DEVELOPMENT OF AN ANDROID BASED MOBILE APPLICATION FOR THE DESIGN AND DETAILING OF ISOLATED PAD FOUNDATIONS ACCORDING TO EUROCODE 2

Article *in* i-manager s Journal on Mobile Applications and Technologies · January 2019

DOI: 10.26634/jmt.6.1.15702

Yusuf Abdulazeez
Federal University of Technology Minna

Mahmud Abubakar
Federal University of Technology Minna

Hammed Aminulai
Federal University of Technology Minna

Abubakar Nade Abdullahi
Bayero University, Kano

DEVELOPMENT OF AN ANDROID BASED MOBILE APPLICATION FOR THE DESIGN AND DETAILING OF ISOLATED PAD FOUNDATIONS ACCORDING TO EUROCODE 2

By

A. YUSUF * A. ISIAKA ** M. ABUBAKAR ***

H. O. AMINULAI **** A. ABDULLAHI ***** T. A. ALAYANDE ******

*-***** Department of Civil Engineering, Federal University of Technology, Minna, Nigeria.
****** Department of Civil Engineering, Covenant University, Ota, Nigeria.

Date Received: 11/01/2019 Date Revised: 26/01/2019 Date Accepted: 03/04/2019

ABSTRACT

In a building construction project, it is the responsibility of the structural engineer to come up with a complete design of all structural elements. When this is done manually it is tasking, time consuming, and produces errors with inconsistent results. However, the design can be done using computer software, but this also comes with some downside; it is expensive and complex to use. Thus, this research developed an android based mobile application for the design of pad foundations to Eurocode 2 to put these challenges in check when designing pad footings. The mobile application designs isolated Axially loaded-only and Axially loaded with bending pad footing to Eurocode 2 accurately, with consistent results and in a timely manner. The application was tested using typical test parameters and results are compared to the manual computations. There was no significant difference in the steel sections provided for both methods. All checks that must be satisfactory in design were all checked and found to be satisfactory.

Keywords: Android, Application, Design, Eurocode, Pad Foundation.

INTRODUCTION

Design and detailing of reinforced concrete were done manually in the past. With the advent of computers, the time, energy, and other resources consumed by manual design methods using computer software and applications have been drastically reduced. Mac Donald (2014), however presented that mobile phones and related devices have been widely used in several disciplines as a computing tool. He also asserted that the introduction of smartphones in 2000, have to a large extent affected the manner in which human beings live, work, and learn.

Until recently, mobile phones were largely used to make phone calls and send text messages. Rapid advancement in information and communication technology over the past decade has led to the manufacture of mobile devices having a processing power similar to the processing power of a supercomputer of the early 1990s (Rajovic, Carpenter, Gelado, Puzovic, & Ramirez, 2013). The modern day mobile phones now possess sophisticated computing functions, but many consumers are not well informed about the abilities of their device (Yusuf, Aminulai, Abdullahi, Abubakar, & Alhaji, 2017). Martin (2015) reported that more than 23.1 million of Nigeria's population possesses a mobile phone as 2015. It was placed 17th in a global hierarchy of mobile phone consuming countries. Bearing these statistics in mind, it can be assumed that majority of construction practitioners will possess a mobile phone or related devices.

StarCounter (2015) opined that the Android Operating System (AOS) is one of the most used mobile platforms in Nigeria. As in July 2013, the Google Play store has had over one million applications published, and over 50 billion applications downloaded. Based on the successes of these apps, a pad foundation design application written for the android platform according to Eurocode 2 will be brilliant as a well-developed pad footing application will enable one to carry out complex designs and detailing easily and consistently within the shortest time possible with accurate results.

The major role of all structural members is to either resist or transmit design loads from one member to an adjoining member or directly to the foundation and eventually to underlying soil strata. The nature of foundation provided in any particular circumstance is influenced by factors such as: the magnitude and nature of applied load, the bearable stress limit of the ground, the amount of tolerable differential settlement, and the position and juxtaposition of surrounding structures (McKenzie, 2004). Foundations most commonly used include; pile, raft, strip, strap, combined, and pad foundations. All these foundations are usually supported by a stable ground or can be supported on piles. The option of choosing the foundation type for a structure is governed by the state of ground and the nature of structure (Arya, 2009). Columns, stanchions, and poles are supported by pad foundations, which can either be made of steel or reinforced concrete and can have square or rectangular cross section.

