

# Software for analysis and design of concrete sheet pile quay wall with relieving platform – RELPT6.0

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**Abstract:** The analysis and design of sheet pile structure involves problems of complex soil structure interaction. The actual performance of the sheet pile for the given site conditions is found to be very difficult to predict as it is influenced by various parameters such as, the angle of internal friction, position of the ground water table, position of anchor, density of soil, tidal variation, surcharge load, type of construction etc. Sheet pile quay wall with relieving platform is suitable wherever unsuitable soil prevents usage of conventional anchorages and large superimposed loads from super structure requiring bearing piles to support them. The analysis of sheet pile wall with relieving platform for layered soil is based on the iterative technique, which when performed manually can be extremely tedious. A software RELPT6.0 has been developed based on the deterministic classical design approach for the analysis and design of sheet pile wall with relieving platform, adhering to the Indian standard codes; using Visual basic 6.0. The software provides the embedded depth required for the stability of the sheet pile quay wall, loads on each pile and the structural design of the cross section of the quay wall, supporting piles and the platform. The software is event driven and extremely user friendly with graphical outputs, which enables the user to analyze the outputs more accurately. The outputs of the software are compared with the manually obtained results and the variation is found to be quite small. This paper presents an outline of the procedure adopted for the analysis and design of analysis and design of sheet pile quay wall with relieving platform using RELPT6.0.

**Keywords:** Sheet pile quay wall, Relieving Platform, Software, Output.

## I. INTRODUCTION

Sheet pile walls are retaining structures consisting of a series of sheet piles driven closely one beside the other to form a continuous wall. Sheet pile walls are used widely for small and large waterfront structures ranging from small pleasure boat launching facilities to large dock structures where ocean going ships can load or unload cargo. Sheet pile wall may be cantilevered, anchored or sheet pile wall with relieving platform. A sheet pile wall with relieving platform is applicable where soil is weak and/or greater height of wall is required. The soil pressure on the wall and consequently the bending moment on the sheet piling will be reduced by the provision of reinforced concrete platform behind the piling, some distance below ground level. This type of structure was developed by Christiania & Nielson (Brinch Hansen, 1946). Relieving platform may be open type or closed type. Sheet piles may be made up of steel, timber, reinforced concrete or composite type.

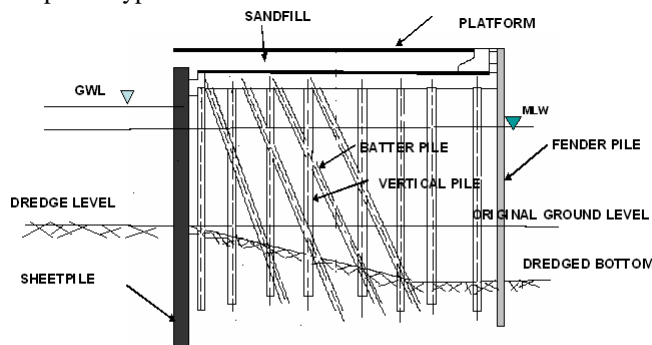


Fig. 1 Open type relieving platform

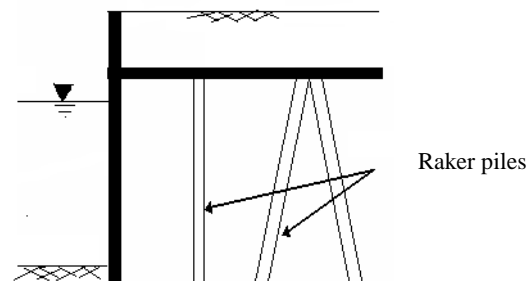


Fig. 2 Closed type relieving platform

The behaviour of these structures is based on the complex soil structure interaction, which till now is not clearly understood. The design of the structure when founded on the stratified soil is based on iterative techniques, which can be tedious when performed manually.

