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RCC Isolated Footing Design and Detailing using VB.Net and AutoCAD Software in Compliance with IS 456:2000 Standards

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Abstract - *Designing a footing for a single column is a repetitive job: the base has to be sized, the soil pressure checked, shear and bending verified and the bar layout drawn again every time the load or column size changes. This paper presents a desktop application, written in VB.NET, that automates the complete design and detailing of rectangular RCC isolated footings according to IS 456:2000 and the detailing practice of SP 34:1987. The user enters the factored axial load, biaxial moments, column size, trial footing size, material grades, safe bearing capacity of soil and clear cover. The program then evaluates the upward soil pressure, effective depth, one-way and two-way shear, flexural steel, development length and bearing stress, and reports whether the section is safe. A companion routine converts the results into a DXF drawing, containing the plan, sections and bar schedule, which opens directly in AutoCAD, and a step-by-step calculation sheet can be downloaded in Word or PDF form. For a test case of 900 kN axial load with 50 kN-m and 20 kN-m moments in M20 concrete and Fe 415 steel on soil of 200 kN/m² bearing capacity, the tool returned a 2.5 m × 2.5 m × 500 mm footing with 12 mm bars at 175 mm c/c, matching hand calculations and manual drawings. The software shortens design time, reduces arithmetic errors and gives consistent, code-compliant output for practicing engineers and students.*

Key Words: Isolated footing, RCC design, IS 456:2000, VB.NET, AutoCAD, DXF drafting, SP 34, design automation

1. INTRODUCTION

Every building column ends in a foundation which transfers the column force safely into the ground. Where columns are reasonably far apart and the soil is fairly uniform, the economical choice is an isolated (single-column) footing: a reinforced concrete base that spreads the load over an area large enough to keep the soil stress below its permissible value and the settlement within limits. Because a medium-sized building may contain dozens of such footings, each with its own load, the routine of calculating and drafting consumes a large share of a designer's time.

The calculation itself follows a fixed sequence of steps in IS 456:2000 [7]. A trial plan size is selected from the column load, soil pressure is checked against the bearing capacity, depth is governed by shear, steel is obtained from the moment at the column face, and anchorage and bearing are verified. When done by hand or in loosely organised spreadsheets, the process is slow, depends heavily on the person doing it, and any change in load forces a full recalculation and a redrawn sheet. Programmed design removes this burden and makes the output uniform.

1.1 Types of isolated footing

Three shapes are in common use. A pad (flat) footing has a uniform thickness and is simplest to construct and reinforce. A stepped footing reduces the thickness in one or more steps away from the column, saving concrete when the moment and shear are small. A sloped footing tapers continuously towards the edges and uses the least concrete for heavy loads, though its formwork is more demanding. In all three, the footing slab behaves like an inverted cantilever loaded by the upward soil pressure, which is why the main reinforcement is laid near the bottom face.

1.2 Software platform

The application was built in Visual Studio with VB.NET on the .NET Framework 4.5. Windows Forms supplies the tabbed interface, and the drafting module writes the drawing in DXF, an open exchange format that AutoCAD reads without any add-on.

2. LITERATURE REVIEW

Ganesh et al. [1] built 3D models of four footing shapes (plain, sloped, stepped and round) in CATIA and loaded them vertically in ANSYS Workbench. The plain flat footing turned out stiffest, with the smallest deformation and von Mises stress, whereas the circular footing carried the largest stress and strain; stepped and sloped shapes gave better stress redistribution and material saving. Tiwari and Dhapekar [2] approached the problem from the software side. In their RCF package, column loads from a frame analysis are used to propose footing sizes against the safe bearing capacity. The program then produces a foundation

schedule and an AutoCAD script. It handles footings under compression only, so tension, moments and overlap between neighbouring footings are left to the designer. The authors state that tapered footings can work out nearly 40 % cheaper than uniform ones, but the paper gives no worked comparison to support this. Zhang et al. [3] tested three column–footing sub-assemblies with different slab steel ratios on a Winkler-type elastic bed made of rubber-wooden blocks; a lower steel ratio shifted failure from flexure to flexure followed by punching shear, and capacity dropped by 15.5 % and 34.1 % in the two lighter specimens. S Balachandar and Narendra Prasad [4] worked out footings by hand to IS 456:2000 for a 1000 kN column load and used the results to test some common design assumptions. The usual allowance of 10–15 % for self-weight did not hold across soils. As the safe bearing capacity rose from 150 to 400 kN/m^2, the self-weight share dropped from about 7.87 % to 3.12 %. Increasing the effective depth from 150 mm to 300 mm cut the required steel from roughly 1905 mm^2 to 840 mm^2. They suggested this trade-off could guide the choice between more concrete or more steel, depending on local cost. They also found that shifting the column to the footing edge raised the steel requirement to about 2.54 times (one-way eccentricity) and 4.1 times (two-way eccentricity) that of a concentric footing. El-Kady and Badrawi [5] compared flat and folded footings by tests and ABAQUS models, and found a 30°-fold to be the best, lowering settlement by as much as 57 % and bar tension by roughly 48 %. Abdrabbo et al. [6] compared predictions of several national codes with 19 reported tests, concluding that most codes were conservative, that shear span-to-depth ratio and contact stress matter most, and that punching shear usually controls the design.

