



Studying The Settlement of Backfill Sandy Soil Behind Retaining Wall Under Dynamic Loads

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KEY WORDS

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ABSTRACT

For a long time, the seismic examination of retaining walls has been contemplated by a few strategies dependent on the basic augmentation of Coulomb's limit equilibrium investigation. These techniques cannot gauge the removal of the refill soil upheld by the wall. A trial examination is completed to contemplate the vertical settlement on sandy soil under dynamic loads with other burden amplitudes, vibration frequencies, relative density, and various separations between the establishment and holding divider. The model balance utilized in this investigation is square. Dynamic burden test is done on cohesion less soil with three burden amplitudes (0.25 ton, 0.5 ton and 1 ton), three vibration recurrence (0.5 Hz, 1 Hz and 2 Hz), two density of sandy soil (30% loose sand and 70% dense sand) and three unique separations between the establishment and retaining wall. It has been seen that the change is increment with the burden of abundance and decreased by increasing the separation between the establishment and retaining wall. There is an unimportant result of recurrence on the aggregate settlement. The settlement decrement by incrementing the relative density.

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1. Introduction

Retaining wall systems are one of the most significant civil engineering construction built to supply side back to soil and are extensively useful in highway walls, mines, underground construction, and soldiery protection. They consist of fundamentally of a retaining wall and backfill soil, the engineering gist of retaining wall is to keep the conserve soil in confirmed situation and preclude it from subsidence (steadiness), or to curb the distortion of the wall and the backfill to preserver it employ duty (serviceability). In management to estimate the steadiness's of these are construction, an exact rating of the lateral earth pressure is very paramount. Dynamic vibration reaction of such

systems is one of the greater areas due to the impact of dynamic that require on the lateral compression, and soil wall distortion.

The trouble of rating seismically instigated parallel earth compression on Retaining configuration has been first tended to during the 1920s in groundbreaking investigation convey out in Japan by Okabe [1] and Mononobe and Matsuo [2]. From that point forward, this proposition acquire recurring advertence from the study society (e.g. Seed and Whitman [3], and Prakash [4]). Be that as it may, it had moderately diminutive collision on plan what's more, designing execution until generally recently. There are the abundant methods for increasing the settlement on sandy soil under dynamic loads with different load amplitudes, vibration frequency, relative density and distance between foundation and retaining walls. The behavior of settlement on sandy soil under dynamic loads was also studied by many investigators utilizing theoretical approach to demonstrate attitude of the soil under vibration load such as Sung [5] who provided the first suitable solution to this vertical vibration of the hard disk with a mass on a semi-flexible area but this solution is not so understood by most engineers. The theoretical method for analyzing the dynamic reaction of the soil on regulation is based on a multitude of easier to hypothesis in connection with soil properties and system. A general analysis of retaining structures subjected to dynamic loads were studied by Al-Shakarchi et al. [6], namely earthquake and harmonic excitation was carried out by the finite element method. It was found that the dynamic earth force is greater than that obtained when applying the M-O theory. An increase in the order of about 150% and 110% greater than M-O theory is obtained for altitude of the wall 4 m and 7 m, respectively. The finite element analysis of retaining walls subjected to earthquake excitations gives greater dynamic earth squeeze than these calculated through M-O method at all heights. The average position of the resultant of the dynamic earth force is found in this work to be located at around (0.38H) over the base of the divider as compared to (0.33H) for linear distribution. Wang et al. [7], completed a test to request the reaction to modification advancements and surplus hole pressure from the foundation on sandy soils. It has been obvious to the sand around the bucket relax or even condenses in the primary stage when stacking expands the adequacy at a basic worth, at a later arrange, the basin settles and the sand layer step by step combines. With solidified melted sand layer and basin leveling, the development of the sand layer and can up to stable condition. A numerical technique through limited component (FEM) for two models: flexible and equal linear was utilized by Raheem and Fattah [8] to examine the seismic conduct of retain divider supporting soaked, liquefiable, cohesion less refill soil. Flat/ Perpendicular relocation, pore water squeeze, even all-out strain in the soil at the substance of the divider and Max.shear strain in the soil at the base were estimated. It be demonstrated in order to the equal sample afford increasingly sensible outcomes and the liquefaction region focused on the detached a portion to a greater extent than the dynamic portion. The greatest even relocation at the highest point of the divider arrives at 0.67 m while perpendicular relocation extended in the range (66-116) % with the divider expanding in measurements. Both pore water squeeze/flat all-out pressure expanded with time/measurements in the range (37%) and (200%), separately. The earth squeeze allocation produced beyond a 20 m, rise retain divider was evaluated utilizing the limited component strategy by Salman et al. [9] contrasted that got from traditional earth squeeze hypotheses. Soil conduct be thought to become elastoplastic together the Mohr-Coulomb disappointment rule. The solid retain divider explained by a direct versatile sample. Two-dimensional plane-strain limited component PC platform CRISP be used in accordance with several alteration. The outcomes demonstrated that Dubrova's technique confer more noteworthy qualities than the Coulomb condition for all methods of divider developments. Though, the outcomes acquired of the limited component examination show in order to the pressure allocation is pretty much equivalent to the Coulomb condition and going at around 90% of the profundity for $\phi=25^\circ$ and 60% for $\phi=40^\circ$. Underneath this profundity, the squeeze allocation turns out to be a lot more noteworthy than that acquired by the Coulomb condition. Run of the tests to decide the perpetual settlement of shallow footing that is dependent on various kinds of dynamic burdens have been accounted for by numerous analysts. Raymond and Komos [10] displayed the aftereffects of the dynamic versus settlement of strip sections on dense sand. By looking into the writing and crafted by previous analysts, it is important to consider the vertical settlement on refill sandy soil behind retaining wall under dynamic burdens with various burden amplitudes, vibration frequencies, relative densities and various distances between the foundation and retaining wall.

