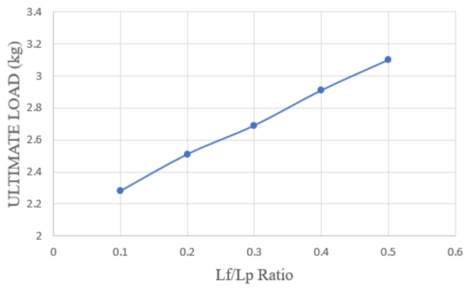


**Fig 14: Lf/Lp ratio effect on load carrying uplift capacity**

➢ IMPACT OF FINS WIDTH ON FINNED PILES' UPLIFT CAPACITY

The upmost portion of the soil encompassing tension-loaded piles plays a critical role in the pile's behavior. To reduce pile head deflection and enhance uplift resistance, the breadth of the fin (Wf) is modified in correlation to the pile diameter (Dp). This modification is predictable to improve the pile's resistance against uplift forces.

Model appraisals were administered using a 90° orientation with a rectangular shape featuring four fins at the top position, along with the optimal Lf/Lp ratio. The study explored a range of Wf/Dp values, including 0.5, 1.0, and 1.5, to examine how the fin width affects the pile's uplift resistance under tension load conditions.

An outcome designated that increasing the fin width leads to an surge in the maximum tension that the fins attached to piles can withstand, thus enhancing the effectiveness of the fins. Moreover, the influence of the wider fins on the ground can be ascertained immediately. Notably, even when the standard pile is surrounded by sand, increasing the fin width beyond the pile diameter (Dp) can still improve the effectiveness of the fins, although the rate of improvement may be slower. The represents multiple Wf/Dp combinations, demonstrating the residual uplift resistance of the pile.

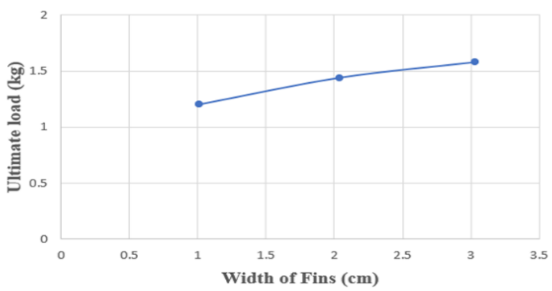


**Fig 15: Impact of fins width on finned piles uplift capacity**

 

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➢ IMPACT OF FINNED PILES SHAPE ON UPLIFT RESISTANCE

The study involves conducting tests on two fins with different shape, triangular and rectangular, both placed at the tip of the piles. Various parameters, such as Lf/Lp values of 0.2, 0.3, or 0.4, a Wf/Dp value of one, and a four-finned diagonal configuration with a 90-degree orientation, are investigated. The foremost ambition is to comprehend how the shape of the fins stimuluses the finned piles subordinated to tension resistance.

The results indicate that rectangular fins contribute the most to the stiffness of the piles, rendering them more resistant compared to piles with triangular fins. The addition of more fins toward apex increases the overall stiffness of the pile, making it more rigid. On the other hand, triangular fins minimize the surface area of resistance, enhancing the pile's ability to resist uplift stress.

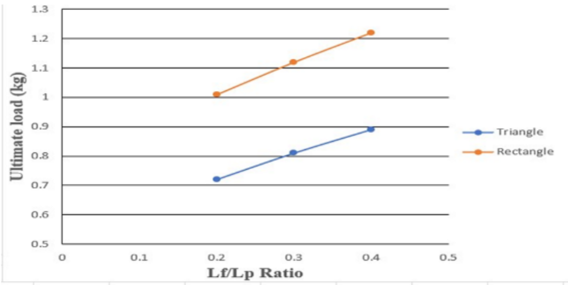


**Fig 16: Impact of finned piles shape on uplift resistance**

➢ IMPACT OF FINS POSITION ON THE CAPACITY CARRYING UPLIFT LOAD

To explore the persuade of fin placement on the uplift resistance of finned piles, model tests are directed with various fin parameters, including Lf/Lp values of 0.1to 0.5. three fin locations along the pile length are examined, namely, pile head, mid, and tip (top, middle, bottom).

The goal is to assess how different fin placements affect the pile's behavior. The figure illustrates the pile's response at each of the three distinct fin positions. From the scrutiny, it can be clinched that the piles bottom fin placement offers higher lateral resistance than the other two positions.

Furthermore, it is determined that the top fin placement provides the ultimate uplift resistance for the pile, associated to the other two positions. As intensification in the pile's stiffness during the submission of lateral loads results in an intensification in its ultimate uplift resistance because torque loads pretend on the pile tip.

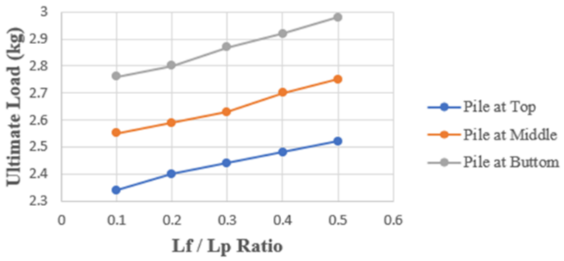


**Fig 17: Impact of fins position on the capacity carrying uplift load**

## V. CONCLUSIONS

Previously, model trials stood steered to contemplate the demeanour of piles attached to fins placed in to the sand coat. These tests involved emplacement of geo-jute with specific parameters. The investigations led to all the following significant conclusions:

✓ Finned piles demonstrated higher ultimate stress and confrontation compared to fins that are not annexed to the pile.

IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

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✓ The use of fins significantly increased the load carrying uplift load, and factors such as sand density, fin orientation, and fin position influenced load that are in tension state.

✓ Fins positioned at the base of the pile generated more resistance compared to fins that are laid at midpoint and pile tip.

✓ Four fins provided better resistance to distortion compared to two fins.

✓ Rectangular fins were initiate to be more efficacious than triangle shaped fins.

✓ Longer pile lengths (Lf/Lp = 0.5) resulted in increased maximum loads.

✓ The knowledge gained from these investigations can be applied in constructing sub-structures for tall buildings that will be subjected to substantial uplift forces.

✓ The displacement of the tests remained within 8% of the vertical displacement, indicating favourable behaviour of the pile length relation.

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