These studies concentrate on analysis, experiments and code comparison. Relatively little is offered to the practicing designer in the form of a tool that carries a footing from input data to a checked section and a finished drawing in one pass. This gap motivated the present work.

3. OBJECTIVES

The work was carried out with the following aims: (i) to develop a digital tool that lets engineers design isolated footings quickly; (ii) to apply the design provisions of IS 456:2000 inside the program so that every mandatory check is performed; (iii) to build a simple Windows interface in VB.NET with provision for storing and reviewing trials; and (iv) to generate AutoCAD detailing and a printable calculation sheet automatically, reducing time, paper and manual error.

4. METHODOLOGY

4.1 Workflow

The project proceeded in four stages: (a) identifying inputs and outputs and working a footing by hand to IS 456:2000 with the drawing prepared in AutoCAD as per SP 34:1987 [10]; (b) coding the design routines and the DXF writer in VB.NET; (c) testing the program on several load cases against the manual results; and (d) refining the interface and drawing output. The sequence followed by the program is summarised in Fig -1.

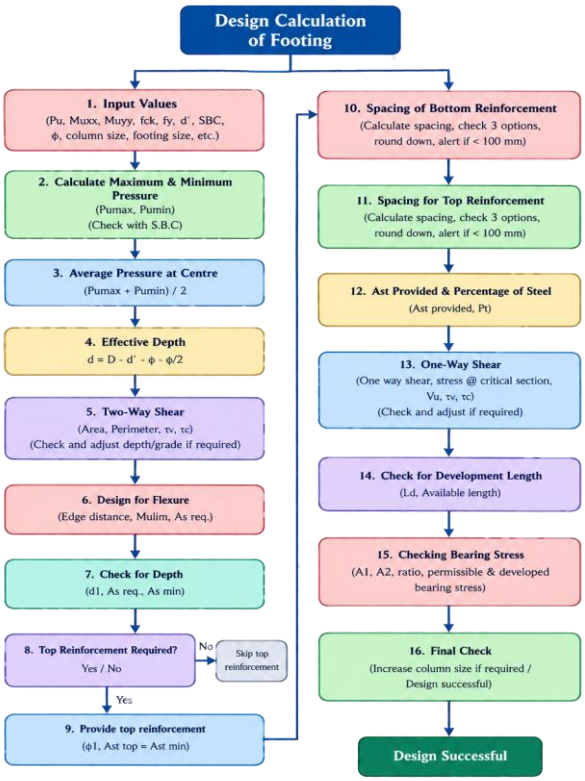


Fig -1: Design sequence followed by the program

4.2 Design basis

Input and output - Inputs are the factored axial load P_u, moments M_{uxx} and M_{uyy}, column breadth and depth, footing length L, breadth B and overall depth D, grades of concrete (f_{ck}) and steel (f_y), safe bearing capacity (SBC), clear cover and bar diameter. Outputs are the check results, reinforcement and drawing.

Soil pressure - The extreme pressures under the base are found from $p = P_u/(LB) \pm 6M_{uxx}/(BL^2) \pm 6M_{uyy}/(LB^2)$. The maximum must stay below 1.5 times the SBC because the loads are factored, and the minimum must be positive so that no tension develops between soil and footing.

Depth and flexure. The effective depth is d = D − cover − Φ − Φ/2 for the outer layer of bars. The design moment is taken at the column face, the depth required for bending is compared with the depth provided, and the steel area is obtained from the limit-state relation of IS 456 Annex G, subject to the minimum of 0.12 % of the gross section for Fe 415 steel (Cl. 26.5.2.1) [7], [8].

Shear. One-way shear is checked at a section d from the column face and compared with τ_c from Table 19 of the code. Two-way (punching) shear is checked on the perimeter at d/2 from the column face, and the nominal stress is limited to $k_s\tau_c$, where $\tau_c = 0.25\sqrt{f_{ck}}$ and $k_s = 0.5 + \beta_c \le 1$ (Cl. 31.6) [7].

