Optimum Cost Design of Raft Foundation

Prashant S. Kilche, V. G. Sayagavi, N. G. Gore, P. J. Salunke

Abstract*— The mat foundation is basically one large continuous footing upon which the building rests. In this case, the total gross bearing pressure at the mat soil interface cannot exceed the allowable bearing strength of the soil. The system is used when the soil bearing capacity is low, and it may prove to be more economical when more than about one-half of the plan area of a building is required for single footings; it also provides a uniform excavation depth. The present investigation deals with the economically optimized and sensitivity design of raft foundation, in which sensitive part mainly depends upon geotechnical aspects, i.e. bearing capacity and settlement of the underlying soil. The algorithm handles the problem-specific constraints using a internal penalty function approach. The optimization procedure controls all geotechnical and structural design constraints to assure that the structure will not overturn and that stresses in the raft foundation and soil do not exceed the strength of the respective materials while reducing the overall cost of the structures. The cost of the raft foundation has been considered as the objective function and the design requirements have been imposed as side and behavioural constraints. The model is analyzed and design by using MATLAB software. Optimization is formulated is in nonlinear programming problem (NLPP) by using sequential unconstrained minimization technique (SUMT).

Index Terms*— Raft foundation, Optimum cost design.

I. Introduction

The mat foundation is designed as an inverted floor structure, but settlements must also be taken into account where the loading or soil pressure distribution depends on the layout of the columns or walls, the magnitude and type of the loads, and on the stiffness of foundation and soil.

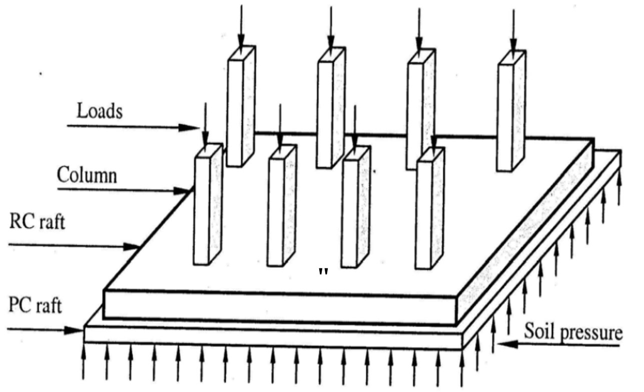


Fig.1" Typical shape of Raft foundation

II. Structural Analysis

In this project, the raft will be designed as flat plate, which has a uniform thickness and without any beams or pedestals.

The design of raft foundation may be carried out by one of two methods:

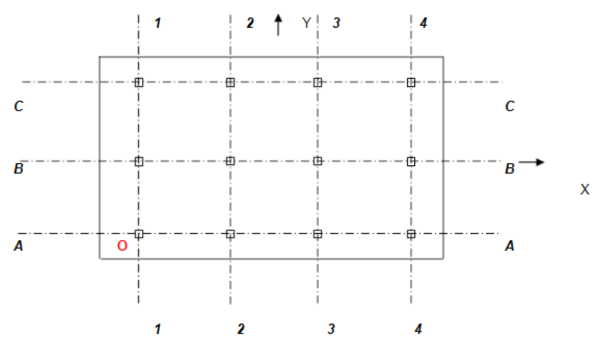
- The Conventional Rigid Method and
- The Finite Element Method

The conventional rigid method is easy to apply and the computations can be carried out using hand calculation. However, the application of the conventional method is limited to raft with relative regular arrangement of column.

In contrast, the finite element method can be used for the analysis of raft regardless of the column arrangement, loading conditions, and existence of cores and shear walls. Commercially available computer programs can be used.

This report shows the structural Optimization of the raft foundation. The raft is modeled in STAAD software. All analysis and design are based on the IS code. In this project the method used in the design called “Conventional Rigid Method” .

The cost of the raft foundation has been considered as the objective function and the design requirements have been imposed as side and behavioral constraints with storey of building, properties such as depth, area, SBC of soil material, as design variables. The problem is formulated as a simple mathematical programming problem to solve numerical examples using the Indian IS: 456-2000, IS 2950:1981 (part I), IS 8009:1976 (part I) Code requirements. The results shown minimum total cost of the raft foundation for minimum raft thickness required considering all safety criteria’s. Length of projection required is also calculated as per appropriate requirement of vertical load and the uplift pressure of soil.



"Fig.2" Typical arrangement of column

III. Design Variables And Constraints

A. Design Variables

A design alternative option, which defines a complete design of a raft foundation, includes the following decision variables:

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1. Edge distances along the X- directions.
2. Edge distances along the Y- directions.
3. Thickness of raft foundation.

B. Constraint equations

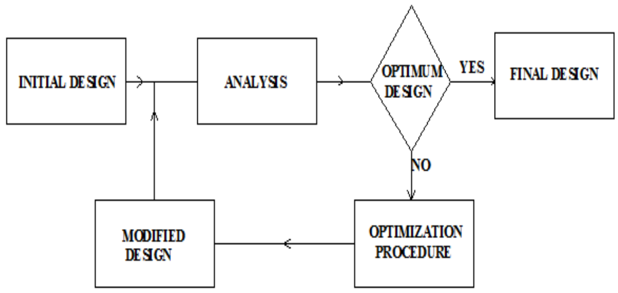
The restrictions that must be satisfied to produce an acceptable design are called design constraints.

