Abstracts of Papers in English

LONGITUDINAL GROOVES AS SUBSTITUTE METHOD FOR SURFACE PREPARATION IN FLEXURAL STRENGTHENING OF CONCRETE BEAMS

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Abstract

Fiber-reinforced polymer (FRP) composites have been considered as a practical and easy-to-use method for the rehabilitation and strengthening of concrete structures. They are being increasingly used as an alternative to steel for reinforcing and strengthening purposes. The main reasons for the increasingly vast interest in application of FRPs for the repair and strengthening of concrete members are: high strength, high modulus, corrosion resistance property, low weight and ease of use. Nevertheless, the debonding of FRP laminates from concrete substrate is a major problem, leading to a decrease in the expected capacity of the strengthened concrete member. To postpone the debonding of the laminates, surface preparation of the substrate is considered a "necessity". The purpose of surface preparation is to remove contamination and weak surface layers, to change the substrate surface roughness and to apply new surface chemical groups to promote the bond between FRP composites and concrete. However, conventional surface preparation is not so easy, in some cases, due to the high cost of preparation, non-access to the member surface, and environmental pollution, etc. In this paper, a new method, named; the Grooving Method (GM), is introduced, to promote the performance of FRP laminates from a debonding point of view. The method includes making longitudinal grooves on the concrete surface and filling the grooves with suitable epoxies. The experimental results of the surface preparation effect, and substitute methods to surface preparation, are presented. The results showed that making longitudinal grooves is a very good alternative to surface preparation to postpone the debonding failure of FRP strengthened concrete beams.

Key Words: strengthening, surface preparation, fiber reinforced polymers (FRP), rupture, concrete beams.

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TORSIONAL CONTROL OF MASS ECCENTRIC ONE STORY BUILDINGS BY FRICTION DAMPERS

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Abstract

Torsion has been recognized as a main failure mode in past earthquakes. One efficient method of reducing earthquake effects is the application of energy dissipation devices, such as dampers. Friction dampers are among the simplest energy dissipation devices. Although there is much research on the use of friction dampers in symmetric buildings, there are fewer studies reported on asymmetric buildings. Results of those limited past studies show that the performance of friction dampers in the control of torsion in asymmetric structures is considerable. The aim of this investigation is to determine effective parameters and their range of effective values for torsional control of asymmetric buildings by friction dampers. For this purpose, steel buildings have been modeled and analyzed by OpenSees. The asymmetric buildings in this study are assumed to be classified as mass eccentric buildings. These models are symmetric, with respect to stiffness and strength distribution, and their eccentricity is due to their asymmetric mass distribution. Different levels of mass eccentricity are considered in parametric studies. Damper placements are investigated to identify their optimum distribution in having the largest effect in reducing the adverse effect of torsion in asymmetric buildings. The characteristics of friction dampers are also changed to cover a wide range of realistic values. Also, considered in parametric studies, are the properties of braces, which are connected to the friction dampers. The effects of these parameters have been evaluated, not only in optimum placement, but, also, in the value of the slip load of friction dampers. The results show that the use of resulted optimum distribution and the recommended characteristics of friction dampers can control torsion in asymmetric buildings.

Key Words: torsion, energy dissipation, friction damper, mass eccentric.

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EVALUATION OF TURBULENCE MODELS IN SIMULATION OF OBLIQUE STANDING SHOCK WAVES IN SUPERCRITICAL CHANNEL FLOWS

