Abstracts of Papers in English

EXPERIMENTAL STUDY OF GROWTH OF A PRE-EXISTING INTERFACIAL FLAW USING THE DIGITAL IMAGE CORRELATION TECHNIQUE

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Abstract

Rocks normally contain defects such as joints, cracks, and pre-existing flaws from small to large scales. The behavior of these defects is highly dependent on their geometrical characteristics and locations in the rock mass. In many cases, these cracks are located at the interface of two materials. Most of the investigations on interfacial cracks have been analytical and there are a few experimental studies available. In this study, crack initiation, growth, and coalescence of a pre-existing flaw in a rock-like material are investigated under uniaxial compressive loading. Specimens are made of two types of rock-like materials with different compressive and tensile strength. The flaw is placed at the center of specimens. Flaw width is equally distributed in both materials. To investigate the effect of geometrical parameters of the flaw on crack growth processes, rock-like specimens with different flaw angles were made. To show the repeatability of results, three identical specimens of each geometry were made. Digital image correlation technique was used for a detailed investigation of crack growth processes from initiation to failure. Nikon D7100 camera was used to take pictures of the specimen during loading. Ncorr software was used to analyze the pictures. The results showed that crack growth, coalescence, and failure pattern depended on pre-existing flaw geometry. By varying the angle of inclination from zero to 45°, the compressive strength decreased and then, increased with increasing the angle of inclination from 45 to 90°. Spec-

imen with 45° flaw had the least compressive strength because theoretically maximum shear happens at this angle. For flaws with angles of 0 to 30 degrees, failures are caused by the growth of wing cracks. However, from 45 to 75 degrees, failures often occur with the propagation of the shear crack along the interface. At the angle of 90 degrees, a tensile crack is formed at the center of the sample along the interface. The results showed that crack growth and failure pattern depended on pre-existing flaw geometry.

Key Words: Interfacial flaw, rock-like material, crack growth, digital image correlation (DIC), failure pattern, uniaxial compression test.

ASSESSMENT OF INOCULUM TO SUBSTRATE RATIO'S EFFECT ON DRY ANAEROBIC DIGESTION PROCESS PERFORMANCE

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Abstract

Nowadays, the world's population growth and improved standards of living have given rise to increased global waste production. This rate is even higher in developing countries. For example, in Iran's capital, Tehran, about 7,000 tons of waste is generated daily. Improper management of these massive amounts of solid waste causes many serious human health and environmental issues. According to statistics, 60% of municipal waste in most developing countries is made up of biodegradable organic materials. Anaerobic digestion (AD) is one of the most common waste management techniques which have been utilized for several decades to manage municipal wastes. Additionally, AD benefits society by producing bioenergy and biosolids that can be used as fertilizers. Today, dry anaerobic digestion (DAD) has gained much more attention in comparison to liquid anaerobic digestion due to its lesser water requirement, smaller reactor volume, and higher biogas production. Since DAD is a biological process, the inoculum to substrate ratio (I/S) is an effective parameter in AD-based processes. In this regard, the effect of the I/S ratio on the DAD of organic waste with fruit and vegetable waste provided by the Tehran fruit and vegetable market at mesophilic conditions was investigated in this study. Experiments were conducted at four different I/S ratios (0.25, 0.5, 1, 2) in bench-scale reactors using the sludge supplied from the South Tehran wastewater plant. Different operational and controlling parameters including pH, chemical oxidation demand (COD), oxidation-reduction potential (ORP), volatile fatty acids (VFAs) concentration, and the composition of the biogas were assessed in the experiments. According to the results, when the I/S ratio was below one, the volume of the biogas decreased due to the accumulation of VFAs. The best result was gained when the I/S ratio was 2 resulting in 0.35 lit CH4/g VS production and 77% removal of Volatile solids (VS).

Key Words: Municipal solid waste management, dry anaerobic digestion, biogas, inoculum.

