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Behavior of Single Micropile Under Different Lateral Load Rates

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K E Y W O R D S

Micropile, Lateral Load, Displacement, Moving Rate.

A B S T R A C T

This paper displays an empirical work of a micropile inserted in the dry river sand with different length to diameter (L/D) ratios (13, 15, 27, 42, and 50). The experimental work is executed on the models of micropile to imitate the side force motion, acting on the micropile head to explain the micropile conduct due to the different side force rates. Forty-five models are tested (eighteen models for short pile, eighteen model for long pile and nine models for intermediate) embedded in different relative densities of sandy soil. The results illustrate that for the same relative density, the lateral load is decreased when the moving rate increasing from (3.37 to 3.97 then 4.59 mm/min), that means frequency (0.55 to 0.65 then 0.75 Hz), respectively.

At the same moving rate of horizontal loading, the value of lateral load increased with the increase of horizontal displacement until reach to the 12mm at the end of the test. The duration of the test decreased with the increase of moving rate and the maximum duration of the test recorded for micropile model has (L/D) of 50 with 75% relative density when the moving rate of lateral load is 3.37 mm/min. Also, it is found that the duration of the test increases when the relative density increased at the same moving rate.

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1. Introduction

The Micropiles are defined as mini diameter piles (generally, less than 300mm), implemented as cast in situ replacement or injected grout. They also referred to as minipiles or pinpiles, which are a deep foundation system frequently used to sustain significant axial loads (compressive or tensile) and lateral loads. This type of piles may be deem as a replace for traditional piles or as one component in a combined soil//pile mass, rely upon the design notion employed. Due to the relatively large flexibility of such piles, it can also be used for seismic retrofit and constructed in different site conditions. the Micropiles are applied as support elements to improve the bearing capacity of present foundations and to prohibit an excessive settlement;for new structures and land stabilization ,they can also be used as foundations. Micropiles are special in providing innovativegroutedanddrilling techniques, which in return present load resistance. The drilling and grouting methods are applied in micropile investiture allow for high grout/ground bond value along with the interface (FHWA, 1997).They have been used for over 60 years. Originally, they were envisioned as innovative solutions to aid in the difficult post-war reconstruction effort. Over the course of 30 years, micropile technology has greatly expanded and evolved from the concept of low-capacity micropile networks to the use of a single, high-capacity element in particular since 1980.

In 1997, FHWA presented a comprehensive literature review on micropile that included laboratory and field test data, design methods, and construction methodologies; Site notes and case studies monitored. Then, rapid developments in drilling equipment and techniques extended the applicability of micropile techniques to infrastructure repair and seismic retrofit. [5]investigated of micropilesbehavior under lateral loading conditions. They recommended installing a larger casing to increase the loading capacity; the diameter or the batter angle should be increased.[2] Check the performance of a single micropile with different length to diameter ratios poured into the sand layer of variable relative density and subject to side loading, as well as vertical or diagonal clouds. It was found that the L / D ratio had a significant effect on it and the relative density of the sand bottom and the drag tilt angle had a significant effect on the failure mechanism.[3] conducted a laboratory study on a full-scale of micropiles installed in the sand. The results showed that the deflection was not significantly affected by the axial load and that the axial load could lead to a slight decrease in both torque and deflection.[4] conducted a field load test for individual and pooled oblique micropiles exposed to lateral loading. The obtained results showed that the lateral capacity increases with the slope of the load from the right side to the left and the opposite direction of the load from the left to the right. For the group of micropiles, the lateral amplitude increases with the slope of the pile due to the effect of stabilization. The area of passive failure and developed skin friction along the pile are factors that contribute to the side load's ability to withstand thin, sloping pegs.This paper introduces an experimental study to investigate the influence of variation of lateral load rates on the horizontal displacement of the single micropile model installed in river sandy has diverse relative densities.

2. Experimental Work

I. Index properties of soil

The dry river sand used in this survey is from the cityof Baghdad at a depth of (2-4 m). A large number of tests are executed according to the standard specifications to explain and recognize both the physical and mechanical properties of sand used as shown in Table I. According to the Unified Soil Classification System, the soil used is classified as poorly graded sand (SP).

II. Micropile model and container

The micropile model used in this study has different length to diameter (L/D) ratios (13, 15, 27, 42, and 50) which cast in the sand bed has different relative densities andsubjected to the different moving rates. Strain gauges are pasted along the micropile shaft at the regular intervals. The model of strain gages used is BF350 with a resistance of (350 Ohm). The length of each gage is 7.1mm and 4.5 mm width with a 2.1 sensitivity factor. The dry sand is compacted in a steel container which has the inner lengths of the box are (750×750×750 mm).

The container was made from five separated parts;the five part of the box were made by using a 6 mm thickness steel platelet. After that, an aluminium casing of micropile with the external diameter 12.7mm and internal diameter 11.5mm is pressed vertically in the sand bed until reaching the desired depth by the jacked method, then the sand inside the casing is sucked and the casting stage is started. The micropiles are cast in different relative densities 35%, 55% and 75%. A 2mm diameter mild steel rod is placed inside the casing as a reinforced element. The casing then grouted with cement slurry having water to cement (w/c) ratio of 0.15.

TABLE I: Properties of the river sandy used

List Property	Value	Standard Specification
Active sizes: D_{10}, D_{30}, D_{50}, D_{60} [mm]	0.12, 0.19, 0.24, 0.27	ASTM D 422 and ASTM D 2487 (2007)
Coefficient of uniformity [Cu]	2.25	ASTM D 422 and ASTM D 2487 (2007)
Coefficient of curvature [Cc]	1.12	ASTM D 422 and ASTM D 2487 (2007)
Classification [USCS]	SP	ASTM D 422 and ASTM D 2487 (2007)
Specific gravity [Gs]	2.67	ASTM D 854 (2006)
Max. dry unit weight, [kN/m^3]	15.99	ASTM D 4253 - (2000)
Min. dry unit weight, [kN/m^3]	13.14	ASTM D 4253 - (2000)
Max. void ratio	0.99	…………
Min. void ratio	0.63	…………
Relative density [RD]	35% 55% 75%	…………
Dry unit weigth natural [γ_d kN/m^3]	14.1 14.6 15.17	…………
Voids ratio [e]	0.86 0.79 0.72	…………
Friction angle, degree	28 30 33	ASTM D3080-11

III. The system of horizontal motion

The side loading system is shown in Figure (1) manufactured by [1] consisting of a horizontal hydraulic jack system and screw steel shaft connected to exert a horizontal load which applied to the load cell from one side. The second side of the load cell is linked by a steel shaft with a penetration cone to apply a point load on the micropile cap.

To study the influence of the side load of the pile cap as shown in Figure 1, the load cell is fixed among the loading point applied to the lint cover and the lever shaft to record the load increase on the lint cover pending the test. The load cell is connected to a weight indicator to read the force applied from the hydraulic socket. The load is stopped when the lateral dial gauge reading reaches the displacement reading of 12 mm. The reason for taking (12 mm) as the maximum horizontal displacement is to simplify discussion of the results of a single laterally loaded pile and based on recommendation of [6].