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Abstract

In this article, the two-dimensional depth-averaged Saint Venant equations, including the turbulence terms, are solved in a supercritical flow with oblique standing waves, and the effects of several turbulence models on the performance of standing oblique shock waves are investigated. The algorithm applies the finite volume Roe-TVD method with unstructured triangular cells. To avoid spurious oscillations at regions where the gradients of the variable are considerable, advanced slope limiter functions are implemented in the numerical algorithm. The effects of bed slope, bed friction and turbulences are considered in the source terms. The bed slope and bed friction terms are computed using the data at the center of each cell. Three depth-averaged turbulence models, including the mixing length,k-ε, and algebraic stress model (ASM), are used to close the hydrodynamic equations. Some experiments are carried out in the flume of a hydraulic laboratory to examine the behavior of the oblique shock waves downstream of a side-baffle. The supercritical flow in the channel is then simulated numerically and results are compared with the experimental data. A comparison of the experimental results and numerical predictions confirm the robustness of the numerical model. In particular, implementation of turbulence models improves the results at the shock positions. Moreover, all of the models are able to simulate the vortex next to the baffle successfully. However, the k-ε model and the ASM demonstrate a stronger vortex pattern. Based on our overall findings, the ASM offer superior results to the other models. The quantitative error analysis confirms this finding as well. Our numerical experiments, however, revealed that amongst the source term components, the negligence of the turbulence terms produces the least relative depth error in comparison with the removal of the bed slope or bed friction terms.

Key Words: finite volume method, mixing length model, k-ε model, algebraic stress model, oblique standing waves.

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EFFICACY OF THE ENHANCED TRANSFORM IN COMPARISON WITH THE CLASSIC HILBERT-HUANG METHOD

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Abstract

The Hilbert-Huang transform (HHT) consists of empirical mode decomposition (EMD) and Hilbert spectral analysis. EMD, as the key part, decomposes a signal to a set of intrinsic mode functions (IMFs), which satisfy the necessary condition to apply Hilbert spectral analysis. Then, Hilbert spectral analysis, by use of the Hilbert transform, presents time-frequency-amplitude characteristics of the signal in a Hilbert spectrum. The latter part of HHT has some mathematical limitations, which may strongly affect the accuracy and efficacy of the results obtained from the HHT method. Also, noise effects inherently existing in wideband signals result in large scattering on recognition of instantaneous frequencies of the IMFs determined by the Hilbert transform. In addition, the large variation of instantaneous frequencies of the first few IMFs leads to the deteriorated readability of the Hilbert spectrum, especially at higher frequency ranges. In the present paper, in order to bypass the above mentioned limitations in Hilbert spectral analysis, a new enhanced Hilbert-Huang transform (EHHT), in which the mathematical limitations of the Hilbert spectral analysis are avoided by use of an additional parameter, is employed to reduce noise effects on the instantaneous frequency of IMFs. Four numerical examples are presented in order to demonstrate the efficacy of the enhanced method. In the first case, a two-component, nonstationary signal, with known frequency modulation, is analyzed by the EHHT method to investigate the ability of the method in accurate estimation of frequency in the time domain. In the second case, to examine the accuracy of the enhanced method in estimation of the envelope of frequency, the ambient response of a typical 3-DOF system with known modal frequencies is considered through the EHHT method. To show the effectiveness of EHHT to improve the readability of the time-frequency-amplitude of the wideband signals, the ground motion record of the El Centro earthquake (1940, N—S) is studied, as a third case. Finally, in the fourth case, the ability of EHHT to make an exact 90 degree shift in the phase functions of IMFs is demonstrated. In each case, results of HHT and EHHT are compared together. The case studies indicate that the proposed EHHT method provides more accurate and physically meaningful results than HHT and is able to be applied as an efficient tool for the time-frequency analysis of signals.

Key Words: HHT, EHHT, hilbert spectrum, instantaneous frequency, T-F-A spectrum, phase function.

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THE INFLUENCE OF LOADING RATE ON THE BEARING CAPACITY OF STRIP FOOTINGS RESTING ON GEOGRID REINFORCED SAND

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Abstract

The loading rate is an effective factor influencing the interaction between soil and foundation. Increasing the loading rate on different footings, particularly those resting on saturated or partially saturated soils may result in a rapid build-up of pore pressure and foundation failure due to a sudden decrease in effective stresses. The problem would be of greater importance in many special foundations, such as those designed to resist explosions, or missile launching platforms, which are under shock and impact loadings.

