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SEISMIC BEHAVIOUR OF PROPPED RETAINING STRUCTURES

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ABSTRACT

The note presents the main results of a number of numerical dynamic analyses of propped embedded retaining structures in the time domain. The numerical model entails the static condition of an excavation 4 m height in presence of a pair of retaining cantilever walls in a dry, coarse-grained soil. Successively, two structural elements (props) that connect the two opposite walls have been introduced. The analyses were carried out considering two strong-motion acceleration time histories, recorded during two Italian earthquakes, and two equivalent analytical waveforms. The results of the analyses indicate a very complex response of the system, due to the effects of local seismic response and soil-structure interaction phenomena. The increment of forces acting on structural elements due to seismic actions is significant and it seems dependent mainly on the seismic load frequency and the number of cycles.

Keywords: Seismic actions, Embedded retaining structures, Dynamic numerical analyses, Non-linear response, Soil structure interaction

INTRODUCTION

In last years, research activities on the seismic behavior of embedded, flexible retaining structures have been mainly referred to cantilevered or single top propped walls. In these cases, the complete mobilization of the soil resistance, uphill and downhill the wall, allows the formation of an instantaneous collapse mechanism. Under these conditions, the system can dissipate seismic energy by cumulating permanent displacements, and its behavior can be interpreted in the framework of the displacements methods (Callisto & Soccodato, 2010). When the geometry of the prop levels prevents the formation of a kinematic collapse mechanism and the structural elements do not achieve yielding conditions, permanent displacements are expected to be negligible and, therefore, seismic actions may cause significant increases of the forces acting on the structures.

In this study the preliminary results of a set of dynamics numerical analyses of a pair of multi-propped, embedded retaining walls are presented. The aim is to furnish a contribution to the understanding of the behavior of this kind of structures under seismic loading.

NUMERICAL MODEL

The parametric analyses have been carried out with reference to the soil model considered by Callisto & Soccodato (2010). The soil was modelled through an elastic-perfectly plastic model with a Mohr-

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Coulomb failure criterion; mechanical soil properties correspond to those of a loose, dry sand. The small strain shear stiffness is variable with mean effective stress and the hysteretic soil behavior was modeled using a typical shear modulus decay curve (Seed & Idriss, 1970).

Two strong-motion accelerograms, recorded during two Italian earthquakes (A-TMZ, A-ASS), and two analytical waveforms corresponding to the impulse peak of the natural recordings (W-TMZ, W-ASS), have been applied to the bottom of the model. The natural accelerograms have about the same Arias intensity, I_A, but different frequency content (Fig. 1a and b). This difference was also kept for the wavelets.

The numerical dynamic analyses were carried out, under plane strain conditions, with the FDM code FLAC 5.0 (ITASCA, 2005); different maximum accelerations, $a_{\max}$, of the input signal were considered.

The pair of walls (L = 8 m) sustain an excavation of height H = 4 m and width 16 m. The geotechnical and structural design of walls was managed with reference to the cantilever configuration, and according to the Italian Technical Code on Constructions. The permanent levels of props, at the wall top and at the bottom of the excavation, were introduced at the end of the excavation stage, before the dynamic stage of the analysis.

RESULTS

The characters of ground motion obtained from the analyses appear greatly affected by a number of overlapping effects:

1. soil stiffness heterogeneity;
2. non-linearity of soil behaviour;
3. system geometry (2D effects);
4. soil-structure interaction.

The comparison between the seismic input parameters and those calculated at ground level in free field conditions allows an estimate of the magnitude of the seismic actions with reference to the effects (1) and (2). In detail, the different acceleration time histories cause a different soil response related to the vibration modes excited by the signals. As shown in Fig.1a and b, it is possible to verify that the frequency content of A-TMZ and W-TMZ excites the system in the first vibration mode, while A-ASS and W-ASS give rise to soil resonance according with the second vibration mode (Fig.1b). Therefore, the transient deformations and the associated hysteretic damping obtained using ASS inputs are lesser than those achieved with TMZ accelerograms.

Within respect to free field conditions, the effect (3) produces, in general, seismic motion amplification behind the walls, due to waves focusing phenomena, and an attenuation at the bottom of the excavation, related to seismic waves diffraction. The effect (4) produces additional reflections, due to the high stiffness of the walls. The interaction between reflected and incident wave fields modifies the shaking amplitude that depends on the phase shift of the two signals. These effects are clearly apparent for the one-cycle seismic input (W-TMZ and W-ASS, Fig.1c and d) by looking at the marked variation of maximum surface acceleration, $a_{\max,s}$, behind the most loaded wall (left for ASS, right for TMZ), for a distance approximately equal to the wall length.

During seismic loading, forces on structures vary rapidly in both magnitude and sign, depending on acceleration value and direction. Referring to A-ASS S01 input ($a_{\max}$=0.27g), Fig.1e shows the horizontal stresses, σ_h, acting on the walls at the instant in which the maximum bending moment, $M_{\max}$, is reached. In front of the wall, stresses increase, and passive limit state conditions extend to a greater depth. Behind the opposite wall, horizontal stresses show a moderate increment in respect of the static condition, while they decrease significantly in front of the wall. The upper prop is nearly unloaded, and $M_{\max}$, which is about two times the maximum static (cantilever) moment, is reached in correspondence of the lower prop.

