

DIS

**DIPARTIMENTO DI
INGEGNERIA STRUTTURALE
POLITECNICO DI MILANO**

SUMMARIES OF PUBLICATIONS 2001 - 02

**DEPARTMENT OF
STRUCTURAL ENGINEERING
POLITECNICO DI MILANO**

This booklet is published every year and contains the summaries of most of the publications of Department of Structural Engineering together with the index of the publications listed in the previous two issues

Papers and books are classified according to the following codes:

- LA1: Books.*
- LA2: Books with international diffusion.*
- LE1: Editing of books.*
- LE2: Editing of books with international diffusion.*
- RV1: Notes and papers published in ISI-classified or equivalent journals.*
- RV2: Notes and papers published in other journals.*
- SA1: Notes and papers published in books.*
- SA2: Notes and papers published in books with international diffusion.*
- CV1: Notes and papers published in proceedings of international conferences.*
- CV2: Notes and papers published in proceedings of national conferences.*

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SUMMARIES OF PUBLICATIONS PAPERS

Paper No. 2609

CV2

Alessandrini G., Binda L., Bartoli Cannada N., Della Torre S.

TOWARDS A PREVENTIVE CONSERVATION STRATEGY FOR HISTORIC BUILDINGS

Proc. 3rd Int. Congr. on 'Science and Technology for the Safeguard of Cultural Heritage in the Mediterranean Basin', Alcalà de Henares (E), July 9-14, 2001 (CD ROM).

In February 1998 the strategic Project for the Lombard Regional Authorities was initiated in collaboration with the Istituto Centrale per il Restauro (ICR) in order to activate the Regional Centre of the risk Map of Cultural Heritage. In May 1999 the project became part of the Framework Agreement between the Cultural Heritage Ministry and the Lombard Regional Authorities. The Risk Map, as it was conceived and realised over the years by the ICR is an important instrument for the planned conservation because it encourages an awareness of the heritage in view of preserving it for long periods. The underlying concept is that it is essential to follow a building throughout its life by constant monitoring and diagnosis in order to prevent the occurrence of major damage later on. Accordingly the Risk Map will evolve in three directions: (i) the creation of the catalogue; (ii) the promotion of planned conservation interventions in the region; (iii) their relations with the territorial and landscape planning. To complement the information systems developed by the ICR, technical methods, systems of incentives and types of professional expertise were identified. The authors will present the results of an ongoing research about monitoring and diagnosis. The aim of the work is to achieve a precise definition of methods, connected to the need of evaluation at different times, and of costs, connected to the need of spending before any damage is in sight. In the meantime, the integrated training programmes

will continue as well as the development of the information system and the campaigns to promote and publicise the project and encourage new entrepreneurs in the sector.

KEY WORDS: risk; conservation; monitoring; diagnosis.

Paper No. 2610

CV1

Anzani A., Binda L., Mirabella Roberti G., Tongini Folli R.

A STUDY OF ANCIENT MASONRY TOWERS UNDER HEAVY PERSISTENT ACTIONS

Proc. 5th Int. Symp. on 'Computer Methods in Structural Masonry' (V STRUMAS), Roma, April 18-21, 2001, T.G. Hughes and G.N. Pande (Eds.), pp. 1-8.

The paper takes a further step to understand the long term behaviour of ancient masonry, thanks to an experimental research performed on the masonry of two ancient buildings tested under constant loads. The laboratory results are interpreted with the help of a simple rheological model for a subsequent application to construction analysis. A comparison between significant aspects of the behaviour of the two materials and the different influence played by damage is shown.

KEY WORDS: masonry towers; visco-elastic rheological model.

Paper No. 2611

SA1

Anzani A., Binda L., Papa E., Taliercio A.

MODELING OF THE TIME EVOLUTION OF DAMAGE IN ANCIENT MASSIVE MASONRY BUILDINGS (in Italian)

in 'Il Progetto di Conservazione: linee metodologiche per le analisi preliminari, l'intervento, il controllo di efficacia', S. Pesenti (Ed.), Alinea, par. 2.5, pp. 151-163, 2001.

The failure of some ancient masonry buildings (e.g., the Civic Tower of Pavia, Italy) can be attributed to creep strains induced by the stresses acting in the structure. If compared to the short-term strength of the material, the intensity of these stresses may be such that the building is not deemed to be unsafe. Nevertheless, because of their persistence in time, they can induce an evolution of mechanical damage (in the form of microcracks) associated to a local decrease in strength, stiffness, etc. This paper synthesizes the results of a research program carried out in the last years on the safety of ancient masonry structures and the relevant interventions. First, a theoretical model developed by the authors is presented, suitable to predict the mechanical response of rubble masonry under sustained loading and up to failure. Then, the model is calibrated according to

experimental tests on specimens taken from the ruins of the Civic Tower of Pavia. After implementation in a commercial finite element code for nonlinear analyses, the model is applied to the structural analysis of the Tower. Special attention is paid to the time evolution of damage and the consequent prediction of the time to failure of the building. Finally, the guidelines are outlined which should be followed when operating on damaged masonry buildings, according to the information provided by the proposed model.

KEY WORDS: masonry; damage; rheological model; viscoelasticity; creep; failure.

Paper No. 2612

CV1

Ardigò C., Biondini F., Malerba P.G.

A CELLULAR AUTOMATA FINITE BEAM ELEMENT FOR DAMAGE EVALUATION AND DURABILITY ANALYSIS OF CONCRETE STRUCTURES

Proc. 2nd Int. Conf. on 'Advances in Structural Engineering and Mechanics' (ASEM'02), Busan (South Korea), August 21-23, 2002 (CD ROM).

