Abstracts of Papers in English

EXPERIMENTAL INVESTIGATION OF THE IMPACT OF THE SPOILER AND PIGGYBACK LINE ON SCOUR HOLES OF THE PARALLEL PIPE LINES UNDER THE ERODIBLE BED

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Abstract

The bed formations of submarine pipelines models were measured to investigate the effect of design parameters such as the distance between two submarine pipelines and also the effect of adjusted rectangular spoiler due to different angles of adjustment. To investigate the hydraulic parameters, three experimental models of parallel pipelines with three distances were made through the hydraulic laboratory. By considering the threshold velocity, the bed profiles were measured experimentally by employing the point gauge apparatus due to changing the angle of considered spoilers. Results indicate that increasing the distance between two submarine pipelines is the reason why that the downstream scour hole was formed independently from the upstream scour hole, which was developed under the upstream pipelines. Also, due to different angles of spoilers, the scour hole of spoiler with angle 90o formed the same as the witness model (with no spoiler), showing that angle 90o has no marginal effect on scour hole formation process. However, the angle of 180o adjusted on two submarine pipelines made the maximum scour hole under the upstream and downstream pipelines. It is assumed that the

spoiler 180o affects the downstream flow of the pipelines and by creating the region with low pressure behind the pipelines, the scour holes were plunged to the bed and the depth of the scour holes increased significantly. Also, the investigation of spoiler position on the two pipe lines illustrates that by adjusting the spoiler on the downstream pipelines, the downstream pipe was buried under the sediment. These conditions were observed by angles of 135o, 180o, and 225o. It is assumed that increasing the distance between two submarine pipelines diminishes the rate of self-burial conditions. It appears that by increasing the distance between two pipelines, the effect of the upstream pipeline was omitted because the downstream and upstream pipelines were scoured as two single pipes; thus, the upstream pipelines did not affect the downstream pipelines.

Key Words: Scour hole, parallel pipeline, submarine, spoiler, -piggy back line.

INVESTIGATION OF AREAS AFFECTED BY VERTICAL CONCAVE CORNERS DURING VERY DEEP EXCAVATIONS AND DETERMINATION OF THE PLAIN STRAIN RATIO

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Abstract

The mechanism of deformation in very deep excavation is more complex than in shallow excavations. The deformation of the excavation near the corners is lower and a three-dimensional effect can be considered in the design in order to optimize very deep excavations. On the other hand, in practical projects, three-dimensional modeling is avoided and the plain strain models ordinary has been used which will increase the project costs. It must also be ensured that the assumption of a plain strain governs the problem. This study examines the results of monitoring a very deep excavation to a depth of 60 meters which has been stabilized by the anchorage method, validates a three-dimensional model, and considers the vertical concave corner effect in three-dimensional models including factors such as the depth and length of the excavation. Also, the Plain Strain Ratio (PSR) in this excavation is evaluated in accordance with parametric studies. The lowest value of the PSR occurred at a distance of 5 m from the corner and was equal to 0.45. By maintaining the maximum deformation, the length of the anchors was designed first without considering the three-dimensional effect; in another case, the effect of the corners was considered and the volumes were compared. The results showed that if the corner effect was included in the design of the stabilization method, about 21% to 55% of the total length of the anchors would be saved, being dependent on the excavation depth. The minimum and maximum values of the plain strain ratio in the corner and middle of the excavation are the same in all dimensions and are equal to 0.75 to 1. Due to the equality of the dimensions of the excavation (length and height), none of them has an effect on the range of the plain strain ratio values.

Key Words: Very deep excavation, corner effect, plain strain ratio, anchor, optimization.