**II. DESIGN BASIS**

The Design of sheet pile Quay wall with relieving platform is preferably made in accordance with the procedure given in the flow chart (Fig. 3). The structural analysis of a relieving platform may be made by breaking up into two parts. Firstly the sheet piling is analysed in the ordinary manner as a beam supported by the platform and at some depth below its intersection with the outside ground surface where the equality exists between active and passive earth pressures. Finally the pile group under the platform can be analysed for the forces acting upon it including the reaction from the sheet pile.

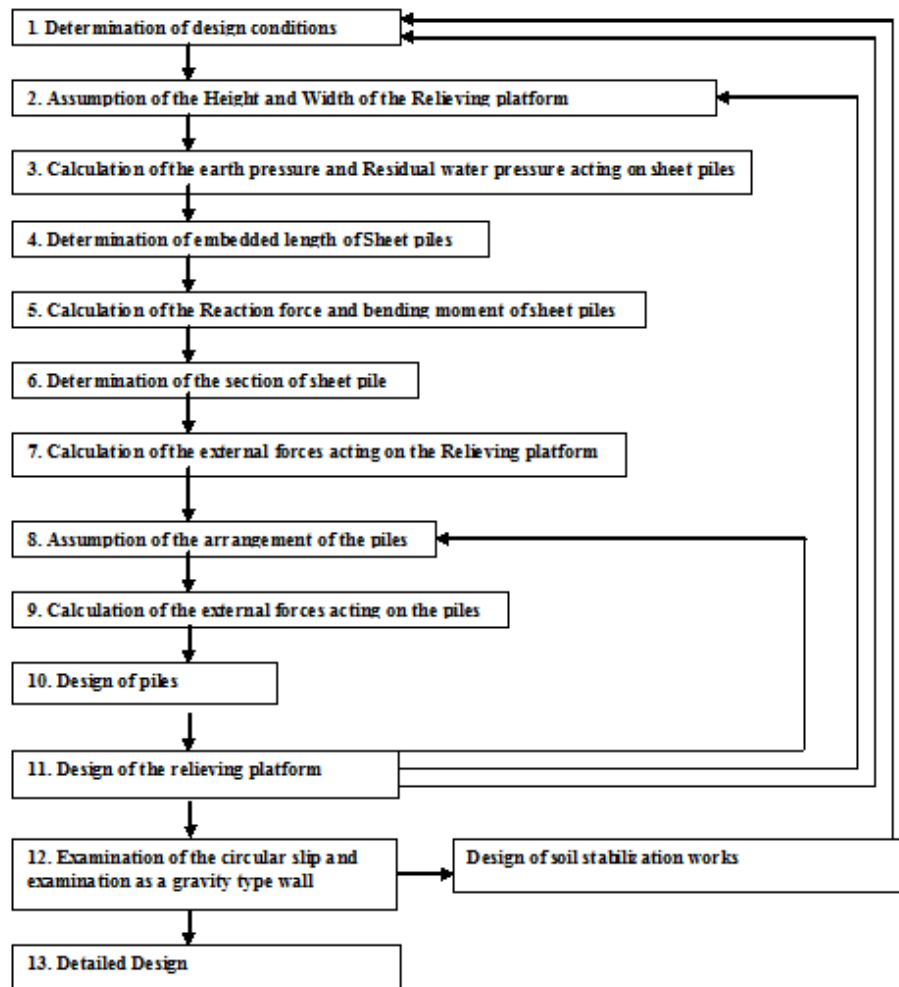


Fig. 3 Design procedure for relieving type platform

Data's required for design includes position of ground water table, mean high and low water level, and dredge level required, soil profile, slope of the ground, Characteristics of the vessel which is expected to berth like length, beam width, displaced weight, loaded draft, velocity of the vessel and various other natural phenomenon like tide, earthquake etc. Various force to be considered for design of sheet pile are dead load, live load, lateral earth pressure, differential water pressure, seepage pressure, berthing force and mooring load.