EVALUATION OF LOCAL DAMPING EFFECT ON STATIC AND DYNAMIC BEHAVIORS OF GRANULAR MATERIALS USING DEM MODELING

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Abstract

Frictional sliding may not be sufficient for the stability of a system. In almost all models in the Discrete El-

ement Method (DEM), a local non-viscous damping is used to balance the system by applying a damping force with a magnitude proportional to the unbalanced forces to each particle. The predicted macroscopic behavior of simulated particle assembly is influenced by the damping coefficient (α). In the present research, after calibrating the DEM simulations with the results of static and cyclic triaxial tests performed on sand samples containing rounded and angular particles under confining pressure of 100 kPa and cyclic stress ratio of 0.5, to study the effect of local non-viscous damping on the static and dynamic behavior of sands, different values of damping coefficient (0.5, 0.6, 0.7, 0.8 and 0.9) were used in simulations (in three-dimensional conditions). Then, the effects of initial void ratio, confining pressure, and particle shape on the behavior of the simulated samples were determined. The simulation results of the samples under static triaxial tests indicate that the effect of local non-viscous damping on the quasi-static behavior of granular materials is not significant. Under the same conditions, the energy stored in the samples with different damping coefficients is approximately equal. Angular specimens have a higher stored energy level. α has no significant effect on the coordinate number, magnitude of contact forces, and the maximum deformation in samples at the end of the static triaxial tests (20% axial strain). Upon increasing the damping coefficient from 0.5 to 0.9, the maximum rotational and translational velocities of both groups of samples are reduced. The higher the value of α considered in the simulation of cyclic triaxial test, the greater the dissipated energy of sample; thus, its damping ratio increases. By increasing the α coefficient, the shear modulus of round and angular particles decreases. The damping coefficient does not have a significant effect on the number of contacts between particles in the samples under cyclic triaxial tests, but the magnitude of contact forces, maximum rotational and translational velocities of the particles, and maximum deformation occurred in samples decreased with damping coefficient.

Key Words: Discrete element method simulations, granular materials, triaxial tests, local non-viscous damping coefficient.

THE EFFECT OF WASTE MARBLE POWDER AND SILICA FUME ON THE MECHANICAL, ENVIRONMENTAL AND ECONOMIC PERFORMANCE OF CONCRETE

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Abstract

One of the most widely used materials in the construction industry is concrete and one of its main constituent elements is cement. Cement production, in addition to consuming non-renewable natural resources, emits greenhouse gases and pollutes the environment. Waste marble powder (WMP) is an industrial by-product that the marble factory generates considerable amounts during stone processing. WMP mostly not used in the industry nor being recycled and causes serious environmental problems. Silica fume (SF), also known as micro silica, is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production. This paper presents the results of an experimental investigation of mechanical properties carried out on the concrete mixes containing WMP and SF as a partial replacement of Portland Cement (PC). In all concrete mixtures, a constant water/binder ratio was used and concrete mixtures with a target initial slump of 80 ± 10 were prepared. All of the concrete mixtures were assessed in terms of environmental, economic and mechanical aspects. Global warming potential, fossil fuel depletion potential and acidification potential were considered as environmental indicators of concrete mixtures production.

Finally, it was observed that the mechanical properties of concrete containing WMP are improved for replacement ratios up to 10%. The use of SF improved the performance of all mixing designs and compensated for the shortcomings in the mechanical properties of concrete containing high percentages of WMP. Mechanically, the best percentages for simultaneous use of WMP and SF are 5% and 10%, respectively. From an environmental point of view, replacing 20% of WMP and 10% of SF with PC, not only leads to the production of concrete with suitable mechanical properties but also reduces the use of cement by 30% and the resulting environmental pollution. The combined index designed in this study showed that the optimal mix design in terms of mechanical, environmental and economic belongs to a mixture in which 5% WMP and 5% SF are used simultaneously.

Key Words: Waste marble powder, silica fume, mechanical, environmental and economic, concrete.

EVALUATION OF SHEAR BEHAVIOR OF SANDWICH PANEL SHOTCRETED BY LOW-CEMENT MATERIAL

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Abstract

In modern life, with the advancement of science and technology, human need for prefabricated structures is felt more. Therefore, the study of prefabricated structures becomes very important. Lightweight prefabricated structures are among the items that need further studies and researches. These panels have high execution speed and are earthquake resistant. These elements are used as wall and ceiling in structures. It is necessary to study the shear capacity and performance of these lateral panels against and reciprocating loads.

