Experimental Investigations on Reinforcement Configurations in RCC Micropiles

Jiji Jacob G.* and N. Unnikrishnan

Department of Civil Engineering, College of Engineering Trivandrum, Kerala, India

*Corresponding author

doi: https://doi.org/10.21467/proceedings.160.9

ABSTRACT

Micropiles are piles of short length and small cross sectional area. The non availability of equipment, high cost of installation of metallic piles and their susceptibility to corrosion have prevented the wide application of micropiling technique. Studies on driven reinforced cement concrete (R.C.C.) micropiles are discussed herein. The investigation was aimed at finding the suitable reinforcement configuration for such R.C.C. driven micropiles. Micropiles of different diameters and lengths were tested. Reinforcement configurations were chosen giving attention to the ease of casting the piles. The selection of concrete mix required several casting trials. Axial load tests and bending tests on laboratory model micropiles were undertaken. Crushing failure was noticed at the ends during axial load tests. Specially designed end sleeves are found to be very useful to prevent the failure of the micropiles at the ends. The use of end sleeves was also found to increase the axial load carrying capacity of the micropiles.

Keywords- Micropiles, Driven, Reinforcement

1 Introduction

The fast pace of infrastructure development necessitates construction on and near slopes and creation of several manmade slopes. The existing highways and railways are being subjected to increasing loads due to ever increasing axle loads. The recent changes in climate and rainfall pattern have made the problem further complex. Several slope failures have been reported in the recent deluge of 2018 in Kerala. Slope failure in such highways which are the lifelines of modern world render them unusable for long periods of time. This affects the economy of the state in an indirect way. Rehabilitation of such distressed slopes is difficult in urban areas due to the restrictions on land take. A number of such highway and railway embankments need to be strengthened to sustain the increased loads. All these need increased emphasis on stability of natural and manmade slopes. There is a need to devise and promote a technique that is environment friendly, cost effective and easy to implement to ensure stability of slopes under distress. Micropiling technique emerges as a solution for the quick repair and rehabilitation of slopes under distress.

Micropiles are piles of short length and small cross section. Inclined micropiles can also be used for the stabilization of the slopes. The inclination allow a better mobilization of the axial stiffness of micropiles and consequently leads to a decrease in both shearing forces and bending moment induced by seismic loading (Marwan Sadek & Shahrour Isam, 2004). From a 3D elastoplastic analysis of the seismic performance of inclined micropiles, an inclination of about 20° was found to be optimal (ShahrourIsam *et al.*, 2012).

Confining micropiles can appreciably increase the load carrying capacity of footings on loose sand deposits (Unnikrishnan & Sachin, 2009). The influences of micropiles on soil bed response was investigated by Zolfegharifar *et al.*, (2015). It was found that micropiles could make improvements in soil beds so that the displacements will decrease significantly. These applications would lead to uniform soil stress distribution, elimination of irregularity in structure response and therefore prevention of possible twists and liquefaction considerably. Micropile foundations provided an alternative to augercast piling at a paper plant (Stuedlein *et al.*, 2008).

Proceedings DOI: 10.21467/proceedings.160; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-9-9

The non-availability of equipment and skilled labour has prevented the widespread application of micropiling techniques. Use of R.C.C. in micopile has not been explored due the difficulty in using large size aggregates and effective provision of reinforcement. There is a need to develop a technique for the easy manufacture of R.C.C. micropiles and their easy installation. Such a simple technique will make micropiling widely acceptable. The potential failures can easily be prevented by the application of the developed technique. In comparison to classical solutions, micropiling of slopes will be a more economical and quick solution. Investigations on driven reinforced cement concrete micropiles are presented. Attempts were made to arrive at a suitable reinforcement configuration that enables easy pre-casting of such R.C.C. driven micropiles of different diameters and lengths. Suitable concrete mix for such small diameter piles was also developed. The micropile shall be capable of resisting the driving and post-installation loads. Load tests were conducted to establish the strength of the micropiles with various reinforcement configurations. Specially designed end sleeves were used to prevent crushing of pile tips.

2 Materials

All material tests were performed as per the provisions in the relevant Indian Standard Codes. Commonly available Portland Pozzolana Cement (43 grade) was used for the preparation of the specimens. The material properties of cement are tabulated in Table 1.

Table 1: *Properties of cement*

Sl.No.	Test	Test result
1	Standard consistency	32%
2	Initial setting time	109 minutes
3	Final setting time	362 minutes
4	28th day compressive strength	45.6 N/mm^2

Coarse aggregate of nominal maximum size 6 mm was used as coarse aggregate. M-sand with maximum size 4.75 mm was used as fine aggregate. The material properties of coarse aggregates and fine aggregates are shown in Table 2. The fine aggregate lies in IS zone II.

Table 2: *Properties Of Fine & Coarse Aggregate*

Sl.No.	Test	Test result	
		FA	CA
1	Specific gravity	2.5	2.7
2	Bulk density	1.995 g/cc	1.75 g/cc
3	Void ratio	0.256	0.543
4	Porosity	20.36 %	35.18 %

Welded mesh reinforcement was used for the study. The welded mesh was selected as it is a locally available material which can be easily bought from a local hardware shop. It is made of GI wires welded together at the joints. Potable water was used for mixing concrete.