1) Depth constrain for raft thickness
   G1=(d/X1)-1 < 1
2) Nominal Shear Stress in punching shear for corner column
   G2=(tv1/tc1)-1 < 1
3) Nominal Shear Stress in punching shear for side column
   G3=(tv2/tc1)-1 < 1
4) Uplift Constrain for maximum pressure
   G4=(maxsp/sbc)-1 < 1
5) Uplift Constrain for Corner C-4
   G5=(sg1/sbc)-1 < 1
6) Uplift Constrain for Corner A-4
   G6=(sg2/sbc)-1 < 1
7) Uplift Constrain for Corner C-1
   G7=(sg3/sbc)-1 < 1
8) Uplift Constrain for Corner A-1
   G8=(sg4/sbc)-1 < 1
9) Uplift Constrain for grid B-4
   G9=(sg5/sbc)-1 < 1
10) Uplift Constrain for grid B-1
   G10=(sg6/sbc)-1 < 1
11) Constrain for Limiting moment of resistance in Raft in strip C-C
   G11=(m1/lmr)-1 < 1
12) Constrain for Limiting moment of resistance in Raft in strip B-B
   G12=(m2/lmr)-1 < 1
13) Constrain for Limiting moment of resistance in Raft in strip A-A
   G13=(m3/lmr)-1 < 1
14) Constrain for Limiting moment of resistance in Raft in cantilever portion along Y- direction
   G14=(m4/lmr)-1 < 1
15) Constrain for Limiting moment of resistance in Raft in strip 4-4
   G15=(m5/lmr)-1 < 1
16) Constrain for Limiting moment of resistance in Raft in cantilever portion along X- direction
   G16=(m6/lmr)-1 < 1
17) Constrain settlement of raft
   G17=(TS/PSF)-1 < 1
18) Constrain Relative stiffness of raft
   G18=(RSF/K)-1 < 1

Where d= depth of raft slab, tv= nominal shear stress, tc= shear strength oc concrete, maxsp= maximum soil pressure, sg= soil pressure, lmr= limiting moment of resistance, TS= total settlement, PSF= permissible settlement for raft, K= relative stiffness factor, RSF= permissible relative stiffness factor.

IV. DESIGN OPTIMIZATION PROCESS

Definition: "The process of finding the conditions that gives the maximum or minimum value of the function".



"Fig.3" Structural optimization flow chart

Optimization is the act of obtaining the best result under given circumstances Primary aim of structural optimization is to determine the most suitable combination variables, so as to achieve satisfactory performance of the structure subjected to functional & behavioral and geometric constraints imposed with the goal of optimality being by the objective function for specified loading or environmental condition.

Three features of structural optimization problem are:
1. The design variable.
2. The constraint.
3. The objective function.

In many practical problems, the design variables cannot be chosen arbitrarily, they have no satisfy certain specified functional and other requirements. The restrictions that must be satisfied in order to produce an acceptable design are collectively called design constraints.

The optimum cost design of raft foundation formulated in is nonlinear programming problem (NLPP) in which the objective function as well as constraint equation is nonlinear function of design variables. In SUMT the constraint minimization problem is converted into unconstraint one by introducing penalty function. In the present work is of the form.

V. VARIOUS PARAMETERS AND CONDITIONS FOR ANALYSIS & DESIGN

For comparative study consideration following parameter are consider for different results.

- Fck =Characteristic strength of concrete
  = M20, M25, M30.
- Fy =Characteristic strength of steel
  = Fy415, Fy500.
- Ccost=Cost of concrete. (Including formwork and labour charges)(As per District Schedule Rate (Maharashtra-Raigad Region 2013))

  M20=7302 Rs./m3
  M25=8580 Rs./m3
  M30=8647 Rs./m3
- Scost=Cost of steel (Including labour charges) (As per District Schedule Rate (Maharashtra-Raigad Region 2013))

  Fy415=64 Rs. /Kg
  Fy500=65.8 Rs. /Kg

VI. ILLUSTRATIVE EXAMPLES

For different conditions and start from starting point and end with optimized point the result shown in graphical form as below.

(Typical format of graph shown here for Storey= G+10,

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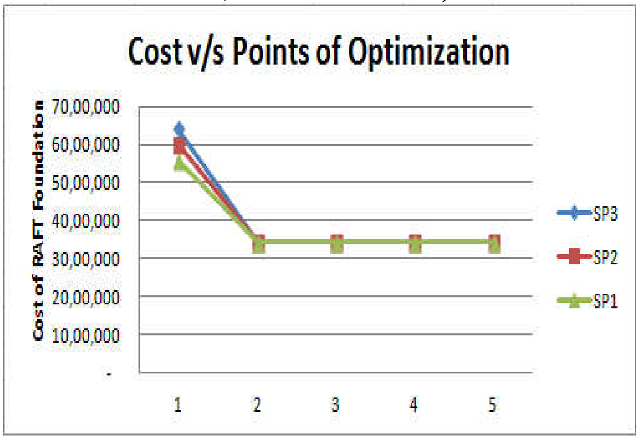
Grade of concrete=20, Grade of steel=415)



"Fig.4" Typical graph of the point of optimization

The problem of cost optimization of raft foundation has been formulated as mathematical programming problems. The resulting optimum design problems are constrained non-linear programming problems and have been solved by SUMT. Parametric study with respect to different type of storey of building, grade of steel and grade of concrete combinations of raft foundation has been carried out. The result of optimum design for raft foundation have been compared and

Conclusions drawn.

- It is possible to formulate and obtain solution for the minimum cost design for raft foundation.
- Interior penalty function method can be used for solving resulting non-linear optimization problems for raft foundation
- It is possible to obtain the global minimum for the optimization problem by starting from different starting points with the interior penalty function method.
- The minimum cost design of raft foundation is fully constrained design which is defined as the design bounded by at least as many constraints as there are the design variables in the problems.
- The optimum cost for a raft foundation is achieved in M20 grade of concrete and Fe500 grade of steel.
- The cost of raft foundation unit increased rapidly with respect grade of concrete.

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