**Abstract**

There are few actual records of near fault ruptures with features different from those of far fields. These features are mostly affected by forward directivity in near field earthquakes. So, investigation into this field of study by using methods such to simulate records would be essential Until now, different methods have been used by researchers to simulate strong ground motion. Stochastic simulation is a method widely used for simulating high frequency ground motion in recent years. This method, which considers a point source, was presented by Boore (1983). The seismic source is considered to be a rectangular fault plane divided by some sub-faults in its longitudinal and traversal directions. Bersneve and Atkinson (1998) have introduced earthquake stochastic simulation based on finite fault modeling. In such simulations, each subfault is considered a point source, using the source model presented by Brune, with a corner frequency and a constant stress drop. The target accelerogram is obtained by summation of accelerograms generated by each subfault and by considering their corresponding delay times. This new modeling considers rupture geometry and the directivity effect; therefore, its results will be more appropriate.

The stress drop parameter is one of the most important parameters in stochastic simulation that has a high uncertainty. This parameter is studied here, based on both stochastic point source and finite fault modeling. For this purpose, the stress drop is calculated for 7 Iranian earthquakes with at least one near field record. Then, these earthquakes have been simulated by using the results of the stress drops. Finally, several parameters, such as nu, t0, gamma, and the impulse peak, which affect near field records and directivity pulses, have been investigated.

**Key Words:** Forward directivity effect, stochastic simulation, point source, finite fault, stress drop, directivity pulse effect.

## EVALUATION OF NONLINEAR BEHAVIOR OF MOMENT-RESISTING REINFORCED CONCRETE FRAME USING THE RESPONSE SURFACE METHOD

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**Abstract**

In recent years, there has been an increasing interest in studying the effect of different parameters on the nonlinear behavior of moment resisting reinforced concrete structures. However, it seems that simultaneous evaluation of some parameters needs a comprehensive statistical analysis. This paper describes a logical investigation into the seismic behavior of a five storey moment resisting reinforced concrete structure under cyclic lateral load, using an inelastic analysis computer program named IDARC. The response surface method was used for the experimental design and analysis of the interaction effect of 4 factors: column dimension ratio, longitudinal and shear reinforcement, column confinement and effectiveness coefficient, on the overall damage index and stiffness degradation of the structure. Using the central composite design method, each 4 factors were defined over 5 levels. 25 IDARC models were analyzed and 4 responses obtained: Damage index at drifts equal to 1.5%, 3% and 4% of the structure height, and the tangent of stiffness degradation in a linear area, were taken from each model. A computer program, named; Design Expert 7, was used for statistical analysis. Results show that in linear areas, the drift equals 1.5% of the structure height. The overall damage index is affected by the column dimension ratio, longitudinal reinforcement and the column confinement effectiveness coefficient. However, in nonlinear areas, where the drift equals 4% of the structure height, the damage index is affected by the column dimension ratio and longitudinal reinforcement. In linear areas, the effect of shear reinforcement, and, in nonlinear areas, the effect of shear reinforcement and the column confinement effectiveness coefficient, on the overall damage index of the structure, is negligible. Furthermore, results show that the stiffness degradation of the structure is affected by the column dimension ratio, longitudinal reinforcement and the column confinement effectiveness coefficient. However, the effect of shear reinforcement on the stiffness degradation of the structure is negligible. The presented numerical model can be used for prediction of the damage index.

**Key Words:** Nonlinear behavior, damage index, reinforced concrete, cyclic loading, response surface method.

for practical application, specifically the modeling of critical phenomenon such as boiling and heaving. Numerical analysis was performed to show the mechanism of failure under various conditions. Comparison of the computational results with experimental data and observations shows that FLAC can model correctly the mechanism of the boiling phenomena based on stress-strain analysis. The effects of the internal friction angle, the angle between the soil and the wall, and, finally, the dilation angle, on the behavior of soil, were investigated in detail. The increase in the internal friction angle caused the safety factor to rise significantly. The results of this study indicate that dilation angle is important in occurring the type and shape of heaving and boiling. Up to 15 degrees, the dilation angle created an increasing safety factor, while, after 15 degrees, the safety factor is decreased.