This paper presents a new approach to durability analysis and lifetime assessment of concrete structures. Firstly, a reinforced concrete finite beam element for non-linear analysis of deteriorating structures is formulated. Subsequently, the damaging process induced by the diffusion of external aggressive agents inside the structure is considered. The diffusion process is modelled by using cellular automata and the mechanical damage coupled to diffusion is then evaluated by introducing some material degradation laws. The proposed methodology is finally applied to the durability analysis of a reinforced concrete continuous T-beam and of an arch bridge.

KEY WORDS: aggressive agents; cellular automata; concrete structures; diffusion processes; durability analysis; mechanical damage; structural lifetime.

Paper No. 2613

CV1

Bamonte P., Coronelli D., Gambarova P.G.

SIZE-EFFECT IN HIGH-BOND BARS

Proc. Int. Conf. on 'Bond in Concrete – from Research to Standards', G.L. Balasz, P. Bartos, J. Cairns and A. Borosnyoi (Eds.), Budapest (H), November 20-22, 2002, pp. 43-52.

Size effect is studied in this paper with reference to the bonding of short, deformed bars anchored to ordinary and high-performance concrete. To this end, 48 short anchorages, each consisting of a purposely-machined high-bond bar embedded in a concrete cylinder, were cast and tested up to the pull-out or the push-in of the bar. The tests were displacement-controlled, in order to measure

the entire load-slip response. All concrete cylinders are confined by a steel sleeve, to prevent or limit cover splitting. For each of the 4 diameters considered in this study ($d_b = 5, 12, 18$ and 26 mm) the specimens are geometrically similar down to the smallest detail. In addition to investigating size effect in high-bond bars, the main objective of this project is to contribute to the formulation of an improved bond stress-slip law, in order to introduce the size effect into the code provisions for bond

KEY WORDS: bond; size-effect; reinforced concrete; high performance concrete; ribbed bars.

Paper No. 2614

SA2

Bamonte P., Coronelli D., Gambarova P.G.

NORMAL-STRENGTH AND HIGH-PERFORMANCE CONCRETE: SIZE EFFECT IN SMOOTH ANCHORAGES

Studi e Ricerche, Scuola di Specializzazione per le Costruzioni in Cemento Armato, Politecnico di Milano, Vol. 23, 2002, pp. 1-18.

The bonding of moderately-long anchorages to both ordinary and high-performance concrete (NSC, $f_c = 29$ MPa, and HPC, $f_c = 65$ MPa) is studied here with reference to size effect. To this purpose, 24 anchorages ($L/d_b = 10$), consisting of a quasi-smooth, slightly-roughened bar embedded in a concrete cylinder, were cast and tested up to the pull-out of the bars, which had 4 different diameters ($d_b = 5, 12, 18$ and 26 mm). For each of the 8 cases examined here (4 diameters x 2 mixes), 3 nominally-identical specimens were tested. Furthermore, to have some information on the roles of specimen supports and bar roughness, 3 more specimens were cast and tested, bringing the specimen number to 27. Though the primary objective of this study is to investigate whether a general-type size-effect law applies to bond in high-performance silica-fume concrete, the modeling of an anchorage by means of a local elastic-fracturing-frictional bond-slip law is also carried out. The propagation of the debonding along the bar is controlled via a stress criterion, which makes it possible to introduce indirectly the size effect by giving the stress peak a size-dependent formulation. The fundamental parameters required by the analysis are worked out through an identification process based on the least-square regression applied to the experimental values of the maximum load and to the values predicted by the model, and the dependence of the nominal local bond strength on the inverse of bar diameter is demonstrated.

KEY WORDS: bar-concrete bond; bar debonding; pull-out tests; size effect (in bond); smooth bars; stress criterion (for bond capacity).

Bamonte P., Coronelli D., Gambarova P.G.

STEEL-CONCRETE BOND AND SIZE EFFECT IN SMOOTH ANCHORAGES:
HPC VERSUS NSC

Befestigungstechnik und Bewehrungstechnik– Festschrift zu Ehren von Prof. Dr. Ing. Rolf Eligehausen anlässlich seines 60. Geburtstages – Fuchs W., Reinhardt Eds., ibidem – Verlag, Stuttgart, 2002, pp. 243-260.

The bonding of moderately-long anchorages to ordinary and high-performance concrete ($f_c = 29$ MPa, and HPC, $f_c = 65$ MPa) is studied here with reference to size effect. To this purpose, 24 anchorages ($L/d_b = 10$), consisting of a quasi-smooth, artificially-roughened bar embedded in a concrete cylinder, were cast and tested up to the pull-out of the bars, which had 4 different diameters ($d_b = 5, 12, 18$ and 26 mm). For each of the 8 cases examined here (4 diameters x 2 mixes), 3 nominally-identical specimens were tested. Though the primary objective of this study is to investigate whether a general-type size-effect law applies to bond in high-performance silica-fume concrete, the modeling of an anchorage by means of a local elastic-fracturing-frictional bond-slip law is also carried out. The assumption that the propagation of debonding along the bar be controlled by the maximum bond stress is introduced (stress criterion), and size effect appears through a size-dependent formulation of the local bond strength. The values of the fundamental parameters of the model are identified by means of a bidimensional, least-square regression procedure applied to the experimental values of the maximum pull-out load and to the values predicted by the model, and the dependence of the nominal local bond strength on the inverse of bar diameter is confirmed.

