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ALGORITHM FOR INTERFACING BETWEEN GIS AND DYNAMIC SITE RESPONSE COMPUTING DOMAINS

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1. INTRODUCTION

In this paper, an algorithm for interfacing between geographical information system (GIS) and dynamic site response computing domains is introduced. DISO 7.0 computer program was developed using Visual Basic programming language in order to manipulate large amount of geotechnical data and to prepare a data input file for performing dynamic analyses. The scattered geotechnical data for soils of the northern coast of Izmir Bay (Turkey) area have been collected and loaded to the constructed dynamic soil database. Dynamic soil parameters were calculated, and liquefaction analysis was performed using DISO 7.0 program following the complete of site-response analyses. The post-liquefaction settlement was also calculated with DISO 7.0. Methodology and processing principles of DISO 7.0 is given, and its application to the soils of the northern coast of Izmir Bay (Turkey) area is presented.

Use of GIS in geotechnical earthquake engineering has enjoyed attention of engineers due to the spatial character of the subsurface data. GIS has been used for computations of spatial seismic hazard analyses, dynamic slope stability and liquefaction analysis over large regions, and more localized ground deformation assessments (Mabey, 1997; Rogers, 1997; Borcherdt, 1997; Divakarla et al., 1998). Besides, GIS tools were used in seismic hazard mapping and evaluation of liquefaction damage (O'Rourke and Pease, 1997, Luna and Frost, 1998; Luna et al., 1998).

2. SCOPE AND METHODOLOGY

The scope of this study is to develop a GIS based methodology in order to perform dynamic site response analyses using geotechnical data. For this aim, geotechnical and strong ground motion databases were constructed, DISO 7.0 software was developed in Visual Basic, and this software was related to dynamic databases according to geographical coordinates. Use of this methodology provides to perform dynamic analysis for any parcel or selected boring locations. Thus, local soil conditions can be taken into consideration for dynamic soil behavior. Besides, geotechnical data, earthquake recordings and dynamic analysis results are loaded to related databases. The methodology was applied to the northern coast of Izmir Bay (Turkey) area soils. The city of Izmir, which is the thirdest greatest city of Turkey, is located on the west coast of Anatolia. The Western Anatolia is one of the major seismically active zones in the Mediterranean due to its active tectonics. Coastal area on the north of the Izmir Bay having thick alluvial strata was selected for application of the methodology.

3. DEVELOPMENT OF INTERFACE SOFTWARE DISO 7.0

The interfacing software DISO 7.0 was developed following the construction of geotechnical database. DISO 7.0 is capable of reading geotechnical data from database, performing calculations of dynamic parameters for dynamic site response analyses, and preparing a data input file for dynamic analysis software EERA (Bardet et al., 2000). The capability of software was increased then in order to perform liquefaction analysis and calculation of post-liquefaction settlement. The major part of the study is development of software that can perform the abovementioned tasks of a geotechnical earthquake engineering problem since the geotechnical data can be used in dynamic site response and liquefaction analyses following additional calculations. One of the main properties of this software is to provide efficient communication with EERA (Bardet et al., 2000) software which is used to perform dynamic site-response analyses. DISO 7.0 provides a graphical user interface (GUIS) in order to link the constructed databases with the GIS software (ESRI, 1999). Besides, data manipulation options such as selection of borehole locations on digital map are available. From this point of view DISO 7.0 can be regarded as small-scale geographic information software. DISO 7.0 is able to perform liquefaction and post-liquefaction settlement analyses similar to its predecessors (Frost et al., 1997; Divakarla et al., 1998).

DISO 7.0 includes subroutine forms of Visual Basic. Geotechnical data, which were collected in Geotechnical Properties database, are read using DISO 7.0, and calculations for dynamic parameters are performed. Data input file for site response analysis is prepared using DISO 7.0. Liquefaction analysis is performed also with DISO 7.0, and post-liquefaction settlement values are calculated. Connection between Geotechnical Properties and Strong Ground Motion databases and dynamic analysis software EERA is provided with DISO 7.0.