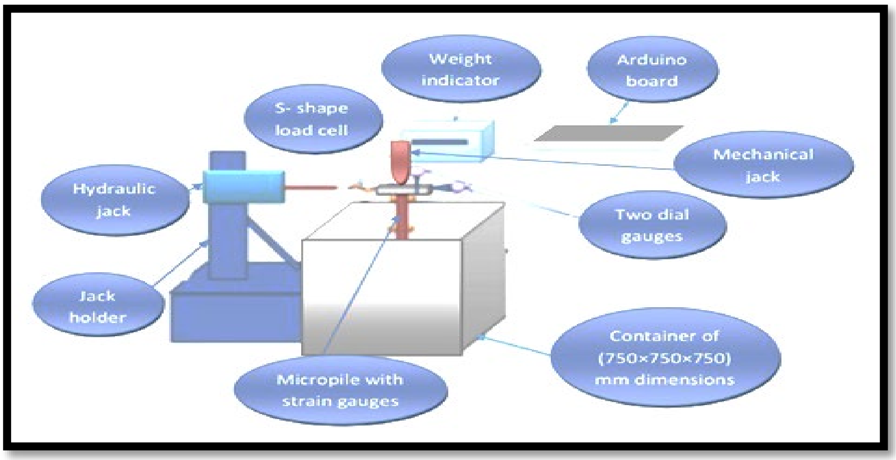


Figure1: System of lateral loading diagram

(a) Hydraulic jack hold by frame

(b) Model setup

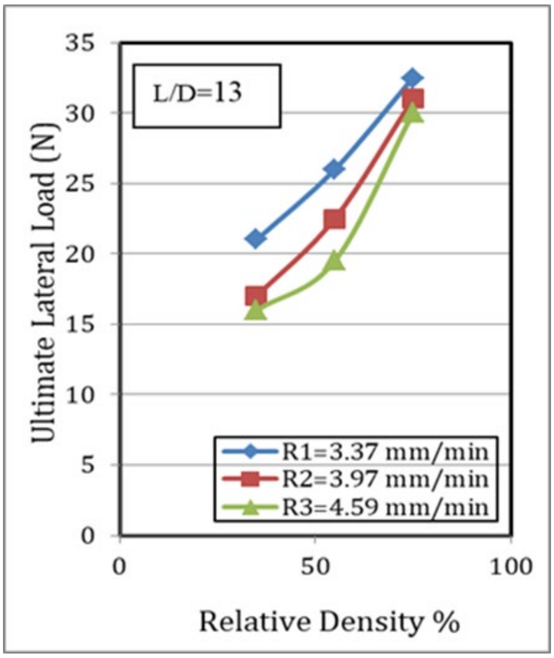
Figures (2): (a, b) Horizontal movement device

3. Model Test Results

Three lateral load rates (R1, R2, R3) are applied on single micropiles embedded in three states of sand consistency (loose, medium and dense).

I. Lateral load with relative density

Figure (3) show the ultimate side force versus relative density of micropile model. It can be seen that side load values increase as an increased in relative density as an outcome of increased shear strength parameters of the river sandy. This behaviour agreed with the results found by [6] who stated that the shear strength of sand increases when the relative density changes from a looser state of the denser state.



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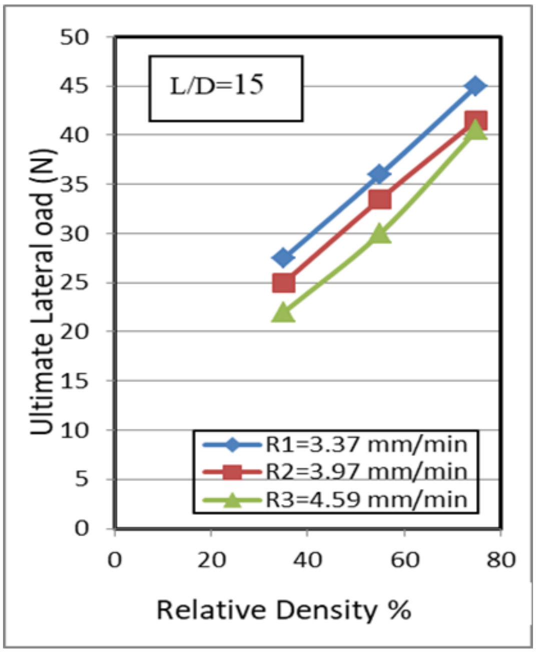

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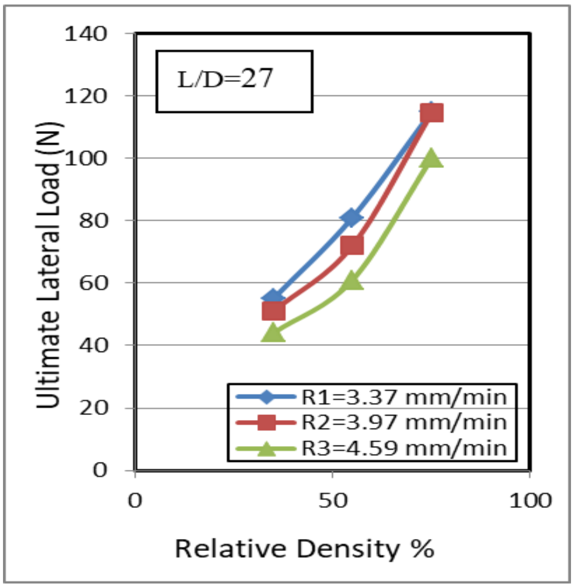

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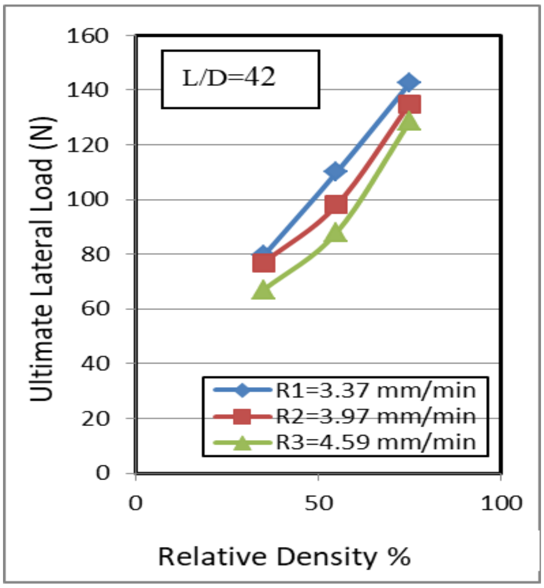