KEY WORDS: bar-concrete bond; smooth anchorages.

Baronio G., Binda L., Tedeschi C., Tiraboschi C.

CHARACTERIZATION OF THE MATERIALS USED IN THE CONSTRUCTION
OF THE NOTO CATHEDRAL (in Italian)

Atti Seminario Internazionale 'Ricostruendo la Cattedrale di Noto e la Frauenkirche di Dresda: due casi di studio di ricostruzione in muratura', Noto (I), February 10-12, 2001, pp. 107-120.

After the partial collapse of the Cathedral of Noto, the authors were required to carry out an extensive on site and laboratory investigation in order to support the designers of the Cathedral reconstruction to check the possibility of preserving the parts which are still standing and to choose the right solutions and the most compatible materials for the reconstruction. The tests carried out in laboratory in

order to characterise the chemical, physical and mechanical properties of the original materials are described and their results discussed.

KEY WORDS: construction techniques; masonry; mortar; chemical-physical analysis.

Paper No. 2617

RV1

Benallal A., Comi C.

MATERIAL INSTABILITIES IN INELASTIC SATURATED POROUS MEDIA UNDER DYNAMIC LOADINGS

Int. J. Solids Struct., Vol. 39, pp. 3693-3716, 2002.

Instabilities in inelastic saturated porous media are investigated here for general three-dimensional states under dynamic loadings using a perturbation approach. Under quasi-static conditions, unbounded growth of perturbations is related to the emergence of stationary discontinuities under drained or undrained conditions, while under dynamic conditions, unbounded growth is related either to the emergence of stationary discontinuities (and these are set by drained conditions) or to the appearance of the flutter phenomenon (acceleration waves). For associative behaviour the onset of unbounded growth always corresponds to localization under drained conditions and the onset of growth of perturbations occurs here only through divergence growth.

KEY WORDS: plasticity; saturated porous media; perturbation; instability; dynamic.

Paper No. 2618

CV1

Benallal A., Comi C.

NUMERICAL ASPECTS OF THE DEFORMATION AND FAILURE OF SATURATED POROUS MEDIA

Proc. CIMENICS 2002, Caracas (Venezuela), April 10-13, 2002, 8 pp. (CD ROM).

The numerical analysis of the dynamic evolution problem concerning an elastic-plastic saturated porous media in presence of softening (or non-associativity) is considered in the framework of the Biot formulation extended to take into account plastic phenomena. The finite step boundary-value problem, obtained by discretization in time of the continuous initial boundary value problem, is studied and the issue of its ill-posedness is particularly addressed. The roles of the algorithmic properties are explicitly exhibited and the results illustrated through a simple example.

KEY WORDS: porous media; softening; localization; finite step problem.

Benallal A., Comi C.

QUASI-STATIC VERSUS DYNAMIC FAILURE INSTABILITIES IN FLUID-SATURATED POROUS MEDIA

C. R. Mécanique, Vol. 330, pp. 339-345, 2002.

Using a linear perturbation approach, we show that under quasi-static conditions, unbounded growth of perturbations coincides with localization under drained or undrained conditions. Under dynamic loadings, unbounded growth is related either to the emergence of stationary discontinuities (and these are set by drained conditions) or to the appearance of the flutter phenomenon (acceleration waves). For associative behaviour the inception of unbounded growth is always set (under both static and dynamic conditions) by the singularity of the drained acoustic tensor. It is only for non-associative flow that unbounded growth may correspond to undrained localization in quasi-static conditions and to flutter under dynamic conditions.

KEY WORDS: plasticity; saturated porous media; perturbation; localization; static; dynamic.

Bergamini A., Biondini F.

OPTIMISATION OF FOLDED PLATES STRUCTURES

Proc. 2nd Int. Conf. on 'Advances in Structural Engineering and Mechanics' (ASEM'02), Busan (South Korea), August 21-23, 2002 (CD ROM).

The optimal design of thin-walled folded plate structures under multiple loading conditions with respect to both static and kinematic limit states is presented. The design variables include geometrical quantities, like the thickness and the dimensions of the structural members, and topological parameters, which define the location and the connectivity of such members and the characteristics of the prestressing system. The objective of the design process is to find the solution which minimises the structural volume and/or the total prestressing force according to both side and behavioural constraints on the stress and displacement state. The solution of the non-linear optimisation problem so formulated is achieved by using the complex method. The structural analyses are performed by means of the finite strip method. Some applications to the optimal design of beams, vaults and bridges show the effectiveness of the proposed procedure.

KEY WORDS: folded-plates structures; finite strip modelling; structural optimisation.

Binda L., Baronio G., Cardani G., Penazzi D., Tedeschi C., Tongini Folli R.

CASE HISTORY (in Italian)

in *'Il Progetto di Conservazione: linee metodologiche per le analisi preliminari, l'intervento, il controllo di efficacia'*, S. Pesenti (Ed.), Alinea, par. 2.7, pp. 174-197, 2001.

The damage occurred to repaired and not-repaired stone-masonry buildings after the earthquake of Umbria and Marche Regions of 1997 shows that a preventive knowledge of masonry geometry and buildings techniques is an essential data both to study the stonework masonry behavior to vertical and horizontal actions and to choose the better repair techniques. A Data-Base is realized by the authors with more than 250 masonry cross sections collected in different Italian Regions. A systematic approach is proposed for investigation on site and in laboratory aimed to measure the essential parameters, to understand the collapse mechanisms and, meanwhile, to reduce times and costs of the tests. In addition the collapse of some heavy buildings and towers in Italy and elsewhere has shown the importance of defining a correct procedure for the diagnosis of the state of damage also of these structures. The long-term behavior and the effects of cyclic loads (wind, temperature variations, etc.) play a fundamental role into the stability of high structures like bell-towers. An application of a procedure based on an extensive laboratory and on site investigation together with analytical modeling and some guidelines are reported and discussed.

