frame structures. Over the past years, much research on the seismic behavior of steel moment connections has been performed in order to determine the behavior of joints. Studies agree that in frame analysis, joint rotational behavior should be considered. This is usually done using the moment-rotation curve. Models, such as analytical, experimental, mechanical and numerical, can be used to determine joint mechanical behavior. The most common is the mechanical model, with several variances. In this study, a summary is given on each model characteristic.
In this paper, the seismic performance of an I-shaped beam to box-column steel connection with top and seat plates was studied using the component method. In the context of the component method, whereby a joint is modeled as an assembly of components and rigid links, concentrating on beam-to-column and beam-to-beam joints, several components contribute to the overall response of the connection. Despite the complexity of the various connection types, the proposed model is able to provide analytical solutions for the moment-rotation response of a steel connection using appropriate transformation criteria for the assembly of components in series and/or in parallel. Also, in order to evaluate the behavior of the connection in a vast range of nonlinear behavior, a modified Ibarra-Krawinkler deterioration model is used. The correctness of results was examined by comparing the moment-rotation and force-drift curves of the beam to column connection with the top and seat plates, which were obtained by the component and experimental methods.
Results show that moment-rotation and force-drift curves obtained by the component and experimental methods are reasonably close to each other; proving the correctness of the above method in evaluating the seismic performance of the connection.

**Key Words:** Top and seat plate connection, I-shaped beam to box column connection, component method, modified Ibarra-Krawinkler deterioration model.

## INVESTIGATION OF SIDESWAY INSTABILITY IN TENSILE ZONE OF STEEL BEAMS USING A SKELETAL MODEL

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 139-144, Research Note



- Received 1 June 2014; received in revised form 23 September 2014; accepted 4 October 2014.

Abstract
Generally, beams are designed to withstand bending and shear stresses, in practice, as well as for local yielding or instability under load and lateral torsional buckling. Another type of instability has been observed as a mode of failure in steel beams under some circumferences, referred to as "web sidesway buckling" or "tension flange instability" in previous work and steel design codes, and is related to the lateral movement of tension flanges and tension zones of the web with considerable reduction in the load bearing of the beam. Experimental and numerical work has been conducted for web sidesway buckling, mostly based on simple analytical, experimental or numerical models that provide a conservative estimate of the load capacity of beams.
In the present paper, a concise study has been carried out on the behavior and occurrence mechanism of this instability, which resulted in proposal of a one dimensional (skeletal) model to describe the instability. This model consists of a column and two tensile members, like cable, for restraining the lateral displacement of the column support. The stability analysis of the proposed model has been undertaken, and then the critical load of the model has been generalized to the real beam, which undergoes instability. The provided expression for the model is related to the parameters of the beam. Furthermore, some coefficients have been used to calibrate the proposed critical load, with respect to the numerical and experiments results of previous research. Effective parameters, such as web thickness, end condition and the tension area of the web were included in the model expression. The proposed model predicts the occurrence of this phenomenon and the load capacity of beams under web sidesway buckling. Results were compared with previous experiments and numerical models and show the good accuracy of the model in load capacity estimation.

**Key Words:** Web buckling, tension flange, skeletal model, steel beam, instability.

tion was proposed for considering depth uncertainties in a conventional framework of probabilistic seismic hazard analysis.

**Key Words:** probabilistic seismic hazard analysis, uncertainty treatment, hazard curves, earthquake depth.

## EVALUATION AND COMPARISON OF ANALYTICAL AND NUMERICAL MODELS AND NEURAL NETWORKS IN PREDICTING THE GROUTING VOLUME OF THE SEIMAREH DAM FOUNDATION

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 119-128, Research Note



- Received 26 April 2014; received in revised form 1 September 2014; accepted 20 September 2014.

### Abstract

A grouting operation is one way to decrease water penetration, and increase the resistance and strength of jointed rocks in locations of dams. One encountered problem in this operation is evaluation of consumed cement and estimation of the penetration and radiuses of cement grout. In this study, analytical models with numerical modeling and a neural network to predict the penetration radius and the volume of grout are introduced.