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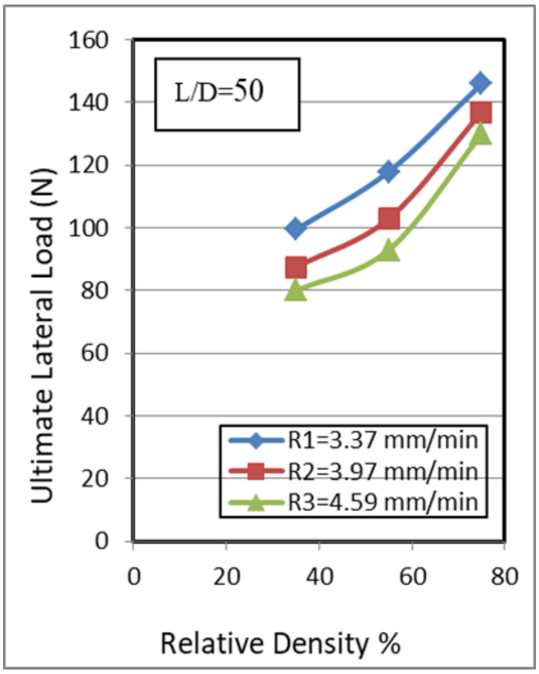
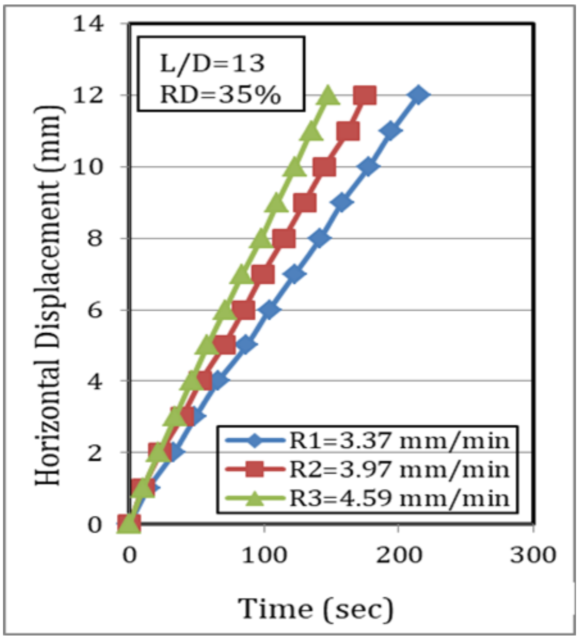


(e)

Figure (3): (a, b, c, d, e) Ultimate side force versus relative density of micropile model

II. Horizontal displacement with test duration

Figure (4) depicts the effect of test time on the horizontal displacement at different moving rates. It can be observed that at the same moving rate, the horizontal displacement is gradually increasing with increasing the duration of the test. Horizontal displacement increased with increases in loading rates. This approach happens as an outcomes of side reduction in negative resistance during side motion Because medium sand has larger areas than dense sand. Therefore, the sand will move and the particles will be replaced by the voids. Also, increasing the horizontal displacement means that the relative density decreased.


L/D=13
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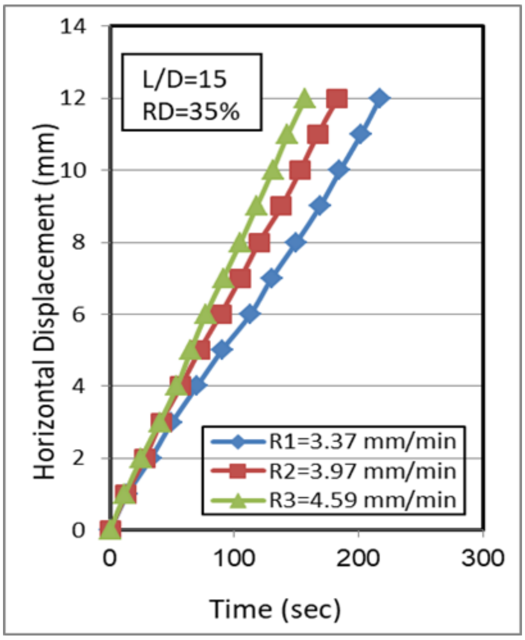
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min
Horizontal Displacement (mm)
Time (sec)

(a)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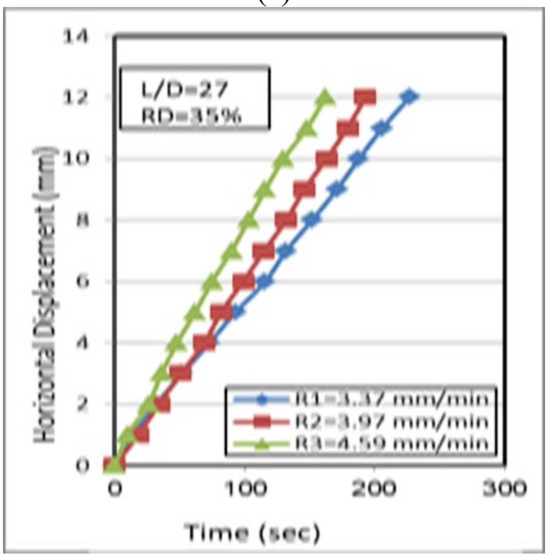
R3=4.59 mm/min
Horizontal Displacement (mm)
Time (sec)

(b)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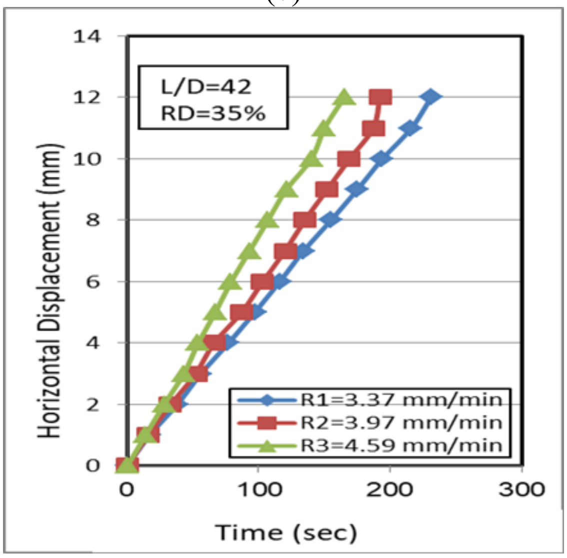
R3=4.59 mm/min
Horizontal Displacement (mm)
Time (sec)

(c)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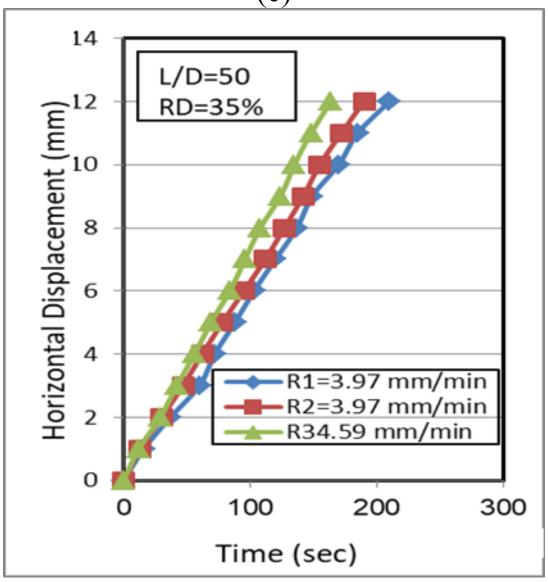
Horizontal Displacement (mm)
Time (sec)