KEY WORDS: stonework masonry; seismic area; systematic approach; on site investigations.

Binda L., Baronio G., Tiraboschi C.

ON SITE INVESTIGATION ON THE REMAININGS OF THE CATHEDRAL OF NOTO (in Italian)

Atti Seminario Internazionale 'Ricostruendo la Cattedrale di Noto e la Frauenkirche di Dresda: due casi di studio di ricostruzione in muratura', Noto (I), February 10-12, 2001, pp. 71-89.

The Cathedral of Noto was damaged after the earthquake which hit Sicily in 1990. Soon after the event cracks appeared on the domes of the lateral naves, but also on the pillars. In 1992 some provisional works had been carried out in view of confining the pillars of the central nave which were damaged. Some pictures made after the earthquake also show clearly the presence of moisture rise on the pillars and walls. A sudden collapse due to the damages was probably not expected, so that no other measures were taken to better strengthen and repair the structures. Only after the collapse of the Civic Tower in Pavia (1989) and the

following research, it was clearly shown that in case of high stresses on low strength masonry an existing damage can lead slowly to partial or total collapse of the structure in a long time. It seems a confirmation of this long term behaviour of the structures that the Cathedral collapse took place in 1996 six years after the earthquake, which had certainly caused high damages to the structure.

KEY WORDS: masonry; non-destructive test; chemical test; uniaxial compressive test.

Paper No. 2623

RV2

Binda L., Saisi A.

STRUCTURAL IMPROVEMENT AND COMPATIBILITY BETWEEN THE NEW MATERIALS AND THE ORIGINAL STRUCTURE (in Italian)

L'Edilizia, No. 2, pp. 34-41, 2002.

Starting from the classification of historic building and masonry typologies the difficulties of studying appropriate solutions for strengthening and repair of masonry structures are pointed out. The failures of some new techniques for strengthening (grout injection, jacketing, etc.) as they were applied in seismic areas without the necessary investigation for the characterisation of the original materials and masonry morphology are described. There are no wrong techniques, but the inappropriate use of the techniques and the poor workmanship are the causes of the occurred failures. Therefore a preliminary on site and laboratory investigation is needed before choosing the appropriate repair technique. Controlling the effectiveness of the repair on site after it has been carried out is also recommended using non destructive or slightly destructive investigation procedures.

KEY WORDS: masonry typologies; reinforcing techniques compatibility; masonry decay.

Paper No. 2624

CV2

Binda L., Saisi S., Messina S., La Rosa R., Tringali S.

AFTER THE COLLAPSE OF THE NOTO CATHEDRAL THE LONG TIME INVESTIGATION ON BEHAVIOUR OF MULTIPLE LEAVES PILLARS OF SOME CHURCHES IN THE EASTERN PART OF SICILY (in Italian)

Atti Conv. Nazionale 'Crolli e Affidabilità delle Strutture Civili', IUAV, Venezia (I), December 6-7, 2001, pp. 233-244.

After the partial collapse of the Cathedral of Noto in Sicily, damaged by the 1990 earthquake which hit the oriental part of the Italian island an extensive investigation carried out on site and in the laboratory allowed to detect a pre-existing damage of the pillars due to long term behaviour of the material under

compressive stresses. The investigation extended to other churches and buildings showed other cases of progressive damage, which can in an unknown time take the structures to sudden collapse. As a premise the research carried out in the field after the collapse of the Pavia Civic tower and the results are briefly presented followed by the description of the case histories.

KEY WORDS: earthquake; masonry long time behaviour; damage process.

Paper No. 2625

RV1

Binda L., Saisi A., Tiraboschi C.

INVESTIGATION PROCEDURES FOR THE DIAGNOSIS OF HISTORIC MASONRIES

Construction and Building Materials, Vol. 14, No. 4, pp. 199-233, 2000.

The Friuli, Irpinia and Umbria earthquakes, and subsequent experiences, have emphasized the need for adequate damage assessment prior to seismic rehabilitation. Furthermore, assessment can be enhanced by preventive studies under the guidance of those in charge of hazard mitigation (architects, engineers, etc.). Research procedures must be defined so that findings can be used for damage assessment and as input data for structural analysis and control models. This paper provides evaluations of in-situ and laboratory tests on materials for existing unreinforced masonry structures and, in particular, touches upon the difficulty of interpreting the results of NDE tests. Also, the need for a design of the investigation prepared by persons responsible for the rehabilitation is indicated.

KEY WORDS: masonry decay; earthquake; non destructive techniques; maintenance.

Paper No. 2626

SA1

Binda L., Saisi A., Zanzi L., Baronio G.

TECHNIQUES AND DESIGN OF INVESTIGATION FOR STRUCTURAL DIAGNOSIS (in Italian)

in 'Il Progetto di Conservazione: linee metodologiche per le analisi preliminari, l'intervento, il controllo di efficacia', S. Pesenti (Ed.), Alinea, par. 2.3, pp. 97-139, 2001.