To predict the grout volume required for grouting and penetration radius, simplifying the geometrical state of the rock and penetration conditions of the grout is necessary. The cement grout used in the grouting operation is known as a Bingham flow. Thus, grout rheological properties, including viscosity, $\mu$ properties, including viscosity, , and yield stress, $\tau_0$, will control its behavioral properties. Viscosity, flow speed of the grout and yield stress will control the most penetrating length of the grout in boring in defined grouting pressures and the constant aperture of joints.

Analytical models for prediction of cement grout have been used in this study. In numerical modeling by UDEC software, the conditions of the rock, joint apertures, and grout bore dimensions and grout pressure values are entered. Because of the low regression coefficient between real and calculated grout volume, a neural network method is used to present better predictions. The purpose of this study is the introduction of calculation methods for evolution of grout volume by these methods. Finally, modeling was undertaken using data from the Seimareh dam, and the obtained grout volume was compared to the real take recorded in this site.

Using analytical models, the required grout volume can be estimated. The fourth model (Lombardi), in comparison to other models, presents a better estimation of grout volume. Numerical modeling, using UDEC software, in comparison to analytical models, has better estimation of grout volume, and the calculated take regression with real take is higher. But, the amount of regression coefficient is not enough ($R^2 = 0.628$). Stimulation results and calculated values in the neural network method by MATLAB software present the best estimation of grout volume and acceptable regression coefficient ($R^2 = 0.92$). Thus, using a neural network system to predict cement grout take in the grouting process is presented.

**Key Words:** Analytical modeling, numerical modeling, artificial neural network, penetration radius, grout take, Seimareh dam.

## SEISMIC EVALUATION OF I-SHAPED BEAM TO BOX-COLUMN CONNECTIONS WITH TOP AND SEAT PLATES BY THE COMPONENT METHOD

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 129-138, Research Note



- Received 31 May 2014; received in revised form 6 October 2014; accepted 20 October 2014.

### Abstract

Major earthquakes that have occurred in recent years have shown that beam to column connections are the main focus in lateral force transference in steel moment

Abstract

Nowadays, in most earthquake resistant design codes, structures are permitted to experience significant inelastic deformations under severe earthquake. Structural experts believe that if structures are designed properly, under severe earthquake, they can deflect in inelastic limits, and, as a result, can dissipate most of the earthquake energy.

A general way to evaluate the inelastic behavior of structures is using nonlinear dynamic analyses. These kinds of analysis are usually time consuming and uneconomic and need a high level of knowledge to be undertaken. Thus, it is not always possible for practicing engineers to perform these sorts of analyses. In order to solve the problem, earthquake resistant design codes permit use of a reduction factor (R). This factor, named the response modification factor, reduces the earthquake design force so that the response of the structure is assumed elastic.

In this study, the ductility reduction factor of ordinary and special concentrically braced frames, using a combination of V and inverted V bracing systems, is investigated. According to the results, the maximum height of ordinary frames, which are braced using a combination of V and inverted V bracing systems, can increase up to 15 meters. This value is larger than that proposed by ASCE7 (10.7 m). Also, results indicate that using ordinary frames, which are braced by a combination of special inverted V and V braced systems, can have a saving of about 0 to 29 percent using materials for frames from 1 to 16 stories, in comparison with ordinary frames. According to the results of this study, the response modification factor proposed by the Iranian seismic design code (2800 standard fourth edition), (R=5.5), is more logical than the one proposed by ASCE7 (R=6). Unfortunately, for frames braced by a combination of special inverted V and V braced systems, when the stories of the frames increase up to 10, the expected ductility demand cannot be achieved. So, as a result, for frames with more than 10 stories, the lower response modification factor should be used. In addition, frames taller than 10-stories do not experience specified target displacement and collapse before reaching the preferred mechanism. This phenomenon shows the necessity of using a different response modification factor for frames taller than 10 stories.