In this study, the compatibility of prefabricated structures with nature and reduction of maximum pollution have been considered. For this purpose, an attempt is made to use materials compatible with nature and replace them with cement. This study is a laboratory study of the lateral bearing capacity of lightweight prefabricated panels and its integration with the desired materials. Five shear walls consisting of a thatched specimen and two specimens are made using bentonite. A one-story structure with bentonite was also examined and reinforced.

The results of the samples are presented in the form of hysteresis curves and push finally hardness diagram. Finally, the results are compared. The sample with a cement grade of 400 had the highest load capacity and was able to withstand 52.33 kN load. Also, the straw sample suffered the least load. The highest difficulty is related to the sample of a one-story building, followed by the cement sample with a grade of 400. The straw sample has the least hardness. The decrease in stiffness occurred in the samples with a steep slope. The amount of energy absorbed by each sample is equal to the area under the cover curve. The sample with a grade of 200 cement has the highest area under the curve, thus absorbing the highest amount of energy. The thatch sample absorbs the least amount of energy. The average ductility of a single-story structural sample is higher than that of other samples. The thatched specimen has the lowest ductility.

Key Words: Sandwich panels, load-bearing capacity, shear behavior, shotcrete, cement.

DISPLACEMENT POTENTIAL FUNCTIONS FOR ELASTODYNAMIC PROBLEMS IN TRANSVERSELY ISOTROPIC MEDIA BASED ON NONLOCAL STRAIN GRADIENT THEORY

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Abstract

Today nanotechnology has become important in many fields, including industry, medicine, engineering, aerospace, national security and electronics. As the dimensions of the structures decrease, the effects of size play a crucial role in properties of the media. Mechanical properties, electrical conductivity, thermal properties and other known chemical and physical properties are some examples that differ on nanoscales. Classical continuum mechanics are impotent to cover the effects of dimensions of the constituents of the media on

nanoscales. Hence, several non-classical continuum theories, including non-local elasticity theory, strain gradient theory, and non-local strain gradient theory, have been developed by researchers to explain size-dependent mechanical behavior on a nanoscale.

In this research, governing equations in terms of displacement potential functions based on nonlocal strain gradient theory are introduced for elastodynamic problems in homogeneous Transversely isotropic media. To this end, the three-dimensional equations of motion of the homogeneous Transversely isotropic media are first calculated using the nonlocal strain gradient theory. Then, using a systematic method, a set of complete displacement potential functions will be presented to solve elastodynamic problems in these media. By use of potential functions, the governing equations of motion will be decoupled. The proposed potentials include two scalar functions. One of them satisfies an 8th-order partial differential equation and 4th-order PDE is governed on the other. These potential functions are obtained in the form of a combination of wave operators, nonlocal parameter, and characteristic length, which are functionally and physically meaningful. These potential functions are obtained in the form of a combination of wave operators, non-local parameter, and characteristic length, which are functionally and physically meaningful. In addition, potential functions for limiting cases namely strain gradient theory and Eringen nonlocal elasticity theory are presented, separately. Also, by neglecting non-local parameters and characteristic length, the solution is degenerated to the Eskandari-Ghadi solution for classical theory of elasticity. Moreover, a new set of potential functions is presented to solve the elastodynamics of nonlocal strain gradient theory for the simpler case of isotropic materials.

Key Words: Displacement potential functions, elastodynamic problems, nonlocal strain gradient theory, transversely isotropic media.