Numerical modeling of this case for dry soils is not possible without developing an appropriate behavioral model, since, in most numerical modeling, the soil is assumed to be a continuum medium. The existing routine models usually evaluate the influence of the loading rate on the liquid phase, and, then, assess the counter effect of the liquid phase on the whole medium. Because development of a suitable model needs a physical modeling, similar to real conditions, to be undertaken, the present study may play an effective role, in this respect, for backing by a new physical model.

In the current research, first, some tests are carried out on soil and the geogrid to determine the physical and mechanical characteristics of the materials, and, then, the initial tests for modeling are implemented using a new physical model developed in the soil laboratory of Amirkabir University of Technology (Mir Hosseini & Abrishami). The capability of the model was checked and evaluated during these tests, as well as the design and planning of the main test programs, to investigate the different effects of soil-foundation interaction, such as loading rate, on reinforced soils.

The main tests in this study consist of two groups, namely: reinforced and unreinforced. The major objective of the unreinforced tests was to get some experimental data as a base reference for evaluation and comparison of the behavior of the footing on reinforced soil. In the group of reinforced tests, a different series of experiments were carried out for different purposes, one of which was planned to study the effect of loading rate on ultimate bearing capacity, and, also, the behavior of footings on sands reinforced by geogrids. Sand density

and the method of testing were quite the same as those used in unreinforced tests. The only difference in this series was the presence of a geogrid layer located at optimum depth, which was revealed to be half of the footing width, according to the results of the initial experiments. Based on the results of the performed tests in this series, the ultimate bearing capacity of reinforced sand, in the opposite direction to unreinforced sand, decreases as the loading rate increases. The amount of bearing capacity reduction is about 12 percent compared to that of unreinforced soils. However, the final settlement of the footing on reinforced sand increases about 10 percent, and the total stiffness of the system is reduced. The main reason for these findings may be attributed to the lack of sufficient time which is needed for the interaction between soils and geogrids to happen entirely. Increasing the loading rate, together with soil inertia, may cause the stress distribution in the mass to attain the state close to punching failure. As a result, a higher stress magnitude is applied to a small area of geogrid, leading to an increase in strain and settlement, and a reduction in bearing capacity, accordingly.

Some other important findings associated with the loading rate on footings resting on reinforced sand have been resulted, a detailed description and technical discussion of which are presented in the full paper.

Key Words: reinforced soil, geogrid, sand, rate of loading, physical modeling, bearing capacity, settlement.

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THE EFFECT OF SOIL MECHANICAL PROPERTIES ON RESPONSE OF SOIL-PILE SYSTEMS UNDER EARTHQUAKE LOADING

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Abstract

In the last few years, although considerable progress has been made in developing methods of analysis and understanding of phenomena related to dynamic soil-pile interaction, much has still to be learned through systematic parametric studies. Due to the progressing knowledge and capabilities of computer software and hardware, a significant amount of study has been conducted to investigate the effect of changes in environmental conditions around the piles on the soil-pile behavior under dynamic analysis. The necessity of evaluating the effects of changes in the soil profile around the pile has significant importance. In this research, dynamic interaction between pile and soil has been examined, and the current methods were introduced. With the aim of a better understanding of the problem, first, a brief review was made on previous research. Then, the behavior of pile-soil under earthquake load and with geotechnical problems has been discussed using Finite Difference Software i.e., FLAC3D. Through using different types of accelerogram, dynamic analysis was conducted to evaluate the effective factors on interaction, such as a comparison of elastic and Mohr-Coulomb elastoplastic behavior. In order to obtain the above-mentioned goals, kinematic effects are described by frequency dependence on the transfer function. The transfer function is defined in the frequency domain as the relative movement of the foundation to a free field in the absence of a structure. The obtained results from analysis are presented as an acceleration time history, as well as the Fast Fourier Transformation of the acceleration of a head pile in relation to a free field in the frequency domain. Maximum shear force and flexural moment applied to the pile have been compared in different modeling. Based on the analysis results, the difference in the stiffness of soil layers may have an appreciable influence on the soil-pile interaction. It should be mentioned that the condition of two-layer soil is more critical than one-layer soft soil, and the lowest interaction, displacement and maximum moment were observed in one-layer soil.

