Abstract

Transportation and logistics play an important role in the economy of countries, while road transport is one of the most important modes of transportation for load transportation, especially in developing countries. Accidents are directly related to driving offenses, and drivers who commit more offenses are more prone to accidents. Therefore, reducing driving offenses can reduce accidents. Hence, the recognition of common driving offenses among heavy vehicle (truck) drivers and the effective factors in directing them to reduce driving offenses can consequently reduce the frequency and severity of accidents. Thus, there is a necessity for conducting further studies to carry out research in this regard more than ever before. The main objective of this study is to identify and evaluate important factors affecting lorry drivers committing traffic offenses. To this end, the required information was divided into six categories: traffic tonnage, not wearing a seatbelt, unauthorized speed, impaired driving, talking on the phone, lacking a scalp leaf, and these factors are known as dependent variables. Also, the influencing factors in the group of driver characteristics, vehicle, and mileage were considered by using a demographic questionnaire and Driving Behavior Questionnaire (DBQ) and interviews with 420 drivers over 60 days at the Shahid Kheibari Terminal in Mashhad. After correcting or removing incomplete questionnaires, the information of 351 drivers was used for statistical analysis. Besides, statistical analysis of data using the multivariate logistic regression model showed that drivers with discharging and loading of five or six times per month are less likely to commit excess tonnage than drivers with discharging and loading of more than 12 times per month. The results also proved that drivers with less slip behavior and not so-called distraction would be less likely to commit unauthorized speed offenses and 85.4% less likely to commit this violation. Finally, analysis of statistical analysis showed that drivers with aggressive driving behavior were more likely to commit lacking a scalp leaf offense.

Key Words: Traffic safety, driver behavior questionnaire, lorry drivers, load transportation, multinomial logistic regression.

building regulation of Iran "design and construction of concrete structures" should be considered in greater detail.

Key Words: Cement heating, strength gain of concrete, finite element method, concrete thermal analysis.

THE ASSESSMENT OF SPACING AND SOIL SOLIDITY INFLUENCE IN MULTIPLE STRUCTURE-SOIL-STRUCTURE INTERACTIONS IN HIGH-RISE BUILDINGS

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Abstract

Simultaneous effects of soil and several structures are known as the site-city interaction (structure-soil-structure interaction), which is very important in areas with high construction density and has been considered by many scholars over the past two decades. Site-city interaction can affect the structure behavior due to the wave propagation between structures. In fact, it decreases the structure responses in some cases, while it increases the responses in some other cases. Many parameters play a role in assessing site-city interaction such as the gender of soil, number and arrangement of structures, height of buildings, shape of earthquake waves, and the main period of structures and soil. The present study aimed to evaluate the effects of gender and solidity of the soil based on 2800 standards and building distances in site-city interaction in three dimensions. The effects of these parameters on the foundation and top of structure responses including maximum acceleration values and Root Mean Square acceleration were assessed. SASSI 2000 software was employed to model structures and soil and analyze the system. In this study, structural models were considered in both single structure and the ideal city (structural groups). The groups were 3×3 including nine identical structures. In the single model, the site-city interaction was not considered, and these effects were considered in the group model. Lumped-Mass Stick Model was used to model each structure and the soil, which was modeled in the software including a semi-infinite elastic environment with horizontal layering, located on the viscoelastic half-infinitely semi-space. Based on the results, regarding the top of structure, the existence of structures alongside each other by considering site-city interaction effects in different soils resulted in decreasing the structural acceleration responses (25% average) compared to the individual structure site-city interaction effects, which increased by decreasing the soil stiffness (5-10% average). Further, the effects of multiple structure-soil-structure interaction decreased (10-15% average) by increasing the distance between structures.

Key Words: Multiple structure - soil - structure interaction, city effects, soil solidity order, site-city interaction, waves propagation.