The dead load (a vertical force) is caused by the weight of the structure itself including fill and any permanent construction which may be supported by it such as transit sheds, warehouses and cargo transfer equipment. The live load includes all moving loads and temporary loads which are expected to act on the structure. Lateral earth pressures are due to the retained fill is an important force for the design of the sheet pile wall. If there is a difference in water level on either side of the pile

then, differential water pressure should be calculated. The largest of the, difference between the level of ground water table and the low water level and half the tidal lag is taken as the unbalanced water height. If the sheet pile penetrates through a pervious soil, the effect of seepage on the distribution of the unbalanced water pressure may be taken as linear variation below the dredge level.

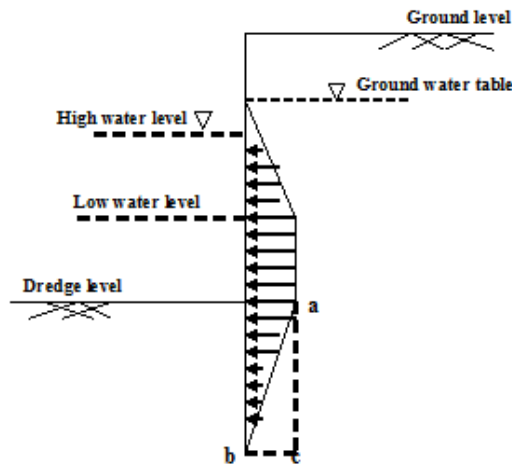


Fig.4 Differential water pressure

Berthing energy imparted by vessels on the berth is given by

$$E = (W_D V^2 / 2 g) \times C_m \times C_e \times C_s \tag{1}$$

Where  $W_D$  = Displacement tonnage of the vessel,  $V$  = Velocity of the vessel in m/s,  $g$  = acceleration due to gravity in  $m/s^2$   
 $C_m$  = Mass coefficient,  $C_e$  = eccentricity coefficient,  $C_s$  = softness coefficient = 0.9 to 0.95.

Mooring loads are the lateral loads caused by the lines when they pull the ship into or along the dock or hold it against the forces of wind or current. Mooring force is given by

$$F = C_w A_w P \tag{2}$$

Where,  $F$  = Force due to wind in Kg,  $C_w$  = Shape factor = 1.3 to 1.6,  $A_w$  = windage area in  $m^2$  and  $P$  = wind pressure in  $kg/m^2$  to be taken in accordance with IS 875: 1964. Wave pressure is calculated by Minikin's or Sainflou's method.

For the determination of the embedded length of the sheet pile wall analysis of the wall is done in the similar way as that of anchored sheet pile wall. For the analysis commonly used methods are free earth support method and fixed earth support method. Other than these there are many empirical methods such as Danish rule, Tschebotarioff method etc. Reactions at the platform support and point of zero shear can be found out from the earth pressure diagrams. Maximum bending moment corresponding to the point of zero shear can be found which is in turn used for the design of sheet pile cross section.

The height and width of the relieving platform shall be determined by examining design conditions, construction cost and the relative difficulty in the execution of the work. The width of the relieving platform shall be wide enough for the arrangement of piles which resist against the external forces acting on the relieving platform. Various external forces acting on the relieving platform includes horizontal force transmitted from sheet piles, earth pressure and residual water pressure acting on the rear of the relieving platform, deadweight of the relieving platform, the weight of soil on the relieving platform and the surcharge.