**Key Words:** Boiling, sheetpile, cutoff, sand, seepage, safety factor.

## NUMERICAL FRACTURE ANALYSIS OF REFLECTIVE CRACKS IN ASPHALT OVERLAYS SUBJECTED TO TRAFFIC LOADING

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**Abstract**

Cracking of asphalt layers and pavements is one of the most common modes of failure in roads and highways, which can significantly increase the cost of repair and rehabilitation. Since asphalt mixtures can behave as brittle materials at low temperature, brittle fracture and crack growth in pavements is usually observed at the surface of roads located in cold regions. Traffic loading, (due to the weight of moving vehicles) and thermal stress (induced by daily or seasonal variations of field temperature), are two major parameters affecting nucleation and propagation of cracks inside the pavements. Reflective cracking is often observed in the overlays, and the growth of such cracks is a an important problem in this field. Thus, understanding the mechanism of crack growth is essential for predicting pavement performance for designing the averlay thickness, as well as in the design and optimization of mixtures. In this study, a two-dimensional multi-layer asphalt pavement containing a reflective crack, and subjected to traffic loading of the front and rear wheels of a moving vehicle, was analyzed numerically using ABAQUS finite element code. Three fracture parameters, including modes I and II stress intensity factors ($K_I and K_{II}$) and the T-stress, are computed for various positions of the vehicle relative to the reflective crack. In the analyzed models, the influence of some parameters, such as wheel positions relative to the crack, elastic modulus, thickness of layers and crack length, was studied on the sign and magnitude of fracture parameters. According to the obtained results, an asphalt layer containing a vertical reflective crack experiences different mixed mode opening-sliding (mixed mode I/II) deformations when a vehicle moves from far distances towards the crack location. It was observed that a wide range of positive and negative $K_I, K_{II}$ and T-stress values is induced in the asphalt layer. The influence of crack length on the fracture behavior of the analyzed crack was also noticeable.

**Key Words:** 2-D finite element analysis, reflective crack, stress intensity factors, T-stress, traffic loading, pavement characteristic specifications.

## INVESTIGATION INTO THE PULSE OF DIRECTIVITY IN NEAR FIELD RECORDS OF IRAN USING STOCHASTIC FINITE FAULT SIMULATION

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**Abstract**

Project scheduling is an important process in project planning. In project scheduling, precedence relations and resource constraints must be considered. In this study, a Multi-mode Resource Constrained Project Scheduling Problem (MRCPSP), as a main problem of project scheduling, is investigated. Exact methods, heuristic procedures and meta-heuristic approaches are different methods for solving the MRCPSP. However, with respect to the fact that exact methods are unable to solve problems with more than 20 activities in acceptable computational time, in recent years, heuristic and meta-heuristic approaches have been further investigated by researchers. On the other hand, it has been proven that the meta-heuristic approach outperforms heuristic methods.

In this study, an improved genetic algorithm (GA) is presented for solving MRCPSP, with minimization of the project makespan, as the objective, subject to resource and precedence constraints. Before starting with GA, the preprocessing procedure is employed to reduce the search space and computational effort. For solving this problem, a random key and a related mode list (ML) representation scheme are used as encoding schemes and the multi-mode serial schedule generation scheme (MSSGS) is considered as the decoding procedure. In this paper, a new fitness function is proposed for reducing computational effort and average deviation from optimality. A new mutation operator is also defined for improving the solution quality.

The well-known benchmark sets, J10, J12, J14, J16, J18, J20 and J30, in PSPLIB are used for testing the proposed GA. Comparison of the results of the proposed GA with other approaches validates the effectiveness of the proposed algorithm to solve the MRCPSP. It is worth mentioning that average deviation from the optimal makespans (in the case of set J30, from the lower bounds), the percentage of optimally solved instances, and the average CPU time, in seconds, are used for comparison.

**Key Words:** Multi-mode resource constrained project scheduling problem, precedence constraints, resource constraints, genetic algorithm (GA), random key representation.

## NUMERICAL STUDY OF BOILING SMOOTH SAND NEAR THE CUTOFF

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**Abstract**

Deep drilling is a major part of construction in urban planning and is necessary for establishment of tunnels, underground parking lots and structures with deep excavations. Usually, vertical and horizontal forces acting on the location of the excavation are braced by various types of sheet pile and cut-off. The water level around the sheet pile is an essential element to determine the excavation depth. Seepage flow through soil reduces the stability of the soil body around the sheet pile, and, finally, causes boiling and heaving phenomena. In this study, by means of software based on the explicit finite difference method, the effects of various factors on the occurrence of failure mechanisms and safety factors against boiling near the sheet pile are investigated. Comparison of experimental data with numerical results indicates that FLAC can model and simulate, properly, the boiling phenomenon, which is based on the stress-strain analysis.