2. Experimental Work

Index Properties of Soil

The soil which is utilized in this exploration is characteristic cohesion less soil (sand) transported of Karbala city in Iraq. The whole pattern was sifted on No. 10 sifter (2.0 mm) and a while later, the implementation of the experience of creation on a sieve to separate the physical properties of the soil experiment. The soil is classified as SP-SM soil as per the Unified Soil Classification System USCS. Subtleties of the test outcomes are given in Table 1, notwithstanding particular followed in every experiment. The cereal volume allocation of the utilized soil is appeared in shape (1).

Table 1: Physical properties of the sand used in the experimental models.

Test	Results	Specification
Specific gravity (Gs)	2.65	ASTM D854-(2010) [11]
Gravel %, > 4.75 mm	0	ASTM D422 (2010) [12]
Sand % , 0.075- 4.75 , mm	96	ASTM D422 (2010) [12]
Clay and Silt % , <0.075, mm	7	ASTM D422 (2010) [12]
D_{60} , mm	0.5	ASTM D422 (2010) [12]
D_{30} , mm	0.3	ASTM D422 (2010) [12]
D_{10} , mm	0.17	ASTM D422 (2010) [12]
Coefficient of uniformity, Cu	2.94	ASTM D422 (2010) [12]
Coefficient of gradation, Cc	1.06	ASTM D422 (2010) [12]
Minimum dry unit weight , kNm^3	15.5	ASTM D4253 (2006) [13]
Maximum dry unit weight, kNm^3	17.2	ASTM D 4254 (2006) [14]
Maximum void ratio , e_{max}	0.68	-----
Minimum void ratio , e_{min}	0.51	-----
Soil classification	SP-SM	ASTM D2487 (2006) [15]

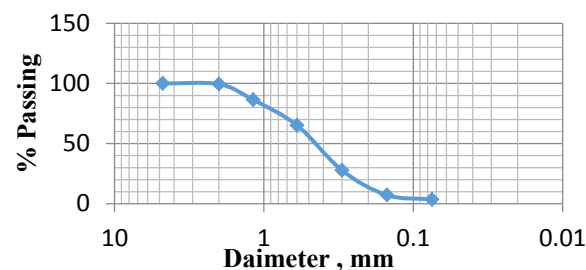


Figure 1: Grain size distribution for the used soil.