(d)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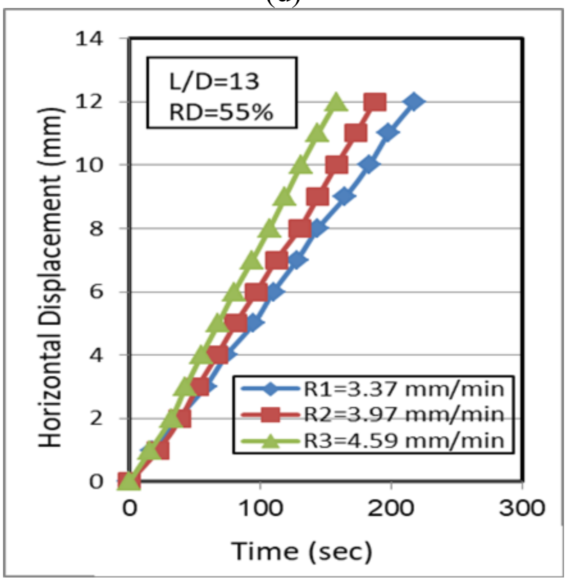
R34.59 mm/min
Horizontal Displacement (mm)
Time (sec)

(e)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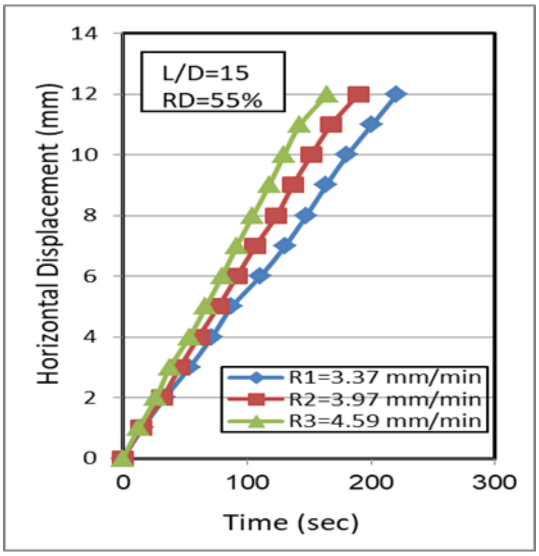
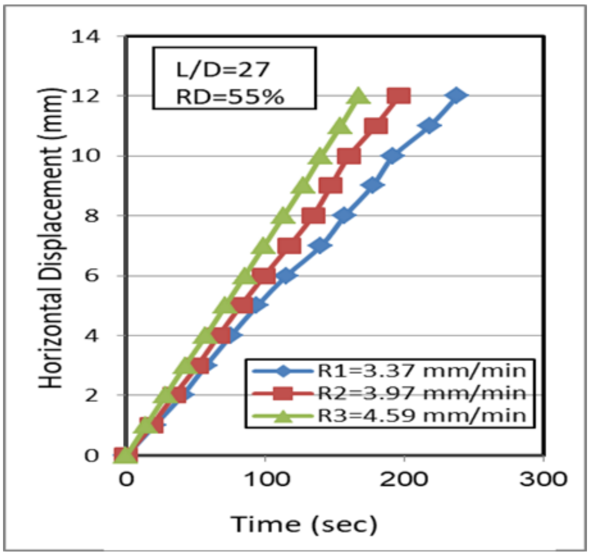
R3=4.59 mm/min
Horizontal Displacement (mm)
Time (sec)

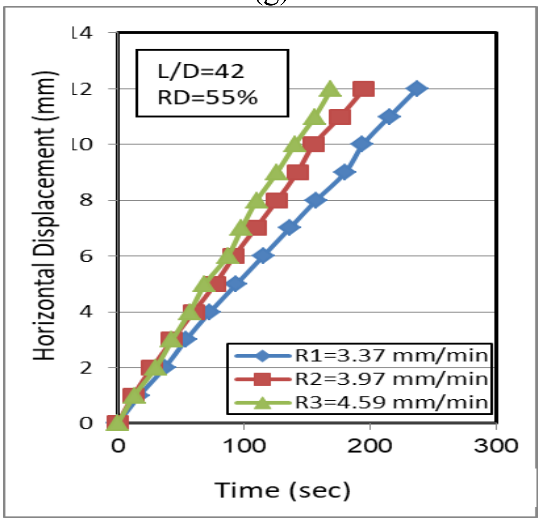
(f)


L/D=15
RD=55%
Horizontal Displacement (mm)
Time (sec)
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min

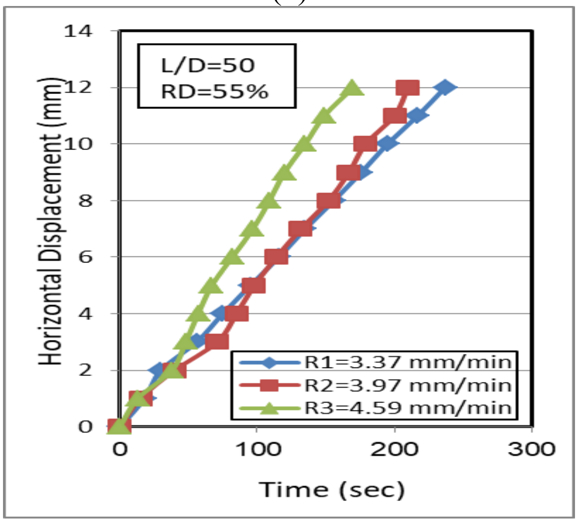
(g)


L/D=27
RD=55%
Horizontal Displacement (mm)
Time (sec)
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min

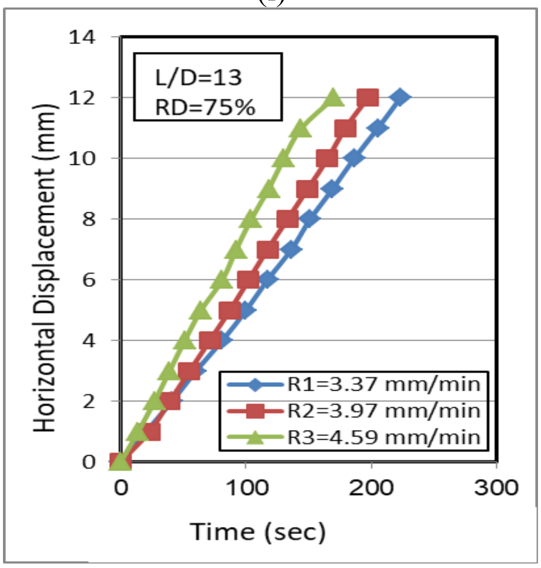
(h)