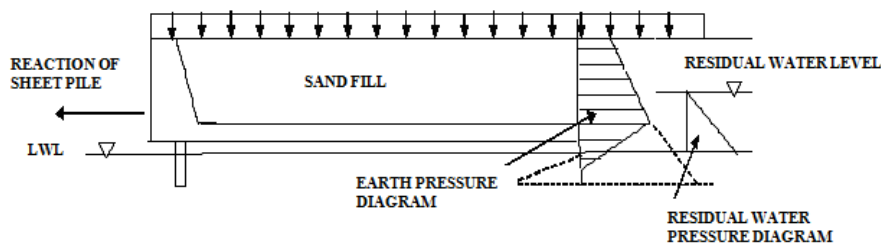


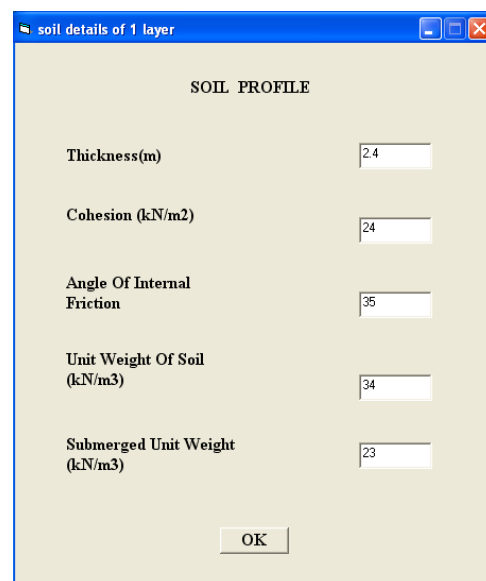
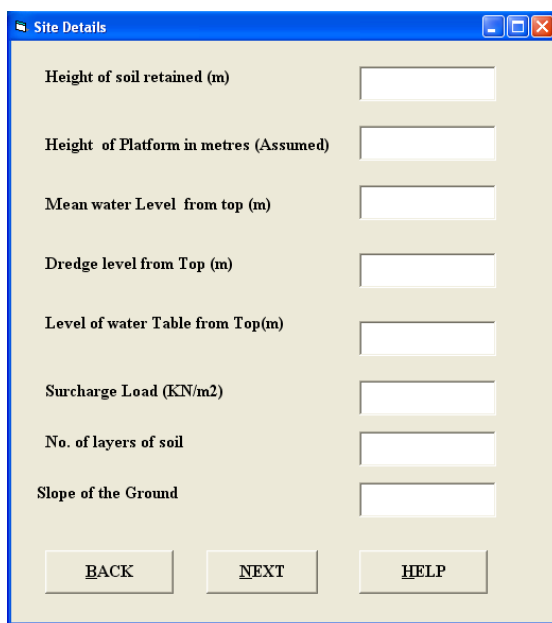
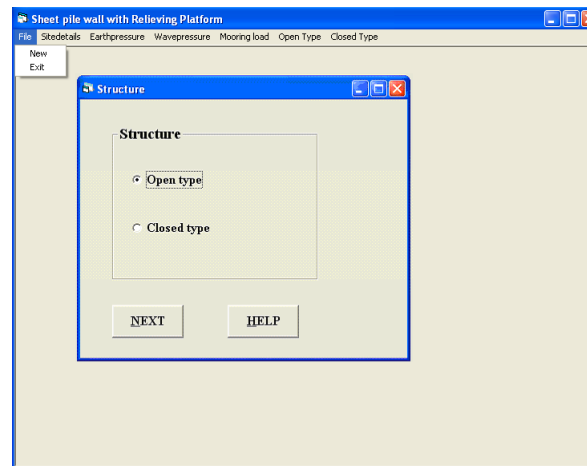
Fig. 5 Forces acting on relieving platform

The bottom slab of the relieving platform shall be designed as a continuous beam supported by pile heads, with the dead weight of the relieving platform, the weight of the soil on the relieving platform and surcharge as loads, by considering the bending moment transmitted from the upright portion and the horizontal force transmitted from the sheet piles.

For the analysis and design of piles various loads to be considered are reaction from the sheet pile, lateral earth pressure from the fill on the rear of the platform, weight of the platform, fill and the paving. The minimum spacing of the piles is recommended by different codes of practice. The British code of practice (BS 8004; 1986) suggests a minimum spacing equal to the perimeter of the pile for friction pile and twice the least width for an end bearing pile. For the design purpose, the load carried by each pile is computed by dividing the total load by the number of piles. For the design of vertical piles dead load, live loads, resolved component of the horizontal force in the vertical direction are the forces that are to be considered. But for the design of the batter pile, the resolved component of the horizontal force along the direction of the batter piles is to be considered.