Boiling and heaving near hydraulic structures with an alluvial foundation are so destructive and undesirable that remedial issues at the downstream part of such structures are vital. Proper modeling of such hydraulic structures (i.e. coastal dikes, levees etc) before implementation can be predicted using safe models and software such as FLAC. Good adaptation of numerical results with experimental data can prescribe accurate models

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**Abstract**

The historical application of tie rods in historical buildings was used in the past to ensure the stability of arches and vaults against gravity and horizontal loads. Therefore, the necessity of tie rod health monitoring is a prevalent subject in the vulnerability assessment of historical buildings. The main purpose of this research is to evaluate the dynamic characteristics of tie rods. Also, the effect of several parameters, such as known and unknown boundary conditions, length and cross section, flexural stiffness and axial load, on fundamental frequency, has been evaluated. As a result, after a series of analytical modeling, practical graphs for three types of beam end connection have been developed. It is possible to calculate axial force with the fundamental frequency of in-situ testing with the proposed graphs. Results showed that the frequency is sensitive to all the aforementioned factors. For instance, under known boundary condition, the effect of the support type is more tangible for long span beams. Also, under constant tensile stress, changes in the boundary condition of tie rods with small cross sections did not affect the frequency considerably. Furthermore, length factors for a pinned-pinned beam with small tensile force are not sensitive in comparison with other support conditions. Comparison of analytical results of axial load and flexural stiffness with experimental data of reference 1, showed an acceptable conformity between them. The maximum error for tensile stress was calculated as 12%. This error was 5% for compressive stress. Furthermore, analytical flexural stiffness approached a full rigid support condition, while tensile force increased. This is due to the geometric effect of tensile force on the stiffness matrix of the beam. Also, for unknown boundary conditions, estimated buckling force, regarding Newmark's analytical formulation, had 3.1% error, with the corresponding force from in-situ dynamic testing obtained from reference 1.

**Key Words:** Tie rod, boundary condition, fundamental frequency, flexural stiffness, axial load.

## MODULUS LOAD TEST RESULT ANALYSIS OF RAMMED AGGREGATE PIERS IN COHESIVE SOILS

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**Abstract**

This article analyzes the results of load tests on 30 real size rammed aggregate piers (RAPs) used in the construction projects of various states in America, between 2001 and 2007. These piers were mostly tested in cohesive soils, including CL and ML. The $N_{avg}$-values of the Standard Penetration Test of these soils were between 3 and 30. In this research, the parameters of pier diameter, pier length, pier slenderness ratio, soil elasticity modulus, pier elasticity modulus, design limit pier top settlement and stress and pier stiffness modulus were considered. The pier diameters were 0.60, 0.75 and 0.90 m, and their length was between 1.8 and 5.1 m. The piers slenderness ratio (length to diameter) was between 2.4 and 31.7 MPa. Test results reveal that when the pier length or slenderness ratio is increased, the average top settlement changes little and shows a constant trend. More precisely, the minimum and maximum settlement values were 6.5 mm and 16.1 mm, respectively, and the average settlement was 11.35 mm. The results of in situ load tests on 12 RAPs in ML soil on small-scale piers, in Iran, in 2011, similarly showed that the minimum and maximum settlements were 7.2 mm and 13.1 mm, respectively, and the average settlement was 10.35 mm. The small-scale pier diameters were 0.185-0.105 m, and the pier lengths were 0.35-1.5 m. Based on these results, it seems that the average pier top settlement value could provide a suitable basis for estimating the piers stiffness modulus and preliminary designing of single RAPs. Based on the parameters affecting the estimation of pier top settlement and regression of results, an equation was achieved in this research which showed good agreement between calculated and measured results. This equation is based on pier slenderness ratio ($L_t/D_P$) between 2.3 and 6.7, and the ratio of pier elastic modulus to matrix soil modulus ($E_P/E_S$) between 5 and 88.