**Key Words:** Ductility, ductility reduction factor, concentrically braced frame, pushover analysis, target displacement.

# INFLUENCE OF DEPTH UNCERTAINTY TREATMENT ON RESULTS OF PROBABILISTIC SEISMIC HAZARD ANALYSIS

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 111-118, Research Note


- Received 11 November 2013; received in revised form 31 May 2014; accepted 17 June 2014.

Abstract

In the conventional framework of probabilistic seismic hazard analysis, depth uncertainties are not recognized and a uniform distribution is assumed for the depth of the earthquake. However, the non-uniform distribution of depth and its remarkable deviation is obvious. The main objective of this paper is to evaluate the influence of the treatment of depth uncertainties on the entire results of seismic hazard analysis. Due to the limitations of the classical approach of hazard analysis, the Monte Carlo method was applied to capture the depth uncertainties. In this method, the random variables can be entered as a probabilistic density function with observed means and standard deviation, or in tabular formats. In this paper, seismic hazard assessment of Azna City, Iran, was undertaken using the Monte Carlo approach. First, the results of the Monte Carlo approach were validated against the classic approach, and, then, a nonuniform depth distribution, based on the observed depth of the earthquake, was assumed in a tabular format; the process of hazard assessment was then completed. Finally, the results, including hazard curves, in different periods, were obtained. In conclusion, the pseudo spectral accelerations derived from nonuniform depth distribution were higher in comparison with uniform distribution, equal to the observed mean of the depth of the earthquake. The differences between pseudo spectral accelerations in two different depth distributions were increased at higher hazard levels. The results of comparison showed that by considering the observed mean minus half of the standard deviation as uniform depth distribution, would have relatively equal results to those of realistic depth distribution. In this study, using the observed mean minus half of the standard deviation instead of the observed mean as a uniform depth distribu-

ratios, having four different opening location patterns and various opening lengths, are considered for this research. According to the design code recommendations, SPSWs are designed per the capacity design principle. The adequacy of the finite element modeling approach for representing the pushover and cyclic responses of SPSWs is verified through comparisons with experimental results. Results show that due to the introduction of openings and LBE, plate strength decreases proportionally with the decrease in plate area, while the frame strength always increases. As a result, the overall system strength may increase or decrease, depending on the location and length of the opening. The stiffness and ductility of SPSWs with stiffened openings are always less than those of the corresponding SPSWs without openings, and, generally, the ratios of the stiffness and ductility values of SPSWs with openings to those of corresponding SPSWs without openings decrease linearly with the relative length of the openings. The system aspect ratio has no significant effect on the ratios of the strength, stiffness and ductility of SPSWs with openings compared to those of the corresponding SPSWs without openings. Moreover, provided that the opening length is not very long, the introduction of openings and LBE increases the energy dissipation capacity of the system.

**Key Words:** Steel plate shear walls with opening, local boundary element, ultimate strength, stiffness, ductility.

## UTULIZATION OF MICRO SILICA FUME TO IMPROVE GEOTECHNICAL PROPERTIES OF NAZLOO CLAY

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 91-100, Original Article


- Received 28 April 2014; received in revised form 5 July 2014; accepted 28 September 2014.

### Abstract
Engineered solid waste landfills are comprised of bottom barrier systems (leachate collection systems and compacted clayey liners) to prevent migration of the contaminants in the leachate from underneath the landfill. Clayey soils are widely used for construction of the landfill liners in engineered landfills. The compacted clayey liners should meet standard geotechnical specifications, such as soil index, strength, hydraulic, and contaminant transport parameters. If the compacted clayey soil cannot meet some of these specifications, it can be modified by means of additive material. The use of micro scale fine grained material, such as micro silica fume (MSF), has attracted the attention of engineers and researchers to modify the geotechnical characteristics of the clayey soils in geotechnical applications.
The effect of micro silica fume additive on the improvement of the geotechnical properties of silty clay soil from the Nazloo region in Urumia City, Iran, was investigated. After determination of the geotechnical properties of the soil and MSF, the soil was mixed with 5 to 30 % MSF by dry weight, and the geotechnical parameters of the mixed material were measured. The addition of 5 to 30 % MSF to the soil caused the plasticity index and optimum water content to increase and the specific gravity and the maximum dry unit weight to decrease. The effect of MSF on soil hydraulic conductivity, shear and unconfined compression strength, and molecular diffusion coefficient, was investigated. The addition of MSF to the soil decreased hydraulic conductivity, improved strength properties, and increased cohesion. The addition of MSF to the soil caused the chloride diffusion coefficient to increase slightly, but the obtained values were in the range of the recommended values for clayey soils.
The overall conclusion of this investigation implies that the addition of maximum 30 % by dry weight of micro silica fume to the Nazloo silty clay soil improves the geotechnical properties of the soil, so that it could be utilized in construction of the solid waste landfill liners in the region.