Since Nigeria's independence, there has not been a formulated unified guideline for the design of reinforced concrete structures. Over the years, design, detailing and modelling of concrete reinforced elements are done according to British standard code of practice (BS8110). This EC 2 has since been adopted by some Engineers in the United Kingdom. The standard stipulates a harmonized technical rules and procedure for the design of concrete, reinforced concrete as well as prestressed concrete structures in accordance to limit state design philosophy. Yusuf et al. (2017) developed a mobile application for the design and detailing of pad foundations to BS 8110. Since most engineers now adopt Eurocode 2 for designing, detailing, and modelling of concrete reinforced elements due to its numerous advantages, it is important to develop an android mobile application that can perform the task of designing and detailing pad foundations based on Eurocode 2.

1. Methodology

Two typical cases of footings were considered in the design. The first considered was an isolated pad foundation subjected to axial load only and that with an axial load and moment. Scheme design embedded with a flow chart outlining the procedures for the design of the footings as specified by Eurocode 2 is presented.

1.1 Main Components and Scheme Design

On initial takeoff, the application shows the central activity. The central activity enables the operator to pick the type of pad footing to design; Isolated axially loaded or isolated axially loaded with moment using radio buttons. The Isolated pad footing option further gives an option as to the loading condition of the pad (axially loaded only or axially loaded with moment). The conditions under which the typical foundation will be designed according to the option in the central activity is revealed after clicking the proceed button. Two buttons provided on options menu include the Design and the bar sizes menus. Picking the "Design" button allows the display of the foundation results in three sections; the loading, bending, and shear sections.

The operator can explore sections by clicking the necessary taskbar or by swiping right or left. The "Bar sizes" button allows the operator the option to pick the reinforcement diameter to maximize the application when carrying out the design. To establish if the design is satisfactory, the operator can click on "Design Check" button on the options menu. The operator can also click on the last activity termed "Design Details". The activity comprises of two sections: The pressure diagram and reinforcement plan. Figure 1 shows the architecture of the application.

1.2 Steps followed in Designing Concrete Reinforced Pad Foundations

The principal steps itemized by EC 2 (2004) in calculations for designing reinforced concrete pad foundations are:

- At the serviceability limit state, use the allowable bearing pressure, and extreme loading combination to estimate the plan size of the foundation.
- Use the ultimate limit state to estimate the bearing pressure as a result of the extreme loading configuration.
- Adopt an appropriate Footing Depth (h) and Effective Depth (d). Ensure that shearing force at the face of

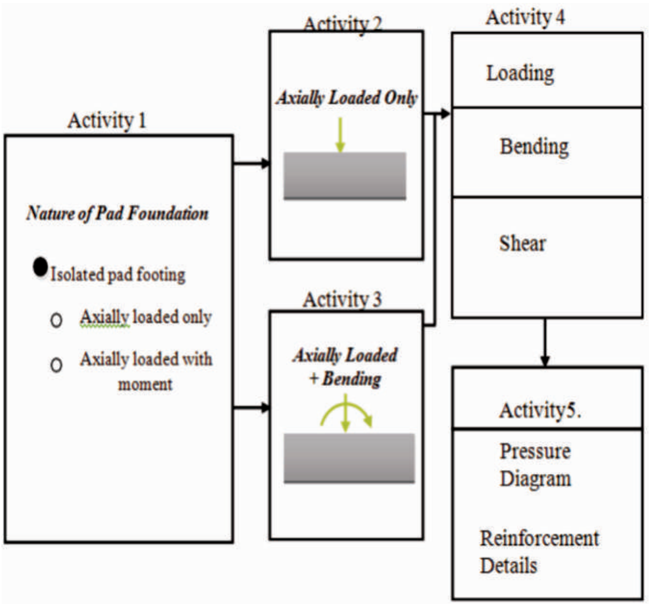


Figure 1. System Architecture of the Mobile Application

column does not exceed $0.5v_1 f_{cd}ud = 0.5v_1(f_{ck}/1.5)ud$, where u is the column perimeter and v_1 is the strength reduction factor $= 0.6(1 - f_{ck}/250)$.