Anchorage and bearing. The development length $L_d = \Phi\sigma_s/(4\tau_{bd})$ is compared with the length available beyond the column face. The bearing stress at the base of the column is limited to $0.45f_{ck}\sqrt{(A_1/A_2)}$, with the root not exceeding 2 (Cl. 34.4) [7].

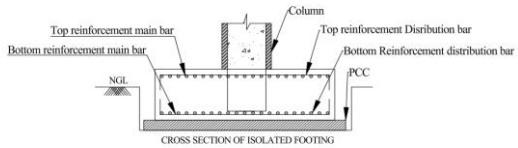


Fig -2: Typical cross-section and reinforcement arrangement of an isolated footing

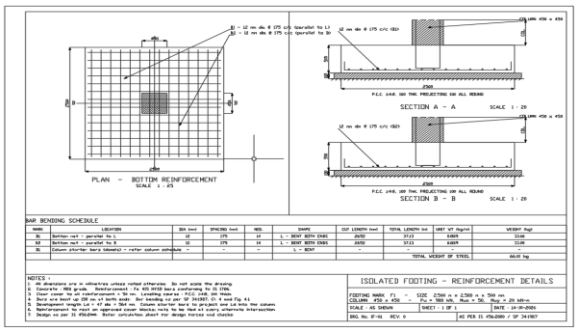


Fig -3: Manually prepared reinforcement detail to SP 34 used to check the generated drawing

4.3 Program development

The interface contains four tabs: INPUT DATA, RESULT, CALCULATION and DETAILING. Three buttons on the input page (Design, Calculation, Drawing) run the corresponding stages, and a message box reports warnings, for example when the pressure exceeds the permitted value. A drawing routine then writes the plan, two sections, the bar bending schedule, general notes and title block of the footing as a DXF file.

4.4 Testing and validation

Several combinations of load, column size, footing size and material grade were run through the software. Each result was compared with the hand calculation, and the generated drawing was compared with the manually prepared sheet (Fig -3), and the program was refined wherever a difference was found.

5. RESULTS AND DISCUSSION

5.1 User interface

The compiled program runs as a stand-alone executable. All input quantities are collected on a single page (Fig -4), with drop-down lists for material grades and bar diameter, and an optional top-reinforcement setting. Pressing the DESIGN button runs the checks and switches to the result page.

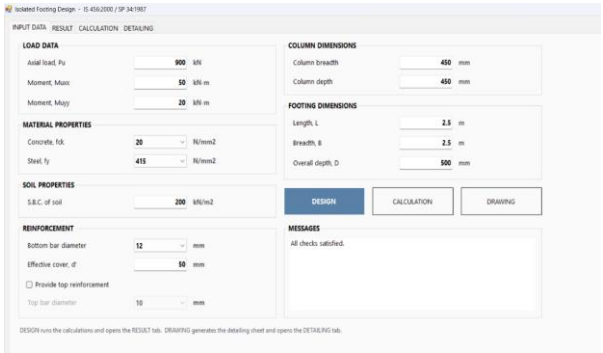


Fig -4: Input data tab of the footing design software

5.2 Worked example

A test case was chosen with the data listed in Table -1.

Table -1: Input data of the test case

Parameter	Value
Factored axial load, P_u	900 kN
Moments, M_{uxx} / M_{uyy}	50 / 20 kN-m
Column size	450 × 450 mm
Trial footing size	2.5 m × 2.5 m × 500 mm
Concrete / steel	M20 / Fe 415
Safe bearing capacity	200 kN/m^2
Cover / bar diameter	50 mm / 12 mm

The result page (Fig -5) lists every check with its status and the section provided. The maximum and minimum upward pressures are 170.88kN/m^2 and 117.12kN/m^2, both well inside the permitted 1.5 × SBC = 300kN/m^2, and

the minimum is positive. Hand verification gives a value identical to the software value.