2.1 Mix Design

The mix design was done to obtain a characteristic compressive strength of 20 N/mm^2 using the above ingredients. Based on the target strength of 27.59 N/mm^2, different mixes were used and trial casting of micropile specimens were carried out. When water cement ratios of more than 0.48 were used, it resulted in the leakage of cement water paste through the joints of the moulds during vibration on the vibration table. Ratios less than 0.48 resulted in honey combing of the specimens. Hence this ratio was selected for the mix.

Table 3: *Mix Proportion*

Ingredients	Cement	Fine Aggregate	Coarse Aggregate	Water	W/C Ratio
Quantity(kg/m^3)	446	577	1035	214	
Ratio	1	1.3	2.3		0.48

The tests performed for determining fresh and hardened properties of the mix were found to satisfy the corresponding IS specifications. The mix proportion selected is given in Table 3. The properties of fresh concrete are tabulated in Table 4.

Table 4: *Properties of Fresh Concrete*

Sl.No.	Test	Test result
1	Slump	40 mm
2	Compacting factor	0.89

3 Specimen Details

3.1 Specimens

Longitudinally split cylindrical moulds of 1m length were made with internal diameters 52 mm, 71 mm and 106 mm. End flanges were used for stiffening purpose and also for facilitating fasteners for attaching another module of the mould for casting longer specimens, if required. The mould with internal diameter 106 mm fixed to the base plate is shown in Figure 1.

Figure 1: *Mould fixed on base plate*

Specimens were prepared using welded mesh as reinforcement. On testing in axial compression most of the specimens were found to fail by crushing at the ends. To prevent this, extra reinforcement was provided at the ends using chicken mesh. However, this could not prevent crushing failure of the cast specimens at the ends during test under axial load. Therefore extra reinforcement was provided with welded mesh itself and again was not found to serve the purpose. Hence, specimens were cast with end sleeves to protect the pile ends. The end sleeves were specially designed to provide confinement. The sleeves were made of galvanised iron sheets through bending, locking and welding. The sleeves were placed at the time of casting itself. These were found to be successful in preventing the failure of the specimens at the ends. The details of the various types of specimens prepared are given in Table 5.

The compaction of 52 mm diameter and 71 mm diameter micropiles were carried out on the vibrating table (Figure 2). Placing of concrete in the moulds and compaction using the vibrating table were done simultaneously. The casting of 106 mm micropiles were done by keeping the mould on the floor and compacting using needle vibrator (Figure 3).

A specimen cast without end sleeves is shown in Figure 4 and a specimen cast with end sleeves are shown in Figure 5.

Table 5: *Designation For Types Of Micropiles*

Designation	Meaning
L1	0.5 m length.
L2	1.0 m length.
M1	Mix 1:1.3:2.3 with w/c ratio 0.48.
R1	Welded mesh reinforcement of 0.83 mm diameter.
R2	Welded mesh reinforcement of 1.38 mm diameter.
R3	Welded mesh reinforcement of 1.38 mm diameter with additional chicken mesh at ends.
R4	Welded mesh reinforcement of 1.38 mm diameter with additional welded mesh reinforcement at ends.
R5	Welded mesh reinforcement of 1.38 mm diameter and sleeves at ends.

Figure 2: *Casting of specimen using vibration table*

Figure 3: *Casting of specimen using needle vibrator*

Proceedings DOI: 10.21467/proceedings.160
ISBN: 978-81-965621-9-9

Series: AIJR Proceedings
ISSN: 2582-3922

Figure 4: *Specimen cast without end sleeves*

Figure 5: *Specimen cast with end sleeves*

4 Experimental Investigations

The specimens were tested for axial compression using 300 T UTM till failure. The failure load and the failure pattern were noted. The axial load test setup is shown in Figure 6.

Figure 6: *Axial load test setup*

The bending tests on 0.5 m long specimens with a span 0.4 m were done using 30 T UTM. The test setup is shown in Figure 7.

Figure 7: *Bending test setup*

5 Results and Discussions

The failure of the specimens at ends during testing in axial compression can be seen in Figure 8. The specimens cast with special end sleeves at the ends are shown in Figure 9. It can be noted in the figure that the failure has taken place away from the ends.

Figure 8: *Specimens with failure at the ends*

Figure 9: *Specimen with failure away from the ends due to end sleeves*

5.1 Axial Load Tests on 52 mm diameter specimens

The details of the results obtained while testing 52 mm diameter specimens with different lengths are given in Figure 10.

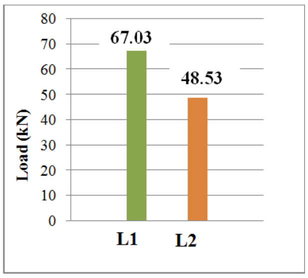

Figure 10: *Comparison of axial load capacities of 52 mm diameter micropiles of mix M1 and reinforcement R1 with different lengths*

As the length is doubled, the axial load carrying capacity of the specimens reduced by 28 % due to increased slenderness.