A DATA MINING APPROACH TO THE IRANIAN LORRY DRIVERS WITH VARIOUS CHARACTERISTIC DRIVER BEHAVIORS, VEHICLES, AND TRAVEL

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Abstract

Generally, Rayleigh damping assumes a specified damping ratio for the structure in the dynamic analysis. Although this assumption is accepted in analysis and design of structures, there is some distance from the experimental results showing that the damping ratio depends on the stress amplitude. In this paper, the damping ratio for each element is a function of its principal stress and its value is determined utilizing a proposed algorithm called Element Developed Energy Dissipation Algorithm (EDEDA). The proposed algorithm was implemented into a code based on finite element, which is able to simulate nonlinear behavior of mass concrete utilizing the smeared crack approach. In this regard, due to stress redistribution in the nonlinear time history analysis, we have a new concept, namely damping ratio redistribution such that when the stress value of each element changes, the relevant damping value is updated. Based on an analysis of a typical concrete gravity dam (Pine Flat dam), two usual methods in the Rayleigh damping approach which include stiffness proportional damping and mass/stiffness proportional damping are considered rigorously. In addition, the brittle damping approach was utilized in the proposed algorithm, where the damping contribution of a cracked element was eliminated from the computing procedure. It was found that when the damping redistribution was taken into account, the damping ratio in each element would be updated at each time step corresponding to the principal stress. This algorithm would produce more real results about the considered gravity dam so that in the low-level seismic excitation, the response of the structure was less than that in the traditional method and raising the excitation level led to higher damping affecting the crest displacement. In addition, the stiffness proportional damping leads to crack profiles in the neck region of the dam body showing more correspondence than the results obtained from the models with mass/stiffness proportional damping.

Key Words: Concrete gravity dam, damping ratio redistribution, non-linear time history analysis, rayleigh damping, smeared crack approach.

EVALUATION OF HEAT TRANSFER AND RATE OF STRENGTH GAIN OF CONCRETE

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Abstract

Stress gain of concrete is a heated procedure. The amount of heat significantly depends on cement type, cement content, and cement-water ratio. While the rate of generated heat is far more than that of heat transfer to the exterior part of concrete mass, temperature of the interior part of concrete element during that procedure increases. Furthermore, the strength gain of concrete is a function of temperature history of every part of element which is influenced by heat caused by hydration. If the stress generated by heat in fresh concrete is greater than acquired strength of concrete, then early cracks will form in the concrete mass. As a result, thermal analysis and checking the strength gain in massive concrete structures like concrete dams, foundations, and bridge decks would be especially important. The terms heat transfer and thermal analysis are composed of some mechanisms. This models the mechanism and simulates the strength gain of concrete by finite element method. After verifying the finite element model, we will study the strength gain of a concrete slab and a reinforced concrete beam. All the experiments are in accordance with ASTM standard to determine the parameters of cement heating procedure. Controlled environment with a constant temperature is used for curing concrete specimens. Six different ages (first age for about 4 MPa compressive strength and next ages are twice the previous age. The specimens are studied at three different temperatures, $15^{\circ}C$,$25^{\circ}C$ and $35^{\circ}C$, 54 specimens are considered. The results show that this numerical method can estimate heat transfer in the concrete body with acceptable accuracy. In addition, the results exhibit that the proposed time for removal of forms in the ninth part of national

capability and an ability to sustain large nonlinear lateral deformations with little damage and negligible residual deformation. In this system, the coupling beam is not embedded into the walls, and coupling of concrete walls is performed by posttensioning beam to the walls using unbonded post-tensioning (PT) steel strands. In this paper, the seismic behavior of hybrid coupled wall systems with post-tensioned steel coupling beam was investigated experimentally. In order to dissipate seismic energy and reduce displacements of system, two friction dampers were used in the beam-to-wall connection region. To study the behavior of the system, a friction damper was first tested at different frequencies; then, four 2/3-scale posttensioned hybrid coupled wall subassemblages equipped with friction dampers were tested subjected to reversed-cyclic lateral loading. Each subassemblage included a half-length steel coupling beam and the adjacent concrete wall region at a floor level. The test specimens consisted of one control specimen without friction damper and three specimens equipped with friction dampers with various damper normal forces and different initial beam post-tensioning (PT) steel stresses. The test results showed that the system had very good lateral stiffness, strength, and ductility with little damage up to 8% lateral drift. The nonlinear deformation in this system occurs because of the gap opening at the beam-to-wall interface. The friction damper uses these gap opening displacements to provide supplemental energy dissipation. Friction dampers provide considerable energy dissipation at the system, while the self-centering capability of the system remains. The restoring effect of the post-tensioning steel strands causes closing the gap upon unloading and provides a self-centering behavior and flag-shaped hysteresis loops for specimens equipped with friction dampers. Based on the test results, the system, even after a severe earthquake, suffers limited damage and requires little repair.

