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STRUCTURAL STEEL COMPONENTS OPTIMIZATION OF PARABOLIC-TROUGH SOLAR CONCENTRATORS

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ABSTRACT

Solar energy exploitation and related new technologies are assuming an increasing interest for industrialized countries where medium-to-long term production of low cost energy with reduced emissions is carried out. Indeed, several solar energy power plants have been designed and are currently under testing in many countries. An Italian law assigned to ENEA the mission to develop an R&D program of systems able to take advantage of solar energy as a heat source at high temperature. One of the most relevant objectives of this research program is the study of CSP systems operating in the field of medium temperatures, i.e. about 550°C, directed towards the development of a new and low-cost technology to concentrate the direct radiation and efficiently convert solar energy into high temperature heat [1]. The problems concerning the use of CSP technologies has been analyzed and reported by several authors [2-4]. After some years of activities, ENEA has built an experimental tool at the Research Centre of Casaccia in Rome [5], which incorporates the main proposed innovative element. The parabolic-trough solar concentrators are one of the basic elements of a solar power concentration plant. The functional thermodynamic process of a solar plant is described in [6]. The main elements of the plant are: the solar field, the storage system, the steam generator and the auxiliary systems for starting and controlling the plant. A solar parabolic-trough collectors line is divided into two parts from a central pylon supporting the hydraulic drive system [7]. Each part is composed by an equal number of identical collector elements, connected mechanically in series. To test these innovative system, a real scale demonstration plant has been foreseen by means of the "Archimede" ENEA/ENEL project at Priolo, in Sicily. The start of a demonstrative phase requires the passage to a more detailed design phase implying the respect of Italian and/or European recommendations. A proposal of classification of such structures and, consequently, of the design criteria to be followed have been presented in [8]. This has been done with

the aim of obtaining a compromise between reaching a sufficient safety level and an adequate budget. The problem of designing linear parabolic solar concentrators is given by the necessity of defining both suitable criteria for assigning an appropriate typology to the structure and a new, appropriate design guide referring to existing national recommendations as well as Eurocodes. However, the international competition introduced constraints to the concentrated solar power systems in terms of economic impact reduction and at the same time increasing their efficiency and reducing the cost of the components. The main codes of practice used in Italy and in the European community have been considered and design criteria chosen to find a compromise between requirements of rules, which should be precisely followed, and costs. Loads, actions and more generally the whole design procedure has been considered in agreement with the "Limit State Method"; a new approach is critically and carefully proposed to use this method in designing and testing the structure such as the one here analyzed. The definition of suitable specific recommendations dedicated to solar concentrators is suggested. Starting from a preliminary examination of the parabolic-trough collector structure, together with the knowledge of codes of practice used in Italy, it has been possible to classify the concentrator as an "special structure". The above classification has allowed the authors to extract all the desired recommendations useful for designing and checking solar concentrators, performing this according to adequate structural design guidelines. Then, complete structural guidelines for parabolic-trough solar concentrators have been built and designed at ENEA to produce an optimized design capable to ensure high performance and low costs but also an adequate safety level. These guidelines have been adopted by ENEA in order to perform a preliminary analysis of the structural behavior of a 100 m collectors line. This analysis has put in evidence that, compared to the 50 m collectors line designed using the allowable stresses method, the limit state design leads to a dimensional reduction for some elements, in spite of the load increment due to the doubled length. The details of this application are described with a discussion on seismic effects. It is additionally underlined that, being the selected codes of practice conceived for civil structures, available codes of practice are too stringent for a structure such as the one analyzed. Hence, suitable specific recommendations should be written for solar concentrators, allowing for optimization of the components and subsequent costs reduction.

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