A relation between $a_{\max}$, $M_{\max}$ and the maximum axial force, $N_{\max}$, on the lower prop seems to be more apparent for natural records rather than for the wavelets (Fig.1g and h). Maximum forces acting on structures seem to be related not only to peak accelerations but also to the coupling between the fundamental frequencies of the soil and the predominant frequencies of the seismic action. The effects of the temporal evolution of the applied seismic loading before peak values occurrence are clearly highlighted by the differences in results obtained for 1-cycle waveforms and for natural accelerograms.

Post-seismic actions seem to be more dependent, all other factors kept constant, on an integral parameter, such as I_A, rather than maximum accelerations (Fig.1i and l). However, with increasing I_A, non-linearity effects, which are different when the two seismic inputs are considered, begin to be more important.

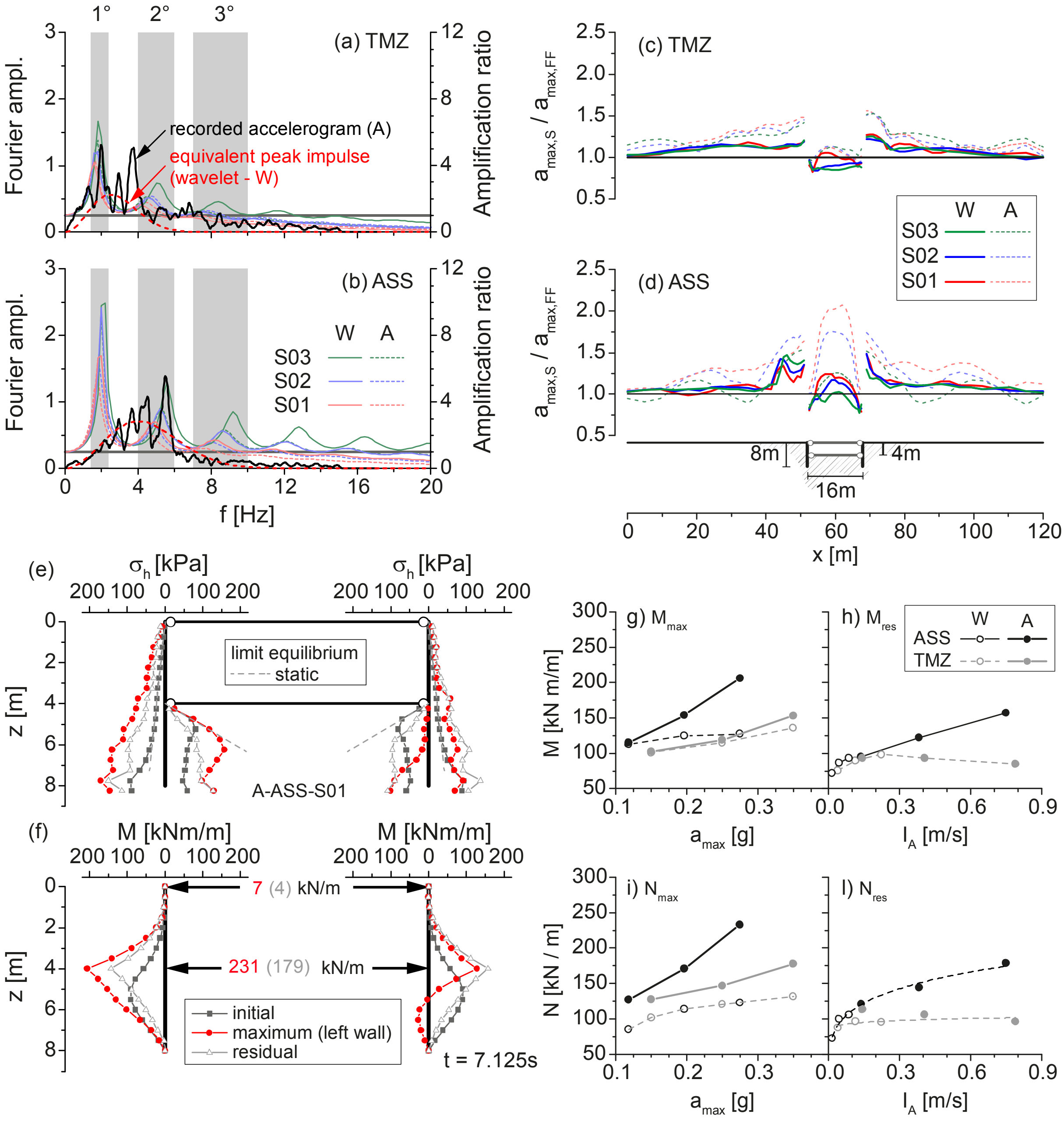

Figure 1. Comparison between Fourier amplitude of input accelerograms and non-linear 1D amplification function computed in free field conditions for ASS (a) and TMZ (b) waveforms; 2D response factors (c, d); horizontal stresses (e) and structural forces (f) for the accelerogram A-ASS (S01). Maximum wall bending moment, M_{max} (g) and prop axial load, N_{max} (h), versus peak input acceleration, a_{max}; post-seismic bending moment M_{res} (i) and prop axial load, N_{res} (l) versus Arias Intensity, I_A.

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