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Development of an Android Based Mobile Application for Design and Detailing of Pad Foundations to BS8110

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Abstract

Many innovative computer software have been developed to perform the task of designing and detailing structural elements such as beams, columns, slabs and foundations. This design and detailing can be done using mobile devices but software developed to operate on such devices have not been fully developed. However, this research is aimed at developing an android based mobile application for the design of pad foundations to Bs8110. The mobile application developed designs isolated axially loaded-only; axially loaded with moment pad footings as well as combined pad footings. The mobile application developed was tested using three typical test parameters and results compared to the manual computations. There was no significant variation in the steel sections required and provided for the manual design and that generated by the mobile application. The steel required by manual design for the axially loaded pad footing was 835mm^2/m and that generated by the application was 837.2mm^2/m. That of the axially loaded with moment gave required steel section as 1019mm^2/m using manual design. This android based mobile application would thus give the structural engineer the leverage to design pad footings anywhere and anytime.

Keywords Android, Bs8110, mobile application, pad foundation

1. Introduction and Concept

Since the introduction of smartphones in 2000, they have had a considerable effect on lifestyles by significantly changing the way people live, work and learn. As such, Smartphones and associated tablets have become the dominant computing platform in many industries (McDonald, 2014). Martin (2015) reported that in excess of 23.1 million Nigerians owned smartphones in 2015 as it was ranked 17th position in a global ranking of countries and this figure is expected to rise to 34 million by 2018. Considering these statistics, it is reasonable to assume that the majority of engineers, scientists and analysts will own, or have access to, a smartphone or related tablet. Many smartphone users are unaware of the computing power available in their devices and or the potential of the smartphone as a platform for the design of structural elements. Recent increase in the processing power of mobile devices have made the current generation of smartphones to have the equivalent processing power to a supercomputer of the early 1990s (Rajovic et al., 2013).

The Android Operating System is one of the most used mobile platform in Nigeria according to StatCounter (2015). Being an open-source platform, it gained the highest market share in Nigeria with a whopping 41.21%, and this has encouraged a large community of developers to develop stunning applications (StatCounter, 2015). As at 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 applications, a pad design application written for the android platform will be brilliant as a well-developed pad footing application will enable one to carry out complex designs easily and consistently within the shortest time with accurate results.

The simplest form of foundation for an individual column or stanchion is a reinforced concrete pad footing. Foundations are required primarily to carry the dead and imposed loads due to the structure's floors, beams, walls, and columns, transmit and distribute the loads safely to the ground (Chanakya, 2009). The purpose of distributing the load is to avoid the safe bearing capacity of the soil being exceeded otherwise excessive settlement of the structure may occur (Chanakya, 2009). There are many types of foundations which are commonly used in buildings, namely strip, pad and raft. The foundations may bear directly on the ground or be supported on piles but the choice of foundation type will largely depend upon the ground conditions and type of structure (Chanakya, 2009).

Recently, the use of computers has gained wide spread use in the design of structures and structural elements while some engineers are still stuck to the pen and paper approach to the design of these elements. However, when these structural elements such as a foundation need to be designed on-the-go, the size of a personal computer becomes a hindrance and the required design charts and guide needed may be unavailable. Even if these charts and guides are available, it is paramount to maintain consistency throughout the design of these elements which may not be obtainable in the pen and paper approach. This research is therefore, aimed at developing an android based mobile application for the design of pad foundations to BS 8110.

In the near future, structural engineers will want to be able to carry out the design and detailing of structural elements of complex structures on-the-go. However, the size of computers still remains an issue when it has to be moved from place to place. By developing a mobile application for the design of pad bases, an engineer will be able to carry out the design easily, accurately, consistently and in a timely manner whenever his smartphone comes in handy. Thus, this paper on the development of an android based mobile application for the design of pad foundations is worthy of been executed.

2. Methodology

Two typical cases of footings were considered in the design – Case 1: Isolated pad footing (axially loaded only and axially loaded with moment); Case 2: Combined footing. Finally, system architecture outlining the procedures for the design of the footing as specified by BS 8110 is presented.