PULSE-LIKE GROUND MOTION SIMULATION USING WAVELET-BASED HILBERT TRANSFORMS

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Abstract

In areas near active faults, ground motions usually show a large pulse in velocity time history. These near-field pulse-like ground motions increase the structural failure and cause extensive damage to structures. Due to the limited number of pulse-like ground motion recorded in a range of magnitude and distance, there is a small set of possible earthquake scenarios for seismic engineering in a given area, especially in areas near the fault. A new method has been proposed in this paper for simulating near-field pulse-like ground motions using instantaneous feature modeling. The proposed method is introduced based on the time-frequency process which is necessary to consider non-stationary characteristics of ground motion. In this method of simulation, wavelet-based Hilbert transform is used to extract the non-stationary characteristics of original pulse-like ground motion. The stationary wavelet transform is first applied to decompose the original ground motion into a series of subband frequency, and then the instantaneous features are obtained by applying Hilbert transform on each subband frequency. Instantaneous frequencies are modeled by Gaussian distribution and the instantaneous amplitude fitted by Gaussian curves. Approximation coefficients obtained from the last level of wavelet transform are also simulated using the Gaussian curves. Pulse-like ground motion will be simulated using Hilbert and Wavelet inverse transforms and the new generated data for the instantaneous characteristics and approximation coefficients. In this study, four pulse-like ground motions of Imperial Valley1979 and Northridge 1994 were used to verify the effectiveness of this simulation method. Simulated ground motions were compared with the recorded pulse-like ground motions and various criteria were used to confirm the effectiveness of the proposed method. Peak ground acceleration, response spectrums, and arias curves which are important parameters of ground motion were used in this paper to validate the proposed method. Simulation results not only captured the main characteristics of the recorded pulse-like ground motion, but also preserved the effects of the pulse as well.

Key Words: Pulse-like ground motion, wavelet transform, hilbert transform, instantaneous frequency, instantaneous amplitude, gaussian distribution.

EFFECT OF AGGREGATES ON THE COMPRESSIVE STRENGTH AND PERMEABILITY OF CONCRETE

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Abstract

Aggregates make up between 60% and 80% of the concrete volume, being surrounded by the cement paste and their properties all have significant impact on the behavior of concrete, during the service life for which it been designed. For this reason, a series of laboratory tests were conducted during this investigation to evaluate the effects of mechanical, durability and geometry properties of aggregates on the compressive strength and permeability of the 28-day concrete specimens. Concrete specimens were made with different types of aggregates, including granite, andesite, silica, limestone, marble and tuff. Studied mechanical properties were compressive, tensile and surface strengths, Los Angeles abrasion index, Schmidt hardness and saturated surface dry density, while permeability, water absorption and porosity were investigated as durability properties. Geometry properties of aggregates, including circularity, solidity and aspect ratio were also measured to investigate the effect of aggregates shape on the concrete compressive strength and permeability. To measure permeability and surface strength, the methods of "Cylindrical chamber" and "Twist-off" were applied, respectively, which were proposed and developed by Naderi. The results obtained revealed that a direct linear correlation, with coefficient of determination higher than 0.89 exists between compressive and surface strengths of the studied concrete specimens and parent rocks. On the other hand, parent rock compressive strength is approximately 140%-270% higher than that of the concrete containing aggregates of the same parent rock, while its permeability is nearly 59%-71% lower than the permeability of the corresponding concrete. It was also observed that concrete compressive strength decreases with increasing its permeability and vice versa. Analysis of the results demonstrated that strong correlations, with coefficients of determination higher than 0.73 exist between concrete compressive strength, concrete permeability and the mentioned mechanical and durability properties of parent rocks and the corresponding aggregates. On the contrary, coefficients of determination lower than 0.1 were obtained for the relationship between geometry properties of aggregates, concrete compressive strength and permeability. This behavior revealed that the impact of aggregates shape on concrete compressive strength and permeability is not significant, compared with the mentioned mechanical and durability properties of the parent rocks and the corresponding aggregates.

Key Words: Compressive strength and permeability of concrete, shape of aggregates, mechanical and durability properties of aggregates.

LABORATORY AND NUMERICAL SIMULATION OF THE EFFECT OF WRAPAROUND ANCHORAGE OF REINFORCEMENTS ON THE BEARING CAPACITY OF SPREAD FOOTING

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Abstract

In this research, the effects of the wraparound anchorage on the bearing capacity of a spread footing on sand reinforced by carbon fiber reinforced polymer strips were studied experimentally and numerically. A steel box with the dimensions of 100 × 100 × 70cm was used as a test setup and the spread footing was simulated using a steel plate with the dimensions of 20×20×2.5cm. Also, a numerical model was developed by FLAC3D software to simulate the physical model for further investigations. Laboratory tests were conducted on unreinforced and reinforced models with and without wraparound anchors with different lengths. The results of these investiga-