Non destructive and minor destructive techniques can be very useful for the diagnosis of an historical building and for the design of the restoration activities. Unfortunately, these techniques are not very much known and sometimes they are not used because of that. On the opposite, sometimes they are used but in a not appropriate way producing incomplete answers or unreliable results. Here, we present a sort of guideline document based on our direct experience in the evaluation of masonry structures and also based on the participation to the tech-

nical discussions within the existing Standard Commissions of this professional sector. We present the principal investigation techniques with indications on their advantages, potential, limits, condition of applicability, expected costs, etc.. For each method, we also give a short description of the equipment and some essential information on how to properly design the investigations and to process the data.

KEY WORDS: historical buildings; masonry; diagnosis; NDT; guidelines.

Paper No. 2627

CV2

Biondini F.

BASIC HYPOTHESES FOR THE NEW VERIFICATION METHODS OF ANCHORS (in Italian)

Proc. of the Technical Seminar "Innovazione nello sviluppo e nella progettazione degli ancoraggi su calcestruzzo", Rome, November 16, 2001, pp. 51-62.

The modern criteria for the strength verification of metal anchors in concrete elements refers to the classical methods of limit analysis. As known, limit analysis assumes a perfectly plastic behaviour of the materials. Although the constitutive properties of the concrete not fulfil this limit scheme, the validity of the results obtained with such an hypothesis can be maintained by respecting some design conditions which, at different scale levels, allow to verify the effectiveness of the materials, the integrity of the elements which compose the model, and the consistency of the model itself with the actual reference stress state. In this context, after the general criteria in defining the effectiveness factor of concrete are briefly recalled, both the validity of the results and the criteria for their calibration in design and verification of anchoring systems are presented and discussed.

KEY WORDS: metal anchors; concrete elements; limit analysis; effectiveness factor.

Paper No. 2628

CV1

Biondini F.

CONCEPTUAL SEISMIC DESIGN OF DAMAGE-TOLERANT BRIDGES

Proc. 7th Int. Seminar on 'Seismic Isolation, Passive Energy Dissipation and Active Control of Vibrations of Structures', Assisi (I), October 2-5, 2001, pp. 453-466.

The optimal seismic design of concrete bridges and viaducts is investigated. Alternatively to the current design trends, a design approach which considers the seismic behaviour of the structure already at the conceptual design stage is proposed. The structural synthesis is based on a three-dimensional beam element able to account for both the mechanical non-linearity associated to the constitutive cyclic properties of the materials, and the geometrical non-linearity due to

the second order effects. The seismic performance of the structure is evaluated by means of a set of suitable damage indexes which, within a minimum damage strategy, lead to formulate a procedure for the optimal design of concrete structures. The solution of the optimisation problem is obtained by means of genetic algorithms. The proposed procedure is finally applied to the case of a bridge subjected to a simulated earthquake. The results show wide possibilities to regulate the seismic response of the system by working on specific conceptions of its structural morphology.

KEY WORDS: bridge structures; conceptual design; non-linear analysis; seismic performance; damage; structural optimization; genetic algorithms.

Paper No. 2629

CV1

Biondini F., Boiocchi S., Malerba P.G., Marchiondelli A.

BIOLOGICALLY INSPIRED EVOLUTIONARY PROCEDURES FOR CONCEPTUAL DESIGN OF THE STRUCTURAL MORPHOLOGY

Proc. 2nd Int. Conf. on 'Advances in Structural Engineering and Mechanics' (ASEM'02), Busan (South Korea), August 21-23, 2002 (CD ROM).

The developments presented in this paper are devoted to the problem of finding the optimal structural morphology of plane framed structures, but can be usefully applied also to other kind of structures. In particular, the optimal morphology is found through a two-level evolutionary approach: the *external* morphology, i.e. the geometrical dimensions and the topology of the structural type, is optimised at the first level (*macro-level*), while the *internal* morphology, like the geometry and the shape of the cross-sections, is selected at the second level (*micro-level*). The global solution process deals with evolutionary procedures which operate on the basis of some analogies with the growing and adaptation processes of natural and biological systems.

KEY WORDS: conceptual design; structural morphology; system based vision; structural optimisation; evolutionary procedures.

Paper No. 2630

CV2

Biondini F., Bontempi F.

EVALUATION OF THE STRUCTURAL DAMAGE BY SOFT-COMPUTING TECHNIQUES (in Italian)

Atti Workshop 'Problemi di vibrazioni nelle strutture civili e nelle vibrazioni meccaniche', Perugia (I), October 12, 2001, pp. 41-50.

The paper deals with the problem of the structural performance evaluation during time. In this context, it is presented a fuzzy neural network numerical technique

for the assessment of the structural damage evolution. Through the measurement of a small number of time series, at least only one, the network identifies the behaviour of the undamaged structure. The error between the predicted structural response and the one actually measured is then assumed as an index of the damage growth development within the structure. The application to a truss structure shows the potentialities of the proposed procedure.

KEY WORDS: structural damage; monitoring; soft-computing techniques; neural networks.

Paper No. 2631

CV1

Biondini F., Bontempi F., Frangopol D.M., Malerba P.G.

DURABILITY ANALYSIS OF DETERIORATING CONCRETE STRUCTURES DUE TO DIFFUSION PROCESSES: APPLICATION TO BOX-GIRDER BRIDGES

Proc. 6th Int. Conf. on Short & Medium Span Bridges, Vancouver (Canada), July 31-August 2, 2002, pp. 745-752.