L/D=42
RD=55%
Horizontal Displacement (mm)
Time (sec)
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min

(i)


L/D=50
RD=55%
Horizontal Displacement (mm)
Time (sec)
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min

(j)


L/D=13
RD=75%
Horizontal Displacement (mm)
Time (sec)
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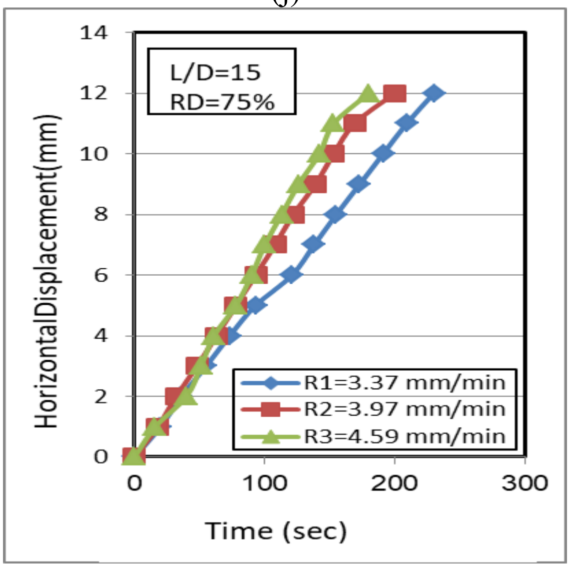
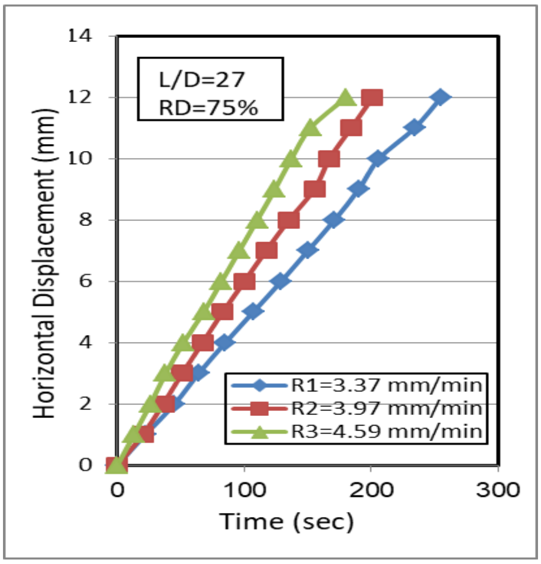
R2=3.97 mm/min
R3=4.59 mm/min

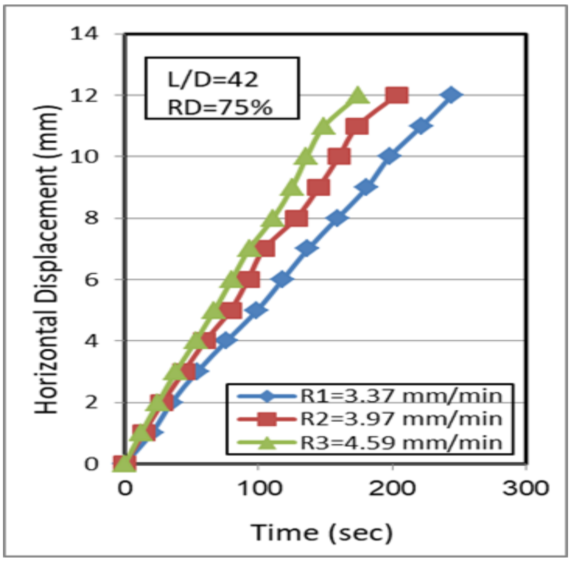
(k)


L/D=15
RD=75%
HorizontalDisplacement(mm)
Time (sec)
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min

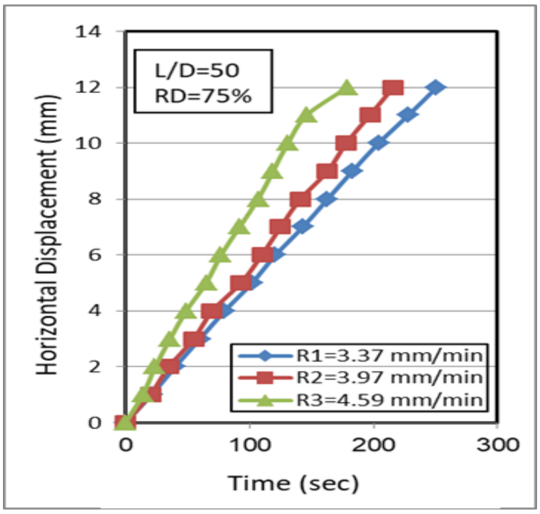
(l)



(m)



(n)



(o)

Figure (4): (a, b, c, d, e, f, g, h, i, j, k, l, m, n, o) horizontal displacement with duration of the test, at different relative densities.

III. Effect of (L/D) with ultimate lateral load

Figure (5) shows the final side load with the difference in length to diameter (L / D).It is found that the values of lateral load increased with increasing (L/D) ratio, but this increase being twice or more when the (L/D) ratios change from 15 to 27, due to change the embedded length of the pile. However, the magnitudes of the lateral load are approximated for the moving rates. The difference between curves is when the length to diameter (L/D) increase that means increase the void between magnitudes.