3. Load Setup

So as to simulate the dynamic burden in the science lab behind the wall, a vibration loading gadget that was produced and created in the labs of the University of Technology; specifically the Soil Mechanics Laboratory was utilized. The gadget was created to help a load ability to (60 kN). This expansion in the burden limit was accomplished by integrating the electric water-driven stacking framework rather than the electric air blower framework and further updating the steel structure of the contraption to withstand the new stacking amplitudes (Aswad, 2016) [16] as showed up in Figure 2.

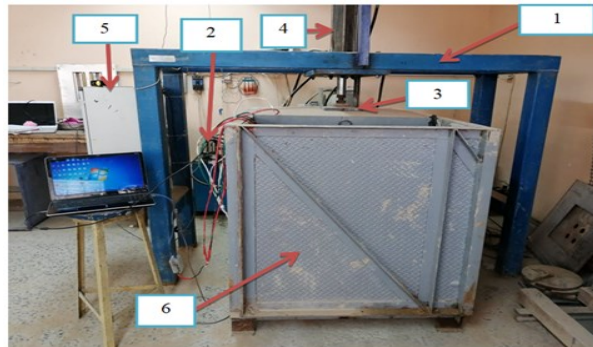
The heap application contraption is included the going with parts:

1. Steel stacking outline. 2. Electrical pressure driven system. 3. Weight spreader plate. 4. Settlement evaluating mechanical gathering. 5. Data getting and logging structure. 6. Steel compartment (1500*900*1000 mm).

I. Steel Loading Outline

To help the verticalness of the chamber system used in applying the central concentrated weight, a steel packaging was organized and manufactured. The steel edge contains dominantly of four

portions and four bars. The cross-sectional zone of each fragment and shaft are made of steel with a square cross-portion territory of (100 mm x 100 mm) and 4 mm thick. The components of the steel diagram (length x width x tallness) are (1700 mm x 700 mm x 1700 mm).



1) Steel loading frame. 2) Electrical hydraulic-driven framework. 3) Burden spreader plate. 4) Settlements estimating mechanical assembly. 5) Information obtaining and logging framework. 6) Steel compartment.

Figure 2: Vibratory stacking gadget

II. Electrical Hydraulic-Driven Framework

The framework includes a water-powered steel tank with a limit point of 70 liters. The tank includes two holes; the upper one is utilized to fill the oil and the lower one is for release. The tank incorporates an apparatus mechanical assembly type water-driven siphon with a fixed geometrical volume giving a release around 12 liters/min with the best weight of 150 bars.

The pressure-driven framework is constrained by a programmable logic controller (PLC). The monitoring unit unlocks and shuts the valve-related with the water-powered attachment, along these lines creating a half-notwithstanding stacking wave. The stacking time interim is set by the client before each test, making a heap wave at a given repeat.

III. Model Footing

A square footing (200 mm×200 mm) stainless steel with 20 mm thick is manufactured to simulate the machine foundation. The dynamic load applied on this footing represents to the traffic load by trucks or railways.

IV. Information Obtaining and Logging Framework

The information procurement framework is utilized to quantify and detect the happening displacement during the tests, which empowers the analyzer to get colossal information of readings in a brief time frame, also, it is utilized to pick the predefined recurrence utilized in the test. The information obtaining framework comprises of a Programmable rationale Controller (PLC) that can be characterized as a computerized PC utilized for electro-mechanistic computerization procedures, and it is a rise innovation preparing unit. This sort of framework investigates the information carefully. PLC gadget includes an LCD contact scanner board that is utilized to review the information and yield information by improved stepping motion logic.

V. Steel Compartment

The tests were done in a steel compartment with an arrangement measurement of 1500 mm length ×900 mm width×1000 mm rising. All piece of the compartment is synthetic or steel sheet 5mm sold. The compartment is synthetic of five fully-solder splices, one for the base and others for the four splices of the compartment. The tall parts were supported remotely by the corner at their border. The base is remotely solidified by three canals of (50 mm web × 25 mm spine).

4. Gravity Wall Model

Gravity retaining wall was manufactured of steel with a width of 16 mm at top and 60 mm at bottom, height 700 mm and length 850 mm. These dimensions were chosen according to the guidelines of

Bowels (1996) [17] presented in Figure (3). Soil prepared and retaining wall placing in the box is presented in Figure (4).