The problem of durability analysis and lifetime assessment of reinforced concrete structures is investigated. A new approach to the modeling of damaging process induced by the diffusion of external aggressive agents inside the structure is presented. The diffusion process is modeled by using cellular automata, taking into account the stochastic effects in the mass transfer, as well as the interaction with the cracking state of the structure. The mechanical damage coupled to diffusion is then simulated by introducing some material degradation laws. The structural analysis is formulated at the sectional level and the damaging process is described by the corresponding evolution of both bending moment-curvature diagrams and axial force-bending moment resistance domains. An application to a two-cellular reinforced concrete box section shows the effectiveness of the proposed methodology.

KEY WORDS: aggressive agents; cellular automata; concrete structures; diffusion processes; durability analysis; mechanical damage; non-linear analysis.

Paper No. 2632

CV1

Biondini F., Bontempi F., Garavaglia E.

FUZZY OPTIMISATION DESIGN OF CONCRETE BRIDGES

Proc. 1st Int. Conf. on 'Bridge Maintenance, Safety and Management' (IABMAS'02), Barcelona (E), July 14-17, 2002, J.R. Casas, et al. (Eds), CIMNE (CD ROM).

The fuzzy optimum design of concrete structures under static loads as regards both serviceability and ultimate limit conditions is presented. In this paper special attention is devoted to the optimal design of reinforced concrete bridges, but the

proposed procedure is also suitable for other kind of structures. Design variables include either the shape and the dimensions of the concrete cross-sections, or the amount and location of the reinforcement. These quantities are assumed as deterministic. However, additional fuzzy variables are considered to take the uncertainties involved in the basic properties of the materials into account. The objective of the design process is to minimize the structural cost of the system according to side and behavioral constraints. An optimal solution is achieved for several levels of uncertainties by using genetic algorithms. The structural analyses needed for the solution process are performed by means of a composite finite beam element able to take mechanical and geometrical non-linearity into account. An application to the optimization of a reinforced concrete continuous bridge shows the effectiveness of the procedure.

KEY WORDS: optimal limit states design; concrete bridges structures; genetic algorithms; uncertainty; fuzzy criteria.

Paper No. 2633

CV1

Biondini F., Bontempi F., Garavaglia E.

FUZZY RELIABILITY ANALYSIS OF MASONRY STRUCTURES

Proc. 1st Int. Conf. on 'Bridge Maintenance, Safety and Management' (IABMAS'02), Barcelona (E), July 14-17, 2002, J.R. Casas, et al. (Eds), CIMNE (CD ROM).

For structural systems having non-linear behaviour, like the masonry bridges, a realistic description of the response under all load levels can be obtained only by taking the actual non-linearity into account. Moreover, the geometrical and mechanical properties, which define the structural problem, cannot be usually considered as deterministic quantities. In the analysis of masonry bridges the uncertainties can involve several quantities like: the load histories, the geometry and the topology of the structure, the dimension of the blocks (brick or stone), the thickness of the joints, the dimension of eventual mortar beds, the material properties of the stone and of the mortar. In this paper the uncertainties connected to the mechanical behaviour of structures composed by blocks of stone are modelled by using a fuzzy criterion. The main feature of this class of structures is the presence of two distinct materials (stone/mortar). Their stiffness and strength properties are so different that one can reasonably assume the deformations to be fully located in the mortar sections, which are then expected to be critical points for the overall equilibrium. Based on such hypothesis, a finite element able to model this class of masonry structures is presented. The stone is supposed to be a linear material, whereas the mortar is modelled as a no-tension material having non-linear behaviour in compression and plastic frictional sliding according to a Coulomb law. The main uncertainties of the problem are usually related to the parameters, which define the material laws and the thickness of the mortar layers. The proposed approach is applied to the analysis of a masonry arch bridge.

KEY WORDS: masonry structures; non-linear analysis; fuzzy uncertainty; genetic algorithms.

Paper No. 2634

CV1

Biondini F., Bontempi F., Garavaglia E.

UNCERTAINTIES IN THE NONLINEAR ANALYSIS OF MASONRY BRIDGE STRUCTURES

Proc. 8th Int. Conf. on 'Structural Safety and Reliability' (ICOSSAR 2001), Newport Beach, CA (USA), June 17-22, 2001 (CD ROM).

The paper deals with the analysis of the uncertainties related to the structural response of bridges composed by blocks of stone. The main feature of this class of bridges is the presence of two distinct materials, the stone and the mortar, having different stiffness and strength properties. The uncertainties involved in the formulation of the problem are modeled by using a fuzzy criterion and the structural response is studied by taking the nonlinear behavior of the system into account. Therefore, the main item of the paper is to show the effectiveness of the fuzzy non-linear analysis in typical engineering problems having practical consequences.

KEY WORDS: masonry bridges; non-linear behavior; fuzzy theory; simulation; uncertainty analysis.

Paper No. 2635

RV1

Biondini F., Bontempi F., Malerba P.G.

STRESS PATH ADAPTING STRUT-AND-TIE MODELS IN CRACKED AND UNCRACKED R.C. ELEMENTS

Structural Engineering & Mechanics, Vol. 12, No. 6, pp. 685-698, 2001.

In this paper, a general method for the automatic search for Strut-and-Tie (S&T) models representative of possible resistant mechanisms in reinforced concrete elements is proposed. The representativeness criterion here adopted is inspired to the principle of minimum strain energy and requires the consistency of the model with a reference stress field. In particular, a highly indeterminate pin-jointed framework of a given layout is generated within the assigned geometry of the concrete element and an optimum truss is found by the minimisation of a suitable objective function. Such a function allows us to search the optimum truss according to a reference stress field deduced through a F.E.A. and assumed as representative of the given continuum. The theoretical principles and the mathematical formulation of the method are firstly explained; the search for a S&T model suitable for the design of a deep beam shows the method capability in handling the reference stress path. Finally, since the analysis may consider the

structure as linear-elastic or cracked and non linear in both the component materials, it is shown how the proposed procedure allows us to verify the possibilities of activation of the design model, oriented to the serviceability condition and deduced in the linear elastic field, by following the evolution of the resistant mechanisms in the cracked non-linear field up to the structural failure.