Key Words: Hybrid coupled wall, steel coupling beam, post-tensioning, friction damper, self-centering.

EXPERIMENTAL STUDY OF MECHANICAL SPLICES OF TENSILE REINFORCED CONCRETE BEAMS UNDER BENDING

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Abstract

In order to investigate into the performance of mechanical splices, 6 RC beams with the same dimensions and materials whose only difference is type and location of splicing, have been tested. This study aims to assess the effect of spacing between the splices with respect to their type. Indeed, the results of this paper are intended to provide a proper understanding from location of splices and its effect on the performance of the reinforced concrete (RC) beams. The results indicated that splices do not cause remarkable change in load-carrying capacity of the specimens. In addition, after applying loads and fracture of specimens, none of the mechanically-spliced rebars was ruptured at the location of splice and coupler remained undamaged. Further, it was observed that the reference beam and mechanically spliced beam (tension rebar in the mid-span and 2 other tension rebars with spacing of 60cm from mid-span and symmetrically distributed along the beam) exhibited minimum effective moment of inertia and thus, the same trend regarding flexural rigidity that is in direct relation to the moment of inertia, was attained. Accordingly, the reference beam and specimen L100 offered minimum displacement ductility. Specimen L33 and M33-60 exhibited 6% increase and 10% decrease in their strength respectively, experiencing maximum and minimum load-carrying capacity.

Key Words: Rebar splicing, reinforced concrete (RC) structures, mechanical splice, RC beam, coupler.

INVESTIGATING EFFECTS OF STRESS-DEPENDENT MATERIAL DAMPING ON THE NONLINEAR SEISMIC RESPONSE OF A TYPICAL CONCRETE GRAVITY DAM

These reinforcements can develop tensile membrane action and through alternative load paths to transfer the load. These reinforcements did not have much influence on the punching shear strength. In the column strip, compressive bars (except integrity reinforcements) did not have much influence on the punching and post-punching shear strength. The bent-up integrity reinforcements significantly increase punching and post-punching shear strength. The additional bent-up reinforcements increase punching shear strength but these reinforcements are not effective to the post punching phase and cannot increase the post punching shear strength. The shear reinforcements increase punching shear strength, but these reinforcements cannot increase post-punching shear strength. Furthermore, if the shear reinforcements are effectively extended, the behavior flat slabs will be more ductile.

Key Words: Post-Punching strength, flat slab, integrity reinforcement, punching shear failure.

NONLINEAR BEHAVIOR OF REINFORCED CONCRETE WALLS WITH SHAPE MEMORY ALLOY REINFORCEMENT SUBJECTED TO EARTHQUAKE

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Abstract

Shape Memory Alloys (SMAs) are new material in structural engineering. They can be used as reinforcement for the concrete walls. In this research, a numerical model was first developed based on an experimental test of a tall reinforced concrete wall with steel reinforcement subjected to an earthquake, and the numerical model responses were compared to the experimental model. Then, three other approaches were examined; first, the shape memory alloys were replaced only as vertical bars on the first story; in the second one, Shape memory alloy bars were replaced only on the first and sixth stories; and in the third approach, the whole vertical bars were replaced with shape memory alloy bars. Nonlinear time history analysis and comparison of model responses were performed. In addition, the parametric study of the responses was also done by changing some model characteristics such as axial force and earthquake intensity. In all three approaches with the shape memory alloy bars, the base moment demand value decreased by approximately 15% compared to the model with steel reinforcement. In the moment demand diagram, the amount of moment demand at the mid-height of the structure is relatively increased compared to the base moment demand. This is due to the effect of higher modes on wall behavior. The moment diagram graph is not uniformly decreasing along the height is not like a straight line. In addition, parametric study of the responses is also performed by changing some model characteristics such as axial force and earthquake intensity. With the formation of a plastic hinge at the base of the wall, approximately, the amount of moment demand in this area remains constant and the effect of higher modes increases the moment demand at the mid-height of the structure and may result in the formation of another plastic hinge at the mid-height of the structure.

Key Words: Nonlinear behavior, reinforced concrete wall, shape memory alloy, earthquake.