2.1 Main components and system architecture

On first launch, the application displays the main activity. The main activity gives the user the option to select the type of pad footing to design (Isolated or Combined) 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). On clicking the proceed button, an activity with the parameters required based on the options chosen in the main activity in a typical footing is displayed. Two buttons are provided on the options menu: 1. Design; 2. Bar sizes. By clicking the "Design" button in the options menu, the "Design Results" activity containing three different fragments: 1. Loading fragment; 2. Bending moment fragment; 3. Shear force fragment, is displayed. Each fragment shows the result of the design output.

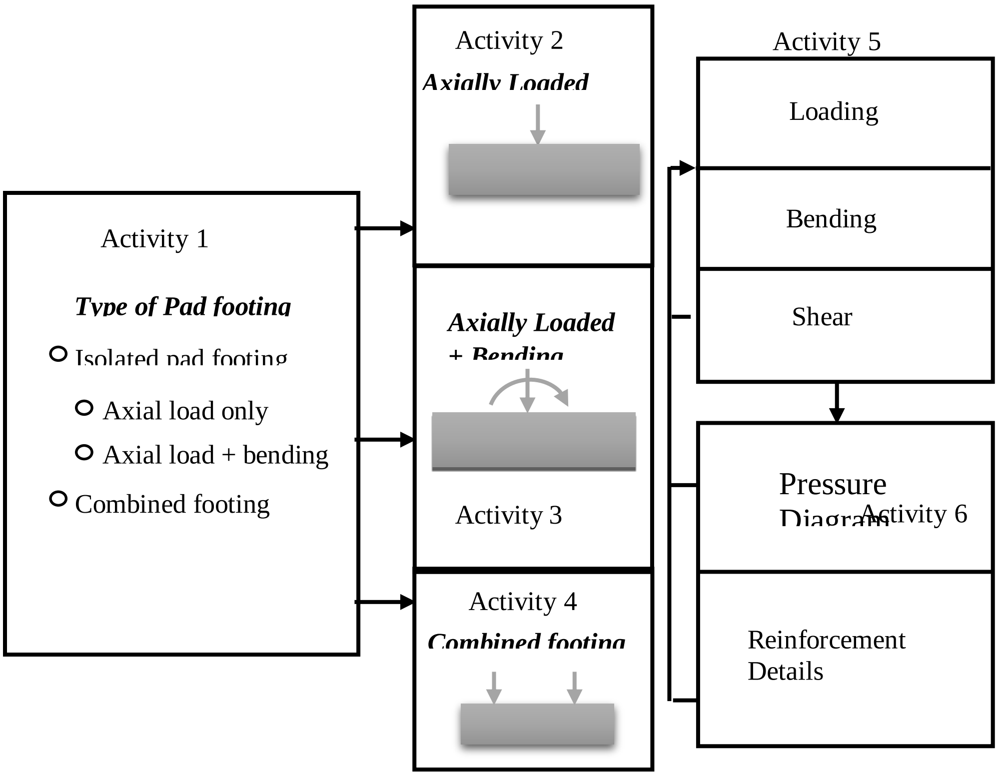


Figure 1. System Architecture of the Mobile Application

The user can navigate between fragments by swiping towards the left or right or alternatively, by tapping on the required taskbar. The "Bar sizes" button on the other hand, provides the user with the option to select the reinforcement sizes to limit the application to, during the design. To ascertain whether all the checks were passed, the user can tap on the "Design Check" button on the options menu. Next to the "Design Check" button is the "Detail" button. Tapping this button takes the user to the final activity called the "Design Details" activity containing two fragments: Pressure diagram and Reinforcement details. Figure 1 shows the architecture of the application.

3 Results and Discussion

3.1 Test parameters and values

Axially loaded isolated pad footing and axially loaded isolated pad footing with bending as well as combined footing, were used to test the accuracy of the android application and a manual calculated design was done to compare the results. The figures below show the test problems that were used.

