Alexandria Engineering Journal (2016) 55, 2665–2678

HOSTED BY

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Structural design of isolated column footings

Fathi Abdrabbo, Zaki I. Mahmoud *, Mariana Ebrahim

Structural Eng. Dept., Faculty of Eng., Alexandria Univ., Egypt

Received 21 November 2015; revised 31 May 2016; accepted 9 June 2016
Available online 9 August 2016

KEYWORDS

Footing;
Codes;
Punching shear;
Shear span;
Correlation;
Contact stress

Abstract Superstructure loads are transmitted to the underlying soil strata through a suitably designed foundation. Therefore, the foundation of a structure is considered the most crucial structural element in a building. The foundation may be classified into two main categories, shallow and deep foundations. Shallow foundation comprises isolated column footings, combined footings and reinforced concrete mat. The design of isolated column footing is accomplished through the application of geotechnical and structural analysis concepts. So that, the input research into isolated column footings comes from two different disciplines, geotechnical and structural. This may be one of the main causes that attributed to the limited research input to the subject. Therefore, the structural design of isolated column footings is based on empirical rules and the calculations of bending moments (BM) and shearing forces (SF) induced in a footing are based on the rules of beam theory, which is questionable. On the other hand, punching theory was developed on relatively thin floor slab, even though the theory is implemented for the calculation of punching shear in relatively thick footings. Also experimental research on isolated column footings is scarce, due to the difficulties involved in the setup of the laboratory models and the cost of experiments. The work presented in this article deals with the correlation between failure loads predicted by different code provisions, ECP203-11, ACI318-08, BS 8110.1-1997 and EC2-2004, of isolated column footings, and the corresponding measured values.

The study showed that shear span to depth ratio of a footing and distributions of contact stress at footing–soil interface are key factors in the structural design of the footing. ECP203-11, ACI318-08, and EC2-2004 code provisions, underestimate the structural failure loads of isolated column footings, while BS 8110.1-1997 overpredicts the failure loads of isolated column footings, if punching provisions at perimeter of column are pulled out from the code.

1. Literature review

It was established that the failure mechanism of floor slab and foundation plate depends on the shear slenderness ratio (a/d) [1,2]. The most important parameters that influence punching shear are the effective or total footing depth, the flexural reinforcement ratio, and compressive strength of concrete [1]. The angle of shear cracks of foundation plate is between 50 and 60

* Corresponding author.

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.06.016
1110-0168

Nomenclature

L	length of footing	γ_s	material coefficient of steel
B	width of footing	γ_c	material coefficient of concrete
d	depth of footing	P_p	predicted failure load due to punching shear
c	width/length of column stub	A	contact area of footing
a	shear span, distance from edge of column to edge of footing	A_o	punching contact area of footing at the level of flexural steel enclosed by line at distance d from the edge of the column
f'_c	cylinder compressive strength of concrete	S_c	one way shear capacity of footing
f_{cu}	cube compressive strength of concrete	P_s	predicted failure load based on one way shear
ρ	reinforcement ratio	P_{upc}	punching shear capacity of footing
V	experimental failure load		

(1 vertical to 1.19–1.73 horizontal) which is significantly higher than the angle for slender slabs, which varies between 30 and 40 (1 vertical to 0.57–0.83) [2].

The difficulties associated with laboratory modeling and testing of isolated column footings, lead to that the experimental research input to the subject is quite scarce [3]. It is worth noting that, the majority of technical regulations do not distinguish between punching through floor slabs and punching through foundation slabs. A comparative analysis [4] indicated that foundation slab failure mechanism is different when compared to slender slabs. Theoretical explanation of the plate punching phenomenon, based on the critical shear crack for the reinforced concrete slab without and with transverse reinforcement was emphasized [5,6]. The theory is referred as critical shear crack theory (CSCT). The theory was recognized by new fib model code 2010, Draft Bulletins 55 and 56. The difference between the punching mechanism of foundation plates and floor slabs has generally been neglected in technical regulations [7]. This can be attributed to that experimental research related to foundations has so far been quite scarce, because of the complicated arrangement of such experiments. Furthermore, there is noticeable difference in the calculations of punching loads given by different codes [7]. Experimental study on 17-column footing revealed that the shear span/depth of footing, which is called shear slenderness ratio, significantly affects the bearing capacity to punching-shear [7].

The punching failure through a footing is brittle, and the use of shear reinforcement increases the punching capacity significantly, and increases the ductility and the possibility of redistribution of forces [8,14].

A review of the theoretical and experimental research work including Codes/Regulations for punching calculation of column footings leads to that cracks pattern because punching depends upon a/d ratio, in which cracks are inclined in case of column footings with greater a/d ratio, than in case of column footings with a smaller a/d ratio [9]. In Switzerland, the shear reinforcement in footing is calculated on the basis of the theory of plasticity, according to SIA 262, and the contribution of concrete to punching capacity is neglected, which leads to conservative calculation results for shear reinforcement [9].

2. Objectives of the research

The main objective of the presented work was to correlate between the predicted structural failure loads of isolated column footings, through the implementation of code provisions, and the measured failure loads documented in the literature. A trial was given to adjust some code provisions during the correlation process to obtain a better correlation results. ECP 203-11, ACI 318-08, BS 8110.1-1997 and EC2-2004 code provisions are considered for the prediction of failure loads. The structural design of isolated column footing, most often is controlled by punching shear induced in the footing. So that, the most attention is given to code provisions dealing with punching shear. No attention was paid to the behavior of footings included shear reinforcement due to the very limited experimental work on such footings.

3. Procedure of the study

The work presented was accomplished through the following steps:

1. The ECP 203-2011, ACI 318-08, BS 8110.1-1997 and EC2-2004 provisions related to the structural design of isolated column footings were used through spread sheets for the calculation of ultimate failure loads.
2. The available previous work documented in literature was reviewed, for experimental work on isolated column footings.
3. The laboratory work completed with enough data on class of concrete, footing dimensions, failure load, reinforcement and grade of steel was tabulated, as data base.
4. The predicted loads using code provisions were obtained using experimental data. One way and punching shear according to ECP 203-11, ACI 318-08, BS 8110.1-1997 provisions were implemented in the prediction. Punching shear only of EC2-2004 provision is considered in the study.

4. One way and punching shear code provisions

Code provisions consider two types of shear in the design of reinforced concrete isolated column footings subjected to axial loads, One-way shear and punching shear. The Egyptian code provisions ECP 203-2011 defined the critical section of one-way shear and punching shear at distance $d/2$ from the edge of the column as shown in Fig. 1. ACI (318-08) provisions considered critical section for one-way shear at distance d from the edge of the column and punching shear at distance $d/2$. BS (8110-1997) provisions considered the control section of one-way shear at distance d from the edge of the column, and to