EXPERIMENTAL INVESTIGATION OF CONCRETE COUPLED WALL SYSTEMS WITH POST-TENSIONED STEEL COUPLING BEAM

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Abstract

Post-tensioned coupled shear wall system is characterized by good seismic specifications like a self-centering

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Abstract

In this paper, a new algorithm is presented for Dynamic Relaxation (DR) method with kinetic damping. In the kinetic dynamic relaxation algorithm, some successive points with maximum kinetic energy are traced in the course of numerical fictitious time integration. In the absence of damping forces, the points with maximum kinetic energy are close to the static equilibrium position of structure. This paper deals with a new formulation for kinetic DR method. For this purpose, Lagrangian interpolation functions were utilized to derive iterative Dynamic Relaxation equations. In the Lagrangian interpolation functions, new estimation of structural displacement vector was obtained based on previous estimations of displacement vector. Therefore, this procedure leads to adopting a trial and error method. On the other hand, this procedure leads to a new formulation that, unlike the ubiquitous DR methods, does not require the calculation of nodal velocities, thereby marching forward only through successive nodal displacement. Elimination the nodal velocities from Dynamic Relaxation process increases the simplicity of DR algorithm. Moreover, the requirement analysis memory is reduced using the suggested technique so that velocity vectors would not be stored in the program memory. Also, the power iteration method was used to determine the optimal time step ratio. By utilizing this time step, the restarting analysis phase, considered as one of the drawbacks of the common kinetic DR strategies, is eliminated. To evaluate the performance and efficiency of the proposed method, several truss and frame structures were analyzed. These structures had geometrically nonlinear behavior (Large Deflection). Results of these analyses were also compared with those of other conventional Dynamic Relaxation methods. Numerical results showed that the convergence rate of the proposed kinetic DR technique was higher than that of common DR algorithms. In other words, the number of the required DR iterations for convergence was reduced using the proposed DR algorithm in comparison with other DR schemes. Moreover, the analysis time of the proposed method was shorter than that of other common techniques.

Key Words: Dynamic relaxation method, lagrangian interpolation, power iteration method, nonlinear analysis.

THE APPLICATION OF SPECIAL REINFORCEMENT TO IMPROVE POST-PUNCHING FAILURE

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Abstract

Punching shear failure is usually the critical failure mechanism for flat slab reinforced concrete structures. The special brittleness of slab-column connections is due to the relative ease with which the flexural reinforcement in the top of the slab can be torn out of the concrete once an inclined failure surface has formed. If unpredictable loads are applied to the flat slab-column connections, punching shear failure occurs with almost no warning signs. According to the brittle manner of this failure, the load carried by the slab-column connection redistributes to adjacent supports and can cause overloading to these supports. It is necessary to provide a secondary load carrying mechanism after punching shear failure. In this Paper, Suggestions for establishing a supporting mechanism in the flat slab connections after punching shear failure are proposed. For this purpose, an experimental study was performed to investigate the post-punching behavior of 11 slab specimens with various reinforcement layouts. The effects of integrity, compressive, shear and bent-up reinforcements on the post-punching behavior of slab-column connections were studied. The results of the experiments show that Integrity reinforcements significantly increased the post-punching shear strength.

the gaps. Automation in the hazard recognition was also utilized in some previous studies to enhance the safety on the job site. This study presents a novel framework to identify and rank the hazardous areas regarding the fatal fall hazard risk drivers on construction projects through the execution phase. The developed framework employs a customized Application Programming Interface (API) to identify the probability of falling from the height in each opening area based on the BIM approach. It also makes use of an image processing analytical model to identify the softness of the surface underneath to estimate the impact of the risk factors that can be used in safety planning process. Thus, the developed framework assists the safety managers on the job sites to identify the fall risk factors automatically. The obtained results in a commercial case study indicate that this model is capable of anticipating the fall risk appropriately. Moreover, it was shown that edges of surfaces would be more prone to be dangers than internal ones and height of fall was the factor most affecting the results.

Key Words: Fall hazard, building information modeling, safety, risk.