MACHINE LEARNING-BASED REGRESSION MODELS FOR ESTIMATING SEISMIC RETROFIT COST OF MASONRY BUILDINGS

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Abstract

Retrofit actions are amongst the most commonly used measures for reducing the seismic vulnerability of build-

ings. For any given building, multiple seismic retrofit options are often available. Each option has specific requirements, cost, and performance. Estimating the cost of each candidate action is essential to the selection, planning, and implementation of seismic retrofit initiatives. Primary cost estimation plays a vital role in allocating budget for retrofit projects. Past studies used a variety of methods to develop cost estimation models. This research harnesses the capabilities of various regression models via modern machine learning methods for cost estimation. A dataset from 167 retrofit projects for masonry school buildings in Iran was used to develop models. Three main retrofit actions were implemented in the projects, namely Shotcrete, Steel belt, and Fiber reinforced polymer. Several regression methods including multiple linear regression, ridge regression, lasso regression, and also elastic net regression were applied to the dataset. The proposed framework comprised 12 models, which were attained by four regression methods on three retrofit actions. The cross-validation method was used for model evaluation in order to use all available data for training and testing. The model at the beginning of the development process contained all the probable effective parameters. Next, to increase the simplicity and accuracy of the models, a simple model reduction method was implemented. This model reduction method eliminated almost two-thirds of the parameters in the majority of basic models. Then, the candidate models were evaluated in terms of quantity and quality of prediction, heteroscedasticity, autocorrelation of residuals, and non-normality. This paper identifies the height of the building as the most influential parameter governing retrofit cost. Furthermore, lateral area of walls, footprint area, and added lateral strength are influential in the mentioned retrofit actions. This research contributes to enhancing the understanding of the factors, the effects, and the costs of the retrofit actions.

Key Words: Seismic retrofit, cost estimation, machine learning, regression.

SEISMIC ANALYSIS OF DAM-FOUNDATION-RESERVOIR-FAULT SYSTEM BY HYBRID DISCRETE WAVENUMBER-FINITE ELEMENT METHOD

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Abstract

Safety assessment of dams as an important part of infrastructure of any country hinges on proper and precise modeling of the coupled system of dam-foundation-reservoir under appropriate seismic excitation. To simulate more realistic earthquake conditions, it is necessary to consider the seismic source, propagation path, and site effects despite the challenges and complexities using appropriate and efficient methods in seismic analysis of structures. In addition to the complexities of numerical modeling in dynamic analysis of the dam-foundation-reservoir system due to the different behavior of the three domains and infinite dimension of foundation and reservoir, dam-foundation-reservoir-fault system analysis is a multi-scale problem. In far field, the seismic source and propagation path effects on an seismological scale with dimensions of kilometers and in near field, the dam-foundation-reservoir system on an engineering scale with dimensions of meter are modeled and analysis results are presented in centimeters. The purpose of this paper is to present a hybrid method of combining discrete wave number and finite element methods based on Domain Reduction Method (DRM) for analysis of dam-foundation-reservoir-fault system. Domain reduction method is a two-step procedure that makes it possible to combine different numerical and analytical methods in the complex large-scale seismic problems assessment. After describing the domain reduction method theory, its implementation in commercial software ABAQUS has been verified with analytical solution for wave propagation. The verification results of the proposed method show that this method can consider the effects of fault and the seismic wave propagation path under real earthquake scenarios and it is cost effective in terms of computational cost. Koyna concrete gravity dam is analyzed under a specific earthquake scenario considering all the interactions by using the proposed method and the conventional massless foundation method. Comparison between the responses obtained from two methods indicates that the maximum tensile

stress and relative displacement of dam crest with the conventional assumptions are higher than the proposed method. The presented hybrid method in this paper, in addition to having the capabilities of the finite element method in solving the complex dam-foundation-reservoir problem, can accurately consider the effects of faults and the seismic wave propagation path in academic and engineering problems.

Key Words: Dam-foundation-reservoir-fault system, domain reduction method (DRM), seismic analysis, seismic wave propagation, numerical solution.

