PUSHOVER SEISMIC ANALYSIS OF A BRIDGE WITH Z_SOIL.PC

1 INTRODUCTION

In recent years, the seismic verification of structures according to European construction norms has evolved. Displacement-based methods taking into account the material nonlinearity of structures, also known as pushover analyses, provide an alternative to force-based methods, and usually reproduce better the real behavior of a structure submitted to earthquake-like loading, without overestimating the resulting displacements and stresses. In this note we apply the pushover (PO) method to the seismic verification of a highway bridge, and we compare it with the classical replacement forces (RF) approach.

2 NONLINEAR PUSHOVER ANALYSIS

This deformation-based method compares the earthquake's action (target displacement w_t, see Figure 1) to the deformation capacity of the structure. This approach is recommended by current design codes (Eurocode 8 2003, SIA 2018 2004).

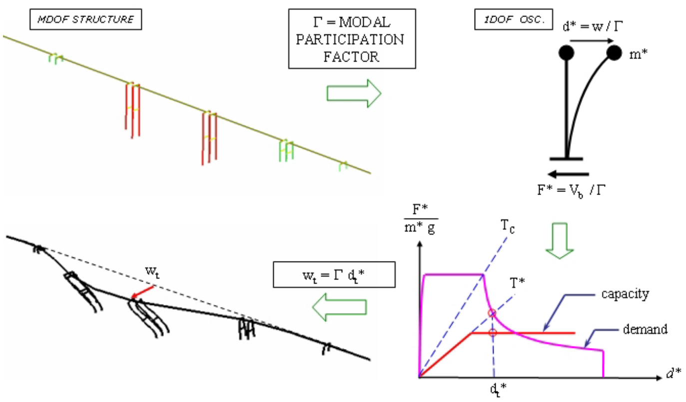

Figure 1. Target displacement computation.

Two lateral load distributions (unitary and modal, both proportionnal to the total mass) are imposed to the structure in its principal directions (usually longitudinal and transversal). These horizontal forces are increased gradually, and one looks at the evolution of the total shear force V in the considered direction with respect to a reference node displacement w (top-floor displacement for a building, maximal deck displacement for a bridge): V = f (w). A capacity curve is then obtained by linearizing this curve in an equivalent 1DOF system: F* = f (d*) (see Fig. 1). The linear acceleration-displacement demand spectrum is then used to define the target displacement, by comparing the capacity and demand spectra. This operation is not straightforward, a detailed description of the procedure can be found in (Belgasmia et al. 2006).

3 CASE STUDY: HIGHWAY BRIDGE

3.1 *Bridge description*

The aforementioned method has been applied to the seismic assessment of an existing bridge (Fig. 2). It is a multi-span continuous motorway bridge located on a Swiss highway. The deck consists of six spans of: 74.15, 3 x 106.75, 79.15 and 38.45 m respectively, thus a total length of 512 m. It has a variable section height, with a maximum value of 5.90 m at supports and a minimal value of 2.20 m at mid-span. It is supported by two abutments at extremities and five piers of 7, 49, 57, 22 and 11 m, respectively. Each pier consists of a group of four columns with hollow rectangular sections, except for pier number 5 which has only two columns with plain rectangular sections. Each column is founded on a deep cylindrical pile whose depth depends on local soil conditions.

Figure 2. Bridge view.

The bridge is located in seismic zone 2, soil type E according to the Swiss norms (SIA 261 2003). The peak ground acceleration for this site is 0.1g.

3.2 *Numerical model*

The numerical simulations have been carried out on a simplified three-dimensional geometry of the bridge using Z_Soil (Z_Soil v7 2007). The deck was modelled by considering an equivalent Timoshenko beam with the same properties (area, inertia moments and torsional coefficient) as the real deck's cross section. Linear elastic behaviour was assumed, which is typical of prestressed concrete bridges under seismic action. The piers' columns were modelled as reinforced concrete nonlinear beam elements.

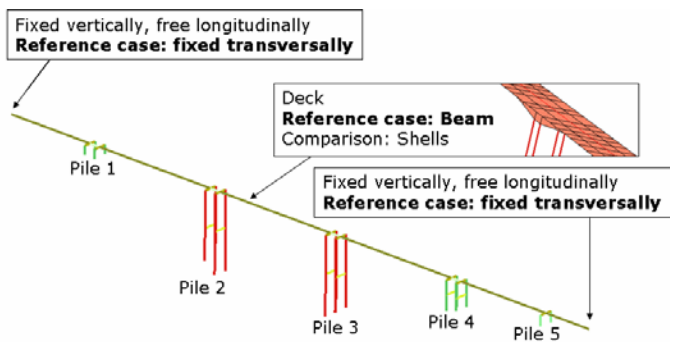

Figure 3. Simplified geometry of the bridge.