**Key Words:** Nazloo silty clay, micro silica fume, solid waste landfill, clayey liner, hydraulic conductivity, strength, molecular diffusion.

## DUCTILITY REDUCTION FACTOR EVALUATION OF COMBINED INVERTED V-BRACED AND V-BRACED FRAMES

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 101-110, Research Note


- Received 12 March 2014; received in revised form 25 May 2014; accepted 17 June 2014.

linear elastic fracture mechanics (LEFM). The fracture is fully fluid-filled at all times. This problem has been examined by Garagash [Engineering Fracture Mechanics, 2006] without considering the interaction effect of inertia and viscosity parameters. In this work, the net pressure in the fracture, the crack opening, and the fracture half-length are obtained from the perturbation solution considering this interaction effect on the otherwise toughness-dominated solution. The results are compared with analytical reference solutions.

**Key Words:** Hydraulic fracture, interaction effect, inertia, viscosity, perturbation method.

deep beams with opening were manufactured and monotonically loaded up to failure. The design of each test specimen was carried out using optimal truss models and the ACI 318-11 provisions for STM. The structural performance of the specimens is compared with that of some similar specimens in previous test series. All test specimens in this study carried loads greater than the factored design loads. Reinforced concrete specimens using optimization-derived truss models have efficient responses, in terms of ratio of ultimate load to steel weight.

**Key Words:** Deep beam, opening, STM, optimization, full homogenization.

## OPTIMIZATION OF STRUT AND TIE MODELS ON DEEP BEAMS WITH OPENINGS

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 67-77, Original Article



- Received 1 February 2014; received in revised form 12 August 2014; accepted 20 October 2014.

### Abstract

Reinforced concrete (RC) members with significant geometric discontinuities and complex stress distributions under loading require considerable analyses and usually complicated reinforcement detailing. Deep beams with large openings are one of the examples. Strut-and-tie models (STM) are a valuable tool for the design of these members. However, the actual stress fields in deep beams with openings are typically different compared with those predicated by STMs, as reported by many experimental investigations. Therefore, an optimization method on homogenization is used for finding optimal strut-and-tie models for RC elements. Previous truss optimization methods are strongly dependent on the element removal ratio and the FE mesh. Additionally, they require many algorithmic parameters to be finely tuned, and their convergence to optimal solution is uncertain. Full homogenization (FH) methods solve most of these problems because of their explicit formulas. Two examples from STM literature are used to illustrate the application of these methods.
In the experimental part of the study, two reinforced concrete and two steel fiber reinforced concrete (SFRC)

## EVALUATION OF THE BEHAVIOR OF STEEL PLATE SHEAR WALL WITH STIFFENED OPENING

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 79-89, Original Article



- Received 4 February 2014; received in revised form 2 July 2014; accepted 28 September 2014.