SEISMIC RESILIENCY ASSESSMENT OF STEEL MOMENT FRAMES WITH NONLINEAR VISCOUS DAMPERS UNDER SECONDARY EARTHQUAKE

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Abstract

Incidents such as earthquakes have led to the formation of a new concept in the analysis of structures and response to events. Resilience is the ability of a system to maintain the desired level of performance and return to service when facing the risks that occur in the structural life cycle. The research process is based on resiliency and calculation of its parameters through maximum structural drift. Three steel moment frames are analyzed based on nonlinear time history analysis under two primary and secondary earthquake records. For damaged frames, viscous dampers with different damping percentages are installed and the intensity of seismic records is increased to the point of structural collapse. It is observed that the presence of dampers in the structure under secondary earthquake results in reduced drift and relative displacement in the floors. Resiliency diagrams of frames are drawn and values of resiliency parameters are calculated. Decreasing the alpha coefficient for each damping percentage increases the robustness coefficient and also increases the level below the resilience diagram for the final performance of the frames. Based on the comparison between alpha coefficient and damping percentage, it has been found that the effect of damping percentage on drift reduction is greater than damping alpha coefficient. It can also be said that the 9-story structure has shown lower resistance to earthquakes and 3-story structure has the best resilient performance.

Key Words: Seismic resiliency, steel moment frame, nonlinear viscous damper, maximum drift, structural control.

EVALUATION OF DUAL SYSTEMS WITH MOMENT-RESISTING FRAME AND SHEAR LINK FRAME

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Abstract

This paper puts forward a new dual system to dissipate energy and presents its numerical studies. Though moment-resisting frames have a good ductility performance, they suffer low stiffness; as a matter of fact, engineers try to increase the stiffness by reducing the span length of these frames. On the other hand, in order to ensure the formation of plastic hinges at the two ends of the beam, the codes suggest a minimum limit for the clear span-to-depth ratio of such frames.

To solve this problem, this paper proposes a new dual system. The proposed dual system includes a moment resting frame and a frame with a replaceable beam with a smaller cross-section than that of the main beam which is placed at the mid-span of the beam designed to act as a shear fuse. This shifts the location of the plastic hinge from the ends of the beam to its middle since the

shear fuse yields shear prior to the flexural yielding of the main beam. This dual system eliminates the need to comply with the rigorous limitation on the clear span to depth ratio of beam that is proposed by seismic design codes. Moreover, this system enjoys an increase in the amount of stiffness. It is worth mentioning that this dual system increases the resilience of the building as the shear fuse is readily replaceable after an earthquake. With verification of an experimental model, the finite element numerical models are produced. The ABAQUS numerical models show that the system which includes both moment-resisting frame and shear link frame function much better than the moment-resisting frame system. As a result, by enjoying this dual system as well as using the ductility of moment-resisting frames, the stiffness of the building does not decrease noticeably.

Key Words: Moment resisting frame, dual system, shear link, low span to depth ratio.

INVESTIGATION OF EFFECTIVE PARAMETERS IN SHORT COLUMN FAILURE USING CORRELATION AND MACHINE LEARNING METHODS

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Abstract

Column shear failure remains one of the most important causes of damage and collapse of reinforced concrete buildings during recent earthquakes, which should be avoided due to its low ductility and brittle failure mechanism. In previous studies, various parameters have been introduced as effective factors in short column mechanism and in each case, the effect of some of them has been studied. However, there is no comprehensive study that investigates the importance of all of these parameters. In this paper, using Monte Carlo algorithm and considering the normal distribution for 10 effective parameters in short column formation, including column cross-section size, column longitudinal reinforcement ratio, column transverse reinforcement ratio, effective column length, concrete compressive strength, reinforcement yield strength, beam length, axial force ratio, infill wall to column height ratio, and wall thickness, a database consisting of 200,000 samples is created. OpenSees software is used to model the concrete moment frame by considering the flexural and shear behavior of the column, and the model is verified by comparison with experimental studies. Then, by using push-over analysis, the type of failure mechanism of the column in a moment frame with infill and opening is determined to be flexural or shear failure. The importance of each parameter is investigated using machine learning methods including Principal Component Analysis (PCA), Decision Tree (DT), and F-Test (FT) as well as Pearson and Spearman correlation methods. DT and FT machine learning methods as well as both Pearson and Spearman correlation methods are well able to identify the importance of each parameter in the formation of the short column. By summarizing the results of all methods, the parameters of the percentage of column shear reinforcement as well as the ratio of wall to column height have been determined as the most important and effective parameters. Also, the least important parameters are fy, L-Beam and axial load ratio. The result of this paper will be useful for designer of RC building and also to develop models and criteria for rapid short column identification in seismic evaluation of existing buildings.