5.2 Axial Load Tests on 71 mm diameter specimens

A comparison of the axial load capacities of 71 mm diameter with different types of reinforcement can be obtained from Figure 11.

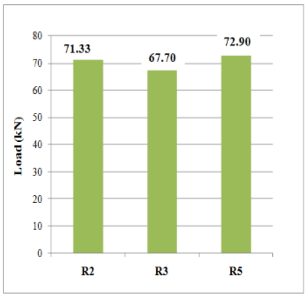

Figure 11: *Comparison of axial load capacities of 71 mm diameter micropiles of length L2 and mix M1 with different reinforcement*

It can be observed that the use of chicken mesh at the ends of the micropiles results in a 5 % reduction in the strength. This is due to the fact that when chicken mesh is used, proper placement of concrete is not possible at the ends, which leads to the formation of a weak zone at the ends instead of strengthening the area. Hence the use of chicken mesh is not advisable. On the contrary, it can be noted that the use of end sleeves increases the strength of the specimens by 2 % compared to specimens without placing any additional reinforcement at the ends.

5.3 Axial Load Tests on 106 mm diameter specimens

Comparisons of results for 106 mm diameter specimens are given in and Figure 12.

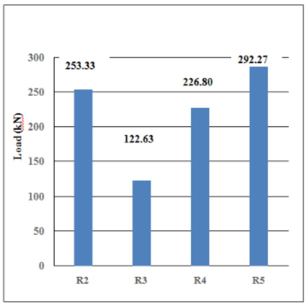

Figure 12: *Comparison of axial load capacities of 106 mm diameter micropiles of length L2 and mix M1 with different reinforcement*

It is evident from the results that the use of chicken mesh or the use of extra welded mesh cannot improve the strength of the specimens. In fact, there is reduction in strength when extra reinforcement is used at the ends. Hence the use of additional reinforcement at the ends is not advisable. The use of end sleeves increases the strength of the specimens by 15 %. Hence it can be concluded that the end sleeves are very effective in increasing the axial strength of micropiles.

5.4 Bending Tests

The results of the bending tests on 52 mm specimens are given in Table 6.

Table 6: *Maximum Central Concentrated Load Carried By 52 Mm Diameter Micropiles*

Sl.No.	Maximum central concentrated load (kN)
1	1.73
2	1.27
3	1.52

It can be inferred from the table that high bending strength could not be attained in the specimens with the use of welded mesh reinforcement.

6 Conclusion

After detailed feasibility considerations, dimensions of laboratory model micropiles were chosen. Ease of manufacturing, handling, transport and installation were the prime considerations. Reinforced cement concrete mix using 6 mm coarse aggregate was designed. Suitable reinforcement configuration using locally available welded mesh was arrived at. Several micropiles were initially cast to master the casting technique. The specimens cast were subjected to axial compression test and bending tests. The specimens were able to carry the expected axial loads. The use of chicken mesh reinforcement nor the use of extra reinforcement at the ends could substantially improve the axial load carrying capacity of the piles. These methods could not prevent the failure of the failure of the micropiles at the ends. The failure at the ends of the micropile in the initial tests could be successfully prevented by using special end sleeves made of metal sheet. The overall load carrying capacity of the micropiles were increased by using these end sleeves. End sleeves prove to be more beneficial in the case of micropiles of larger diameter. The sleeves can also prevent the crushing failure at the top of the micropiles when they are dynamically driven during installation in the field. The use of alternative reinforcement techniques can be explored at places where micropiles require high bending strengths.

7 Declarations

7.1 Acknowledgement

The authors are thankful to Kerala State Council for Science, Technology and Environment for financially supporting this research.

7.2 Publisher’s Note

AIJR remains neutral with regard to jurisdictional claims in institutional affiliations.

How to Cite

Jiji & Unnikrishnan (2023). Experimental Investigations on Reinforcement Configurations in RCC Micropiles. *AIJR Proceedings*, 77-84. https://doi.org/10.21467/proceedings.160.9

References

[1] Arwin, W., Stuedlein, Matt, D., Gibson, Garry, E., Harvitz (2008). Tension and Compression Micropile Load Tests in Gravelly Sand. 6th International Conference on Case Histories in Geotechnical Engineering, Arlington, VA, August 11-16.

[2] Marwan, S., ShahrourIsam (2004). Three-dimensional Finite Element Analysis of the Seismic Behaviour of Inclined Micropiles. *Soil Dynamics and Earthquake Engineering*, 24:473-485.

[3] ShahrourIsam, Alsaleh H., SouliMhamed (2012). 3D Elastoplastic Analysis of the Seismic Performance of Inclined Micropiles. *Computers and Geotechnics*, 39:1-7.

[4] Unnikrishnan, N., Sachin, P. (2009). Influence of Confining Micropiles on the Bearing Capacity of Sand. Proceedings of the ASCE Conference.

[5] Zolfegharifar, S.Y., Daram, H., Rahimi, M. (2015). Static Analysis using Finite Element Method for Micropiles Application Evaluation: Empirical and Numerical Perspective. *Cumhuriyet University Faculty of Science, Science Journal*, Vol.36, No.4, Special Issue.