**Key Words:** Rammed aggregate piers, pier settlement, inflection stress, pier stiffness modulus, modulus load test.

## SOLVING A MULTI-MODE RESOURCE-CONSTRAINED PROJECT SCHEDULING PROBLEM USING A GENETIC ALGORITHM

wall to experience higher displacement than its top. The time history of monotonic bending moment infers that considerable moment is applied to the wall root by the loose section behind the root. This moment is the main reason for the "escape" of the wall root. The remediation method, by deep vibro-compaction of the weak area, is considered as a liquefaction countermeasure. The effectiveness of soil improvement in zones adjacent to the embedded section is discussed, based on analytical dynamic responses. Implemented countermeasures are found to considerably reduce deformations in the wall; however, in order to prevent failure at embedment, improvement of soil located behind the wall root is more effectual. The compacting of this section not only reduces driving moment applied to the wall root, but also creates resistant moment against root escaping. In addition to the impact of base acceleration amplitude, the optimum extension of improved zones is introduced.

**Key Words:** Liquefaction, quay wall, improvement, DIANA.

## REMOVAL OF CR (VI) FROM AQUEOUS SOLUTION BY ADSORPTION ON POLYANILINE-ACTIVATED CARBON ADSORBENT

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**Abstract**

Heavy metals, such as lead, chromium and nickel, are known to be major environmental pollutants and highly toxic to humans and other organisms, even at low concentrations. Chromium is widely used in many industries in various forms, but chromium (VI) is considered a definite carcinogen and, thus, should be almost completely removed from industrial wastewater to meet environmental laws and regulations.

Many techniques are used to treat wastewater, containing Cr (VI), including; reduction followed by precipitation, Ion exchange, adsorption by clay or activated carbon and reverse osmosis. However, these processes often produce too much sludge, or are inefficient when large volumes of wastewater are involved or do not meet environmental standards. Adsorption is another effective method with very few disadvantages compared to others. In recent years, synthetic polymers have been considered as quality adsorbents for removal of Cr(VI) from wastewater. The aim of this study is to investigate the possibility of absorption of chromium from aqueous solutions by a new and innovative adsorbent produced from Polyaniline-activated carbon. The effect of various operative parameters on the adsorption of Cr (VI) was studied. Experiments were carried in batch mode and the effect of variables, such as the initial concentration of Cr (VI), amount of adsorbent, adsorption time, and initial pH value and temperature, were studied. The maximum adsorption of Cr (VI) was obtained at $40^0C$, with an initial concentration of 15 ppm, with an initial solution pH of less than 5 and addition of 10 g/lit Polyaniline-activated carbon. Recovery of the adsorbent was carried out by desorption with nitric acid, where 2 M nitric acid was used to recover 83% of Cr (VI). The results indicate that Polyaniline-Activated carbon can be effectively used in the treatment of wastewater containing Cr (VI). Kinetic studies on adsorption behavior closely followed the "Langmuir adsorption isotherm" model for a single layer.

**Key Words:** Polyaniline, activated carbon, heavy metals, adsorption, recovery.

## ANALYTICAL INVESTIGATION OF THE VIBRATION PERFORMANCE OF TIE RODS WITH SENSITIVITY ANALYSIS OF EFFECTIVE FACTORS ON BEAM FREQUENCY

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**Abstract**

The effect of suction on consolidation behavior has a dominant role to play in the constitutive modeling of unsaturated soils, and, therefore, has received the researchers attention in this field. In this paper, the effect of the initial conditions of compacted specimens of a clayey soil on their consolidation behavior, under saturated and unsaturated states, is investigated. After determining the compaction curve of the soil, the samples were statically compacted at different initial suctions and void ratios (moisture content, dry densities). In order to investigate the volume change behavior of collapsible soils, the cylindrical samples were loaded to a definite stress in conventional oedometer apparatus. Then, while keeping the vertical stress constant, the volume changes of samples due to wetting were measured. After completion of the collapse settlements, the stepped loading of the samples was continued and the end of the primary consolidation line of the samples were attained. The saturated normal consolidation lines of samples with different initial water contents and dry densities are compared. It is shown that the normal consolidation line is almost unique and its position is not affected by the initial condition of the samples. This result suggests a simple method for predicting the collapse potential under different conditions. The method can be described as follows: The effective stress after saturation is calculated. The initial void ratio (before saturation) subtracted from the void ratio of the soil in a saturated normal consolidation line, corresponding to the effective vertical stress at saturation, would be the change of void ratio due to saturation. The collapse settlements could then be easily calculated. Since determination of the saturated normal consolidation line is a conventional and inexpensive procedure, the proposed method can be regarded as a versatile and inexpensive technique for forecasting the collapse potential.