3.2.1 *Boundary conditions*

Concerning boundary conditions, two options have been investigated. The first one, referred to as BC 1, assumes all bridge columns founded on 12 m deep piles. Soil-structure interaction is considered in a simple form through boundary springs to which reasonable stiffness values are assigned.

The second option, BC 2, assumes all bridge columns fixed at their bases at surface level, neglecting therefore the flexibility of the foundations.

3.3 *Results*

Figure 5 illustrates the determination of the target displacement in the longitudinal and transversal directions (modal loading).

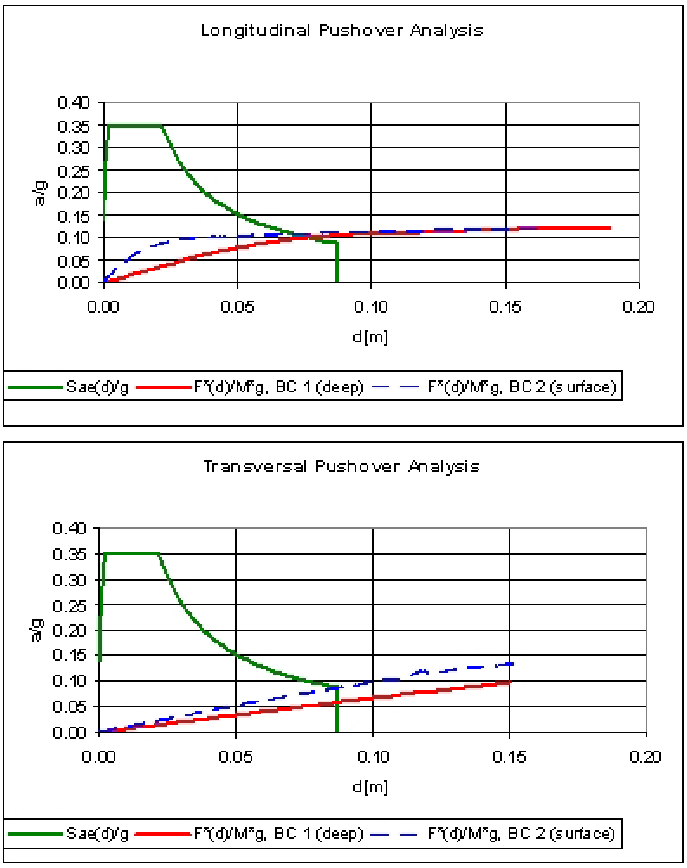

Figure 5. Pushover capacity and demand spectra.

To assess the seismic safety of the bridge, a ratio α between the seismic action and the structural resistance - called conformity ratio - is evaluated for each pier's column.

In the replacement forces approach, it is obtained from computed forces, whereas in the deformation-based approach (Fig. 6), this ratio is obtained by dividing the column's ultimate capacity of deformation (moment-curvature analysis) by the corresponding calculated deformation (pushover analysis).

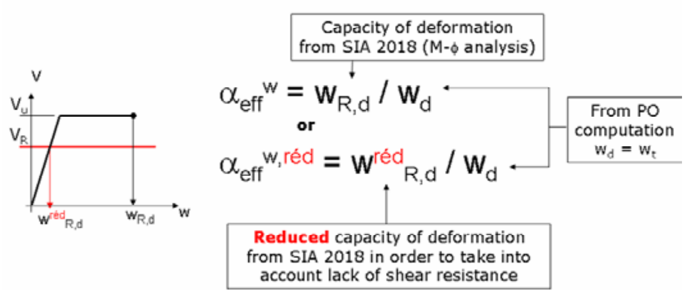

Figure 6. Conformity ratio computation.

The obtained ratios (Fig. 7) for replacement forces and pushover analyses are compared to the Swiss norms minimal and admissible values. It is shown that PO α-ratios are usually higher than RF ratios and that PO approach permits to take advantage from the flexibility of the structure to evaluate its seismic safety.

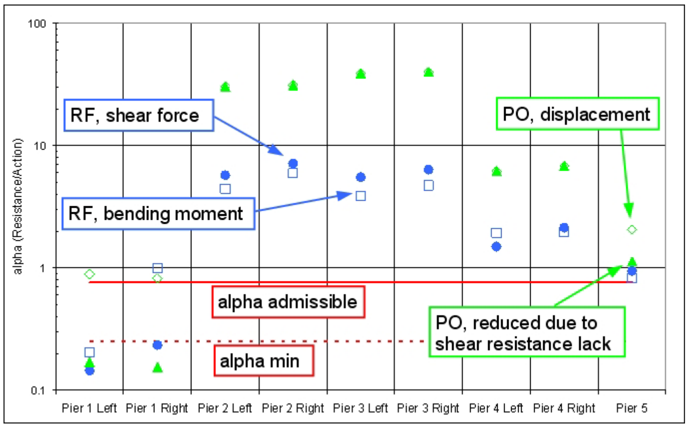

Figure 7. PO and RF alpha ratios (resistance/action) compared to Swiss norms limits (longitudinal, BC 1).

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