tions indicated that the effect of the wraparound anchorage on the bearing capacity of the foundation was highly dependent on the return length of the anchor. Its effect on the improvement of the bearing capacity of the foundation was noticeable when the length of the anchor was long enough that the end of the reinforcement placed under the footing. Otherwise, the effect of the wraparound anchor on the improvement of the bearing capacity of the footing was negligible. Depending on the length of the return anchor, two distinct load-settlement behaviors were observed. When the length of the return anchor was not long enough, the bearing capacity of the footing showed some improvement in low settlement levels, but it approached the bearing capacity of the footing with unanchored reinforcements as the settlement was increasing. There was at least 10% improvement in the bearing capacity in this situation. For models with long return anchors, increasing the settlement of the footing increased the bearing capacity of the footing when compared to the behavior of reinforced model without wraparound anchor. The improvement of the bearing capacity of the footing was up to 27% for long anchors depending on the length of the wraparound anchor. The results of the numerical simulations indicated that the wraparound anchorage changed the stress distribution and increased the confinement of the soil elements located under the footing. Increasing the length of the return anchors led to a uniform distribution of the confining pressure under the footing.

Key Words: Spread footing, reinforced soil, carbon fiber, wraparound anchor, bearing capacity.

MODIFIED EQUATIONS FOR DISPLACEMENT-BASED METHOD OF STEEL BRACED REINFORCED CONCRETE STRUCTURES

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Abstract

For reinforced concrete (RC) structures located in earthquake prone areas, inherent brittle behavior of concrete may have adverse effects on their seismic performance. Buckling-restrained braces (BRBs) are commonly employed as ductile bracing components located in seismic areas where configuring these elements in RC frames can develop a ductile steel braced reinforced concrete structures. By evaluating key limit states governing dual frame design, this study aims to present a direct displacement-based design (DDBD) method as an alternative approach to the seismic design of steel braced reinforced concrete structures. The force-deformation expression of the steel braced reinforced concrete structures was developed. The new approach for numerical modeling was proposed and validated to simulate the nonlinear behavior of dual system. Then, a number of steel braced reinforced concrete structures considering different height and bracing configurations were designed to perform nonlinear time-history (NTH) analysis under real earthquakes. The seismic response including the maximum displacement profile of all models was acquired. The maximum value of least mean square error was calculated 11% for high-rise sample models that the predicted displacements can be reliably matched with the demanded displacements of the steel braced reinforced concrete structures. The analytical results of the current study indicate that DDBD approach can be used to design ductile steel braced reinforced concrete structures in seismic zones.

Key Words: Ductile frame, RC frame, displacement-based design method, the least-squares method, nonlinear dynamic analysis.

REVIEW OF THE POTENTIAL USE OF BACTERIAL PRECIPITATION IN SELF-HEALING, IMPROVING DURABILITY AND PROPERTIES OF CONCRETE

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Abstract

Concrete is one of the most widely used constructional materials which is disposed to cracking for various reasons. Cracking is one of the unavoidable defects in concrete. When micro-cracks develop and join together, a continuous network of cracks is formed inside the concrete. Cracks increase the permeability and reduce the impermeability against moisture and aggressive substances such as sulfate ions, chloride ions, and acids. These factors affect the structure durability and reinforcement corrosion and destroy the concrete matrix. The concrete self-healing approaches appear to be an appropriate idea to remove this damage. Among the different self-healing ways which are basically chemical, the Calcium Carbonate precipitation, resulting from the micro-organisms metabolic activities, is a new environmentally friendly strategy. Their ecological variety is high and can be found in different natural settings. In this way, to treat damaged structures, a microbial process is applied wherein the combination of bacteria, urea, and a calcium source forms calcium carbonate crystal that results in crack reduction, impermeability, and improved concrete mechanical properties. Biologically, the calcium carbonate precipitation helps heal the small cracks, fill pores, and bind other materials such as sand and gravel in concrete. These precipitations are the byproducts of the usual metabolic processes such as photosynthesis, urea hydrolysis, and sulfate reduction. To obtain a useful insight in this important researching area and to protect the environment, this article investigates different approaches of using bacteria in concrete, the bacteria potential to heal the cracks. Improving the properties of concrete was examined, and the laboratory results were interpreted. Investigation of the concrete micro-structure indicated the formation of the calcite crystals in the samples and confirmed the promising performance of bacteria in healing micro-cracks, improving the mechanical properties, and the concrete durability in the destructive environments. By reducing structural pores, bacterial participation at a concentration of $10^5 - 10^7$ cells/ml led to an increase in compressive strength by 49% and a decrease in the penetration of chloride ions and water absorption to 69% and 94% , respectively. Moreover, the maximum crack healing width at a concentration of $10^7 - 10^9$ cells/ml about was 1.2 mm.