The methodology for dynamic site response analysis is based on the equivalent linear model. The parameters G_{max} (maximum shear modulus) and ξ (damping ratio) are referred to as equivalent linear parameters of the soil material. These parameters are used to describe the dynamic behavior of soils in site response analysis. Dynamic soil parameters (G_{max} and ξ) are calculated with DISO 7.0 utilizing geotechnical data collected at Geotechnical Properties database. Maximum shear modulus (G_{max}) can be calculated from empirical relationships for clays (Hardin and Drnevich, 1972) and for sands (Seed and Idriss, 1970). G_{max} can be also determined from corrected SPT-N values (Ohta and Goto, 1976, Imai and Tonouchi, 1982). The variation of the modulus ratio (G/G_{max}) and damping ratio (ξ) with shear strain (γ) is computed from Ishibashi and Zhang (1993) formulations. Modulus ratio and damping ratio values for each layer of the soil profile are calculated for shear strains varying between 0.0001 and 10 percent using DISO 7.0. These values are recorded to the material property sheets in the data input file of EERA. The modulus reduction and damping curves are drawn for each material sheet during this process.

4. DYNAMIC SOIL BEHAVIOR ANALYSES

Dynamic site response analysis is the backbone of any deterministic seismic hazard analysis. The equivalent linear methodology was selected. The spreadsheet format of SHAKE (Schnabel et al, 1972) algorithm, EERA (Bardet et al., 2000) software was preferred. The input data file for EERA was prepared using DISO 7.0. The modular structure of DISO 7.0 is shown in Figure 1. Detailed algorithm tree is given in Figure 2. Running procedure is shown also in Figure 2.

