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Preface

Madrid, 20 de Junio de 2018,

La dinámica estructural es un campo de interés común y de importancia creciente en diversas especialidades de la ingeniería y de la ciencia. Mientras que en algunos campos como las máquinas o los vehículos de transporte ha sido siempre un elemento básico, en otros como la ingeniería civil y la arquitectura, más preocupados tradicionalmente con la estática, se ha convertido en un aspecto muy relevante.

Esta primera conferencia a nivel nacional pretende ser un foro en el que tengan cabida los trabajos de investigación, desarrollo y aplicaciones, permitiendo la discusión, difusión, contacto con otros grupos y establecimiento de colaboraciones. Se organiza con proyección internacional y europea, contando con el apoyo de la European Association for Structural Dynamics (EASD) organizadora de los congresos EURODYN, así como con el apoyo de la Sociedad Española de Métodos Numéricos (SEMNI).

La participación incluye tanto trabajos basados en métodos teóricos y computacionales como experimentales. Por otra parte abarca todos los campos de la dinámica estructural, como son la ingeniería mecánica, el transporte, ingeniería civil y arquitectura, ingeniería sísmica e ingeniería de materiales. Aunque ubicados en especialidades de ingeniería distintas todos estos campos comparten conceptos y métodos comunes de dinámica.

Esta primera conferencia pretende iniciar una serie que se desarrolle de forma periódica. Asimismo se propone constituir una Asociación Española de Dinámica Estructural que articule las actividades de colaboración y difusión, y que sirva de interlocutora con otros órganos nacionales e internacionales como la EASD.

Desde el comité organizador queremos dar la bienvenida a todos los participantes y ponernos a disposición para el desarrollo de la conferencia.

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SECTION 6: Seismic engineering, soil-structure dynamic interaction

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NUMERICAL MODEL FOR THE ANALYSIS OF THE DYNAMIC RESPONSE OF THE SORIA DAM INCLUDING SOIL—STRUCTURE INTERACTION

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Abstract. Soria arch dam and reservoir is the largest infrastructure of this type that exists in the Canary Islands both in capacity (32 hm^3) and height (120 m). It is located in the south of the Island of Gran Canaria, between the municipalities of Mogán and San Bartolomé de Tirajana.

The goal of this paper is the development of a numerical model for the analysis of the dynamic and seismic behavior of this arch dam. The model includes both the concrete arch dam and the surrounding area, so that soil-structure interaction phenomena can be taken into account as accurately as possible. On the contrary, the water-soil-structure interaction effects are not included in the model. The model is used to evaluate the magnitude of soil-structure interaction and also the influence of the accuracy of the geometrical representation of the surrounding topography on such soil-structure interaction effects.

To do so, two different numerical models are built. On the one hand, a Finite Element Model of the actual geometry of the concrete dam wall is developed and used to perform a modal analysis of the fixed-base model. Then, several three-dimensional frequency-domain Boundary Element models of both the concrete dam and the surrounding topography are built. All of these models include the actual geometry of the dam wall and different approximations of the surrounding soil, ranging from a very simplified straight prismatic canyon to an elaborate model of the actual topography. These BEM models are used not only to estimate compliant-base natural frequencies and mode shapes, but also to study the seismic response of the system when subjected to incident planar seismic waves.

The results show that the influence of the soil—structure interaction effects on the dynamic response of the system is quite significant. At the same time, the relevance of developing a very precise mesh of the surroundings is not important when studying the dynamic response of the dam itself, unless the response around the abutments is of interest.

Key words: Arch dam, Boundary Element Method, dynamic soil—structure interaction.

1 INTRODUCTION

Located in the south of the Island of Gran Canaria, between the municipalities of Mogán and San Bartolomé de Tirajana, the Soria dam is a concrete double-curvature arch dam. The structure was constructed from 1962 to 1972. It is 120 meters in height (above foundation) and with a thickness of the crown cantilever decreasing from 17,30 m at the base to 3 m at the crest. It is provided with 5 galleries inside its body [1]. Some pictures of Soria dam are shown in Fig. 1.

Fig. 1 : Soria arch dam (Gran Canaria).

The present study aims at building a three-dimensional numerical model for the analysis of the dynamic and seismic behavior of the Soria arch dam, that can later be used for monitoring the structural health of this infrastructure. In order to do so, the influence of the soil-structure interaction effects, and of the accuracy of the geometrical representation of the surrounding topography, will need to be assessed.