Key Words: Short column, pushover analysis, monte carlo, machine learning, correlation analysis.

INVESTIGATION OF THE BEHAVIOR OF STABILIZED SILTY SAND WITH COLLOIDAL SILICA AGAINST LIQUEFACTION

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Abstract

Chemical injection is a useful geotechnical procedure for stabilizing soils and also making them impermeable. For characterizing the soil stabilized by colloidal silica, the clean and silty sand samples with silt values of 20 and 40 percent, in both unstabilized and stabilized conditions, were prepared with different concentrations of the stabilizer from 5 to 30 percent, and the effects of colloidal silica on its behavior were evaluated under cyclic loading. 30 cyclic triaxial tests were performed on various samples. A 100 kPa confining pressure was used in these tests. All 15 experimental samples were loaded at cyclic stress ratios of 0.2 and 0.4 with a frequency of 1 Hz and up to 200 sinusoidal cycles. In this research, for the stabilized and unstabilized samples, the double amplitude of axial strain of five percent or the pore water pressure ratio of one, whichever occurs earlier, was considered as the liquefaction criterion. By performing cyclic triaxial tests, it was observed that by stabilizing clean and silty sand with colloidal silica, liquefaction phenomenon is postponed. Thus, adding even low concentration of colloidal silica such as 5 percent can prevent liquefaction of soil at the low level of dynamic loads (such as cyclic stress of 0.2). By adding colloidal silica, the double amplitude of axial strain and the pore water pressure ratio were reduced in cyclic loading. For example, in silty sand with a silt content of 40%, by increasing the stabilizing concentration from 10% to 30%, the pore water pressure ratio reduced from 1 (the state of full liquefaction) in 10 cycles to about 0.1 in 100 cycles, and also the double amplitude of axial strain decreased from 5% in 10 cycles to about 0.7% in 100 loading cycles. Gelatinization of colloidal silica between soil grains causes elastic behavior for the soil sample and prevents permanent deformation between soil grains. Reducing permanent deformation in undrained conditions reduces the development of excess pore water pressure in the soil during cyclic loading. The choice of colloidal silica concentration to prevent the liquefaction of sand and silty sand in a specific area depends on the cyclic stress ratio in that area; thus, at a cyclic stress ratio of 0.2, colloidal silica concentration of five percent is sufficient. However, at a cyclic stress ratio of 0.4 (higher level of dynamic loads), colloidal silica with a concentration of 20% or more should be used.

Key Words: Soil stabilization, colloidal silica, silty sand, liquefaction, cyclic loading.

THE SOCIAL IMPACTS OF INFRASTRUCTURE FAILURE: ESTIMATION OF THE VALUE OF A STATISTICAL LIFE FOR COMMUNITY RESILIENCE ANALYSIS IN IRAN