**Key Words:** Consolidation behavior, unsaturated soil, collapse, filter paper method, collapse potential.

## EFFECTS OF SOIL IMPROVEMENT ON SEISMIC BEHAVIOR OF ANCHORED SHEET PILE QUAY WALLS EMBEDDED IN LIQUEFIABLE SITES

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**Abstract**

The seismic performance of quay walls is found to be strongly dependent on liquefaction occurrence. Besides, in some existing walls that were designed without consideration of the liquefaction hazard, due to the relatively long length of quay walls, the orientation of soil strata probably caused the liquefiable layers to appear unavoidably neighboring the wall roots. In this paper, the dynamic response of anchored sheet pile quay walls embedded in liquefaction susceptible soil was investigated numerically, utilizing the strain space plasticity model for cyclic mobility available in the DIANA finite element program. Based on the results, the extension of liquefiable soil around the wall root leads to the "failure at embedment" mode. Deformed mesh indicates that the most visible deformations are localized in loose soil around the embedded section. Beside the noticeable heave of the seabed, its seaward displacement causes a significant reduction in its supporting role for the embedded section, and leads to the large tilt of the wall. Consequently, an active wedge, extending from the embedded section to the back of the anchors, is formed. Moving along this wedge, the anchors endure significant overturning. The mentioned deformation shape was previously observed in shaking table tests conducted by the authors. The leeward section of the loose layer is recognized as the most vulnerable zone against liquefaction. Besides the effect of soil softening in this zone, dynamic active pressure behind the wall causes the bottom of the

the specimens. Three specimens were used as control. Three specimens were retrofitted by a diagonal GFRP plate; 100 and 200 mm wide. For the last three specimens, a reinforcing horizontal rebar (3mm diameter) and vertical (10mm diameter), recommended by the Iranian seismic, code was used. For this purpose, 2 holes were made, with 600 mm space and 60 mm diameter, for a 10mm diameter vertical rebar. After montage of one rebar in a hole, grout was used to fill the other parts of the hole.
Reinforced AAC walls have higher resistance in diagonal tension tests. Diagonal strength increased by 32 percent, and the crack width achieved more than 22mm without any collapse of the reinforced walls, but, control specimens have brittle failure. Three specimens were retrofit with 100 and 200 mm FRP width in a diagonal direction, which increased the energy absorption 12.9 and 21 times.
The mortar in the shear strength tests has more resistance than the shear strength of AAC walls with a compressive strength 3.2 MPa block. The wall behavior in this strength class of AAC showed that the failure modes consisted of: 1-diagonal tension failure mode and 2- crashing is on the toe.

**Key Words:** AAC, diagonal tensile test, reinforced walls, the polymer-fiber FRP.

## STUDY OF TEMPORAL COMPONENTS OF CARBON MONOXIDE CONCENTRATION AND METEOROLOGICAL VARIABLES IN TEHRAN

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**Abstract**
Carbon monoxide is one of the most important pollutants. It is a serious pollutant in terms of the air quality index (AQI) found in Tehran before 2000. Local meteorological conditions and transport systems are the strongest factors for changing pollution levels. Because of some restrictions in this paper, we discuss the effects of meteorological variables on CO concentration. Examining the trend of this pollutant and the effects of meteorological variables in a comprehensive plan to reduce air pollution is described in this paper. In order to discern changes in CO data, it is necessary to separate their different temporal components. Hence, study of the CO time series and its temporal components is needed. Also, meteorological signals must be removed in order to make better air quality management decisions for the future. Various methods have been developed for decomposing the time series into long-term (overall emission, pollutant transport, climate and policy related), seasonal (solar cycle induced), and short-term (weather related) components. These techniques are PEST, anomalies, wavelet transform, and the Kolmogorov-Zurbenko (KZ) filter. Kolmogorov-Zurbenko, as a low-passed filter, can be applied to datasets with missing data, and is much easier to use than the other methods, with acceptable precision. In this paper, it is used to separate the temporal components of average hourly CO and meteorological variables between 2000 and 2008. Results of this study indicate that CO has decreased from 11 ppm to 5 ppm, while temperature and wind vectors have an increasing trend in the years studied. One of the most possible reasons for a decrease in CO is improvement in the transport system. Moreover, long term components contribute less than 10 percent to the total variance of the time series. Long term components of CO concentration and meteorological variables have more correlation than other temporal components. Accordingly, CO concentration has strong correlative contributions with wind vector and relative humidity. These results are useful for examining emission-related CO trends in Tehran.