### III. VALIDATION OF SOFTWARE RELPT6.0.

The validation of this software for the analysis and design of sheet pile wall with relieving platform is done by cross checking the results obtained from the software with manual calculation. First of all input parameters such as type of relieving platform, soil properties, site condition and other details are to be inputted to the software as shown in the following input windows of Figure 6.



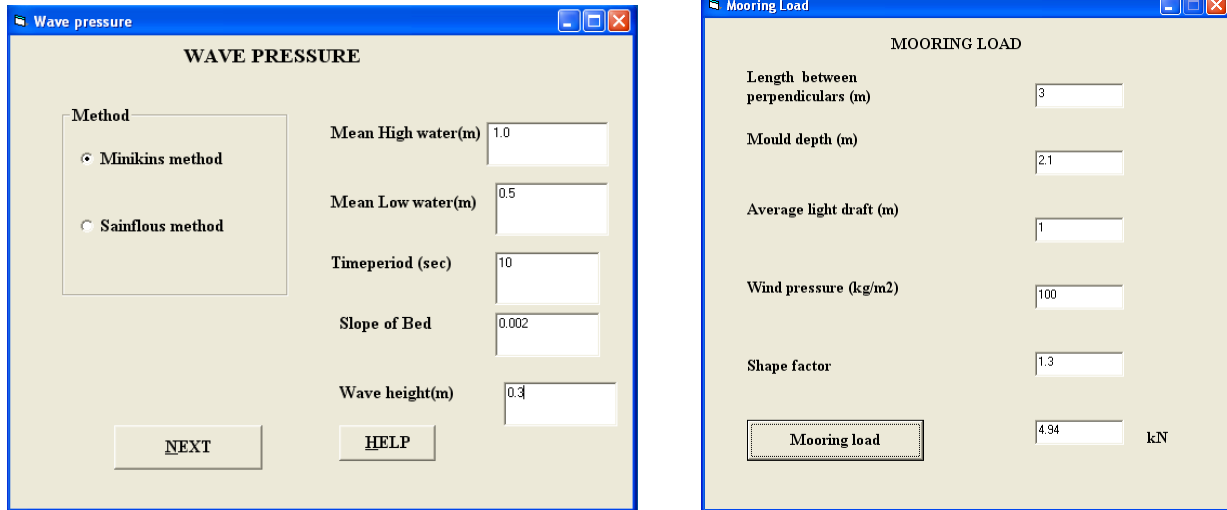


Fig.6 Various Input details

Depending on the inputs of the site and soil conditions given, the software plots the profile as shown in figure 7. It also plots the variation of lateral earth pressure with respect to the soil parameters and ground water details given and is shown in figure8.