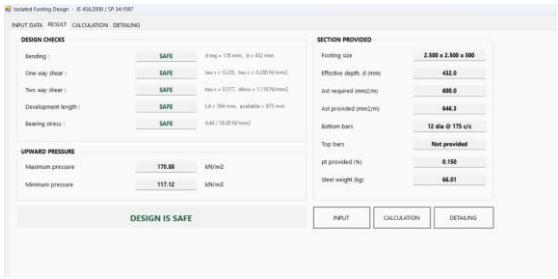


Fig -5: Result tab showing design checks and the section provided

Table -2: Summary of design checks for the test case

Check	Computed	Limit	Status
Bending: d required	176 mm	d = 432 mm	Safe
One-way shear, τ_v	0.226 N/mm^2	τ_c = 0.280	Safe
Two-way shear, τ_v	0.517 N/mm^2	1.118 N/mm^2	Safe
Development length	564 mm	975 mm	Safe
Bearing stress	4.44 N/mm^2	18.00 N/mm^2	Safe

Table -2 shows that the 432 mm effective depth is far above the 176 mm needed for flexure, and that one-way shear (0.226 against 0.280 N/mm^2) is the closest check. Steel required is 600 mm^2/m, governed by the minimum-steel clause, and 12 mm bars at 175 mm c/c supply 646.3 mm^2/m (p_t = 0.150 %). The total weight of steel for the footing is 66.01 kg. The punching perimeter is 3528 mm and the nominal shear stress of 0.517 N/mm^2 is less than half of the permissible 1.118 N/mm^2.

5.3 Calculation sheet and drawing

The CALCULATION tab prints a numbered, step-by-step working in plain text (Fig -6), which can be downloaded as a Word or PDF file, with the detailing drawing attached if required. This makes the output easy to check and submit.

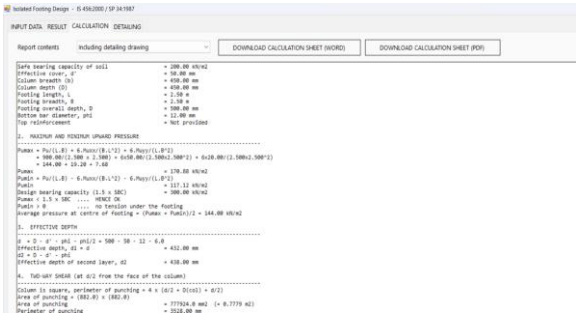


Fig -6: Calculation sheet generated by the software

On the DETAILING tab the drawing is generated on demand (Fig -7). The user can zoom to fit the sheet and download it as DXF for AutoCAD or as PDF. The drawing shows the bottom mesh in plan, the footing and column starter bars in section, the bar bending schedule and the notes.

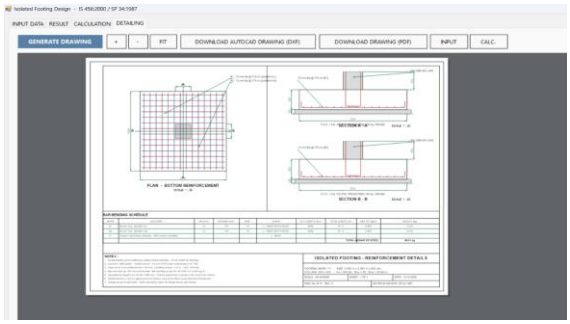


Fig -7: Detailing tab with the generated footing drawing

When the DXF file is opened in AutoCAD (Fig -8) the sheet appears as generated by the program and can be edited like any other drawing. Its layout is comparable to the manual drawing of Fig -3, but it is produced on demand without manual drafting.

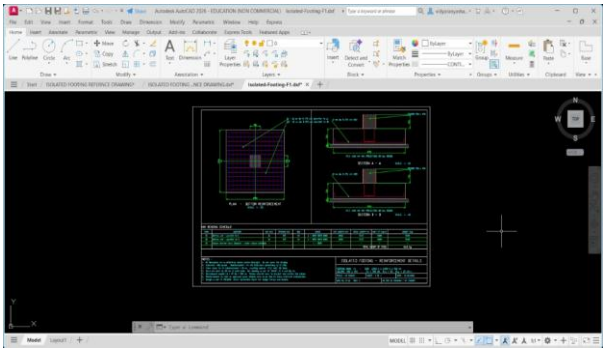


Fig -8: Footing detailing produced by the program, opened in AutoCAD

6. CONCLUSIONS

A VB.NET application has been developed which designs RCC isolated footings to IS 456:2000, carrying out the checks for soil pressure, bending, one-way and two-way shear, development length and bearing, and informing the user whether the section is safe. The results for the test case agreed with hand calculation. Linking the program to AutoCAD through DXF output removes manual drafting and produces a clear, consistently formatted drawing with a bar schedule, while the downloadable calculation sheet documents every step.

The tool can be extended to other soil and loading situations such as eccentric, inclined and seismic loads and a high-water table, to stepped and sloped shapes, and to

cost optimization of the section. Automated error detection and integration with analysis software would further widen its use in design offices.

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