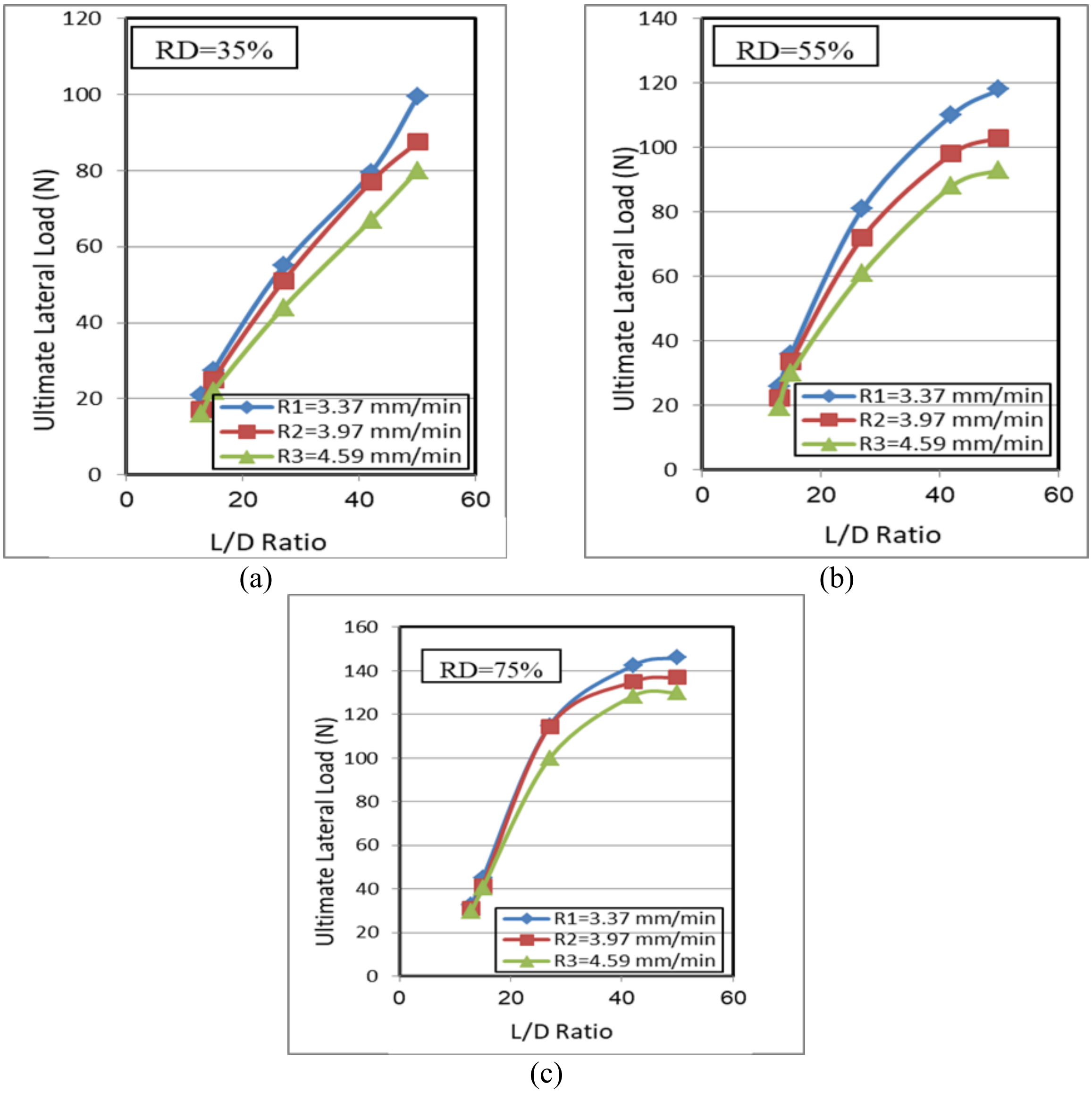
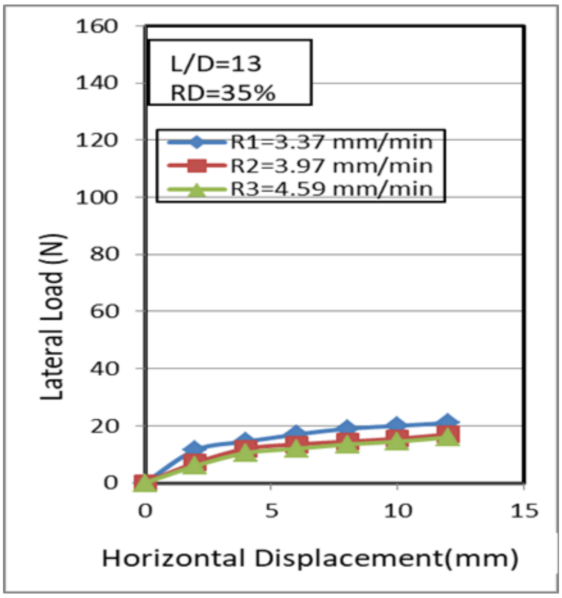


Figure (5): (a, b, c) Effect of (L/D) ratio with the ultimate lateral load.

IV. Lateral load with horizontal displacement

Figure (6) present the lateral load – horizontal displacement relationship for single micropiles models. It can be seen that the relationship between the lateral load and a horizontal displacement is nonlinear for all studied cases of micropile models. At the same relative density, the lateral load is decreased when the moving rate increasing from (3.37 to 3.97 then 4.59 mm/min) respectively. Also, the side force increased an increased embedded length to diameter ratio of the pile. At the same moving rate of horizontal loading, the value of lateral load increased with the increase of horizontal displacement until it reaches to the 12 mm end of the test.


L/D=13
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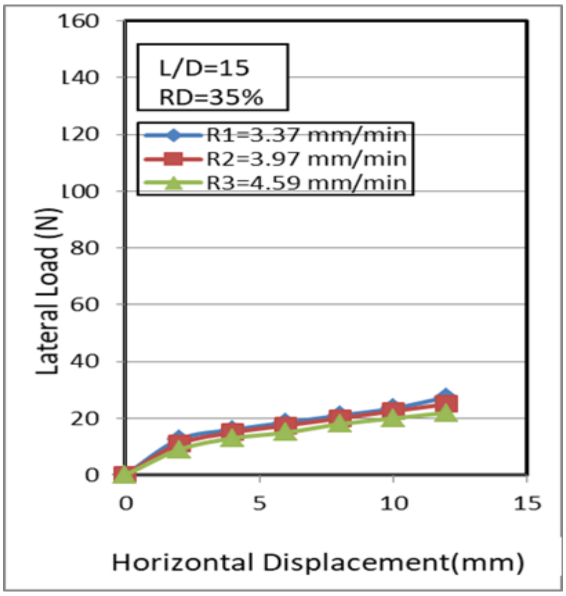
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)

(a)


L/D=15
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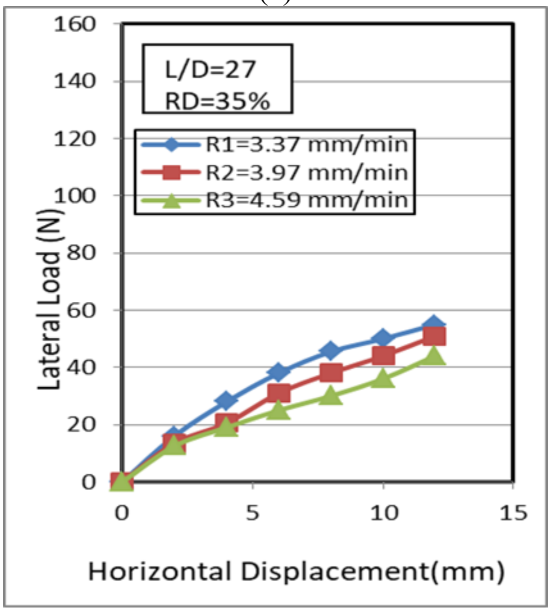
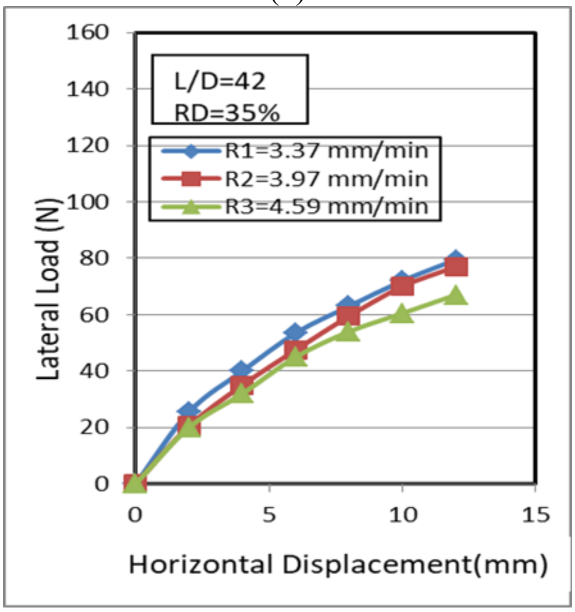
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)