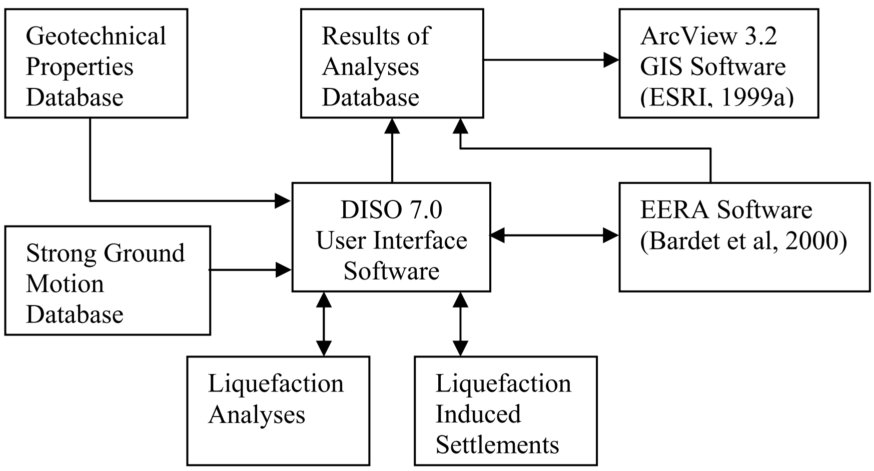

Figure 1. Modular Structure of DISO 7.0 Processing Units

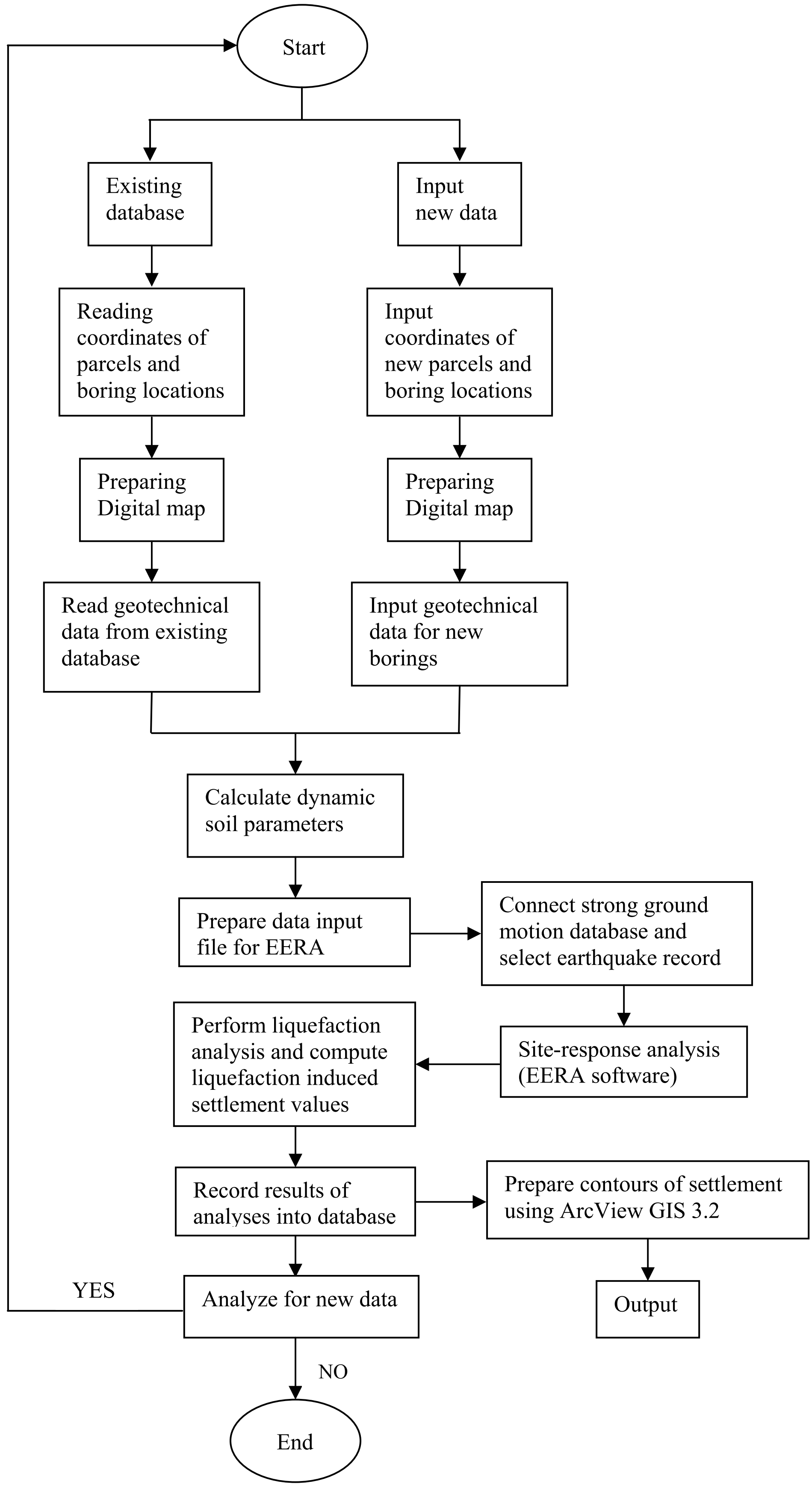

Figure 2. An Algorithm Tree of DISO 7.0 Software

Liquefaction analysis is performed following the estimation of maximum ground surface acceleration from dynamic analysis. The state-of-the-art methodology developed by Youd and Idriss (1997) is employed during liquefaction analysis. Estimation of two variables is required for evaluation of liquefaction resistance of soils: The cyclic stress ratio (CSR) and the cyclic resistance ratio (CRR). The cyclic stress ratio required to generate liquefaction was calculated using the simplified methodology developed by Seed and Idriss (1971). The cyclic resistance ratio can be determined from $(N_1)_{60}$ value for M=7.5 earthquake. The cyclic resistance ratio for other magnitudes can be obtained by multiplying CRR for M=7.5 earthquake by magnitude correction factors (Youd and Idriss, 1997). The ratio of cyclic resistance ratio to cyclic stress ratio gives the factor of safety against liquefaction, FS_L. Factor of safety less than 1.0 means saturated layer liquefies, otherwise liquefaction does not occur. Liquefaction induced settlements can be calculated using Ishihara and Yoshimine (1992) approach based on Tokimatsu and Seed (1987) methodology.

A sample liquefaction analysis for Borehole #169 in Bostanlı region of Izmir (Turkey) was performed using DISO 7.0. Liquefaction potential was determined in sand layers (red color displays that liquefaction may occur in the analyzed depth) of soil profile shown in Figure 3 for M=6.5 earthquake and a_{max}=0.27g. The post-liquefaction settlement within the 20m depth from ground surface was obtained as 28 cm. Since liquefaction was not estimated to occur below 20m depth, sand layer, having liquefaction potential, between 32.0-35.0m depths would not be taken into account. Dynamic soil behavior analyses were performed for 238 borehole locations available at constructed database. Then, results of site response and liquefaction analyses were related to the geographic coordinates of borehole locations using GIS software, and contour maps of dynamic parameters were prepared using GIS mapping techniques.

