Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(4) (2020) 235-238
DOI: 10.22060/ceej.2018.15093.5827

A New Failure Criteria for Hollow-bar Micropile Based on Full-Scale Static Load Tests

M. A. Fakharnia, H. Bayesteh*

Department of civil engineering, University of Qom, Qom, Iran

ABSTRACT: Recently, the use of hollow-bar micropiles has increased rapidly. These micropiles reduce the time and cost and not only were used as a reinforcement element but also used to improve the surrounding soils. Despite the increasing use, few studies have been conducted on the performance of this type of micropiles, in particular the determination of load capacity, failure criteria, and interpretation of loading tests. In this study, 22 hollow bar micropiles with simultaneous injection methods in different lengths and soils were executed and full-scale tension and compression loading tests were performed on them. Then, by using the six common failure criteria for pile foundation, the performance and ultimate load of these tests were evaluated. Using mathematical relations, assumptions about load-displacement curves and using numerical modeling of the observed load-displacement behavior, field test results have been developed to reach the geotechnical failure. The results show that since the diameter and bond strength of hollow bar micropiles is more than theoretical ones, the existing failure criteria are not suitable for interpretation of their load-deformation behavior. The existing failure criteria do not take into account the increase in the bond strength and the reduction of the elastic length. Based on the information obtained from the existing failure criteria and considering the effect of elastic shortening on the loading test results, a failure criterion has been proposed to determine the failure load of hollow bar micropile based on the Davison method.

Review History:

Received: 10/5/2018
Revised: 10/25/2018
Accepted: 12/15/2018
Available Online: 12/15/2018

Keywords:

Hollow bar micropile
Static load test
Failure criteria
Full scale

1. INTRODUCTION

In recent years, the use of hollow-bar micropiles has been developed to use in soft soils. In this method, hollow-bars are used which the drilling, injection, and reinforcement operations are performed simultaneously using a high strength steel rod [1]. The static loading test ordinary has been used to evaluate the performance of the hollow bar micropiles [2, 3]. The main challenge during the interpretation of the result of the static load test is finding the failure point. Failure criteria are methods that interpret and determine the amount of failure or ultimate load pile in a static loading test and can be used for design purposes [4]**.** The literature review indicates that a suitable failure criterion for micropiles, especially hollow bar micropiles has not been addressed yet. Based on the existing codes on micropiles, they did not provide a single failure criterion for these types of micropiles [5]. In the present study, to determine the failure load and to evaluate the performance of the hollow bar micropiles, 22 full-scale hollow bar micropiles have been executed in two types of soils and were tested under full-scale static compression and tension loading test. By analyzing the efficiency of existing failure criteria, using the results of numerical modeling of the observed behavior and using existing analytical approaches, a new geotechnical failure criterion for determining the ultimate load in hollow bar micropiles was developed.

2. METHODOLOGY

In this research, the implementation of 22 hollow-bar micropiles and performing full-scale static load tests took place at the Bushehr Province in the South of Iran in two sites with different soil types. The geotechnical specifications of each site are summarized in Table 1. The experimental micropiles consist of main micropiles and reaction micropiles. To execute the compression (C) and tension (T) micropiles, the grout was injected using a swivel as a drill injection adaptor at the top of the drifter, which allowed for continuous grout injection through the hollow bar. The micropiles were executed at 9 and 15 meters in length. The simultaneous drilling grouting was carried out at a grout-to-water cement ratio of 0.5–0.7 with a pressure of up to 0.7 MPa. In Fig. 1, the arrangement of the compressive and tensile micropiles in two sites is shown. To evaluate the performance of micropiles, 22 compression and tensile loading tests were carried out following the relevant standards and in accordance with the recommendations of the FHWA (2005) Code, up to twice the design load, in some cases, more than twice the design load [5].

Due to the lack of the failure criteria for hollow-bar micropiles, six commonly used failure criteria were selected consist of Davison, Butler and Hoy, Fuller and Hoy, Chin-

*Corresponding author's email: h.bayesteh@qom.ac.ir

Table 1. Geotechnical parameters of selected sites

Site	**Soil**	**Depth (m)**	$(N_1)_{60\,AVE}$	$kN/m^2\ C_u$	φ	γ kN/m^3	ν
1	CL	0-16	15	75	0	17.5	0.4
2	GC-GM	0-15	30	10	35	20	0.35

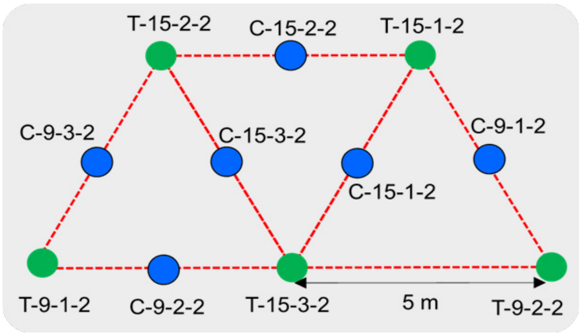

Fig. 1. Arrangement of the compression and tension micropiles

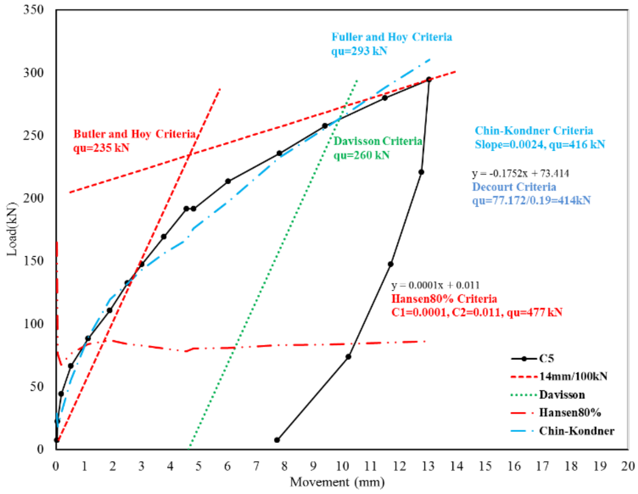

Fig. 2. The load-displacement curve of compressive micropile with the used failure criteria

Kondner, Hansen, and Decourt methods which have been recommended by references. These methods were used to analyze the load-deformation curve from the results of static loading tests. In Fig. 2, a sample loading-displacement curve is shown along with the application of the selected failure criteria.