### Abstract

In this paper, the behavior of steel plate shear walls (SPSWs) with stiffened rectangular openings used as windows or doors in buildings is studied using the finite element method, and compared with corresponding systems without openings. In the case of such large openings, the use of local boundary elements (LBE) around the opening to anchor and transmit the infill plate tension forces to the surrounding boundary members (beams and columns) at their ends is inevitable. It is found to be more economical to extend the opening to the story height, whether needed or not, so that horizontal local boundary elements will not be needed, and which would lead to considerable cost saving in construction. Therefore, the openings are assumed to have a constant height and extend along the full height of the systems. A number of single-story SPSWs, with different aspect

Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 49-58, Original Article


- Received 30 December 2013; received in revised form 31 August 2014; accepted 26 October 2014.

Abstract
The construction of high-rise and light-weight buildings is widespread. These structures are highly flexible, usually have low damping levels, and are sensitive to dynamic loads such as earthquakes. Consequently, structural control devices are becoming an integral part of structural systems. ATMD is an active structural device successfully used for suppressing building vibrations. This study focuses on application of an active tuned mass damper (ATMD) for controlling the response of an 11-story realistic building. The control action is achieved by combination of a fuzzy logic controller (FLC) and the Particle Swarm Optimization (PSO) method. The fuzzy logic controller is used to handle the uncertainty and nonlinearity phenomena, while the Particle Swarm method is used for optimization of the fuzzy system, known as PSFLC. Minimization of the top floor displacement has been used as the optimization criteria. The optimization process of the fuzzy logic system has been performed for an 11-story building with an active tuned mass damper placed on the top floor, under earthquake excitations recommended by the International Association of Structural Control (IASC) committee. Hachinohe and El Centro earthquakes are used for far-field ground motion and Kobe and Northridge earthquakes as near-field ground motion. Performance of the designed PSFLC has been checked for different disturbances of both far-field and near-field excitations. It is found that the active tuned mass damper system, driven by a fuzzy logic controller, with the help of the Particle Swarm method, is highly effective in reducing the maximum displacement of the building and the Root Mean Square (RMS) displacement of the top floor. The results show that although the maximum required control force in PSFLC and FLC systems are approximately the same, PSFLC decreases peak displacement and the RMS displacement of the top floor by about 10%-30% more than that of the FLC.

**Key Words:** Active tuned mass damper (atmd), fuzzy logic controller (flc), particle swarm optimization (pso), psflc, displacement reduction, earthquake excitations.

## HYDRAULIC FRACTURE PROPAGATION IN BRITTLE ROCK: CONSIDERING INTERACTION TERM BETWEEN FLUID INERTIA AND VISCOSITY PARAMETERS

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 59-66, Original Article


- Received 26 January 2014; received in revised form 18 October 2014; accepted 26 October 2014.

Abstract
Modeling of fluid-driven fractures, arguably one of the most challenging computational problems in geoengineering, has been the subject of numerous investigations. The thrust of these efforts has been directed, however, towards the mechanics of deep hydraulic cracks, with subsurface hydraulic fractures receiving comparatively little attention. Nonetheless, there are numerous circumstances when the propagation of a fluid driven fracture in a solid medium is influenced by the presence of a free surface: remediation of contaminated soils, excavation of hard rock by injection of fluids, preconditioning and cave inducement in mining, waste disposal, and fracture propagation in dams. Furthermore, there are also spectacular examples of geological processes that involve near-surface magma-driven fractures. Investigations have addressed various aspects of the problem, both analytically and numerically, for some further references. It is, however, only recently that there has been a rigorous effort to study the parametric dependence of a fluid-driven fracture and the corresponding different limiting regimes. An explicit solution for fracture propagation in the toughness-dominated regime has been constructed by Garagash [Engineering Fracture Mechanics, 2006], when the energy dissipated in the viscous fluid flow inside the fracture is negligibly small compared to the energy expended in fracturing the solid medium. It was also shown that the established method of asymptotic expansion in small parameters is equally applicable to study other small effects (e.g., fluid inertia) on the otherwise toughness-dominated solution. This paper represents an analytical method for solving the problem of plane-strain hydraulic fracture propagating in an impermeable brittle rock under large toughness and axisymmetric conditions. The flow of incompressible fluid in the fracture is unidirectional and laminar. Fracture propagation is described in the framework of