KEY WORDS: strut-and-tie models; limit analysis; reinforced concrete; design criteria; structural optimisation.

Paper No. 2636

CV1

Biondini F., Bontempi F., Malerba P.G., Martinez y Cabrera F.

RELIABILITY ASSESSMENT OF CABLE-STAYED BRIDGES

Proc. IABSE Conf. on 'Cable-Supported Bridges', Seoul (South Korea), June 12-14, 2001 (CD ROM).

The paper is dedicated to the reliability assessment of cable-stayed bridges, but it is thought that the presented methodology is generally applicable. Due to several sources of uncertainties, the geometrical and mechanical properties which define the structural problem cannot be considered as deterministic quantities. In this work, such uncertainties are modelled by using a fuzzy criterion which considers the model parameters bounded between minimum and maximum suitable values. The reliability problem is formulated in terms of safety factors identified with the values of a load multiplier associated to given limit states. The structural analyses are carried out by taking both material and geometrical non-linearity into account. The interval of the structural response is found by means of a genetic optimisation algorithm. An application to the cable-stayed bridge over the Cujabà river in Brazil shows the effectiveness of the proposed procedure.

KEY WORDS: cable-stayed bridges; structural design; reliability; uncertainty; fuzzy criteria; non-linear analysis; genetic optimisation.

Paper No. 2637

CV2

Biondini F., Bontempi F., Radogna E.F.

THE REALISTIC MODELLING OF REINFORCED CONCRETE STRUCTURES (in Italian)

Proc. of the 2002 Conference of the Italian Society of R/C and P/C Structures - Giornate AICAP 2002, Bologna (I), June 6-8, 2002, pp. 61-72.

The paper is devoted to the problem of the structural modelling and it discusses both the theoretical basis and practical aspects which lead to a reliable and realistic process of structural analysis. In this context, the attention is focussed on the evaluation of the structural performance and the different aspects involved in

both the design of new structures and the assessment of existing structures is highlighted. The fundamental role played in such cases by a non linear analysis is finally examined, by discussing either the limits of such an approach or the basic criteria for the check of the results.

KEY WORDS: reinforced concrete; structural modelling; non-linear analysis; structural performance.

Paper No. 2638

CV2

Biondini F., Bontempi F., Sgambi L.

ADVANCED MODELS FOR THE THREE-DIMENSIONAL ANALYSIS OF BRIDGE PIERS (in Italian)

Proc. of the 2002 Conference of the Italian Society of R/C and P/C Structures - Giornate AICAP 2002, Bologna (I), June 6-8, 2002, pp. 73-81.

A modern conceptual design of a bridge structure should be open to wider criteria, which assure that the structure is endowed with static, dynamic and ductile characteristics sufficient to tackle the seismic events. The satisfaction of these requirements, as well as the exploration and the verification of innovative structural schemes, requires refined and advanced tools for structural analysis. In this paper the attention is mainly focussed on a specific typology of bridge piers subdivided into two parts having different geometric and mechanical properties. The first part has a box section, highly stiff; two flexible blades connected at the top compose the second part. The goal of this work is to show that a full three-dimensional non-linear analysis is required in order to grasp some peculiarities of the structural behavior.

KEY WORDS: bridge piers; seismic design; three-dimensional modelling; non-linear analysis.

Paper No. 2639

CV1

Biondini F., Bontempi F., Simone A.

OPTIMISATION OF THE STRUCTURAL PERFORMANCE IN REINFORCED CONCRETE DESIGN

Proc. 2nd Int. Conf. on 'Advances in Structural Engineering and Mechanics' (ASEM'02), Busan (South Korea), August 21-23, 2002 (CD ROM).

An automatic procedure for the optimal design of reinforced concrete structures of prescribed performance is presented. The proposed procedure has been derived using the stringer-and-panel method and an optimisation procedure based on the simplex method. The non-linear response of the structure has been computed using the Modified Compression Field Theory (MCFT). The excellent

agreement between the prescribed and the computed load-displacement curve validates the procedure. Details of the methodology are fully elaborated.

KEY WORDS: concrete design; structural performance; stringer-panel modelling; non-linear analysis; structural optimisation.

Paper No. 2640

CV2

Biondini F., Ferrara L., Negro P., Toniolo G.

RESULTS OF PSEUDODYNAMIC TEST ON THE PROTOTYPE OF A PRECAST R.C. FRAME (in Italian)

Proc. 14th Conf. of the Building Technicians Board (CTE), Mantua (I), November 7-9, 2002, pp. 535-544.