(b)


L/D=27
RD=35%
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)

(c)


L/D=42
RD=35%
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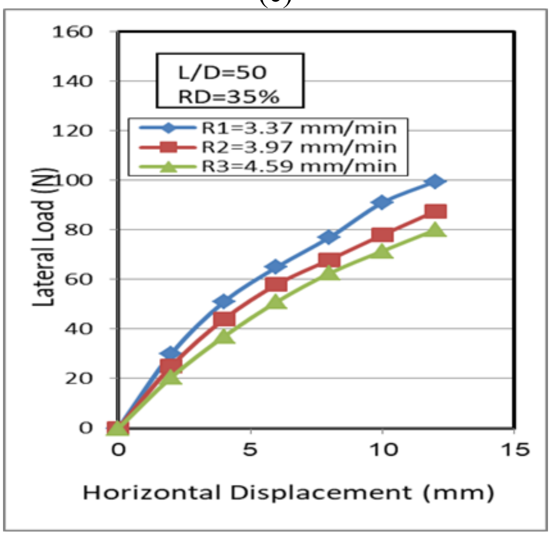
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)

(d)


L/D=50
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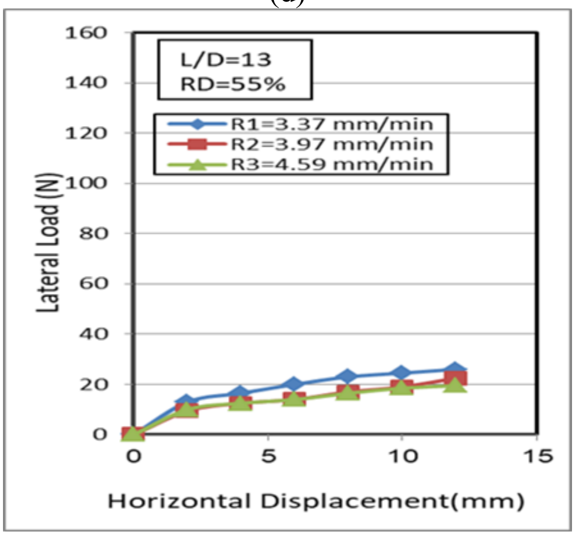
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement (mm)

(e)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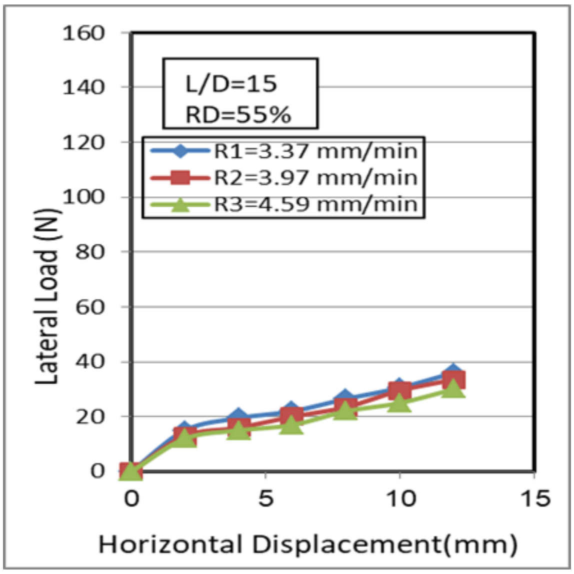
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)