Key Words: dynamic analysis, kinematic interaction, soil-pile behavior, earthquake loading, fast fourier transformation, acceleration time history.

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EXPERIMENTAL BEHAVIOR OF BRICK-INFILLED CONCRETE FRAMES STRENGTHENED BY CFRP WITH IMPROVED ATTACHING TECHNIQUE

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Abstract

Due to various deficiencies and inadequate lateral stiffness, many reinforced concrete buildings have been highly damaged or collapsed in Iran and throughout the world

during the last major earthquakes. In this study, the retrofitting of undamaged infilled reinforced concrete frames using carbon fibre-reinforced polymer (CFRP) is discussed in detail. The main objective of the extensive experimental program is to reinforce the masonry infilled concrete frames, which are known to contribute to the seismic performance of the reinforced concrete structures significantly, and to improve the behavior of such buildings to prevent total collapse. CFRP sheets are wrapped around the top and bottom of the columns to prevent column shear failure, which is known as a catastrophic failure mode. CFRP sheets are also attached to the masonry wall faces and anchored to the concrete frame to carry diagonal tension. The frame of the specimens is designed and detailed in accordance to the Iranian old codes. Four, 1/2 scaled, 1-story, 1-bay, brick infilled concrete frame are tested; namely, a control specimen and three rehabilitated specimens. The specimens are tested under reversed cyclic quasi-dynamic load to failure. The strength, stiffness, and story drifts of the test specimens are determined. The control specimen showed combined brittle column shear and corner crushing infill failure modes, while the rehabilitated specimens showed a more ductile failure mode. CFRP sheets improved the structural integrity and prevented collapse and debris fallout. The experimental results show that CFRP strengthening would not be effective unless CFRP is properly anchored to the infill and the frame members. The maximum increase in initial lateral stiffness due to strengthening was about 10%. But, if the lateral stiffness of the structure, considering that the contribution of the infills is adequate to control the drift of the frames, the increase in strength due to CFRP strengthening, without significant increase in stiffness, can be considered as an advantage. This paper is to discuss the specific design, test setup, and analytical and theoretical background, as well as improved results, that were obtained during testing. Finally, a series of recommendations is proposed for the actual use of CFRP's in industry.

Key Words: concrete, infilled frame, CFRP, masonry, retrofitting.

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CENTRALIZED AND DECENTRALIZED ACTIVE CONTROL OF 3-DIMENSIONAL STRUCTURAL MODELS WITH VELOCITY AND DISPLACEMENT FEEDBACK

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Abstract

The application of control systems, active or passive, in reducing structural vibrations has been explored during the last few decades; some of them being practically employed. However, in large structural systems, the transfer of data from the sensors located at different places in the system to the processors, and sending back the control signals to the actuators in a very short time, is of great concern. That is the main reason behind the new concept of segregation of original large structural systems into smaller controllable units. In this paper, besides reviewing existing algorithms for centralized active control of tall buildings, the concept of decentralized active control of large structural systems is elaborated, and its application to the control of 3-D structural models is demonstrated. For this purpose, while proposing a method to divide 3-D structural models into several substructures, a velocity-displacement feedback control algorithm is used to reduce the response of the sub-structures. In the considered performance index for derivation of the control algorithm, the weighting matrices are determined using the Lyaponuv function to guarantee the stability of the dynamic system. It is followed by a case study, in which the performance of the decentralized control is compared with that of the regular centralized control approach. It is assumed that the actuators are located on all floors. Extensive parametric studies are performed to determine the sensitivity of the proposed control algorithm to a number of parameters, such as the number and size of substructures, eccentricity, and type of earthquake records. The obtained results indicate that, in all cases, the control algorithm guarantees the stability of the structural models, and the performance of the centralized and decentralized control approaches are almost the same. The effect of eccentricity is investigated using a number of earthquake records. It is shown that more control forces are needed in eccentric buildings, caused by the lateral-torsional seismic response of the structural system. The optimization of the size and number of sub-structures, to minimize the required control forces, is not the aim of this study, and will be dealt with in future work. In the developed control algorithms, both the structural model and the control system are assumed to behave linearly, and no time delay is considered in activation of the actuators (active

tendons). Matlab software was used for performing the numerical analysis.