Test Problem 1

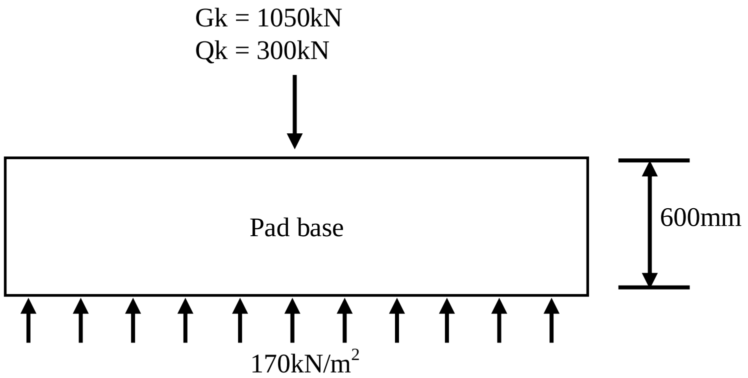
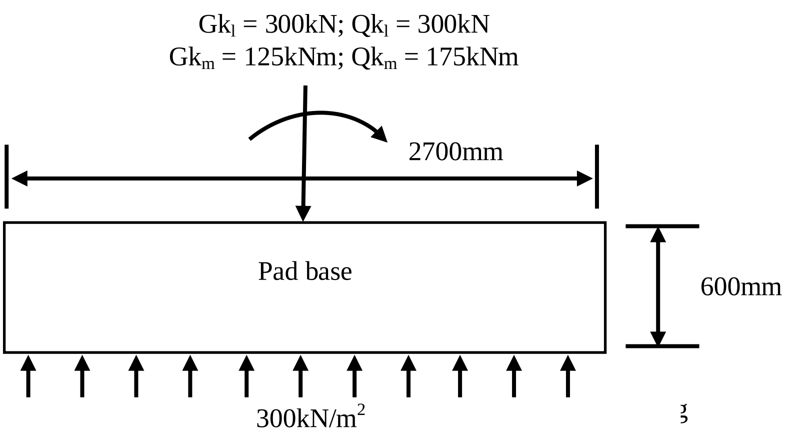


Figure 2. Axially loaded isolated pad footing

Characteristic strength of concrete (Fcu)	= 35N/mm^2
Characteristic strength of steel (f_y)	= 500N/mm^2
Column size	= 400mm x 400mm
Concrete Cover	= 50mm

Test Problem 2



Characteristic strength of concrete (f_{cu})	= 40N/mm^2
Characteristic strength of steel (f_y)	= 460N/mm^2
Base width	= 1750mm
Column size	= 375mm x 375mm
Concrete cover	= 50mm

Test Problem 3

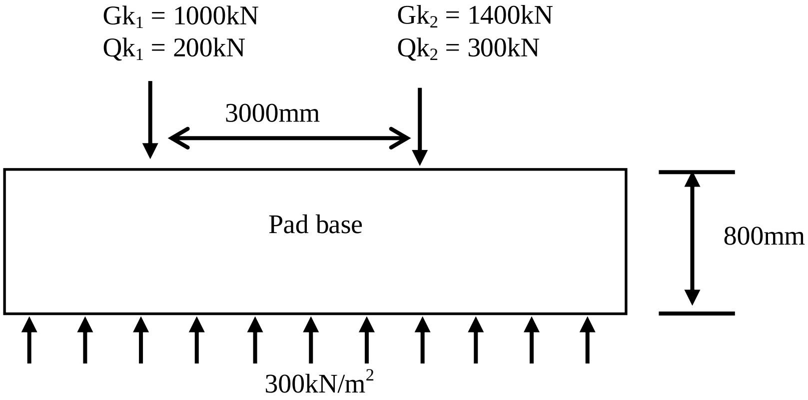


Figure 4. Axially loaded combined pad footing

Base width	=	2300mm
Characteristic strength of concrete	=	$35N/mm^2$
Characteristic strength of steel	=	$460N/mm^2$
Column size (1)	=	300 x 300mm
Column size (2)	=	400 x 400mm
Concrete cover	=	50mm

Using three test cases, manual calculation was done and compared to that obtained using the mobile application. The results obtained are tabulated in tables 1-3.

3.2 Axially loaded pad footing

The result for axially loaded pad footing gave similar results when designed using the mobile application and when designed manually. The base area provided using both methods was $9.0m^2$.