tists in various fields, such as geology, seismology, engineering, mathematics, computer science and even social sciences, who study different aspects of the matter to find new solutions. Efforts in this field are divided into long-term and short-term predictions. The short-term predictions are based on precursors such as foreshock, seismic quiescence, decrease in radon concentrations and other geochemical phenomenon. Due to numerous complexities and unknown factors inside the earth, exact prediction of earthquakes is difficult and practically impossible. During the last two decades, many techniques have been developed to discover the pattern of seismic data and predict three earthquake parameters, namely; time of occurrence, location and magnitude of future earthquakes. Soft computing and data mining techniques, such as neural networks, fuzzy logic and clustering methods are appropriate tools for problems, such as earthquake prediction, that suffer from inherent complexities. Many researchers have used these approaches to reduce uncertainty in results.

In this paper, the b-value of the Gutenberg Richter law has been considered as a precursor to earthquake prediction. Prior to earthquakes equal to or greater than $M_w = 6.0$, temporal variation of the b-value has been examined in Qeshm island and neighboring areas in the south of Iran, from 1995 to 2012. The clustering method, by the k-means algorithm, and a self-organizing map (SOM) have been undertaken to find a pattern of variation of the b-value. Three clusters are obtained as an optimum number of clusters by the Silhouette Index and the Davis-Bouldin index. Prior to all the mentioned earthquakes ($M_w \geq 6.0$) a cluster, known as a decrease in b-value, has been seen; so, a decrease in the b-value before main shocks has been considered as a distinctive pattern. Also, an approximate time of decrease has been determined.

**Key Words:** Earthquake prediction, data mining, clustering, pattern recognition, Gutenberg-Richter law.

## IMPROVEMENTS IN THE ENERGY DISTRIBUTION OF STEEL BUILDINGS USING FLUID VISCOUS DAMPERS

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 39-48, Original Article


- Received 10 December 2013; received in revised form 16 July 2014; accepted 23 September 2014

### Abstract
Buildings adjacent to each other may create risks during earthquakes, due to catastrophic structural response. This phenomenon is referred to as the impact of non coherent vibration of adjacent buildings that are not constructed far enough apart. Considering that Iran is located on an active seismic belt, and with due regard to the need for safety, due to the expansion of towns and villages as well as retrofit buildings, it is obvious that research is needed regarding the risks of injury during seismic hazard. The simplest way to cope with this phenomenon is to construct buildings of sufficient distance from each other. However, this is not always applicable, and other means are required to reduce the impact of this phenomenon. One of the most modern methods of applying seismic dampers is necessary resistance against lateral forces using energy applied to the amortized and maintaining structures, known as energy dampers. Fluid viscous dampers are passive energy dissipation systems for seismic rehabilitation of old buildings. These dampers are uniform at all levels with the same scrollable frame placed between them. According to energy intake, the damper at each floor number was optimized and linear spring elements were used to model the impact of the gap. For analysis of nonlinear dynamical performance, 3D software was used and the main structural elements were made of plastic. This study showed that the performance within the frames of the viscous damper significantly reduced the impact energy dissipation rate, and the distance between the impact energy absorption. For a viscous fluid damper, the amounts of energy absorbed by the damper at all distances are almost identical.

**Key Words:** Impact, viscous fluid damper, energy dissipation, adjacent frames, non-linear dynamic analysis.

## DESIGN OF AN OPTIMIZED FLC SYSTEM FOR SEISMIC STRUCTURAL RESPONSE REDUCTION

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ent parameters of a knee brace on the strengthening of RC frames is investigated, analytically and numerically. Also the effect of knee brace location and cross section is investigated by dynamic and pushover analysis. The results show that the proposed hinge relocation technique is able to restore the lost strength and displacement capacity of RC members.

**Key Words:** Plastic hinge, knee brace, retrofit, damaged RC building.

## STRUCTURAL DAMAGE DETECTION IN SHEAR FRAMES BASED ON SIGNAL PROCESSING AND GENERALIZED S-TRANSFORM WITH COMPLEX WINDOW

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 19-28, Original Article


• Received 6 October 2013; received in revised form 23 September 2014; accepted 4 October 2014.