NUMERICAL MODELING OF INTERACTION BETWEEN MARINE WAVES AND INFLATABLE MARINE STRUCTURES

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Abstract

Inflatable marine structures are flexible cylindrical structures attached to a rigid base. These structures are generally cylindrical tubes, made of rubberized material, and inflated by air and/or water. Although these structures are permanently inflated, they have the advantage of being deflated and lie flat when not needed and then, inflated in a short period when required. They are relatively easy to install, do not corrode, require little maintenance, and have the capability to withstand extreme temperatures. Due to elasticity of the structure and continuous variation of its shape during operation, inflatable breakwater or sea-wall structural and hydraulic analyses are more complicated than the rigid types. Large deformation of the membrane due to the internal and external loads makes the governing equations of such problems non-linear and complex. In the present study, the behavior of an inflatable marine structure under loading by marine waves was simulated based on 2D numerical modeling. For this purpose, the deformed equilibrium geometry of the breakwater was calculated by solving the prevailing equations through the linear dynamic response of the system. The central difference method was employed to solve the governing equations of the linear dynamic response of the system of finite elements. According to the results of former studies, for 2D modeling of the aforementioned problem, the length of the tube was assumed infinity. Therefore, the effects of lateral supports and boundary conditions were neglected. This study carried out the numerical analysis of the inflatable marine structures for solving the flow-based problem associated with static and dynamic structural analyses. For this purpose, the two-dimensional fluid-structure interactions were analyzed numerically. It was shown that the equilibrium shape of the structure was a function of rubber thickness, elasticity modulus of the material, internal pressure, the dam foot width, and external loads. All the influential parameters of both flow and structure including internal pressure, water depth, wave height, wave period, etc. were attained based on the dimensional analysis. Accordingly, the results describing height and cross-sectional profile of the inflatable tubes loaded by marine waves were obtained.

Key Words: Central difference method, fluid-structure interaction, inflatable marine structures, numerical modeling.

A NEW FORMULATION FOR KINETIC DYNAMIC RELAXATION METHOD BASED ON LAGRANGIAN INTERPOLATION

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Abstract

The curve presenting the relationship between water content and the soil matric suction is called Soil Water Characteristic Curve (SWCC). The water retention potential of the soils is dependent on Grain Size Distributions (GSD), soil texture, and soils origins. Calcareous soils are soils with a high carbonate content, unique particle shapes, and high intraparticle porosity; and, they consist of skeletal remains of marine organisms. They are common in the tropics between30° North and South latitudes. Due to the nature of their origin, one of the most important attributes of the calcareous soils that makes their properties different from those of silicate soils is their significant intra-particle void space. The majority of near-surface soils are unsaturated over at least some portion of the year; consequently, the calcareous intra-particle porosity coupled with soil suction as the main characteristic of unsaturated soils signifies the necessity of the studies of calcareous soil behavior under unsaturated conditions. In this study, the Scanning Electron Microscopy (SEM) and Mercury Intrusion Prosimetry (MIP) tests were performed to study the particular microstructural characteristic of the calcareous soil particles compared with those of silicate soils. Besides, a series of tests were conducted for determining the Soil Water Characteristic Curve for different gradations of calcareous soil (from Hormoz Island of Iran) and reference Silicate soils using pressure plate and controlled-suction oedometer apparatuses in Laboratory of Soil Mechanics (LMS) at Ecole Polytechnique Federale de Lausanne (EPFL). Studies on the soil textures have revealed a further level of porosity in calcareous soil due to its intra-particle pores and the samples with larger grain sizes showed higher intra-particle porosity. The pressure plate test results showed that for similar gradations of silicate and calcareous soil in higher suctions, the calcareous soil retained much more water than the silicate soil due to its intra-particle voids. The controlled-suction oedometer showed that owing to their microstructural pores, the hydraulic hysteresis behavior of the calcareous soils would be different from that of the silicate soil.

Key Words: Unsaturated soil , calcareous soil, SWRC, hydraulic hysteresis, pressure plate extractor, controlled-suction oedometer, scanning electron microscopy (SEM), mercury intrusion prosimetry (MIP).

