Available online at www.sciencedirect.com

ScienceDirect

Journal of Computational Design and Engineering 4 (2017) 150–157

www.elsevier.com/locate/jcde

Performance of isolated and folded footings

Mahmoud Samir El-kady[a,b], Essam Farouk Badrawi[c]

[a]Structural Engineering Department, Faculty of Engineering, Zagazig University, Egypt
[b]Civil Engineering Department, AlJouf University, Kingdom of Saudi Arabia
[c]Civil Engineering Department, University of Business and Technology, Kingdom of Saudi Arabia

Received 13 February 2016; received in revised form 6 September 2016; accepted 9 September 2016
Available online 14 September 2016

Abstract

Folded foundations have been used as an alternative to the conventional flat shallow foundations, in situations involving heavy loads or weak soils. They can be geometrically shaped in many forms especially for isolated footings. The purpose of this paper is introducing an alternative foundation shape that reduces the cost of foundations by reducing the amount of reinforcing steel by minimizing or even eliminating the tension zones in the folded isolated footings. Also, achieving lower soil stresses through changing the isolated footing shape will consequently reduce the expected settlements and the footing stresses. Experimental and numerical studies are performed on five (5) quarter scale footings of which one (1) footing of flat shape is tested as a reference sample and four (4) footings are of folded shape by folding angles of 10°, 20°, 30°, and 40° with the horizontal. Results showed that the folded isolated footings achieve economic design by decreasing the quantities of reinforcement. It also induced less soil settlements, and stresses. In addition, the tensile stresses in the reinforced concrete footing body are also less in folded isolated footings than the flat one. Results show that the folded isolated footing have a better load carrying capacity when compared with the conventional slab/flat footing of similar cross sectional area for both cases of experimental and numerical analysis.

Keywords: Folded isolated footings; Settlement; Folded angle; Tensile stress

1. Introduction

Shell foundations have attracted many researchers from the 70s worldwide. Iyer and Rao [1] conducted a series of experimental tests to investigate the bearing capacity of shell foundations and compared the results with their rectangular counterparts. Results indicated that the bearing capacity of shell foundations is higher than that for flat foundations. This difference is related to the stiffness and geometry of shell elements. Kurian and Jeyachandran [2] conducted experimental tests on various shell foundations and their rectangular counterparts to investigate the effect of footing configuration on the bearing capacity. Agarwal and Gupta [3] performed tests on conical, hyper and their flat counterpart's foundation under axial loading on sand. Results indicated that an increase in the bearing capacity of shell foundations is related to the difference in footing configuration and interface within footing and soil. Hanna and Abdel-Rahman [4] investigated the behavior of shell foundations in terms of bearing capacity and settlement. They performed their tests on conical, triangular and pyramidal shell foundations and circular, strip and square flat foundations. They noted that shell foundation performance is better than flat foundations and the failure surface in the former is deeper than the latter. Kurian and Varghese [5], Kurian and Mohan [6], and Kurian [7] studied the bearing capacity and distribution of the contact pressure of shell foundations. In this paper, experimental testing and numerical analysis are performed to investigate the ultimate load capacity, stresses, and settlement variations of folded isolated foundations on sand.

2. Experimental program

2.1. Material tested

The particle size distribution curve of sand soil used in the experiments is shown in Fig. 1. The soil is classified as well-

Peer review under responsibility of Society for Computational Design and Engineering.
http://dx.doi.org/10.1016/j.jcde.2016.09.001

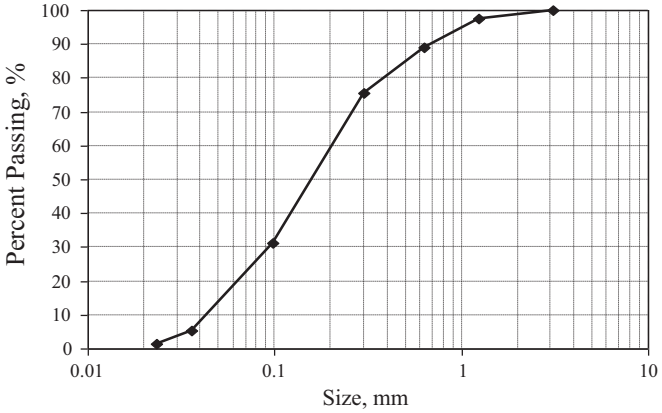

Fig. 1. Grain size distribution curve of sand.