Table 1 Result of axially loaded pad footing

	Manual Design	Application Design
Design Axial Load	1485kN	1485kN
Plan Area	$8.70m^2$	$8.74m^2$
Base Length	3.0m	3.0m
Base Area Provided	$9.0m^2$	$9.0m^2$
Total Ultimate Load	1950kN	1950kN
Earth Pressure	$217kN/m^2$	$217.0kN/m^2$
Design Moment	183kNm/m	183.37kNm/m
Effective Depth	530mm	530.0mm
Ultimate Moment	1534kNm	1533.71kNm
Steel Required	$835mm^2/m$	837.2mm/m
Min. Steel Required	$780mm^2/m$	$780mm^2/m$
Steel Provided	$1010mm^2/m$	$1010mm^2/m$
Bar size	Y16	Y16
Spacing	200mm c/c	200mm c/c
Ultimate Punching Force	1094kN	1093.66kN
Punching Stress	0.26N/mm	$0.26kN/m^2$
Shear Stress	$0.41N/mm^2$	$0.38N/m^2$
Maximum Face Shear	$2.3N/mm^2$	$2.3N/mm^2$
Permissible Face Shear	$4.73N/mm^2$	$4.73N/m^2$
Transverse Shear (X)	501kN	501.27kN
Transverse Shear (Y)	501kN	501.27kN
Transverse Shear (X)	$0.32N/mm^2$	$0.32N/mm^2$
Transverse Shear (Y)	$0.32N/mm^2$	$0.32N/mm^2$

Though there was a slight difference in the plan area of base. This can be attributed to the fact that the test parameters used a specific self-weight of footing to estimate service loads but the application used 10% of the design axial load to estimate service load. The area of steel provided by both method was 1010mm^2/m and the diameter of bar chosen was 16mm at 200mm centers. This is the case because steel area provided were chosen from steel table based on the diameter of steel that gives an area of steel satisfactory to the area of steel required. The punching shear, transverse shear and face shear were satisfactory.

3.3 Axially loaded pad footing subjected to bending

The results obtained for axially loaded pad footing subjected to bending provided a base area of 4.725mm^2. The design bending moment however showed slight differences. The manual method gave ultimate design moment of 397 kNm whereas the application design gave 404.49 kNm. The area of steel provided by the manual design was 1019mm^2/m and that provided by the application was 1147mm^2/m. The difference in the self-weight used in the manual and application method may be the reason for the slight differences.

Table 2- Result of axially loaded pad footing with bending

Description	Manual Design	Application Design
	BS8110	BS8110
Design Axial Load	600kN	600kN
Total Moment	300kNm	300kN
Eccentricity	500mm	500mm
Base Area Provided	4.725mm^2	4.725mm^2
Earth Pressure	269kN/m^2	268.9kN/m^2
Net Bearing Pressure	403.5kN/m^2	403.35kN/m^2
Cantilever length	1150mm	1162.5mm
Base Thickness	575mm	581.25mm
Effective Depth	536mm	530mm
Length in Direct Shear	1936mm	1917.5mm
Bearing Pressure (L)	221.5kN/m^2	219.5kN/m^2
Bearing Pressure (R)	306.3kN/m^2	303.3kN/m^2
Design Bending Moment	397kNm	404.49kNm/m
Ultimate Moment	3137.27kNm/m	3067.43kN/m
Area of Steel Required	1019mm^2/m	1147.1mm^2
Minimum Steel Required	780mm^2/m	780mm^2/m
Steel Provided (X)	1510mm^2	1510mm^2
Steel Provided (Y)	1510.0mm^2	1510mm^2
Shear Force (L)	628.9kN	633.56kN
Shear Force (R)	381.3kN	391.09kN
Shear Stress	0.43N/mm^2	0.45N/mm^2
Max. Shear Stress	0.41N/mm^2	0.42N/mm^2
Face Shear Stress	1.21N/mm^2	1.14N/mm^2
Max. Face Shear	5.05N/mm^2	5.06N/mm^2

3.4 Combined footing

The results obtained for a combined footing provided a base area of 4.725mm^2. The design bending moment however showed slight differences. The manual method gave ultimate design moment of 397 kNm whereas the application method gave 404.49kNm. The area of steel provided by the manual method was 1019mm^2/m and that provided by the application was 1147mm^2/m. The difference in the self-weight used in the manual and application method can be the reason for the slight differences.