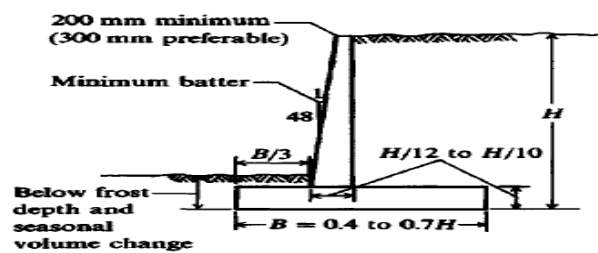


Figure 3: Tentative design dimensions for a cantilever retaining wall (Bowles, 1996)



Figure 4: Soil and retaining wall placing in the box.

A gathering of 54 model tests was performed on sandy soil as a source under dynamic load utilizing two diverse relative densities; 30% and 70% which are comparing to loose and dense sand, individually. After the consummation of the readiness of sand, the upper roof was leveled to bring as close as conceivable a level roof. The balance was then acquired in reach with the upper roof of the bed of the sample. Later the readiness of balance superficially layer of sand, a dynamic load was connected all through a predestinate arrangement. The utilization of dynamic load proceeds up to 10^4 cycles.

5. Sample Experimental Results under Dynamic Load

I. Impact of Dynamic Load on the Perpendicular Adjustment

Figures 5 to 16 demonstrate the relation of perpendicular adjustment against the numeral of cycles for various burden capacities. Clearly as found in these shapes, the measure of vertical adjustment incremented with incrementing the burden amplitudes. It tends to be discovered that there is a little impact of recurrence on the cumulative vertical settlement. The estimations of vertical settlement decremented by incrementing the relative densities. Likewise, the estimations of vertical settlement decreased by increasing the distance between the foundation and retaining wall.

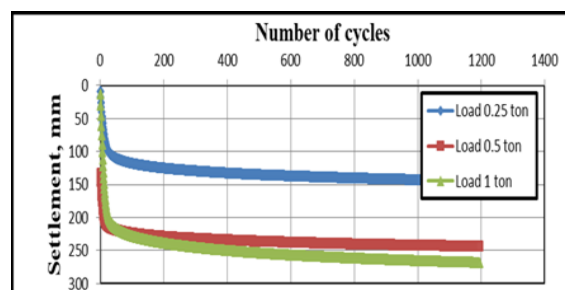


Figure 5: Settlement versus number of cycles for a retaining wall under different load amplitudes with sand relative density = 30%, frequency 0.5 Hz and a load at 0.2H distance.

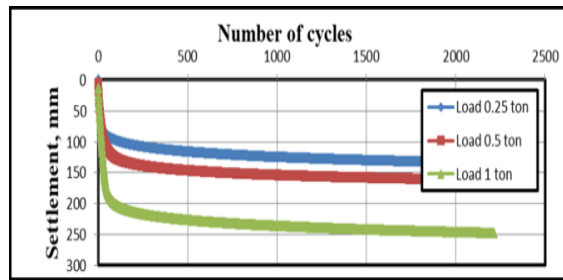


Figure 6: Settlement versus number of cycles for a retaining wall under different load amplitudes with sand relative density = 70%, frequency 0.5 Hz and a load at 0.2H distance..

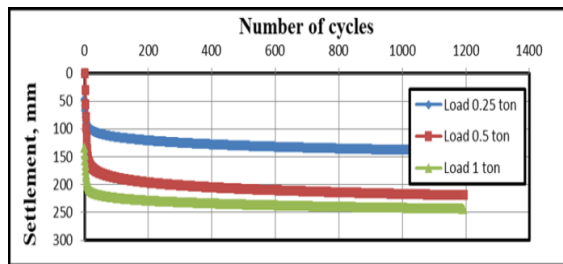


Figure 7: Settlement versus number of cycles for a retaining wall under different load amplitudes with sand relative density =30%, frequency 1 Hz and a load at 0.2H distance.