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Abstract

This study aims to provide a model for estimating the direct social loss incurred by communities in Iran due to the loss of life resulting from the earthquake-induced damage to infrastructure systems. Once estimated, the direct social losses caused by an earthquake can be used to quantify and analyze community resilience. Numerous past studies have focused on estimating the direct and indirect economic consequences of earthquake-induced infrastructure failure. However, a review of the relevant literature demonstrates a lack of appropriate models for calculating social costs associated with such events considering the characteristics of the subject community. Research is needed to develop suitable analytical models that quantify the social costs of earthquakes. Previous research studies have proposed using concepts like the value of a statistical life to quantify the social losses caused by hazards such as accidents, environmental pollution, and Terroristic Attacks and Fatal Diseases. Accordingly, past studies on the quantification of community seismic resilience used the value of a statistical life for countries such as the United States in conjunction with the exchange rate to arrive at costs incurred by a community due to earthquake-induced casualties. Since Iran is a country with high seismicity, underestimating the damage caused by the death of individuals and as a result, incorrect estimation of the amount of social loss incurred by the community may misguide the vulnerability reduction efforts. This will have adverse economic, political, and social consequences for the community. Several methods have been proposed to calculate the value of a statistical life, the most important of which are “Revealed Preference” and “Stated Preference.” This study uses the revealed preference method to calculate the value of a statistical. This manuscript reports the methodology adopted for collecting the relevant data and the development of the model that estimates the value of a statistical life.

Key Words: Value of a statistical life, social impacts, resilience, hedonic functions, machine learning, revealed preferences, infrastructure failure, interdependent infrastructures.

INVESTIGATION OF THE EFFECT OF HYBRID FIBERS AGAINST ELECTRICAL RESISTANCE AND DYNAMIC RESISTANCE AGAINST CONCRETE EXPLOSION

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Abstract

With the increasing development of concrete structures, properties such as strength and durability of concrete have become particularly important. Therefore, it is necessary to use special concretes and obtain new combinations. Ordinary concrete is brittle and frangible, and if rebar is not used, other materials such as fibers should be added to the mixture to remove the brittleness of the concrete. Fiber is used to control cracks in concrete, which in addition to controlling cracks, improves impact resistance, fatigue, shear, bending, as well as energy absorption of concrete. In this research, fiber concrete made of steel, barchip, and macro synthetic fibers and the combination of each fiber with different volume ratios is subjected to explosive load and the failure rate of each sample and the resistance of fiber concrete with hybrid fibers to explosion have been investigated in laboratory and field. Also, the special electrical resistance of hybrid fiber concrete against the electric current has been evaluated, which can be considered as a measure to evaluate the permeability and parallel absorption of concrete water. The results showed that concrete with macro synthetic fibers had greater explosion resistance than other samples. Also, the electrical resistance of concrete with macro-synthetic fibers has been higher than that of other samples, which will have special applications in corrosive areas with high penetration of chloride ions due to higher electrical resistance and consequently lower permeability. Also, for estimating the cost of fiber performance in concrete, the lowest excess cost of using fibers in concrete was related to the use of 1.5% of the concrete volume of macro synthetic fibers due to the low cost of these fibers and its high resistance to electrical resistance and resistance to explosive load. The use of these fibers in concrete to withstand explosion and electric current has been cost effective.

Key Words: Fiber concrete, steel fibers, barchip fibers, synthetic fibers, explosive, electrical resistance.

EXPLAINING THE EFFECTS OF NATIONAL CULTURE DIMENSIONS ON THE ADOPTION OF BUILDING INFORMATION MODELING (BIM) TECHNOLOGY IN TEHRAN PROVINCE CONSTRUCTION COMPANIES

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Abstract

It appears that Building Information Modeling with its reported benefits can help solve the inefficiency of Iran's construction industry. However, a review of some previous literature shows that the adoption status is unfavorable. There are various obstacles including legal, financial, technical, and behavioral ones to adopting BIM. One of the behavioral barriers to BIM adoption is cultural factors. Factors that make users resist change and fear new technology include the fear that they will not

be able to work with new technology or that their organizational position will be endangered. The dimensions of national culture in each country or organization vary and as a result, the adoption of new technologies that are affected by these dimensions can be different. As a result, the conceptual model of the present study was developed with the aim of explaining the effect of national culture dimensions on BIM adoption in the first-ranked construction companies in Tehran province. In this conceptual model, the effect of five dimensions of national culture on the three variables of BIM adoption (TAM model) was evaluated. In this way, a researcher-made questionnaire was prepared and taken from the variables of the conceptual model and was distributed in four categories: employer, consulting, Design and Build, and contracting company. Analysis of 95 valid samples was performed using SPSS22 and SmartPLS3 software and it was shown that the adoption rate of BIM in construction companies ranked one in Tehran province, being lower than average. Also, the lower the power difference and uncertainty avoidance, individualism, and masculinity, the more members of companies find BIM implementation beneficial. Also, as risk-taking increases, company members find it easier to use BIM and are more eager for its adoption. The findings of the present study help construction companies that intend to adopt BIM technology for the first time to move towards adoption and implementation of BIM with stronger encouragement and support.