Key Words: decentralized control, active control, displacement-velocity feedback, lyapunov function.

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PROPOSED EQUATIONS FOR PERMANENT SEISMIC DISPLACEMENT OF SLOPES ACCORDING TO IRAN SEISMIC DATA

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Abstract

Every year, a great deal of financial damage and many casualties occur during earthquakes, due to the sliding of slopes in various parts of the world. Iran is a mountainous country located on a seismic zone, where many buildings are constructed on natural slopes. Seismic slope stability analyses mainly consist of pseudo statistical methods, dynamic analysis and simplified methods, which are based on estimation of an index displacement. In this paper, a number of relations for determining the permanent seismic displacement of slopes is proposed based on the available seismic data of Iran. The study was conducted based on dynamic analysis of different slopes, evaluation of earthquake acceleration in a sliding mass, and calculating the permanent displacement of the slope, using the Newmark sliding block .A two dimensional model of a typical slope was considered, and, by conducting dynamic analyses, the slope performance was studied for different geometries, strength parameters and shear wave velocities. Such a performance has been studied by assessing the record of acceleration in a sliding mass (the mass above the critical sliding surface), and calculating the slope displacement, using the Newmark method.

Due to the limited number of strong ground motion records for a specific area in Iran, records related to the earthquake events in the whole country were gathered, 14 of which, related to 6 earthquakes with the largest magnitudes and accelerations, were chosen for dynamic analyses. A range of soil strength parameters and shear wave velocities were considered and the slopes were analyzed.

The proposed relations in this paper can be used in the seismic design of slopes by choosing an allowable displacement and determining the proper pseudo-static coefficient. Results of this study show that the seismic permanent displacement of a slope is mainly affected by the ratio of critical acceleration to maximum acceleration in the sliding mass (k_{max}/ k_y). Also, it was found that seismic permanent displacements by the proposed relations are less than those proposed by the "Guidelines for Analyzing and Mitigating Landslide Hazards in California.

Key Words: permanent displacement, seismic design of slopes, acceleration of sliding mass, screen analysis, performance design.

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STABILITY OF ENGINEERING AND RHEOLOGICAL PROPERTIES OF BENTONITE DUE TO TEMPERATURE VARIATIONS IN RADIOACTIVE WASTE DISPOSAL

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Abstract

Bentonite is commonly used as a buffer material in high level nuclear waste (HLW) repositories due to its swelling and water adsorption properties. The stability of the engineering and rheological properties of bentonite is an essential factor in radioactive waste disposal projects. Such a change in properties might occur, due to the high temperature in HLW repositories. In spite of much research conducted on the stability of mechanical properties of bentonite, there has not been enough attention paid to the temperature impact on the stability of these properties. Therefore, the main objective of this paper is to focus attention on the stability of the engineering and rheological properties of bentonite, due to temperature variations in radioactive waste disposal. To achieve this objective, a series of mechanical and geo-environmental experiments were performed. These include Atterberg limit testing, suction experiments, XRD, viscosity measurement, and the swelling experiment. These experiments were performed after curing samples under dif-

ferent temperature conditions. The smectite soil used in this research was provided by the "Iran Barit Company". The engineering analyses were conducted using the procedures described in the laboratory manual of the Geotechnical Research Center of McGill University and in the manual of EPA.
The experimental results of this paper show that an increase in temperature will change the initial properties of bentonite. These changes mainly occur if the temperature goes above 100 C°. According to the achieved results, at temperatures above 200 C°, there will be 15 percent reduction in water retention and 8% reduction in the swelling of bentonite. In addition, based on viscosity and XRD results, the change in bentonite properties can be attributed to the change in attraction and repulsive forces among clay particles, which create a noticeable change in the microstructure of soil. Furthermore, according to experimental results, it is concluded that the impact of temperature changes on the micro-structural units of smectite will contribute to the building blocks for the macro-structure of the clay soil. Also, the influence of temperature on micropores and macropores forms the overall soil structure, which will change the permeability of heated smectite. Finally, it is concluded that the instability of bentonite properties at temperatures above 100 C° makes it necessary to control the temperature of radioactive waste under 100 C° prior to their disposal.