Key Words: Self-Healing, calcium carbonate precipitation, bacteria, crack healing, mechanical properties and durability.

SEMI-EXPLICIT UNCONDITIONALLY STABLE TIME INTEGRATION METHOD BASED ON GENERALIZED-α TECHNIQUE

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Abstract

In structural dynamic analysis, various time integration techniques have been proposed. Generally, these algorithms discretize the time domain into a finite number of intervals and approximate the displacements, velocities, and accelerations via mathematical expressions at each time increment. Based on the structure of these approximations, time integration schemes are classified as explicit and implicit. Explicit schemes are much simpler and often march forward only through pure vector operations. On the other hand, implicit strategies require more computational efforts especially in nonlinear behaviors since they involve solving a system of simultaneous equations at each time step using iterative techniques. Although computationally more expensive, implicit schemes are unconditionally stable, meaning that the growth of solution errors at each time increment remains bounded. On the contrary, explicit techniques suffer from instabilities which manifest as unrealistic growth of amplitude of the responses. To overcome this issue, time step size should be chosen small enough to meet the stability criterion. In this paper, by gathering the advantages of both approach, a new semi-explicit unconditionally stable time integration method based on the well-known implicit Generalized-α (G-α) technique is proposed. To this end, first, the fundamental approximating relationships of the suggested method is introduced for a single degree of freedom system with the unknown integration parameters. Then, using the concept of amplification matrix, these unknown parameters are determined so that the method possesses the same characteristic equation as the G-α technique. This leads to a set of model-dependent integration parameters that are no longer scalar constants. Due to this kind of formulation, similar stability and accuracy behavior are observed when comparing the proposed method with the G-α technique, both analytically and numerically. After

generalization of the proposed algorithm to the multi-degree of freedom systems, some numerical examples are solved and comparisons are also made with other similar time integration schemes. Findings reveal the merits of the proposed algorithm over the other well-known time stepping techniques.

Key Words: Dynamic analysis, numerical integration, structure-dependent method, unconditional stability.

EXPERIMENTAL STUDY OF THERMAL AND SIZE EFFECTS ON THE UNIAXIAL COMPRESSION STRENGTH OF GRANITE

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Abstract

The exploration and extraction of hydrocarbon resources (oil and gas) as well as the geothermal energy at great depths of the rock layers have posed challenges for the stability of the drilling well wall at high temperatures. Also, the burial of nuclear waste leads to a great increase in temperature in the surrounding rocks and affects the properties of the rocks. In addition, drilling deep oil wells at a high temperature of the drilling area illustrates the importance of investigating the effect of heat on the rock strength. Therefore, understanding the effect of temperature changes on the physical and mechanical properties of rock is vital for designing rock structures and evaluating safety in rock engineering.

In this study, uniaxial compressive strength of granite, a common type of rock in the Earth's crust, under different temperatures and in different sizes is investhgated. For this purpose cylindrical specimens with diameters of 28 mm, 54 mm, and 84 mm were prepared and tested at laboratory temperatures and temperatures of 100, 200, 400, and 600°C. The samples were subjected to compressive loading and heating simultaneously. The results of the tests showed that uniaxial compressive strength decreased with increasing the temperature. At temperatures below 400°C, water begins to evaporate and escape through the cracks at a relatively slow rate. This creates a high air pressure and intensifies the formation and expansion of the cracks and pores and increases the cracks. As temperature rises above 400°C, chemical changes occur in the rock, which may reflect the color change of the sample. The quartz phase transition results in an increase in microcracks due to different expansion between the quartz grains and other minerals, which is one of the reasons for the decrease in strength between 400 and 600°C. The reduction in strength at 600°C was obtained for 28 mm diameter, 47%, for 54 mm diameter was 53% and for 84 mm diameter was 56%. Also, at a constant temperature, the uniaxial compressive strength decreased as the diameter increases. These changes are observed at all sizes.

Key Words: Thermal effect, size effect, uniaxial compression strength, granite.