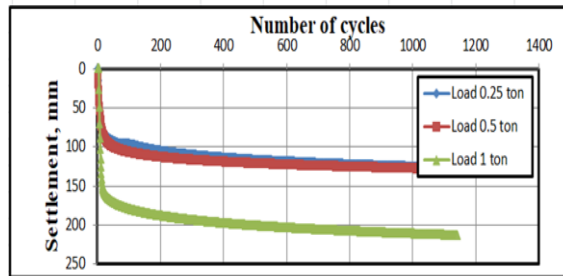


Figure 8: Settlement versus number of cycles for a retaining wall under different load amplitudes with sand relative density =70%, frequency 1 Hz and a load at 0.2H distance.

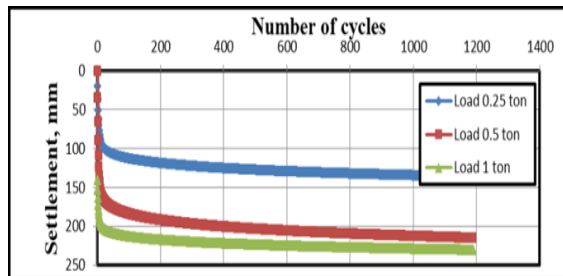


Figure 9: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 30%, frequency 2 Hz and a load at 0.2H distance.

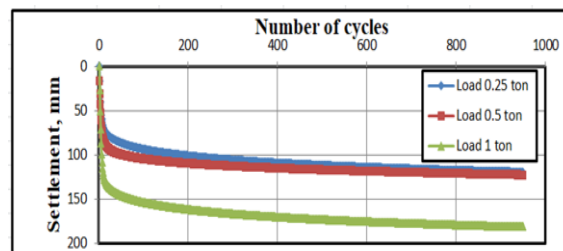


Figure 10: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 70%, frequency 2 Hz and a load at 0.2H distance.

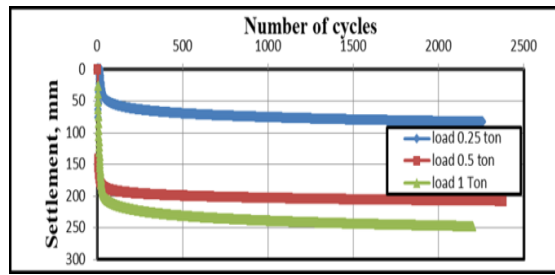


Figure 11: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 30 %, frequency 0.5 Hz and a load at 0.3H distance.

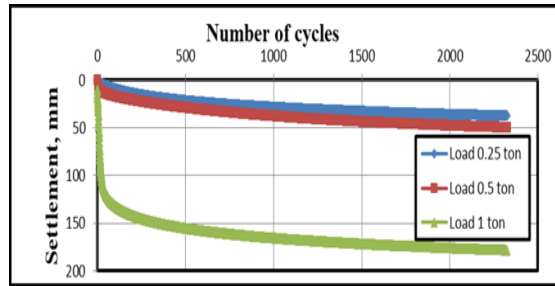


Figure 12: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 70 %, frequency 0.5 Hz and a load at 0.3H distance.

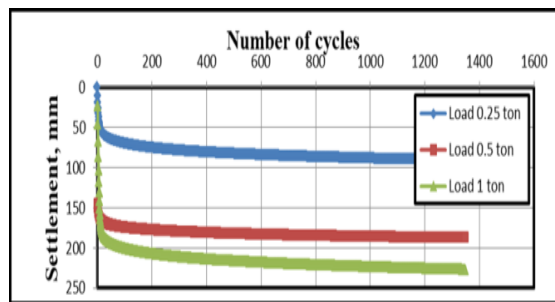


Figure 13: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 30 %, frequency 1 Hz and a load at 0.3H distance.

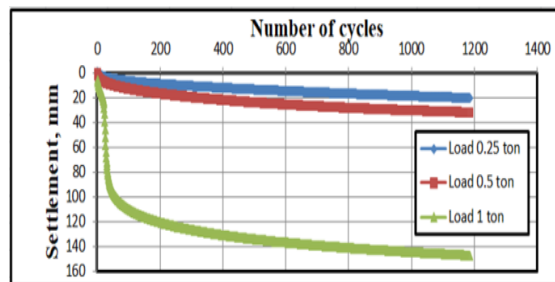


Figure 14: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 70 %, frequency 1 Hz and a load at 0.3H distance.