Table 3- Result of combined footing

	Manual Design	Application Design
	BS8110	BS8110
Total Load on Column 1	1200kN	1200kN
Total Load on Column 2	1700kN	1700kN
Total Characteristic Load	2900kN	2900kN
Total Axial Load	3150kN	3150kN
Centroid of Pad	1.24m	1.24m
Plan Area	10.5m^2	10.81m^2
Base Length Provided	4.6m	4.7m
Base Area Provided	10.58m^2	10.81m^2
Right Overhang Length	1.06m	1.11m
Left Overhang Length	0.54m	0.59m
Total Ult. Load on Col. 1	1720kN	1720kN
Total Ult. Load on Col. 2	2440kN	2440kN
Ultimate Load on Pad	4160kN	4160kN
Earth Pressure	393kN/m^2	384.83kN/m^2
Effective Depth	730mm	730mm
Distributed Earth Pressure	904kN/m	885.109kN/m
Moment on Col. 1	132kNm	154.05kNm
Moment on Col. 2	508kNm	545.27kNm
Ultimate Moment	2909.63kNm	2909.63kNm
Minimum Steel Required	1040mm^2	1040mm^2
Moment at Midspan	708kNm	646.88kNm
Steel Required (Midspan)	1094mm^2	1013.4mm^2
Steel Provided (Midspan)	1260mm^2	1130mm^2
Bending Moment at Face	366.48kNm	366.48kNm
Steel Required (Face)	517mm^2	1040mm^2
Steel Provided (Face)	1050mm^2	1130mm^2
Moment (Transverse)	260kNm	254.47kNm
Steel Required (Transverse)	950mm^2	398.6mm^2
Steel Provided (Transverse)	1050mm^2	1130mm^2
Max. Shear Stress	0.41N/mm^2	4.73N/m^2
Face Shear Stress Col. 1	1.47N/mm^2	1.96N/m^2
Face Shear Stress Col. 2	2.09N/mm^2	2.09N/m^2
Shear Force on Col. 1 (L)	488kN	522.21kN
Shear Force on Col. 1 (R)	1232kN	1197.79kN
Shear Force on Col. 2 (L)	1482kN	1457.53kN
Shear Force on Col. 2 (R)	958kN	982.47kN

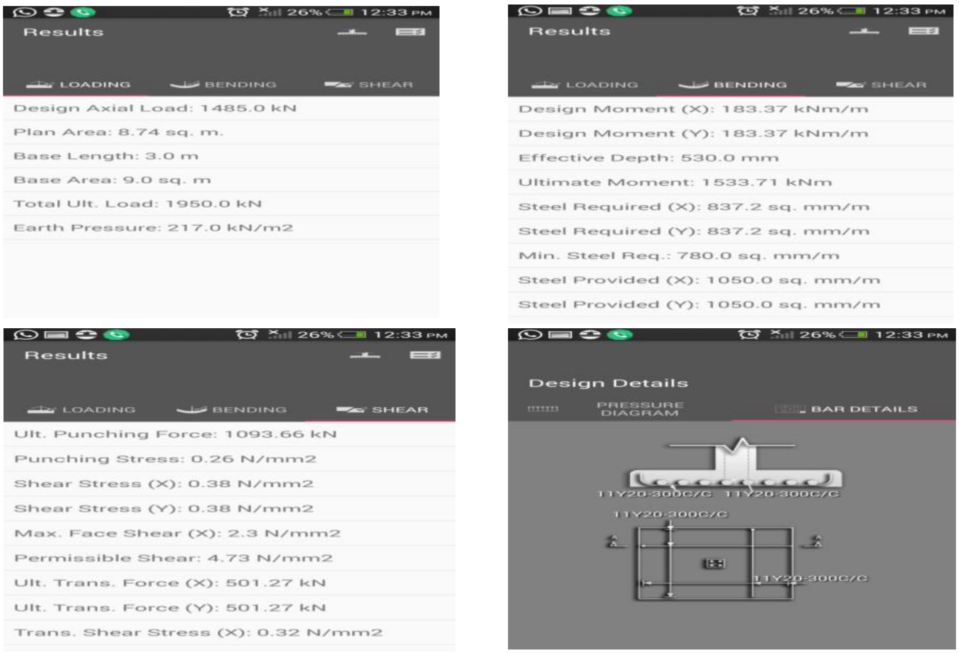


Figure 5. Result obtained for axially loaded pad footing using the pad design mobile application.