(f)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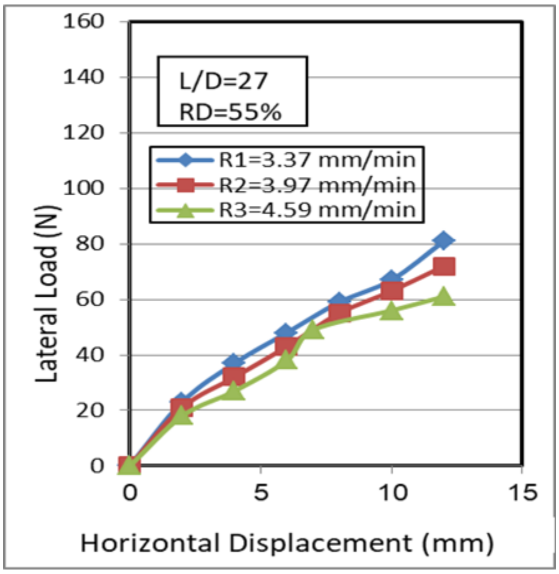
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)
(g)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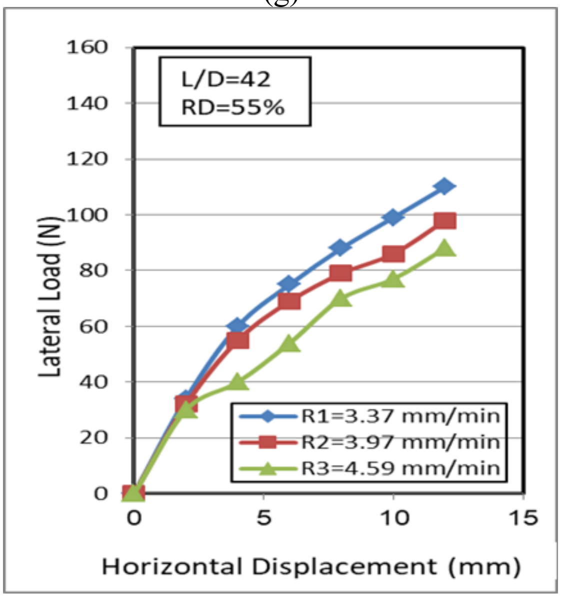
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement (mm)
(h)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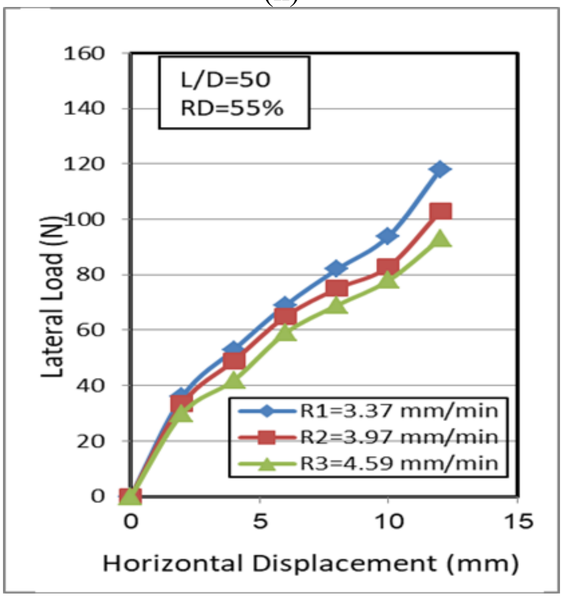
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement (mm)
(i)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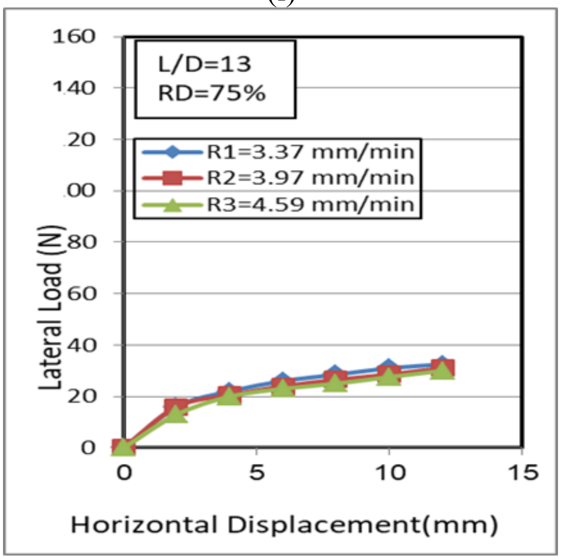
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement (mm)
(j)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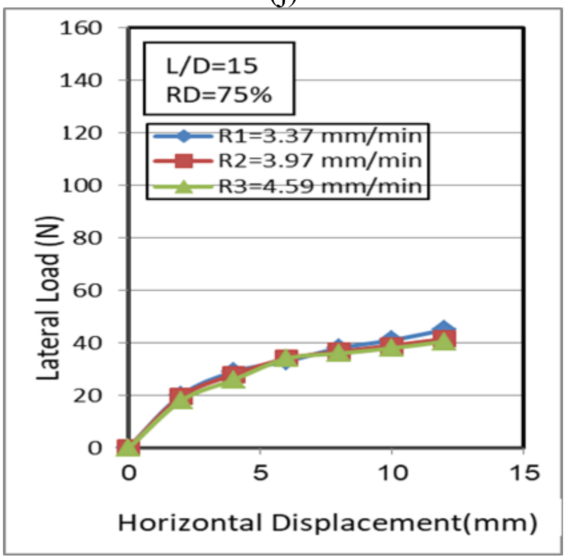
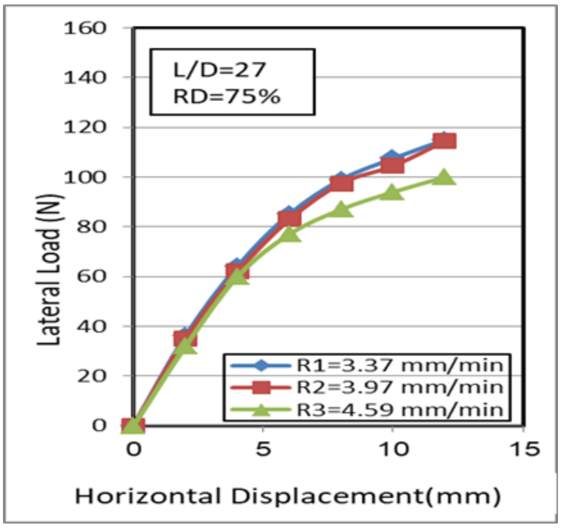
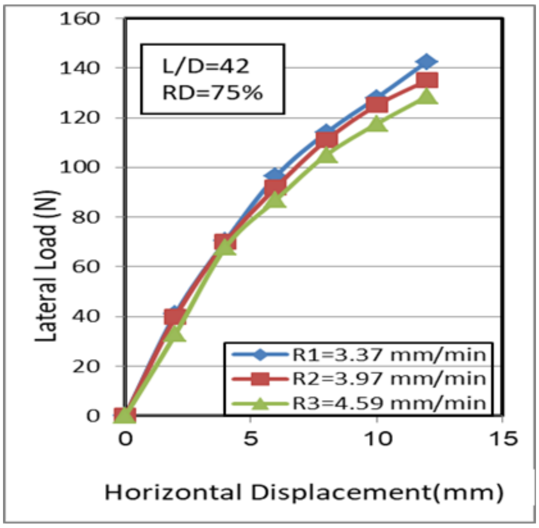
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)
(k)

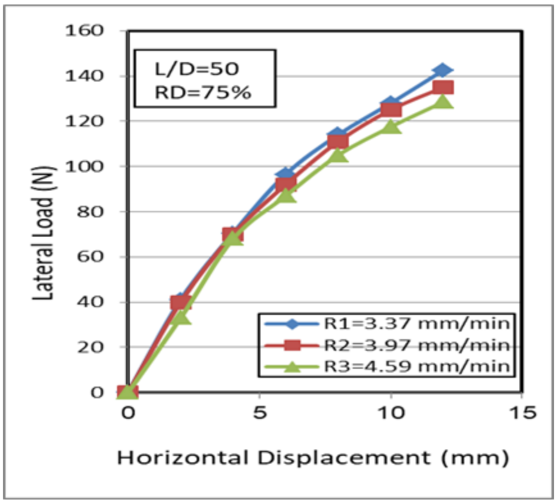

L/D=15
RD=75%
R1=3.37 mm/min
R2=3.97 mm/min
R3=4.59 mm/min
Lateral Load (N)
Horizontal Displacement(mm)
(l)



(m)



(n)



(o)

Figure (6): (a, b, c, d, e, f, g, h, i, j, k, l, m, n, o) Lateral load versus Horizontal displacement curves of single micropile model.

4. Conclusions

The conclusions obtained from testing of 45 models of micropiles under lateral loading can be listed as follows:

1. The relationship between the lateral load and a horizontal displacement is nonlinear for all studied cases of micropile models.
2. For all lengths, the magnitudes of lateral load increase as average 51%, 49% and 54% with the increase of the relative densities 35, 55 and 75% respectively.
3. The lateral load decreases in the rate of 9.8% and 10.4% when the moving rate increased {(3.37 to 3.97 mm/min) (frequency 0.55 to 0.65 Hz)} and {(3.97 to 4.59 mm/min) (frequency 0.65 to 0.75 Hz)} respectively.
4. At the same moving rate, the horizontal displacement increases gradually with the increase of test duration.
5. At the same length to diameter ratio, the sand densification has little effect on the duration of the test. The test duration marked a slightly increased with increasing of the sand densification.
6. For the same length to diameter ratio (L/D). The ultimate lateral load proportional with increasing of the relative density increase.

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