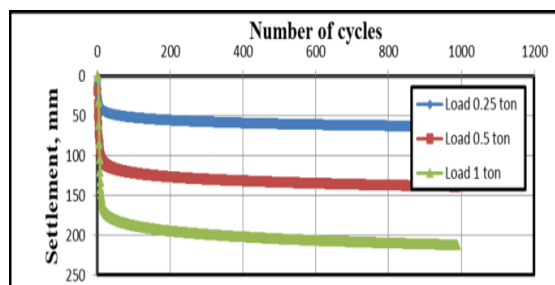


Figure 15: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 30 %, frequency 2 Hz and a load at 0.3H distance.

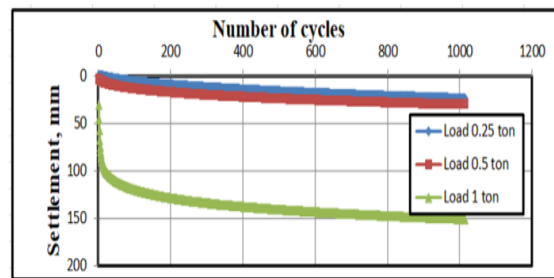


Figure 16: Settlement versus number of cycles for a retaining wall under different load amplitudes with relative density = 70 %, frequency 2 Hz and a load at 0.3H distance.

Clearly as found in these shapes, the measure of adjustment increment with incrementing the burden capacity, there is a fast increment in adjustment up to the Cycle 30-100 and later that, a steady-state is come to. There is a continuous increment to level out between 100 to 2500 cycles relying upon different parameters. These discoveries concur with those of Paute et al. (1996) [18] who presumed that “there will be a decrease in the rate of permanent deformation in granular material under repeated loading and that it is possible to derive a limit value for the accumulation of permanent strain”

Tables 2 and 3 summarize the values of maximum settlement of the backfill soil behind the wall at two relative densities; 30 and 70%, respectively. As the dynamic load amplitude increase, the lateral displacement caused by the active thrust on the wall will be increased, this will accompanied by vertical displacement (settlement) of the refill soil. As the refill soil relative density increment, the lateral active earth squeeze on the divider and hence the lateral displacement will decrease, this in turn decreases the soil settlement. Salman et al. [19] concluded that the wall movement increments as Poisson's proportion increments in worth. The conduct of the retaining wall is affected by the variety of the Poisson's proportion estimations of the foundation soil.

Table 2: Vertical settlement of the wall after 100 cycles, $D_r=30\%$ under different frequencies and different distances between the foundation and retaining wall.

Load (ton)	Vertical Settlement (mm)								
	0.5 Hz			1 Hz			2 Hz		
	0.2H	0.3H	0.4H	0.2H	0.3H	0.4H	0.2H	0.3H	0.4H
0.25	118	57	43	115	70	37	113	52	32
0.5	224	192	182	188	175	116	184	122	101
1	229	215	211	224	201	164	213	188	116

Table 2: Vertical settlement of the wall after 100 cycles, $D_r=70\%$ under different frequencies and different distances between the foundation and retaining wall.

Load (ton)	Vertical Settlement (mm)								
	0.5 Hz			1 Hz			2 Hz		
	0.2H	0.3H	0.4H	0.2H	0.3H	0.4H	0.2H	0.3H	0.4H
0.25	98	9	5	96	7	4	94	7	2
0.5	127	17	22	106	12	8	104	13	5
1	203	132	57	181	111	51	155	121	43

6. Conclusions

In view of the outcomes acquired from the model tests performed on the different variables to think about the impact of the dynamic burden on the settlement of cohesion less backfill soil behind retaining wall under dynamic load, the following conclusions could be obtained:

1. The vertical settlement is increasing with the load amplitude and decreased by increasing the distance between the foundation and retaining wall.
2. There are insignificant impacts of recurrence on tests the cumulative settlement.
3. The settlement decreased by increasing the backfill soil relative density.