Table 1
Parameters of sand soil.

Soil Property	Medium Dense Sand	R.C.
E_s (MN/m^2)	40.0	1.97×10^4
ϕ (deg.)	35.0	–
C (kN/m^2)	5.0	–
γ_d (kN/m^3)	17.0	24.0
υ (Poisson's ratio)	0.35	0.16

Where:
Es = elastic modulus of dry sand soil (young modulus).
ϕ = angle of friction of dry sand, degree.
C = cohesion of dry sand, (due to presence of some fines in the sand soil).
γ_d = dry unit weight, (kN/m^3);
υ = Poisson's ratio.

graded sand (SW) according to the Unified Soil Classification System (USCS). Other properties of the soil are shown in Table 1. The shear strength parameters and the maximum dry unit weight of the sand are obtained from direct shear and proctor tests. The densities of the soil in the direct shear tests are the same as in the loading tests. Compressive strength test is carried out on three cubic samples of concrete and the properties of the concrete used in the folded footing in the lab are listed in Table 1.

2.2. Experimental model tests

The structural behavior of folded and flat isolated footings is studied experimentally using five (5) quarter scale footings of which is flat in shape and tested as a reference sample and four (4) folded footings of folding angles of 10°, 20°, 30°, and 40° with the horizontal. The footing material is reinforced concrete with Modulus of Elasticity of concrete $E_c = 1.97 \times 10^4$ MN/m^2, and Poisson's ratio $\mu = 0.16$ according to Egyptian Code of practice and design for R.C. structures [8]. Isolated footings are square with dimensions (0.40 m length x 0.40 m breadth x 0.05 m height), due to quarter scale of tested footings and practical limitations. Footings will be reinforced with minimum reinforcement ratio according to

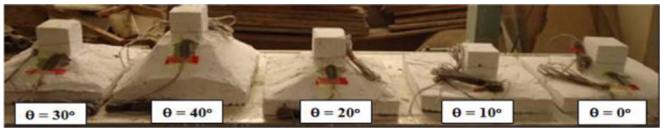

Fig. 3. Overall views of the tested isolated footings.

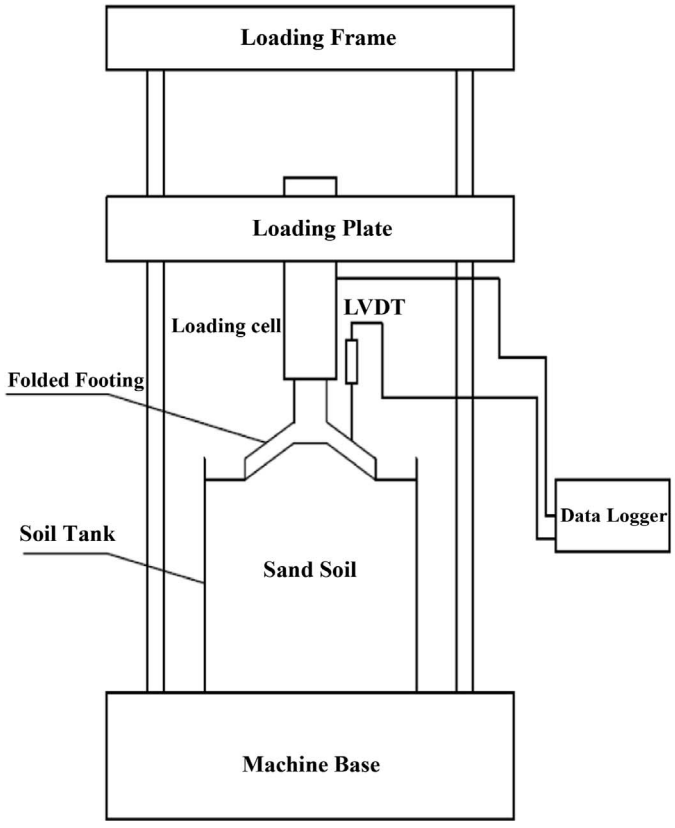

Fig. 2. Configurations of the model and testing machine.