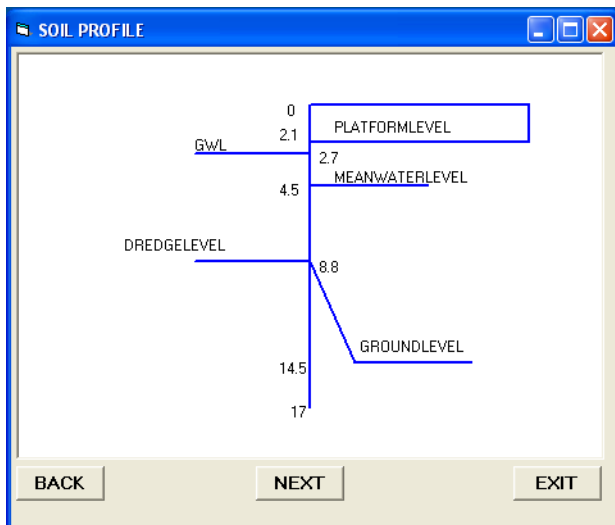


Fig.7 Soil Profile

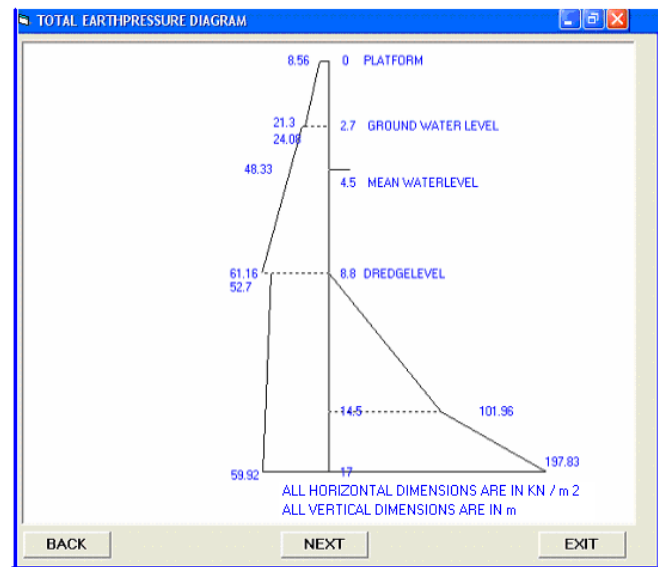


Fig.8 Total earth pressure diagram

Various results obtained by analysis using the software RELPT6.0 is shown in figure 9. It was seen that there is a negligible variance of the software from that of the manually obtained parameters. By using this output and IS standards, software calculated the design parameters and graphical outputs which is very useful for the better understanding of the results and are shown in figure 10.

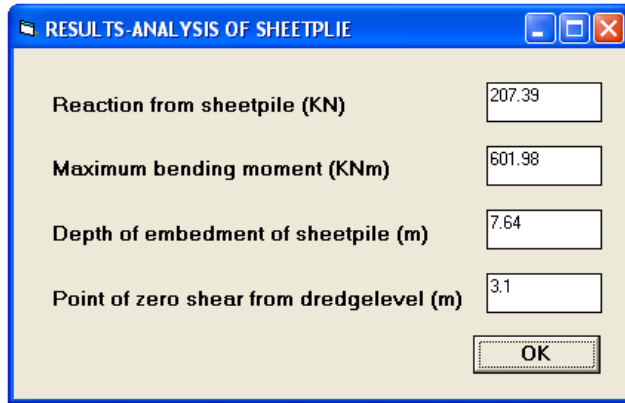


Fig.9 Results for analysis of sheet pile

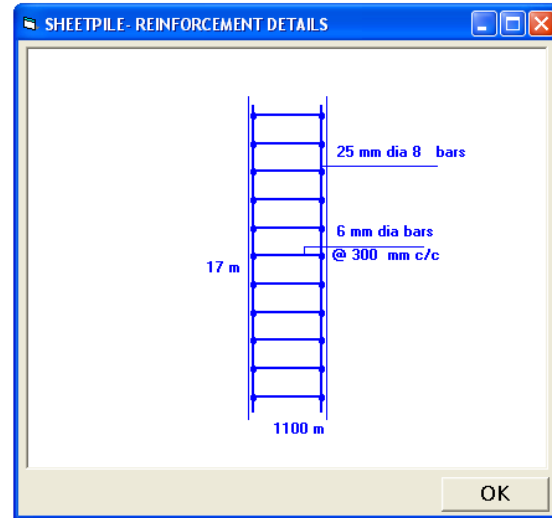


Fig.10 Reinforcement details.

Software analyses the loads acting on each pile and is shown as table below in figure 11. Output for the analysis and design of piles are shown in figure 12. Output for Platform design is shown in figure 13&14.