2 METHODOLOGY

Firstly, a geometrical model was developed consisting of two parts: the dam wall and the canyon. The geometry of the dam wall was constructed according to the information gathered from a specific study made in 1991 [2]; on the other hand, a geometrical representation of the actual canyon and surroundings was obtained from topographic information available in the databases of Gobierno de Canarias [3].

Secondly, a modal analysis was carried out. For that, a 3D finite element model of the dam wall was developed to obtain the mode shapes of vibration of the fixed-base model. The finite element mesh corresponding to the geometry of the dam wall was constructed by means of 4250 tetrahedral 3D elements and 7805 nodes (Fig. 2). For the Finite Element Analysis, Code_Aster was used, which is a Finite Element Analysis software engine [4].

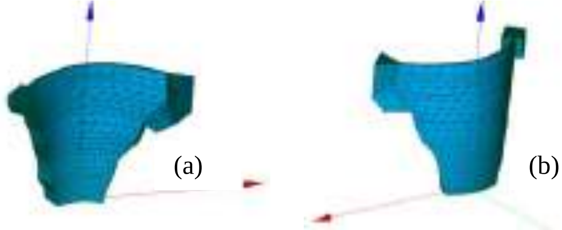

Fig. 2: 3D mesh used for the FEM analysis. (a) downstream side view (b) upstream side view.

Thirdly, harmonic analyses of the system, considering both fixed- and compliant-base configurations, were carried out using the multidomain Boundary Element Method code in the frequency domain described in Maeso et al. [5]. Wall and surrounding ground are modelled as coupled homogeneous viscoelastic media. In this case, the Boundary Element Method allows to take intrinsically into account the unbounded character of the soil medium, without the need of absorbing boundaries or any other mathematical artifact. On the contrary, the free-field mesh is truncated at a distance such that only the scattered wave fields are sufficiently damped. Nine-node quadrilateral elements and six-node triangular boundary elements are used to mesh the boundaries.

Fig. 3 shows the boundary element mesh used for the fixed-base model. At the same time, the influence of soil-structure interaction and of the accuracy of the geometrical representation of the surrounding topography on such soil-structure interaction effects needs to be evaluated. In order to do so, three of the BE discretizations are used. Figures 4, 5 and 6 show the actual geometry of the dam wall and different approximations of the surrounding soil, from a straight prismatic canyon with two different amounts of free-surface (Fig. 4 and 5, for free-surface extensions equal to two or three times the height of the dam wall) to a model of the actual topography (Fig. 6).

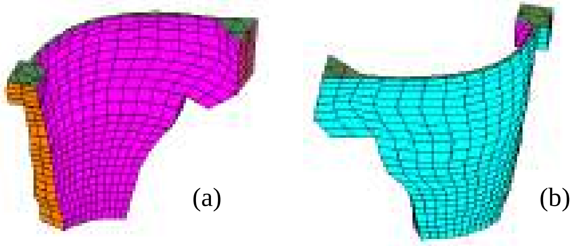

Fig. 3: 3D mesh used for the BEM analysis of the dam wall. (a) downstream side view (b) upstream side view.

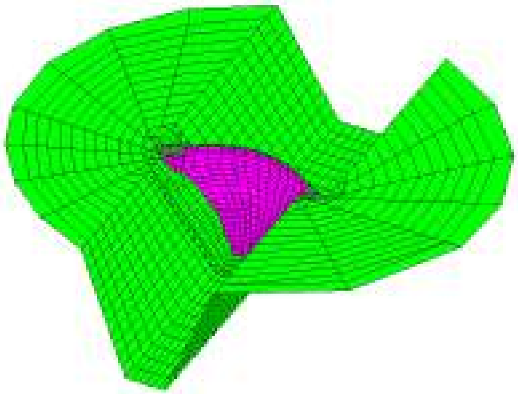

Fig. 4: BE model, prismatic canyon. Extension of the free-field discretization: 240 m

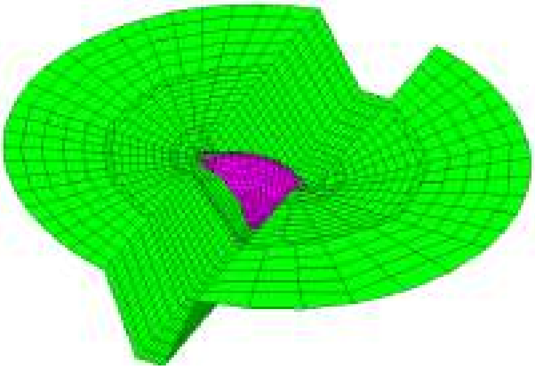

Fig. 5: BE model, prismatic canyon. Extension of the free-field discretization: 360 m