CONCLUSIONS

In this study, a methodology and processing principles of DISO 7.0 computer program is introduced, and its application to the soils of the northern coast of Izmir Bay (Turkey) area is presented. DISO 7.0 computer program was developed using Visual Basic programming language in order to manipulate large amount of geotechnical data and to prepare a data input file for performing dynamic analyses. DISO 7.0 provides an interface between geographical information system (GIS) and dynamic site response computing domains. The large amount of geological and geotechnical data for soils of the northern coast of Izmir Bay area have been loaded to the constructed dynamic soil database. Acceleration records of these earthquakes occurred in the vicinity of Izmir are loaded to the "Strong Ground Motion" database. DISO 7.0 provides a link between these databases. Dynamic parameters required for equivalent-linear 1-D dynamic site response analyses are calculated using DISO 7.0. Dynamic site response analyses are performed using EERA (Bardet et al., 2000) software, and liquefaction analyses are performed with DISO 7.0 using results of dynamic analyses. The post-liquefaction settlement values are also calculated with DISO 7.0. A sample application of liquefaction analysis is given for the northern coast of Izmir Bay area soils.

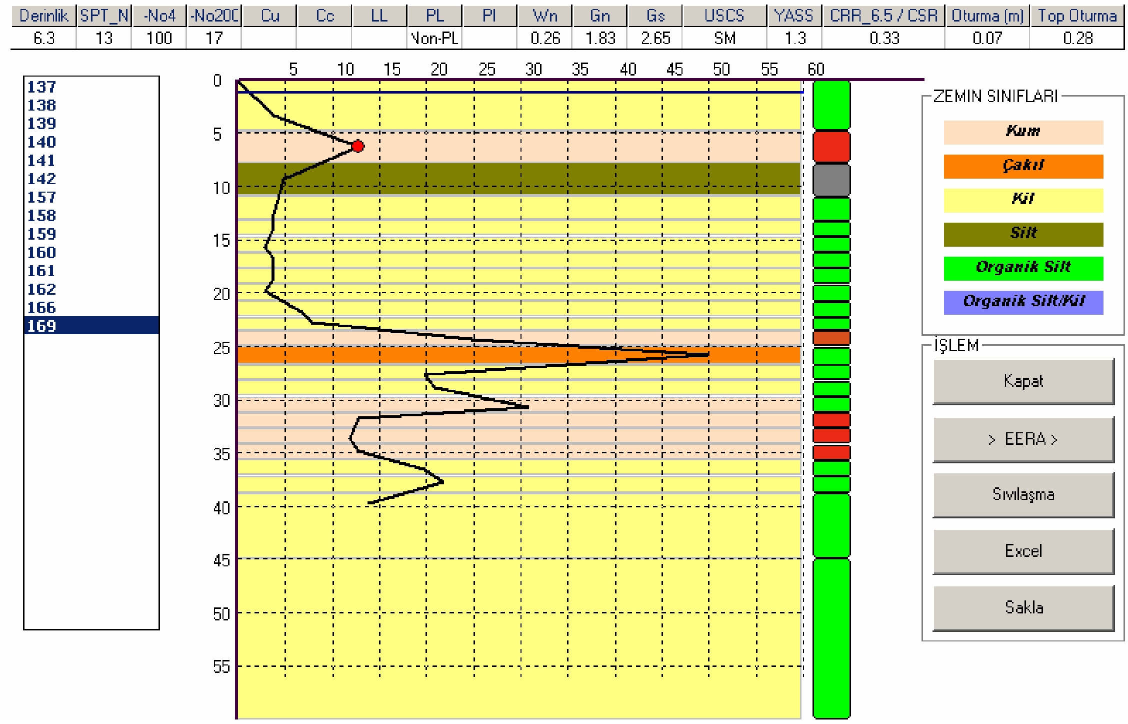

Figure 3. Liquefaction analysis window for Borehole #169 (DISO 7.0 software)

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