### Abstract
Damage detection and structural health monitoring (SHM) have become vastly popular within the field of structural engineering over the past few decades. These methods and procedures are utilized in order to characterize the structural integrity of a system and to provide a decision whether or not the system has the appropriate bearing capacity. The S-transform has been developed over the last few years in an attempt to overcome inherent limitations of wavelet transform in the time-frequency representation of signals. S transform combines the characteristics of short Fourier transform and wavelet transform, but the window used in S transform is invariable, so, may be unsuitable for some non-stationary procedures, such as seismic signals. The generalized type of this transform is the S-transform with a complex window and phase modulation that has high potential in better time-frequency localization of similar waveforms on the time series. This paper presents a method for damage detection in shear frames on the basis of signal processing using S-transform with complex window and phase modulation (SCW). In this research, the SCW-transform has been employed due to its favorable performance in determination of damage locations and estimation of damage extent. Determining the extent of damage is of significant importance in priority settings and critical management after seismic events, in order to enhance the safety of a building and its inhabitants. The efficiency of the proposed algorithm was investigated for different damage scenarios and intensities, and, also, in the presence of measurement noise in multi-story shear frames. The method performance has been verified using two numerical examples. By way of comparison between the location and amount of damage obtained from the proposed method and simulation model, it is demonstrated that the method is sensitive to the location and severity of structural damage. In addition to the detection of damage locations, it also gives good estimation of damage severity in both the absence and presence of measurement noise in the recorded signals.

**Key Words:** Damage detection, generalized s-transform with complex window ($s_c w$), signal processing, shear frames.

## PATTERN RECOGNITION OF SEISMIC DATA USING A CLUSTERING METHOD FOR EARTHQUAKE PREDICTION

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 29-37, Original Article


• Received 12 November 2013; received in revised form 20 October 2014; accepted 1 November 2014.

### Abstract
Iran is known as one of the high risk seismic regions of the world. Over the past 50 years, many destructive earthquakes have occurred in this area, causing much human loss and financial damage. So, from the perspective of emergency-management and hazard preparedness, it is essential to make an effort to predict earthquake occurrence. Earthquake prediction is an instance of interdisciplinary research, which is a concern of many scien-

# Abstracts of Papers in English

## REHABILITATION OF RC BUILDINGS USING PLASTIC HINGE RELOCATION WITH KNEE BRACE

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Sharif Civil Engineering Journal
Volume 32, Issue 2.1, Page 3-17, Original Article


- Received 14 September 2013; received in revised form 28 May 2014; accepted 24 September 2014.

**Abstract**
Depending upon the severity of the earthquake, regions of inelastic deformation, or plastic hinges, may form in the components of reinforced concrete buildings. These components must then be replaced or retrofitted in order to restore the structural integrity of the structure to its originally intended design performance. Due to the high cost of replacement, retrofit is often an efficient and viable option. For large earthquakes, the formation of plastic hinges in columns can lead to the buckling and rupture of longitudinal steel. Traditionally, once initial buckling occurs, columns are generally replaced, as the cost of replacing portions of bars can be prohibitive. Replacement is deemed necessary since the inelastic strain capacity of reinforcing bars is severely diminished once buckling occurs, making the structure vulnerable to collapse during the next seismic event. Past research on RC member retrofit has focused on issues related to deficiencies in shear, lap splices, or confinement. Numerous techniques have been developed for retrofitting, including, steel, concrete or advanced composite jackets. These retrofit techniques can also be utilized to repair elements with deficiencies exposed during seismic loading, or to retrofit well designed members that have formed mild plastic hinges (without any signs of bar buckling). However, once buckled or ruptured bars are observed, it is assumed that repair is no longer feasible. It is the objective of this paper to challenge this assumption via relocation of the plastic hinge to a position where the member remained essentially elastic during the initial seismic attack. This is accomplished through the use of a knee brace. In this study, the influence of differ-