- Ensure that footing will not fail in punching by ensuring that the punching shear stress does not exceed the bearing capacity of the footing thickness for adequate performance.
- Estimate the amount of reinforcement necessary to prevent bending.
- Re-check that punching failure will not occur with the provided reinforcement.
- Confirm shear force at transverse and face of footing.
- Confirm total stability of the structure and designed foundation at the ultimate limit state.
- Check that the provided reinforcement at the foundation bottom does not extend at least a full tension anchorage length beyond the critical section of bending.

The following were considered in the design:

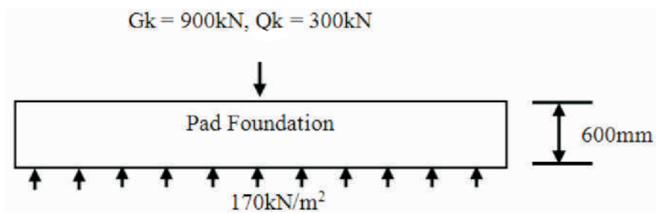
- Bending reinforcement design
- Critical shear reinforcement limit
- Punching shear limit
- Face shear limit
- Transverse shear limit
- Direct shear limit
- Spacing limit

2. Results and Discussion

After carrying out manual calculations and estimation using the mobile application, using three test cases/parameters - Case 1: Constraints used for Testing; Case 2: Axially loaded pad; Case 3: Axially loaded pad with moment:

2.1 Constraints used for Testing

Two footing categories were employed to test the reliability of the android application. Axially loaded isolated foundation and axially loaded isolated foundation with moment were used to test the correctness of the Android application and a manual calculation design was done and the results are compared. The test problems used are as given below.



Problem one:

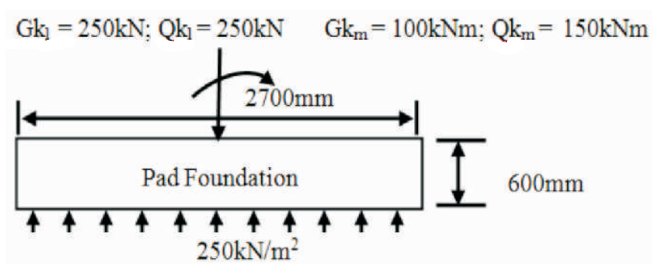
Material strength for concrete (f_{cu}) = 30 N/mm^2 Material

Strength for reinforcement (f_y) = 460 N/mm^2 Column

Dimension = 300 mm x 300 mm

Cover to reinforcement = 50 mm

Problem Two:



Material strength for concrete (f_{cu}) = 30 N/mm^2 Material

Strength for steel (f_y) = 460 N/mm^2

Foundation width = 1750 mm

Column dimension = 375 mm x 375 mm

Cover to reinforcement = 50 mm

Using the above test problems, manual design was done and compared to that obtained using the mobile application. The results obtained are tabulated in Tables 1 and 2.

2.2 Axially Loaded Pad Foundation

The design result for axially loaded pad foundation is shown in Table 1. There was no significant variation between the results obtained using the android mobile application and that obtained by manual design. There was little difference between the areas of base provided. This is due to the fact that the self weight of footing was assumed to be 100 kN while the mobile application took the self-weight as 10% of the total dead and imposed load. The area of steel provided and diameter of bars provided using both methods was 1010 mm^2/m and 16 mm, respectively. Punching shear, face shear, and transverse shear was satisfactory using both methods. The android application can therefore be used to design axially loaded pad footing in a shorter time compared to manual design method.