Key Words: Building information modeling, adoption, national culture, construction companies.

EVALUATION OF SEISMIC BEHAVIOR OF SMRFs WITH AND WITHOUT STEEL SHEAR WALL AGAINST SEQUENCING EARTHQUAKES

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Abstract

A better understanding of the dynamic behavior and seismic performance of structures has led to advances in structural design in recent years, but despite recent advances, many existing structures are not earthquake resistant. Steel Moment Resisting Frames (SMRFs) are one of the common structural systems in construction that has been considered by engineers due to its ease of implementation, relatively good seismic behavior and architectural considerations. However, Steel Moment Resisting Frames, in addition to being costly and performing defects in joints, has a low lateral stiffness compared to other strong systems and does not have good resistance to high horizontal displacement and structural and non-structural elements are exposed to damage. Near-fault Earthquakes are among the factors that increase damage to the structure and also intensify lateral load intensity. In this paper, the seismic behavior of SMRFs with and without Steel Plate Shear Walls (SPSWs) against 40 artificial near and far fault seismic records are evaluated using nonlinear time history analysis. For this purpose, 8-, 15- and 20- story frames were designed without considering the permissible drift criteria. Then, a steel shear wall was added to the frames and while redesigning, the drift criterion was met. The results show that in both cases with and without SPSWs the need for seismic near the fault sequences is greater than the far fault seismic sequences. The presence of SPSWs reduces the need for deformation (except for absolute floor acceleration), and this effect is more pronounced for near faults scenarios. In all cases, the presence or absence of SPSWs has no effect on the maximum floor acceleration. Adding SPSWs always increases the need for base shear force, but the force is still more significant from near fault than far fault scenarios. The results of comparing the effect of successive earthquakes near and far from the fault show that near-fault earthquakes always act to increase the need for the structure.

Key Words: Seismic evaluation, steel moment frames, steel plate shear wall, sequences earthquakes, seismic scenario.

INVESTIGATION OF EFFECT OF SIZE AND CONTENT OF NANO/SiO_2

ON THE STRENGTH AND DURABILITY OF RCC IN FREEZING-THAWING CYCLES

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Abstract

RCC remains a widely used construction material over the last decade. RCC is placed in a manner similar to paving; the material is delivered by dump trucks or conveyors, spread by small bulldozers or specially modified asphalt pavers, and then compacted by vibratory rollers. By definition, Roller Compacted Concrete (RCC) is the concrete compacted by a roller in a hardened state. RCC is a special type of concrete that has essentially the same ingredients as concrete. However, at different ratios, partial substitution of fly ash is increased for Portland cement. This type of concrete has facilitated constructing many new dam and pavement projects and reducing costs by shortening the time duration of implementation. Rolled concrete materials are generally applied instead of the soil-cement mixtures in projects. Soil-cement and rolled concrete are both completely compacted mixtures of cement, aggregate, and water, while their main differences are the type and size of aggregates. Using this kind of concrete has provided a chance for the construction of many dams and new pavements with economic advantages, leading to the quick construction management. Since these structures are exposed to climatic factors, their durability, especially against alternate thawing-freezing cycles, is of paramount importance. In the current research, silica nanoparticles were added to the RCC mix of three different diameters (10, 15, and 30 nm) and three different ratios (1, 3, and 5% by cement weight) in 50, 100, and 300 cycles to investigate their effects on compressive strength, dimensions, and weights of RCC samples. The experimental results illustrated that mixtures containing nano-silica had a better durability and strength than non-additive mixtures.