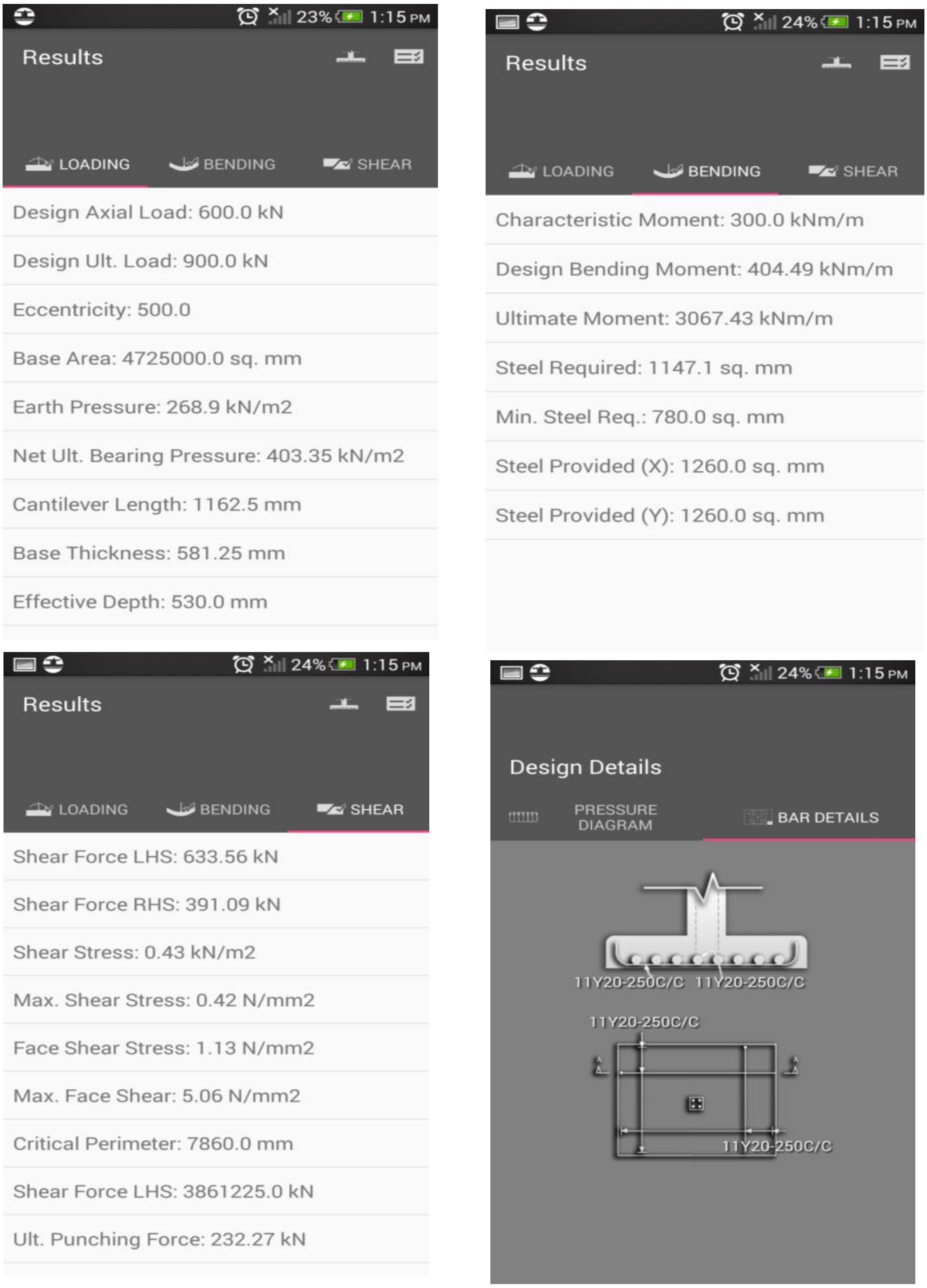


Figure 6. Result obtained for pad footing subjected to axial load and bending using the pad design mobile application