2.3 Axially Loaded Pad Foundation subjected to Moment

The design result for axially loaded pad foundation subjected to moment is shown in Table 2. The design ultimate load as well as the base area provided using both methods was the same. A little difference in steel area provided in the X and Y axis was observed. The Android application gave 1010 mm^2/m while the manual method provided 1050 mm^2/m as the area of steel in the X direction. This is because the android application picks the most satisfactory and economical area of steel while the designer can choose an area that is satisfactory for design but not necessarily economical. The diameter of steel provided was 16 mm for both methods. Punching shear, transverse shear, and face shear was satisfactory for both methods. Therefore, the android application can conveniently design axially loaded pad foundations subjected to moment accurately in a timely manner.

Calculated Parameters	Manual Design	Application Design
Design Axial Load	1320 kN	1320 kN
Plan Area	7.76 m^2	7.76 m^2
Base Length	3.0 m	2.8.0 m
Base Area Provided	9.0 m^2	7.84 m^2
Total Ultimate Load	1665 kN	166 5kN
Earth Pressure	185 kN/m^2	212.0 kN/m^2
Design Moment	168.58 kNm/m	165.63 kNm/m
Effective Depth	530 mm	530.0 mm
Ultimate Moment	1407.31 kNm	1407.31 kN
Steel Required	798.18 mm^2/m	822.0 mm^2/m
Min. Steel Required	983.55 mm^2/m	982.28 mm^2/m
Steel Provided	1010 mm^2/m	1010.0 mm^2/m
Bars and size	Y16	Y16
Spacing	200 mm C/C	200 C/C
Ultimate Punching Force	614.25 kN	584.53 kN
Punching Stress	0.15 N/mm^2	0.14 kN/m^2
Shear Stress	0.39 N/mm^2	0.37 N/mm^2
Maximum Face Shear	1.75 N/mm^2	2.62 N/mm^2
Permissible Face Shear	5.28 N/mm^2	5.28 N/mm^2
Transverse Shear Force (X)	479.3 kN	427.39 kN
Transverse Shear Force (Y)	479.3 kN	427.39 kN
Transverse Shear Stress (X)	0.30 N/mm^2	0.29 N/mm^2
Transverse Shear Stress (Y)	0.30 N/mm^2	0.29 N/mm^2

Table 1. Design Result for Axially Loaded Pad Foundation to EC 2

Calculated Parameters	Manual Design	Application Design
Design Axial Load	500 kN	500 kN
Design Ultimate Load	712.5 kN	712.5 kN
Eccentricity	500 mm	500 mm
Area of base Provided	4.725 mm^2	4.725 mm^2
Earth Pressure	224.3 kN/m^2	224.1 kN/m^2
Net Bearing Pressure	319.45 kN/m^2	319.34 kN/m^2
Cantilever length	1150.2 mm	1162.5 mm
Base Thickness	575 mm	581.25 mm
Effective Depth	536 mm	530.0 mm
Length in Direct Shear	1936 mm	1917.5 mm
Bearing Pressure (L)	174.0 kN/m^2	173.8 kN/m^2
Bearing Pressure (R)	240.4 kN/m^2	240.1 kN/m^2
Design Bending Moment	331.20 kNm	320.25 kNm/m
Ultimate Moment	2537.5 kNm/m	2462.79 kNm/m
Area of Steel Required	830.35 mm^2/m	908.2 mm^2/m
Minimum Steel Required	900 mm^2/m	982.28 mm^2
Steel Provided (X)	1050 mm^2	1010 mm^2
Steel Provided (Y)	1050 mm^2	1010 mm^2
Shear Force (L)	497.4 kN	501.62 kN
Shear Force (R)	305.3 kN	309.62 kN
Shear Stress	0.39 N/mm^2	0.36 kN/m^2
Max. Shear Stress	0.34 N/mm^2	0.33 N/mm^2

Table 2. Design Result for Axially Loaded Pad Foundation Subjected to Moment According to EC 2

Conclusion and Recommendations

The algorithm for the design of pad foundations resisting axial load only and that resisting axial load and moment according to Eurocode 2 was implemented using a

Graphical User Interface (GUI) designed using Android Studio after developing a flow chat for the design procedure followed. The mobile application was debugged and tested on an emulator and a real-time android-based mobile smartphone and the result was satisfactory. In conclusion, a mobile application for the design of pad foundations according to EC 2 has been successfully developed for the android platform. The Android application gives accurate and consistent results. Hence, a structural designer can design pad foundations any place, anytime provided that his Android smartphone is handy.