Key Words: radioactive waste, temperature, bentonite, structural change, change in engineering properties, XRD.

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DAMAGE ASSESSMENT AND RETROFITTING OF WALL & SLAB SYSTEMS BY NONLINEAR STATIC ANALYSIS

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Abstract
The Wall & Slab system is one of the most widespread conventional systems used in Iran and other countries like Turkey, Chile, and Canada, etc. Buildings with a Wall & Slab system diverge from other conventional reinforced concrete structures due to the absence of beams and columns in their structural system. Post-earthquake reconnaissance missions reported the surprisingly good seismic behavior of structural wall buildings, and, because of their good performance in past earthquakes, this system has been widely used since then. Instructions of damage assessment have not mentioned any separate procedure for structures of this type. Practical studies on Slab & Wall systems specifying nonlinear behavior to the walls are very important because there is no special standard for these buildings and information about how to evaluate their seismic behavior is not sufficient.
Vulnerability assessment has become more important than ever since structural designers started to employ performance based design methods, which require that structural and member behaviour at different limit states be predicted precisely. For investigation into the performance of systems, this article uses nonlinear static analysis instead of other simple and unreal methods that only estimate wall behavior in linear form. Investigations into Slab & Wall structures with simple symmetric plans and primary designs, on the basis of the 3rd version of the Iranian Seismic Building Code (2800), in four, eight and twelve stories, is done for the basic safety objective (BSO) level of instruction for seismic rehabilitation. These buildings are made as three-dimensional space frame structures, with shear walls in both orthogonal directions, in ETABS 9.1.6 software, according to ACI 2005 for the initial design, and Ram Perform 3D 4.0.1 software is used for nonlinear analysis. For modelling the nonlinear behaviour of the wall, in this analytical program, a section analysis using a fibre model was employed. The results of analysis showed that the structures had the expected performance.

Key Words: damage assessment, nonlinear static analysis, wall & slab system.

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A STUDY ON THE VARIATION OF COMPRESSIVE STRENGTH AND POROSITY IN THE CENTER OF MASSIVE HIGH STRENGTH CONCRETE

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Abstract
An investigation was carried out to compare the effects of hydration heat and standard curing on the strength development and absorption water capacity of high strength concrete. In this regard, a temperature matched curing system (TMCS) was designed for simulation of

the temperature rising of massive concrete within early stages. In this way, the freshly mixed concrete was cast into a cylindrical(150 × 300-mm) mold and placed in a semi-adiabatic chamber. A thermocouple was dipped in the sample and the history of the temperature rising of the mixtures, via the designed system, was applied to the concrete samples, which were put inside a box to simulate hydration heat cured samples. Eight mixed proportions, with a water-binder ratio of 0.3, were prepared and the specimens were cured under both standard and heat curing conditions. Natural pozzolan, at 15% and 30%, and low-calcium fly ash, at 15% and 25%, by weight of cement, were used as a replacement for cement in the mixtures. Cement was also replaced by silica fume at three percentages of 5, 8 and 11. The results showed that the peak temperature of both natural pozzolan and fly ash specimens decreased compared to those made without pozzolan, whereas silica fume had no impact on the peak temperature of the mixtures. The results also declared that both early and later stages of compressive strength were seriously affected by the curing condition. Hydration heat curing, due to the rising temperature, had a positive impact on the later stage strengths of natural pozzolan and fly ash specimens, whereas heat curing diminished the later stage strengths of silica fume specimens. The later stage strengths decreased as the percentage of silica fume increased. These findings revealed that care should be taken for utilization of silica fume in massive concrete structures. It is also concluded that a later stage of 91 days was more conservative for the specified strength of mass concrete. The results also showed that utilization of natural pozzolan, fly ash and silica fume diminished the absorption water capacity of the heat cured specimens, compared to those cured under standard conditions.