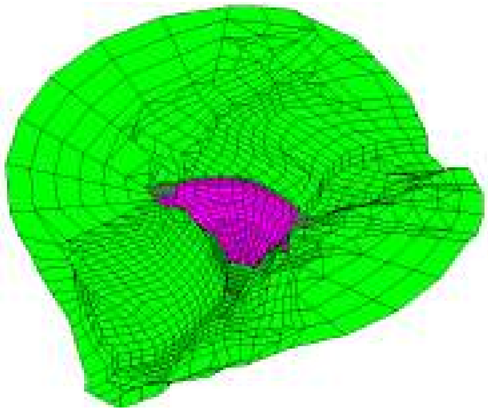

Fig. 6: BE model. Approximation of the actual topography of the canyon. Extension of the free-field discretization: 240 m

The node studied is approximately located at the midpoint of the dam crest, so frecuency response functions obtained by BE method in this node will be plotted for 4 cases: Fixed-base, and compliant-base with different geometries (Fig 4, 5 and 6). On the one hand, in the fixed-base analysis, a unit harmonic horizontal displacement along the upstream direction was given at the abutment of the dam; on the another hand, for the compliant analysis, the system is assumed to be impinged by seismic time-harmonic plane waves. For this analysis, it was assumed that the incident wave field consists solely of plane SH waves propagating vertically with a horizontal upstream free-field ground surface motion (upstream).

The concrete dam wall and the foundation rock material are assumed to be viscoelastic with the properties shown in Table 1 [1, 6].

Property	Dam concrete	Foundation rock
Shear modulus, G (MPa)	8167	12083
Mass density, ρ (kg/m^3)	2300	2143
Poisson's ratio, υ	0,2	0,2
Internal damping ratio, ξ	0,01	0,01

Table 1: Material properties

4 RESULTS

The first three symmetrical mode shapes of vibration obtained with a modal analysis of the fixed-base FEM model, together with the modes infered from the harmonic analysis with the fixed-base BEM model, are shown in Figure 7. A very good agreement is observed between the two sets of results, in terms of both frequency and shape, which contributes to validate the BE wall mesh used below in the compliant-base analysis.

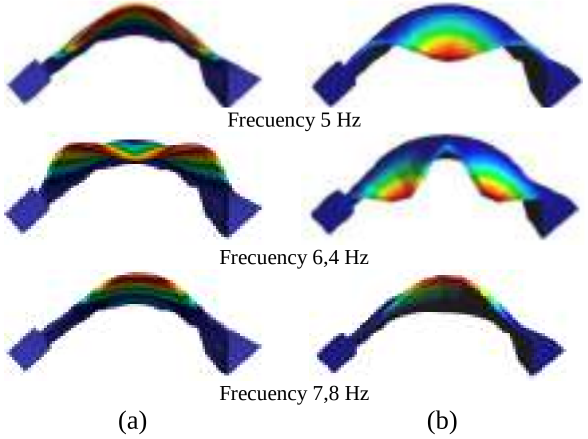

Fig. 7: Symmetrical mode shapes : (a) FEM ; (b) BEM.

The frequency response functions obtained with the frequency domain analysis of the fixed-base and compliant-base models with different geometries at the node studied are plotted in Fig. 8.

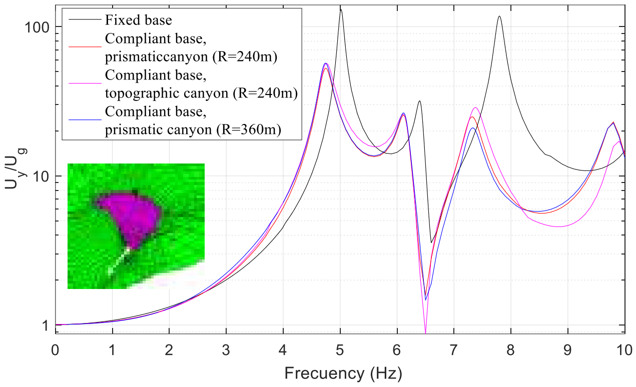

Fig. 8: FRFs. Transversal response of the midpoint of the dam crest.

5 CONCLUSIONS

The frequency-domain analyses carried out show that the soil—structure interaction has an important influence on the seismic response of the dam wall (the vibration frequencies on compliant base are 7% lower than in fixed base); nevertheless, the actual topography of the canyon around the dam wall seems to have a very low influence.

After having estimated the most relevant natural frequencies and modal shapes of the structure, an experimental campaign will be carried out in order to extract the empirical dynamic properties of the system and perform a model updating procedure on the numerical model presented herein.

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