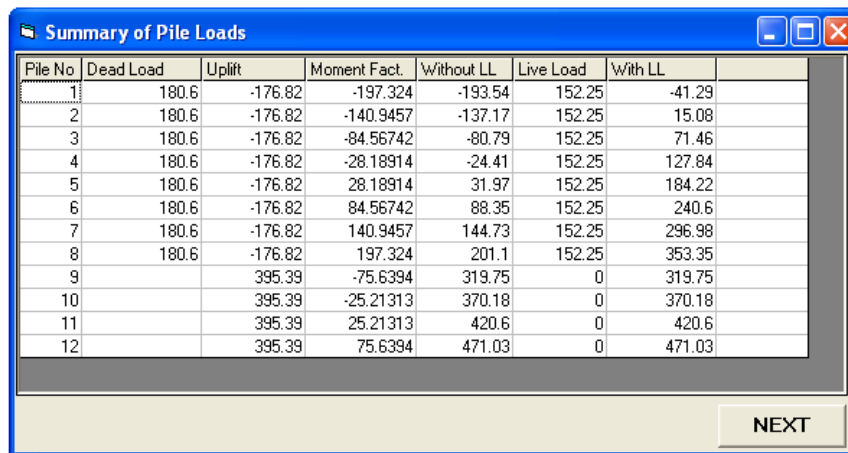


Fig.11 Summary of pile loads

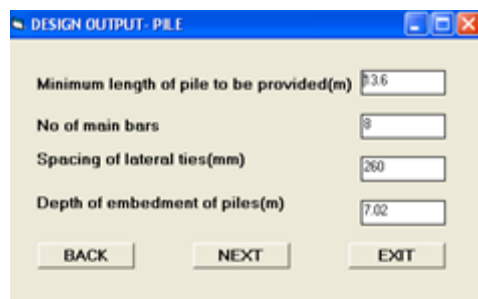


Fig.12 Output pile design

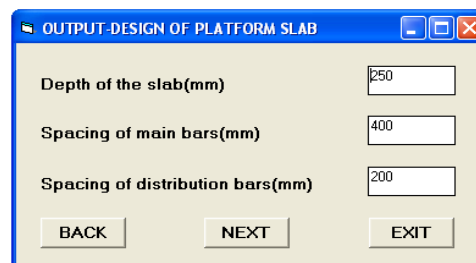


Fig.13 Output platform design

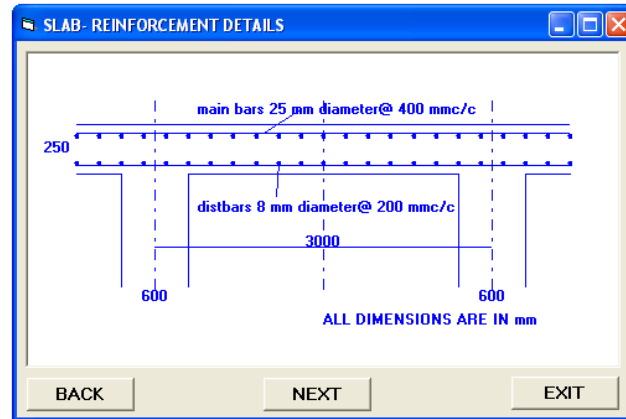


Fig.14 Reinforcement details.

The output of RELPT6.0 is compared with the desirable outputs in a wide range of conditions involving cohesive and cohesion less soil in homogeneous and stratified soil layer. It was found that, the variation of output of RELPT6.0 and the desirable values are within the limits and hence RELPT6.0 can be used confidently for field applications.

#### IV. MANUAL FOR RELPT6.0

This software (RELPT6.0) enables the analysis and design of concrete sheet pile wall with relieving platform. The application is event driven and continues in a sequential manner making it very simple to use. The graphical output of the results helps in making proper analysis of the output data.

#### V. CONCLUSIONS

- RELPT6.0 was developed based on the guidelines laid down by the Bureau of Indian standards and the proven literature available in this area.
- The software is highly user friendly and event driven. It does not require any prior hands-on experience to run the software.
- The graphical output at various stages in the design steps makes the analysis of results easier.

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### BIOGRAPHY



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