Acknowledgment

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References

- [1] S. Okabe, "General theory of earth pressure," J. of the Japanese Society of Civil Engineers, Tokyo, Japan, 12, 1, 1926.
- [2] N. Mononobe, and H. Matsuo, "On the determination of earth pressure during earthquakes," Proceedings, World Eng. Conference, Vol. 9, 176 p, 1929.
- [3] H. B. Seed, and R.V. Whitman, "Design of earth retaining structures for dynamic loads," ASCE Specialty Conference, Lateral Stresses in the Ground and Design of Earth Retaining Structures, Cornell Univ., Ithaca, New York, 103-147, 1970.
- [4] S. Prakash, "Dynamic earth pressures," State of the Art Report-International Conference on Recent Advances on Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Missouri, Vol. III, 993-1020, 1981.
- [5] T. Y. Sung, "Vibrations in semi-infinite solids due to periodic surface loadings," Proc., Symp. Dynamic Testing of Soils, ASTM Special Technical Pub. No. 156, ASTM, West Conshohocken, Pa., pp.35-54, 1953.
- [6] Y. J. Al-Shakarchi, M. Y. Fattah, M. Y., and A. S. Hassan, "Non-linear dynamic finite element analysis of cantilever retaining walls", international conference on geotechnical engineering, University of Sharjah, October 3-6, 2004, Sharjah, UAE, pp. 96-104, 2004.
- [7] Y. Wang, Z. Shi, and S. Wang, "Response of bucket foundation in calcareous sand under horizontal dynamic loading," The Open Ocean Engineering Journal, Vol. 3, pp. 964-973, 2005.
- [8] F.A. Salman, M. Y. Fattah, S. M. Shirazi, and M. Mahrez, "Comparative study on earth pressure distribution behind retaining walls subjected to line loads," Scientific Research and Essays, Vol. 6 (11), pp. 2228-2244, 4 June, 2011, Available online at <http://www.academicjournals.org/SRE> ISSN 1992-2248 ©2011 Academic Journals.
- [9] G. P. Raymond, and F. E. Komos, "Repeated load testing of a model plane strain footing," Canadian Geotechnical Journal 15 (2), 190-201, 1978.
- [10] American Society of Testing and Materials ASTM, "Standard test method for specific gravity," ASTM D 854, American Society for Testing and Materials (ASTM), West Conshohocken, Pennsylvania, USA, 2010.
- [11] American Society of Testing and Materials (ASTM), "Standard test method for particle size-analysis of soils," ASTM D422-63 (2010), West Conshohocken, Pennsylvania, USA, 2010.
- [12] American Society of Testing and Materials (ASTM), "Standard test method for maximum index density and unit weight of soils using a vibratory table," ASTM D425300 (2006), West Conshohocken, Pennsylvania, USA, 2006.
- [13] A. M. Raheem, M. Y. Fattah, 2008, "Analysis of Retaining Wall Subjected to Earthquake Loading", Journal of Kirkuk University – Scientific Studies, Iraq, Vol. 3, No. 1, 2008, p.p. 1-20.
- [14] American Society of Testing and Materials (ASTM) (2006). "Standard Test Method for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density" ASTM D4254-00 (2006), West Conshohocken, Pennsylvania, USA.
- [15] American Society of Testing and Materials (ASTM), "Standard practice for classification of soils for engineering purposes (united soil classification system)," ASTM D2487 (2006), West Conshohocken, Pennsylvania, USA, 2006.
- [16] M. F. Aswad, "Behavior of improved railway ballast overlying clay using geogrid," Ph.D. thesis, University of Technology, Baghdad, Iraq, 2016.
- [17] J. E. Bowles, "*Foundation analysis and design*," 5th Edition, McGraw-Hill Companies, Inc., New York, 1996.
- [18] J. L. Paute, P. Hornych, and J. P. Benaben, "Repeated load triaxial testing of granular materials in the french network of laboratories des ponts et chaussées," Flexible Pavements, Proc., European Symposium Euroflex 1993, A. G. Correia, ed., Balkema, Rotterdam, the Netherlands, 53-64, 1996.
- [19] F. A. Salman, M. Y. Fattah, D. K. Sabre, 2011, "Long term behavior of a retaining wall resting on clayey soil," International Journal of the Physical Sciences <http://www.academicjournals.org/IJPS>, Vol. 6 (4), pp. 730-745, 18 February, 2011.