Key Words: mass concrete, hydration heat, pozzolan, compressive strength, absorption water.

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EFFECT OF FRP STRENGTHENING FOR CONFINEMENT OF BOUNDARY ELEMENTS ON THE BEHAVIOR OF REINFORCED CONCRETE SHEAR WALLS

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Abstract

Concrete shear walls are major systems resisting lateral loads due to earthquakes in high rise buildings. Nevertheless, structural damage and early code shortcomings have effectively harmed the function of existing structural walls against earthquakes. In recent years, Fiber Reinforced Polymer (FRP) materials have been used extensively in the strengthening and retrofitting of structural elements. The excellent features of FRP materials, such as very high tensile strength, high tensile modulus, low density, and corrosion resistance, set them as the first alternative in strengthening projects. However, a review on previous studies shows that, so far, very limited analytical and/or experimental studies have been conducted on the FRP strengthening of slender RC shear walls under monotonic loading. In this study, the effect of FRP confinement of boundary elements in slender RC shear walls on the overall behavior of boundary elements is investigated. The finite element software is calibrated and verified using available experimental data. Nonlinear finite element analysis of reinforced concrete walls is performed using a damage plasticity model and tension stiffening effects. Results show that longitudinal strengthening plays a major role in the wall load carrying capacity, while transverse strengthening for confinement considerably affects wall displacement and ductility. Furthermore, increasing the number of FRP layers has a significant effect on overall wall behavior. In addition, results show that in the wall strengthening layout, it is sufficient to emphasize boundary elements only in the plastic hinge region.

Key Words: shear wall, finite element analysis, damage plasticity model, tension stiffening, strengthening, FRP.

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DASHTEGAN-RUDBAR HUGE LANDSLIDE (RASHT — QAZVIN, FREEWAY ROUTE): INVESTIGATION AND METHOD OF STABILIZATION

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Abstract

The huge landslide of Dashtegan—Rudbar occurred on the Rasht-Qazvin freeway of Guilan province in Iran. This region is located in the western part of the Alborz Mountains, in the northern area of Iran, which is prone to landslides, due to seismic and tectonic activity and specific geological conditions. The landslide of Dashtegan—Rudbar involved 1.5 million cubic meters mass volume of soil and rock, beginning in December 2004, and, finally, occurring, after six months, in June 2005. These events blocked the Rasht—Qazvin freeway route, and stopped the executive procedure of freeway construction. The upper part geometry is a mixture of soil and rock, underlain by a silty clay layer located on the bedrock. In this paper, after gathering geological and geotechnical information, stability control and back analyses were performed by GEOSLOPE software for an unsaturated state (before sliding). The back analysis shows a factor of safety at about 1.2 for the critical section of the unsaturated condition, which indicates a stable situation in advance of any sliding. Investigations denote that major factors for sliding are related to the great reduction of soil strength parameters in fine-grained portions, due to water infiltration from the upper part, and the consequences of excavations at the toe level of the slope, which removed the supporting passive zone. A couple of remediation methods, including excavation of the upper part, overburdened geomaterial mass, and different cantilever retaining wall systems, have been studied to prevent long-term delay in project blockage, and a decrease in costs and expenses prior to the sliding failure mechanism, so that the construction work of freeways may be continued. Stability analysis, regarding the retaining wall supported by guard piles, indicates reasonable earth work and less shear and moment forces at the wall base, which lead to optimum structural design. Realizing technical, economical and practical aspects, the cantilever retaining wall supported by guard piles, among other measures, is the superior alternative.

Key Words: dashtegan-rudbar huge landslide, slope stability, back analysis, retaining wall, guard pile.

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