3. RESULTS AND DISCUSSION

Due to the limitations of the full-scale loading test in applying high loads (to reach the geotechnical failure), it is not possible to load onto the microplate more than its structural capacity, so the geotechnical failure maybe not occurred. To accurately evaluate the existing failure criteria and suggest a new failure criterion for hollow-bar micropiles, the mathematical hyperbolic function and numerical modeling were used to develop the results of field tests have up to geotechnical failure. Due to the construction method of the hollow-bar micropiles which induced the more bond resistance in comparison with the traditional micropiles, the amount of elastic shortening is the most important for developing failure criteria. The existing failure criteria are not suitable for the interpretation of the results of hollow-bar micropile loading and do not consider increasing the strength of the skin friction and reducing the elastic length. On the other hand, the Fuller and Hoy failure criterion has been suggested by FHWA (2005) and previous studies for the determination micropile failure load [1, 5]. This is even though its use is associated with errors in the determination of ultimate load. However, Davison's criterion determines the amount of ultimate load using a specific relationship and provides a unique response so it is more commonly used rather than other methods. The Davison relationship consists of three sections of elastic shortening (PL/EA), a variation proportional to the mobilization of the tip resistance (4mm) and a portion proportional to the diameter of the pile (D/120). Due to the construction method of the hollow-bar micropiles and increasing the interlocking with surrounding soil, a decreasing coefficient was applied to the elastic shortening term of the Davison method. According to the average estimated amount of ultimate load from the six used failure criteria, especially the Fuller and Hoy method, the coefficient (less than one) was applied to the Davison relation to reaching the results be the proposed method close to the average value of the existing methods as depicted in Fig. 3.

Finally, the Davison relationship is corrected and proposed in the form of Equation 1.

$$\Delta = \left(0.45\right)\frac{PL}{AE} + 4(mm) + \frac{D}{120} \tag{1}$$

In the above equation, Δ is the corresponding displacement of the pile failure load, P is the maximum applied load, L is the micropile length, A is the equivalent cross-section, D is the diameter of the drill bit (mm), and E is the micropile elastic modulus which in tension is equal to the elasticity of the steel rod and in the compression is mixed of the grout and the steel rod.

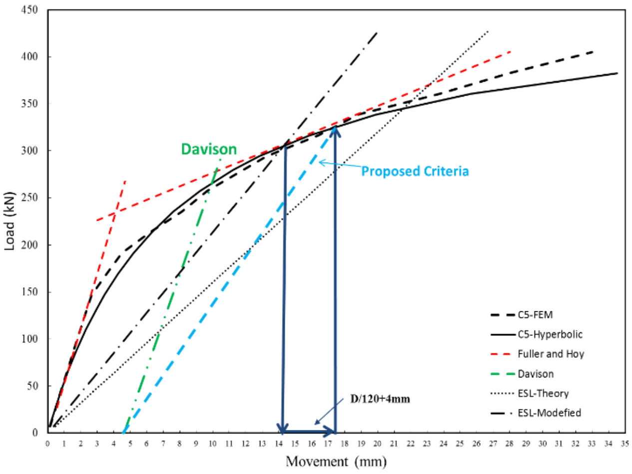

Fig. 3. Modification methodology of the Davison method

4. Conclusions

- A series of full-scale static load tests were executed on the hollow bar micropile in two different soils.
- The Davison relationship was corrected by applying a decreasing factor such as elastic shortening, taking into account the effect of elastic deformation according to the behavior and performance of hollow-bar micro piles.
- To provide a failure criterion, the mean value of the reduction factor including the elastic shortening due to the skin friction of the micropile, is 0.45.

REFERENCES

[1] O.F.E.H. Drbe, M.H. El Naggar, Axial monotonic and cyclic compression behaviour of hollow-bar micropiles, Canadian Geotechnical Journal, 52(4) (2014) 426-441.

[2] A.Y. Abd Elaziz, M.H. El Naggar, Performance of hollow bar micropiles under monotonic and cyclic lateral loads, Journal of Geotechnical and Geoenvironmental Engineering, 141(5) (2015) 04015010.

[3] J.E. Gomez, C.J. Rodriguez, H.D. Robinson, J. Mikitka, K. L., Hollow core bar micropiles—installation, testing, and interpolation of design parameter of 260 micropiles, in: In Proceedings of the 8th International Workshop on Micropiles, Toronto, Ont., (2007).

[4] C.W. Ng, T.L. Yau, J.H. Li, W.H. Tang, New failure load criterion for large diameter bored piles in weathered geomaterials, Journal of Geotechnical and Geoenvironmental Engineering, 127(6) (2001) 488-498.

[5] FHWA(Federal Highway Administration), Micropile design and construction—Reference manual, FHWA NHI-05-039, US Department of Transportation, McLean, VA (2005) 436.

HOW TO CITE THIS ARTICLE

M.A. Fakharnia, H. Bayesteh, A New Failure Criteria for Hollow-bar Micropile Based on Full-Scale Static Load Tests, Amirkabir J. Civil Eng., 52(4) (2020) 235-238.

DOI: 10.22060/ceej.2018.15093.5827