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Failure analysis of subsidence in an effluent treatment plant in a thermosolar power plant

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ABSTRACT

An essential section in the normal operation of a thermosolar power plant is the management of those effluents that are generated by the diverse processes that take place in the power plant equipment. Due to environmental regulations, it is necessary to develop an effluent treatment plant before all those fluids can be discharged into the environment. In such a plant, a neutralization process is performed, by adding certain chemicals, resulting in an environmentally safe spill.

During the execution of this kind of facility in La Asturiana thermosolar power plant, all design requirements were fulfilled, without any incident.

Nevertheless, during the commissioning of the facility, several pieces of equipment showed settlements that were much higher than the established limits, which led to a temporary shutdown of the facility. In order to discover the causes, evaluate the risk of repetition in other areas of the power plant and to be able to select the best corrective action, a forensic study was carried out. This study started with several field data tests and was concluded with the development of a computer model.

The above mentioned study focused on one of the affected pieces of equipment, and on the surprising conclusions obtained with regard to the causes of the incident, which are developed in the present article.

1. Introduction and background

The energy received from the sun is one of the unlimited resources available for energy generation. Currently, this energy is mainly obtained by means of thermosolar power plants, where solar radiation heats up a heat transfer fluid (HTF). Such fluid is used to generate steam by means of a dry heat exchange in a water-steam circuit in the power plant. Once the steam is generated, a Rankine cycle is developed in order to generate energy through a generator.

The aforementioned water-steam circuit needs to use demineralized water in order to protect the internal parts of the turbine against corrosion. Demineralized water is produced in the water treatment plant, inside the power plant, usually by an osmosis procedure.

The effluent treatment plant is fed with the osmosis rejection fluid as well as with the collection of all the chemical and oily effluents of the power plant. Those effluents must be chemically treated before they can be discharged into the environment in order

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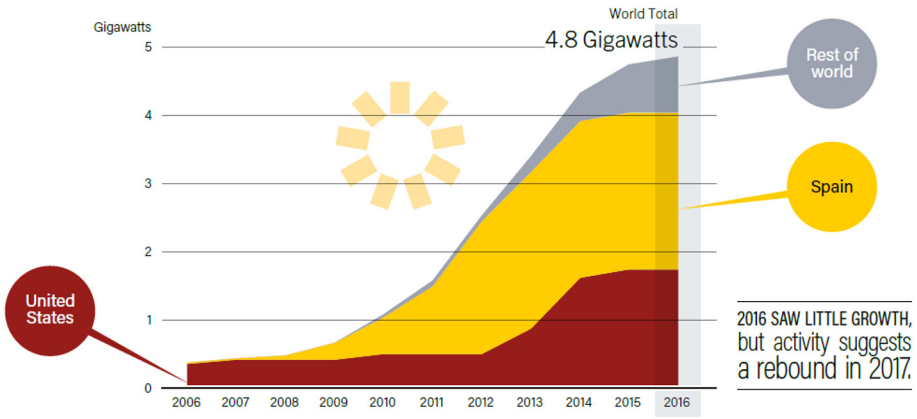

Fig. 1. Concentrating Solar Thermal Power Global Capacity, by Country and Region.
Source: REN21 – Renewables Global Status Report 2017.

to fulfill all the environmental regulation codes.

The importance of the effluent treatment plant is therefore critical to the operation of a thermosolar power plant, even more so when solar technology implementation has been rising from 2005, as it can be observed in Fig. 1:

This article corresponds to a forensic analysis of a pathology that occurred in the effluent treatment plant of La Asturiana Thermosolar Power Plant, located in Southern Spain.

Excessive settlements recorded in several equipment foundations in the power plant endangered the plant operationality. Consequently, an exhaustive analysis of the pathology causes was carried out in order to not only correct them but also to dismiss the possibility of the same problems appearing in the rest of the facility.

Settlement phenomenon in isolated foundations has been comprehensively studied for decades. Terzaghi & Peck [1] established the basis to understand the effect of the vertical pressures on soils and determine the expected settlements.

Thereon, uncountable manuals and books have been written explaining the calculation of isolated foundations and its settlements, such as Braja M. Das [2], J.Calavera [3] o R. W. Day [4]. To a large extent, those settlements are linked to the inner soil fluid drainage, where two situations can be reached: the migration of the fluids due to the overload imposed by the foundation, or its drainage following the overload (aquifer pumping, nearby excavations, etc…)

In 2009, Roy & Robinson [5] studied the interaction between long term settlements and the water depletion of the lower soil layers by continuous pumping. They concluded that the settlements occurred as a result of the weakest soil layers consolidating due to the aquifer depressurization.

Also in 2009, Herrera & Fernandez [6] analysed the sinking of the metropolitan area of Murcia (Spain), which was related to the over exploitation of ground water and the resulting consolidation of the upper soil layers.

From the numerical modelling point of view, Hui-Long Shen & Ye-Shuang Xu [7] developed a numerical model in which the ground water flow was simulated in three-dimension conditions and the soil deformation in a unidimensional way. They simulated the variation of the compressibility coefficient, the hydraulic conductivity coefficient, as well as the consolidation process, in order to obtain a model to predict those parameters in the long term.

In 2004 Rodríguez-Gutiérrez & Dario Aristizabal-Ochoa [8] proposed a new model that can be used for the calculation of settlement and vertical stresses in soils subdued to vertical load distributed in the horizontal plan in an arbitrary way. The model is able to solve the elastic or inelastic settlements and the vertical stresses in any point under the loaded area. They used two variations of the Elasticity module of the soil: 1) linear variation due to depth, 2) Module variation due to the intensity of the vertical load. Finally, the Boussinesq equations were solved for several pressure distributions under an isolated foundation.

From the foundation pathologies' point of view, Ishikawa [9] developed a study based on real scale models, in which it was possible to simulate the behaviour of isolated foundations when founded over low permeability clayey sands and subjected to several seismic events. In those studies, it can be observed that there is a long term settlement due to the large soil deformation under a liquefaction event.

In [10], Conte presents an analysis based on finite elements of the behaviour of shallow foundations in soils with strain-softening behaviour. In this study, it is stated that the generated stress under foundations is not uniform, and so, the resistant soil parameters cannot be mobilized simultaneously, diverting in a soil failure.

In 2008, Gonzalez-Nicieza presented a forensic analysis [11] regarding a group of collapsed foundations. There were serious doubts about whether there had been some effect of some excavations and works done near the already existing foundations. Although in this specific case the collapse was due to land consolidation, the methodology applied in the analysis is also applicable to the case analysed in this article.

Finally, in [12] C. Gonzalez-Nicieza presents an analysis of the causes of the failure of a buried sewer pipe. In this analysis, the ground water flow is considered as well as the fines wash and how the soil geotechnical parameters change due to these factors. All these factors seem to be related to the probable failure causes of the foundations analysed in the present article.