AUTOMATED ASSESSMENT OF FALL HAZARD RISK USING BUILDING INFORMATION MODELING AND IMAGE PROCESSING

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Abstract

Statistics of Occupational Safety all around the world shows that construction industry in many countries such as Iran experiences one of highest accident rates among all industry sectors; therefore, safety has a prominent role in construction project progress which is related to injury and fatality rates of the project. Falls from height can be enumerated as a major concern because they contribute to a great part of fatalities in construction projects. Various studies have been conducted to assess the risk and enhance safety on the job site. Because of the inefficiency of traditional risk assessment methods (e.g., expert view gathering and documentation of past incidents), novel trends and technologies such as Building Information Modeling (BIM) were utilized to fulfill

were considered. Also, different sizes of elements (1, 0.5, 0.25, and 0.125 m) were selected based on the shortest wavelength. The results showed that the receiver spacing should be proportional to half of the shortest wavelength and minimum thickness of the shallow layer. The resolution range of the dispersion spectrum increased approximately twice by increasing the length of the receiver arrays from 12 m to 24, 24 to 48, and 48 to 96 m. Also, the results of the element resizing showed that considering 8 or more elements (10) in one wavelength would be necessary to obtain the optimal accuracy of the simulations. Generally, with regard to the condition of the site and the expected goal, it could be possible to obtain suitable results with desirable accuracy in field-data acquisition analysis and software simulations by utilizing the effect of the mentioned parameters in different ranges. Moreover, the presented result in this paper can be used as guidelines for field parameters related to data acquisition in the MASW method.

Key Words: Surface wave, MASW, dispersion spectrum, receiver spacing, data acquisition, rayleigh waves.

FREE VIBRATION ANALYSIS OF TRANSVERSE ISOTROPIC THICK RECTANGULAR PLATES ON TWO-PARAMETER PASTERNAK FOUNDATION

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Abstract

In this research, an exact solution for free vibration analysis of thick transversely isotropic simply supported rectangular plates on the Pasternak foundation was proposed using the displacement potential function method. By means of the proposed displacement potential functions for dynamic problems by Eskandari-Ghadi, the differential governing equations in terms of displacements were converted into two linear partial differential equations of second and forth order. These differential equations were solved based on the separation of variables method and satisfying exact boundary conditions. In order to validate the results, the obtained results were compared with other available analytical works for isotropic and transversely isotropic plates, and it indicated remarkable agreement. Having no simplifying assumptions for the strain or stress distribution in the plate thickness, the obtained results in this paper were applicable to any arbitrary plate thickness with no limitation on its thickness ratio such as thin, moderately thick, and thick plates. Thus, the obtained results of the present work can be used as a benchmark solution for other analytical and numerical studies. To investigate the effect of various parameters on the vibrational plate response, the precise non-dimensional frequencies were obtained in different range of thickness ratios, aspect ratios, elastic foundation coefficients, and mechanical characteristics of plates. It was observed that with increasing thickness ratio and aspect ratio of the plate, the non-dimensional natural frequencies of plate decreased and increased, respectively. In addition, comparative results of isotropic and transversely isotropic plates showed that shear modulus in transverse direction would have significant influence on the vibrational behavior of rectangular plates. It was shown that when the value of the thickness ratio increased, the sensitivity of non-dimensional frequency response to values of foundation stiffness coefficients decreased. In addition, it can be conducted that the effect of the shearing layer of elastic foundation coefficient value increased by increasing the thickness ratios of plates.

Key Words: Free vibration, transversely isotropic, thick rectangular plates, pasternak foundation, displacement potential functions.

EVALUATION OF WATER RETENTION PROPERTIES OF HORMUZ ISLAND CALCAREOUS SOIL

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Abstracts of Papers in English

EFFECT OF ACQUISITION PARAMETERS ON THE RESOLUTION OF DISPERSION IMAGE IN MULTI-CHANNEL ANALYSIS OF SURFACE WAVES METHOD

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Abstract

Multi-channel Analysis of Surface Waves (MASW) is a method for determining the shear wave velocity profile in depth. Shear wave velocity is an important parameter for geotechnical, earthquake, and geophysical engineers. Configuration of data acquisition by the MASW method is variable based on the purpose of the work (depth of identification, data resolution, etc.). For instance, the resolution of dispersion image will be different according to the recorded data by different configurations of the MASW method. Hence, in this paper, the effects of data-acquisition parameters on the resolution of dispersion spectrum were evaluated in the frequency-velocity domain. These parameters consisted of the receiver spacing, length of the receiver array, offset, and the element size. Different receiver spacings with 8, 4, 2, and 1 meters were evaluated in two layered soil models with the shallow thickness of 2 and 4 meters. The distance between the source and the first receiver (offset) and the length of the receiver array were selected based on the desired depth and the maximum wavelength. In this regard, different lengths of the receiver array with dimensions of 96, 48, 24, and 12 meters