

## Design of tall bridge piers by ant colony optimization

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### ABSTRACT

This paper describes a methodology for the analysis and design of Reinforced Concrete (RC) tall bridge piers with hollow rectangular sections, which are typically used in deep valley bridge viaducts. Piers are usually considered tall when the shaft has a height of 50 m or more. Three different types of rectangular hollow tall piers have been studied for road piers of 90.00 m in height: RTRA90, RLON90 and RLT90. RTRA90 has the two side walls inclined, RLON90 has the two frontal walls inclined and RLT90 has all four walls inclined. The procedure used in the present study to solve the combinatorial problem is a variant of the ant colony optimization. RTRA90 leads to the most economical pier, both in column and foundation cost, since it is the most efficient set up for horizontal loads. Regarding the cost of the vertical column only, i.e. excluding the foundation, the cost of RTRA90 and RLON90 are similar, but the cost of the column RLT90 is higher due to its larger unit cost of interior formwork.

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### 1. Introduction

Bridge piers are crucial for the design of prestressed concrete viaducts, especially when the piers are tall, since they can make up more than 50% of the total cost of the viaduct. Fig. 1 shows a frontal and a side elevation of a hollow rectangular tall bridge pier. Tall bridge piers include a bottom foundation, which can be either a surface footing as in Fig. 1 or include deep piles; the main hollow shaft with inclined walls; and the top block end part that sustains the reactions due to the pair of pot bearings of the bridge deck. Piers are usually considered tall when the height of the shaft reaches 50 m or more. Shafts shorter than 50.00 m are generally considered as high piers. High piers do not generally require inclined walls because a constant cross-section is sufficient and facilitates the construction procedure. The construction sequence is normally done in shaft stages of approximately 5.00 m in height. The main parameters affecting their design are the pier height, the vertical and horizontal loads transferred by the bridge deck and the permissible ground stress. The behavior of a tall pier resembles that of a loaded cantilever. Rectangular hollow cross-sections are most frequently used for tall piers (see Fig. 2). These sections efficiently distribute the weight of an area and resist axial loading and the bending moments due to the eccentric traffic loading, together with the bending

due to the horizontal loads at the top of the pier and along the column. Additionally, the high radius of gyration of rectangular hollow cross-sections improves the strength against instability due to second order effects. Piers are generally calculated to sustain the actions prescribed by the loading code considered in the analysis [1] and must comply with the limit states prescribed by the concrete code under consideration [2].

An engineering model for the optimum design of high piers with constant cross-sections was developed in a previous study [3], which described the optimization model in terms of cost function, design variables, parameters and structural constraints. The optimization methodology was based on two types of algorithms: population algorithms (ant colony and genetic) and neighborhood-based algorithms (simulated annealing and threshold accepting). The ant colony algorithm appeared to be more robust and was chosen for the present study of optimum design of tall piers. While the initial publication concentrated on the development of an automatic design model for high piers, the present publication upgrades and generalizes the model so as to cater to the analysis and design of tall piers of any height and variable cross-sections. It is worth noting that high piers can be designed by a combination of simplified buckling methods, spreadsheet calculations and elemental software for cross-section computations which are available to most postgraduate specialists. On the other hand, tall piers require specialized software which is rarely available.

Most traditional procedures for structural concrete adopt initial designs based on cross-section dimensions, steel reinforcement and material grades arising from sanctioned common practice. The selection of initial solutions in the traditional approach is followed by the analysis of the structure and checking the passive reinforcement. Should the dimensions, reinforcement or material