References

[1]. **Arya, C. (2009).** *Design of Structural Elements: Concrete, Steelwork, Masonry and Timber Designs to British Standards and Eurocodes* (3rd Ed). CRC Press, Taylor and Francis Group.

[2]. **EN, B. (2004).** *Eurocode 2: Design of concrete structures–Part 1-1: General rules and rules for buildings.* European Committee for Standardization (CEN).

[3]. **Mac Donald, B. J. (2014).** An object-oriented smartphone application for structural finite Element Analysis. *International Journal of Advanced Computer Science and Applications (IJACSA)*, 5(7), 59-65.

[4]. **Martin, E. (2015).** Nigeria Ranked 17thin Global Smartphone Usage. *IT Pulse*. Retrieved from http://itpulse.com.ng/nigeria-ranked-17th-in- global-smartphone-usage/

[5]. **McKenzie, W. M. C. (2004).** *Design of Structural Elements* (1st Ed). New York, Palmgrave Macmillan.

[6]. **Rajovic, N., Carpenter, P., Gelado, I., Puzovic, N., & Ramirez, A. (2013).** Are mobile processors ready for HPC. In *IEEE/ACM Supercomputing Conference.*

[7]. **StatCounter, (2015).** "The Free Invisible Web Tracker. Hit Counter and Web Stats. Retrieved from https://statcounter.com/

[8]. **Yusuf, A., Aminulai, H. O., Abdullahi, A., Abubakar, M., & Alhaji, B. (2017).** Development of an Android based Mobile Application for design and detailing of pad foundations to BS8110. *Epistemics in Science, Engineering and Technology*, 7, 513-521.

Appendix

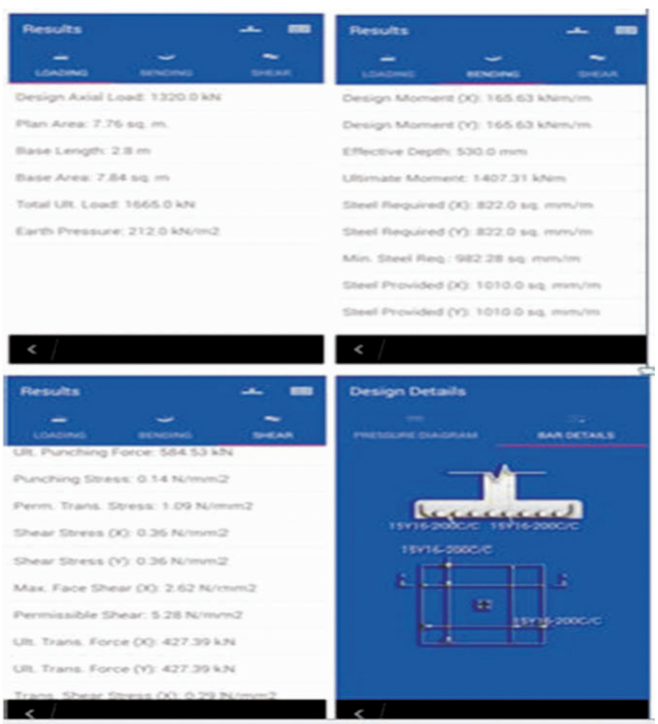


Plate 1. Result for Axially Loaded Pad Foundation using the Android Mobile Application

Plate 2. Result for Axially Loaded Pad Foundation Subjected to Moment using the Android Mobile Application

ABOUT THE AUTHORS

*-***** *Department of Civil Engineering, Federal University of Technology, Minna, Nigeria.*

****** *Department of Civil Engineering, Covenant University, Ota, Nigeria.*