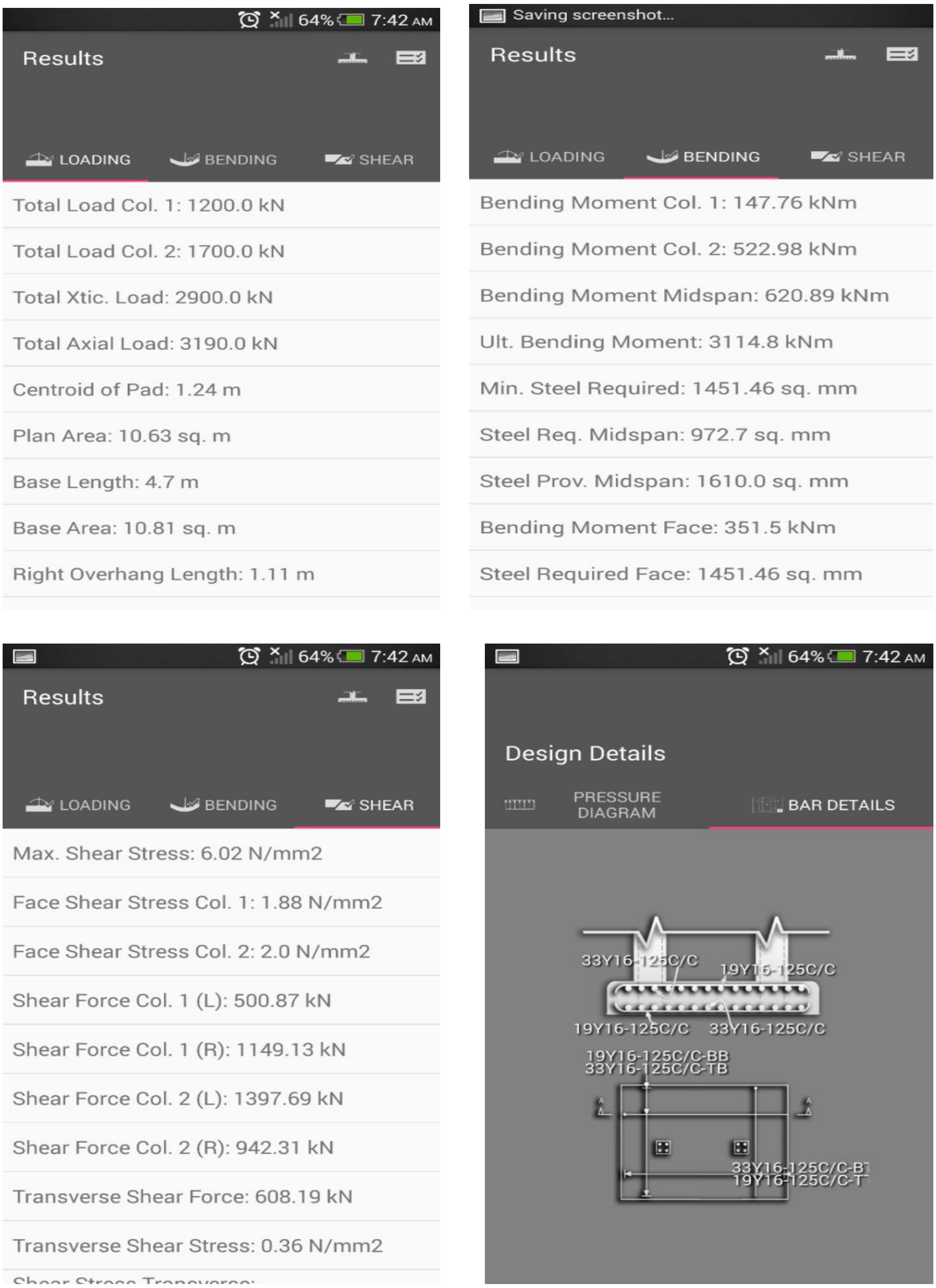


Figure 7. Result obtained combined footing using the Pad Design mobile application

4. Conclusion

The algorithm for the design of pad foundations according to BS 8110 was implemented using a Graphical User Interface (GUI) designed using Android Studio. The mobile application titled Pad Design was debugged and tested on an emulator and a real-time android-based mobile smartphone providing satisfactory results. It can therefore be concluded that the mobile application for the design of pad foundations has been successfully developed for the android platform which not only eases the design of isolated and combined pad footings to BS 8110, but also provides accurate and consistent results.

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