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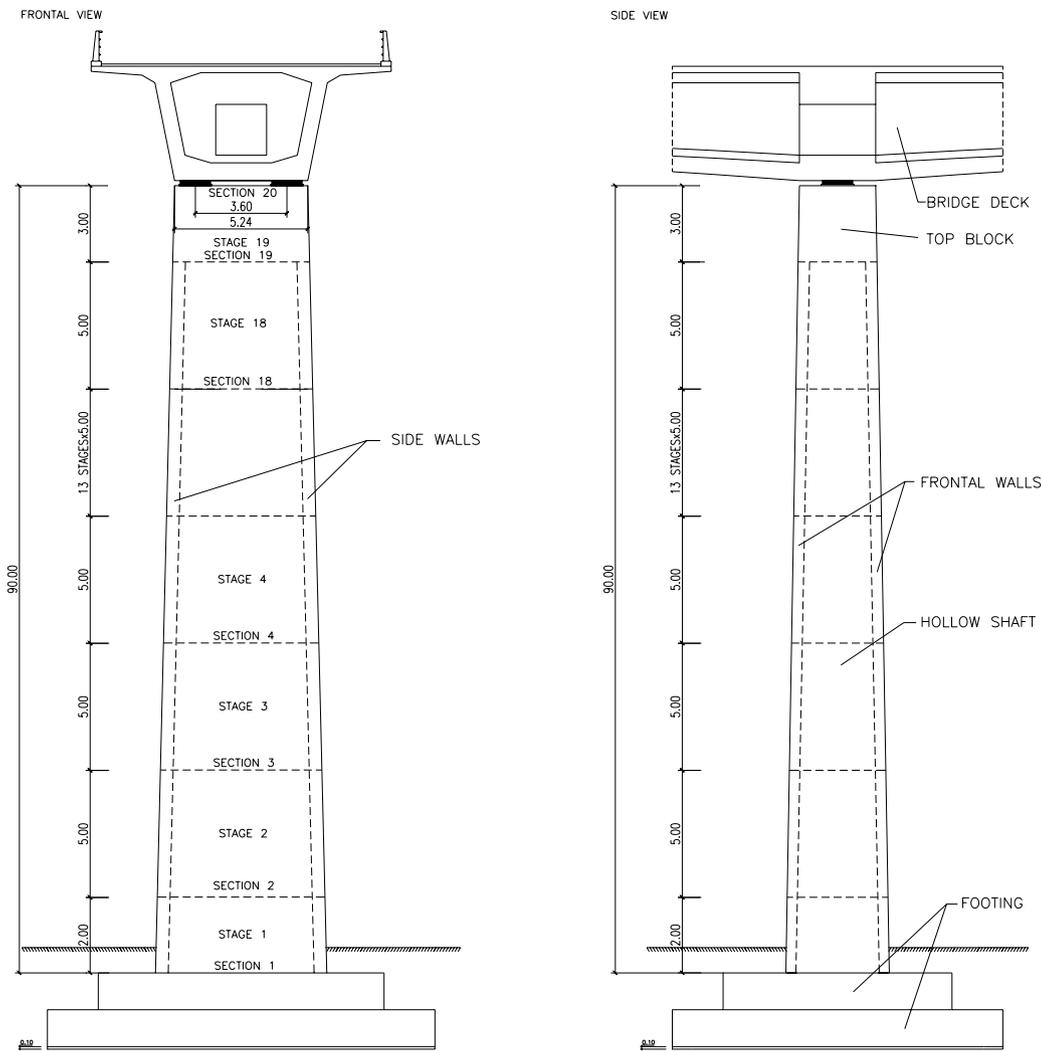


Fig. 1. Typical frontal and side elevations of a tall bridge pier.

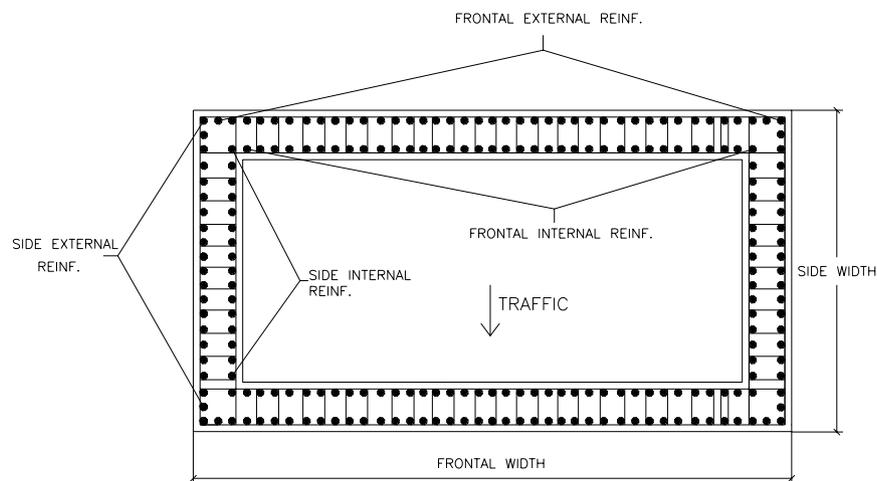


Fig. 2. Typical rectangular hollow section.

grades be insufficient, the structure is redefined on a trial-and-error basis. This process is not automatic and leads to safe designs, but the cost of the reinforced concrete (RC) pier is, consequently, highly dependent upon the experience of the structural designer. Modern artificial intelligence procedures define the structure based on the design variables, automatically calculate and validate

the structure and then redefine it by means of an optimization algorithm that controls the flow of a large number of iterations in the search for the optimum structure. This optimum structure has to satisfy the limit states prescribed by concrete codes. Heuristic optimization methods are a clear alternative to experience based methods. However, it is worth mentioning that experience is

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