**Key Words:** Air pollution, carbon monoxide, meteorological variables, kz filter, temporal 1components.

## CONSOLIDATION BEHAVIOR OF COLLAPSIBLE CLAYEY SOILS IN SATURATED AND UNSATURATED CONDITIONS

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3D steel frame as a benchmark. Different damage scenarios, such as single and multiple defects of beam-to-column connections, are investigated. Results show that the presented method is reliable for operation monitoring of connections in moment resistant frames by considering the low number of mode shapes, and its high accuracy in damage detection.

**Key Words:** Moment resistant frame connections, structural health monitoring, Hilbert-Huang transform, mode shape curvature.

## EVALUATION OF EFFECTIVE PARAMETERS ON WAVE DIFFRACTION OF FAR-FAULT GROUND MOTIONS USING ARTIFICIAL NEURAL NETWORKS

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**Abstract**
Local site conditions have a great effect on ground motion and, consequently, underground structures, as important lifelines, have a vital influence on disaster management after earthquake occurrence. Among the local site topographies of interest are tunnels, which are located underground. A tunnel is an underground passageway, completely enclosed except for openings for the entrance and exit, commonly at each end. A tunnel may be for pedestrian or vehicular road traffic, for rail traffic, or for canals. Some tunnels are aqueducts to supply water, for consumption or for hydroelectric stations, or are sewers. Upon impact with a tunnel, induced earthquake motion would generate diffraction waves, which increase the damage in adjacent structures. In order to investigate the effect of wave diffraction on near fault ground motions, the twin tunnels of the Shiraz subway and their adjacent structures have been studied in the present article. Artificial neural networks (ANNs) are a field of science aimed at mimicking natural learning using mathematically based approximation. A single biological neuron is composed of three major parts: the cell body, the axon, and the dendrite. With known combinations of input and output data, a neural network can be trained to extract the underlying characteristics and relationships from the data. Then, when a separate set of input data is fed to the trained network, it will produce an approximate but reasonable output. Neural networks are highly nonlinear and can capture complex interactions among input/output variables in a system without any prior knowledge about the nature of these interactions. In this study, an appropriate artificial neural network has been generated in order to estimate the amount of diffraction of near fault earthquake waves. The results show that an idealized neural network has a high level of precision in comparison with results derived from finite element analysis. Finally, a sensitivity analysis was performed on input parameters and their percent of importance was evaluated.

**Key Words:** Wave diffraction, ground motion, artificial neural network, sensitivity analysis.

## EXPERIMENTAL EVALUATION OF AAC BLOCKS WALLS RETROFITTED BY BARS AND GFRP

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**Abstract**
In this paper, the experimental behavior of an autoclaved aerated concrete (AAC) block, and the shear strength of the mortar used for construction of an AAC wall was given. Six specimens with micro silica mortar, suitable to the class of compressive behavior of AAC blocks, were tested. 9 specimens of an AAC wall, with dimension of 1200*1200*250, based on ASTM E519, were constructed. The diagonal testing program was used for

# Abstracts of Papers in English

## DAMAGE ASSESSMENT IN CONNECTIONS OF MOMENT RESISTANT FRAMES USING HILBERT-HUANG TRANSFORM

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**Abstract**

Environmental conditions and uncertainty in materials and service loads cause operational defects in structures. Detection of damage at the earliest stages can increase the life expectancy of structures and also prevent occurrence of disaster. So, structural health monitoring has been of interest over the last decades.

Among the various methods for damage detection, vibrating response processing is one of the best and most efficient methods. Structural health monitoring systems are set up in such a way that the natural and forced vibrations can be investigated. So, by using reliable monitoring systems, structural behavior can be controlled in various stages of construction or operation.

Occurrence of damage in a structure causes changes in its dynamic characteristics, such as its natural frequencies and mode shapes. Comparison of frequencies and mode shapes or mode shape curvature under various conditions can be used for health monitoring. For minor damage situations, direct comparison of modal parameters is not very useful. Instead, evaluation of mode shape curvature can be considered.

In this paper, in order to detect damage in the connections of a moment resistant frame, a method based on analysis of the free vibration response of a frame, using Hilbert-Huang transform, is presented. In this methodology, natural frequencies and mode shapes of the frame are predicted by processing the acceleration response of the structure. Variation of the mode shape curvature is considered as damage index. This method is tested on the numerical model of a 2D concrete frame and a