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ON FASTER TRANSIENT ANALYSIS OF STRUCTURAL SYSTEMS AGAINST EARTHQUAKES: CASE STUDY OF AN EARTH DAM

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The safety of large structural systems especially infrastructures against major earthquakes is of high importance. Considering issues like nonlinearity of the behaviors in severe earthquakes, probable interactions with soil and water, size of the current computational models, and the everyday smaller digitization steps of recording devices, transient analysis against earthquakes is generally time consuming. To reduce this run-time, a technique was proposed in 2008 (Soroushian, 2008), that replaces the earthquake record with a record digitized in larger steps. Application of this technique to analysis of many structural systems has reduced analysis run-times without noticeably changing the accuracy (e.g. see (Garakanienzhad & Moghadas, 2015), when the enlargement scale, n, i.e.

$$n = \frac{{}_f\Delta t_{new}}{{}_f\Delta t} \tag{1}$$

satisfies the condition below:

$$n\ {}_f\Delta t \le \frac{T}{100} \quad , \quad n = 2,3,4,\ldots \tag{2}$$

In Equations 1 and 2, ${}_f\Delta t$ and ${}_f\Delta t_{new}$ are the digitization steps of the original record and the record after implementation of the technique respectively, T is the smallest worthwhile period contributing the target response, and '100' is adequate for many nonlinear behaviors (see NZS1170, 2004). Ambiguities exist in the definition of T. Accordingly, Equation 2 cannot be simply checked, especially prior to the analysis. However, values for n satisfying Equation 2 existed in the studied cases. The only case for which the technique was not applicable because of Equation 2 was analysis of an earth dam reported in (Hosseini, 2018). In 2017, the technique was enhanced (Soroushian et al., 2017), such that to replace Equation 2 with:

$$n\ {}_f\Delta t \le \frac{T}{100} \quad , \quad n > 1 \quad , \quad n \in R^+ \tag{3}$$

where R^+ implies the set of positive real numbers. Replacement of Equation 2 with Equation 3, though cannot eliminate the drawback originated in T, enhances the chance of applicability. Note that, in using Equation 3 instead of Equation 2, n can be obtained between one and two leading to considerable faster analysis. Considering the importance of dams in civil engineering, the considerable transient analysis run-time, and the weak point reported in (Hosseini, 2018), in this study, the authors test the performance of the enhanced technique (Soroushian et al., 2017) in transient analysis of a specific earth dam studied in the literature by times (Hunter & Fell, 2003; Daziano, 2017), see Figure 1. As some main modeling details, the material model is Hardening Soil (Hunter & Fell, 2003), the soil structure interaction is taken into account, using absorbing elements in the boundary, and the excitation is taken into account by applying the earthquake record to special nodes at the bedrock. As the earthquake record, twelve records are selected from the databanks of Iran, USA, Japan, Taiwan, and Turkey. For design purposes, the enlargement scales are set such that the resulting digitization steps equal 0.0225 sec. Using the 2D

PLAXIS finite elements software, the fifteen node triangular elements displayed in Figure 2, the average acceleration time integration method (Newmark, 1959), the modified Newton-Raphson iterations, and 0.01 as the nonlinearity tolerance, the transient behavior of the dam is analyzed once with the original and then with the reduced records. The results display considerable reduction of run-time in the price of tolerable loss of accuracy (see Table 1). (Further study is ongoing to clarify in very detail the effect of replacing Equation 2 with Equation 3.) Especially taking into account the cases in Table 1 with enlargement scales smaller than two, we can conclude that the enhancement proposed in (Soroushian et al., 2017) can bring about more applicability for the technique proposed in (Soroushian, 2008). Repeating the study for other structural systems specifically the case addressed in (Hosseini, 2018), and meanwhile study on full elimination of the shortcoming originated in T, are areas for future research.

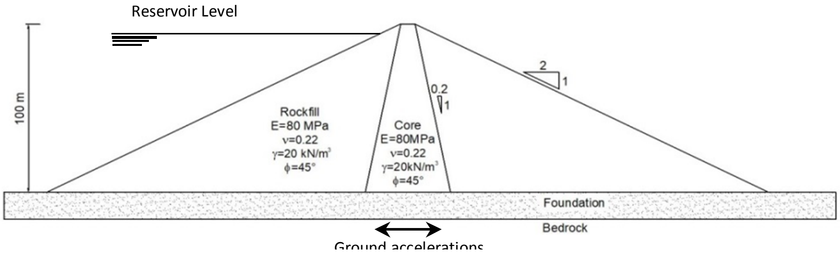

Figure 1. Cross section and material zone of a specific dam subjected to ground acceleration.

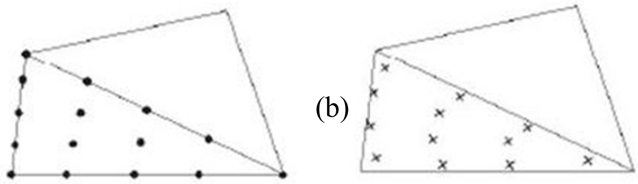

Figure 2. 2D Soil elements: (a) Nodes, (b) Stress Points.

Table 1. Run-times of analyses of the dam in Figure 1 when implementing the techniques proposed in (Soroushian, 2008; Soroushian et al., 2017) against four earthquakes and comparison with run-times of the ordinary analyses.

	Event	$_f\Delta t$ (sec)	Duration (sec)	Run Time (hour)		Crest Settlement (m)	
				Ordinary	New	Ordinary	New
1	Tabas, Iran (1978)	0.02	32.84	5.92	4.36	9.07	9.88
2	Kobe, Japan (1995)	0.02	44.78	8.67	7.70	5.25	5.39
3	Loma Prieta, USA (1989)	0.05	24.26	16.11	5.32	2.29	2.21
4	Chi-Chi, Taiwan (1999)	0.004	121.96	54.83	18.58	3.66	3.49

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