Key Words: Rolling Compacted Concrete (RCC), Nano−, SiO_2, freezing and thawing, strength, durability.

OPTIMIZATION OF COMPOSITE PARABOLIC CHANNEL CROSS-SECTION BASED ON CHANGES IN DISCHARGE AND FREEBOARD

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Abstract

This paper presents an optimal cross-section of a composite parabolic channel by considering four models based on freeboard changes. In this research, four models were presented separately to present the optimal shape of the parabolic cross-section. In the first model, the freeboard was considered zero. In the second model, a freeboard of 0.5 m was considered. In the third model, the freeboard was considered as a function of the discharge according to the standard regulations of India; in the fourth model, the freeboard was considered as a function of the flow depth in the optimization process. The objective function is to minimize the cost of lining and excavation costs. Design variables include flow depth and side slopes. Constraints include the Manning equation constraint to maintain a uniform flow, the Froud number constraint to ensure subcritical flow in the channel, total top width, and the velocity constraint to control sedimentation and erosion. The above optimization problem is solved using the optimization algorithm and the

method of simultaneous perturbation stochastic approximation (SPSA). The results show that increasing the discharge increases the flow depth, left and right side slopes, total top width and water surface width, channel cross-sectional area and flow area, the total channel perimeter and wetted perimeters, flow velocity, Froud number, and the cost. By examining the relationship between cost with design variables, constraints and geometric parameters of parabolic channel cross-section at different iterations, the characteristic of the model that won the most number of iterations is based on the increase in left and right side slopes, total top width and water surface width, the cross-sectional area of the canal and the flow area, the total channel perimeter and the wetted perimeters, the Froud number, the cost increase. In contrast, increasing the depth and flow velocity reduces the cost. Comparison of the results of the four models with each other shows that the cost values in the first model are lower than those in other models. In the third model, they are higher than all models.

Key Words: Composite parabolic channel, optimization, SPSA algorithm, freeboard.

EXPERIMENTAL AND THEORETICAL STUDY OF BUCKLING BEHAVIOR OF STEEL CYLINDRICAL SHELLS WITH VARIABLE WALL THICKNESSES UNDER COMBINED LOADING OF AXIAL COMPRESSION AND EXTERNAL PRESSURE

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Abstract

Thin-walled steel cylindrical shells are industrial structures that play an important role in the storage of petroleum and refineries, potable water supply, and fire extinguishing systems. Steel storage cylindrical shells are manufactured with variable thicknesses in height for economic reasons. Each steel cylindrical shell structure is made of several individual cylindrical parts of constant thickness. These shells with fixed roofs are subjected to axial pressure due to wind effect and snow accumulating on the roof. The cylindrical shells are also subjected to external pressure due to wind load and/or vacuum load when the containing liquid is discharged. The combination of axial compression and external pressure may lead to the failure of the shell structures. In this paper, two experimental studies were performed to investigate the effect of initial buckling during the axial compressive preloading or at the external pressure phase on the buckling behavior of cylindrical shells with stepwise wall thickness under combined loading of axial compressive preloading and external pressure. The results showed that the buckling capacity decreased under axial preloading and external pressure when the initial buckling occurred during the application of axial compressive preloading. Also, more deformations and buckling waves formed in the thinner individual section of cylindrical shell and also failure occurred faster and the structure became unstable faster, when initial buckling occurred during the axial compressive preloading. Theoretical relationships, in which geometric imperfection is considered, were employed to predict the buckling load of cylindrical shells with variable thicknesses subjected to combined loading of axial compression and external pressure. One of these two relationships shows a closer correlation with experimental results. Also, the results showed that the buckling behavior of cylindrical shells was very sensitive to the applied axial compressive preloading; therefore, as the axial compressive preloading increases, the quasi-empirical theoretical relationships become more conservative.

Key Words: Steel cylindrical shells, thin wall, stepwise wall thickness, combined loading, buckling.