On July 2001 the research project “Seismic behaviour of r.c. industrial buildings” has been approved within the Ecoleader Programme, which is reserved to the European Consortium of Laboratories for Earthquake and Dynamic Experimental Research (JRC – Contract n° HPRI-CT-1999-00059). The programme provides for European funding of the testing activity, to be made with the large scale facilities of the JRC, Joint Research Centre, ELSA European Laboratory for Structural Assessment of Ispra. The cost of the prototypes and of the other research activities are supported by a consortium of three national precast concrete associations (ANDECE for Spain, ANIPC for Portugal and ASSOBETON for Italy) and of Progetto ULISSE (pool of AITEC, ASSOBETON and ATECAP) for Italy again. Two high educational institutions, Politecnico di Milano and University of Ljubljana, participate to the research. The objective of the project is to provide specific experimental evidence about seismic behaviour of precast one-storey frames for industrial buildings as compared with cast-in-situ analogous structures. The expected results are particularly important for the correct calibration of Eurocode 8 design rules. To this purpose two structural prototypes have been designed, both consisting of six columns connected by two lines of beams and an interposed slab. The connections between columns and beams are made with monolithic joints for the cast-in-situ arrangement and with hinged joints for the precast one. The 5th and 6th September 2002 the pseudodynamic test on the precast structure has been performed. After a general framing of the problem and a detailed description of the prototype, the paper gives a first report of the test and the related results. In particular the seismic action has been simulated by an artificial accelerogram, compatible with the response spectrum type 1B of Eurocode 8. It has been applied three times for as many levels of peak acceleration, starting from $a_g = 0.36$ g and attaining up to $a_g = 0.72$ g and $a_g = 1.08$ g. The last level corresponds to about the expected ultimate capacity at collapse limit of the structure following a calculation based on Eurocode 8 rules. The test at this upper level had to be stopped in advance because of the end of stroke of the jack pistons. This occurred at a top displacement of 400 mm, when the columns were in a yielded stage with visible damage still limited. The results are given in terms of the top displacement time history and of the force-displacement diagrams.

Some final considerations are added about the experimental behaviour and the residual damaging of the structure.

KEY WORDS: seismic behaviour; design reliability; concrete structures; full-scale prototype; pseudodynamic tests.

Paper No. 2641

CV2

Biondini F., Toniolo G.

PROBABILISTIC ANALYSIS OF THE SEISMIC RESPONSE OF REINFORCED CONCRETE FRAMES (in Italian)

Proc. 14th Conf. of the Building Technicians Board (CTE), Mantua (I), November 7-9, 2002, pp. 71-80.

The paper gives a contribution to the quantitative assessment of eurocode 8 rules for the seismic design of r.c. Structures. In particular the one storey frames for industrial buildings are considered, both cast-in-situ with monolithic arrangement and precast with hinged connections between columns and beams. In some previous works the results of a comparative analysis of the seismic behaviour of the two types of structures have been presented, where both the cast-in-situ and the precast frames were dimensioned for the same horizontal forces and subjected to the same vibratory motion of the ground. The dynamic analyses had been performed on proper models, taking into account the non-linear behaviour of the material and the geometrical effects of second order. In particular, for the cyclic stiffness of the r.c. Columns a degrading elastoplastic model had been adopted, as calibrated with preliminary experimental investigation. The results of these analyses show that the structure with hinged beam, which has critical sections at the columns base proportioned for the corresponding clamping moments, may dissipate the same amount of energy which the monolithic structure dissipates in its more numerous critical sections, proportioned as they are for halved moments. These results have been obtained for structures having defined vibratory properties, without any consideration of the probabilistic uncertainties inherent to the definition of the seismic action and of the mechanical properties of the structure. The present work tries to give a more general validity to the results previously obtained in a deterministic way. To this end, the comparison between the two types of structures, the cast-in-situ and the precast frames, is extended to two different structural sizes with sensibly different natural vibration periods. For each structural size, hundreds of dynamical simulations are performed, following Monte Carlo method, varying both the characteristics of the seismic input and the material properties, where the seismic input is represented by proper artificial accelerograms and the material properties by proper constitutive laws. All variabilities follow given probabilistic distributions. The results are then elaborated through statistical models to obtain the comparative assessment between the two quoted types of structures. The examination of these results confirms the behaviour equivalence of the cast-in-situ and precast structures for what concerns

their ultimate strength. It confirms also the correctness of the value 4.5 assumed by eurocode 8 for the behaviour factor of r.c. frames.

KEY WORDS: seismic response; design reliability; concrete; simulation; artificial earthquakes.

Paper No. 2642

CV1

Biondini F., Toniolo G.

PROBABILISTIC CALIBRATION OF BEHAVIOUR FACTORS OF EC8 FOR CAST-IN-SITU AND PRECAST FRAMES

Proc. 17th BIBM Congress, Istanbul (Turkey), May 1-4, 2002 (CD ROM).

The paper presents the results of some investigations on the seismic behaviour of one-storey reinforced concrete structures for industrial buildings. The investigations are based on proper analytical models, calibrated against initial cyclic and pseudodynamic testing. An incremental collapse dynamic analysis is applied together with a statistical procedure, following Monte Carlo method, for the sorting of seismic input and the final interpretation of results. The problem concerning the choice of ground accelerograms, recorded or artificial, are discussed. Finally the representative values of seismic capacity obtained from the analyses are shown to demonstrate that precast structures have the same seismic capacity of the corresponding cast-in-situ structures and that both the structures have in general a large superabundance of strength in earthquake conditions.

KEY WORDS: seismic behaviour; design reliability; concrete structures; recorded accelerograms; artificial accelerograms.

Paper No. 2643

CV1

Biondini F., Toniolo G.

PROBABILISTIC PARAMETERS OF THE SEISMIC PERFORMANCE OF REINFORCED CONCRETE FRAMES

Proc. 1st FIB Congress, Osaka (J), October 13-19, 2002, Paper E-228.

The paper gives a contribution to the reliability assessment of the design methods of Eurocode 8 for concrete structures in seismic zones, with reference to r.c. frame systems. To this purpose a large number of dynamic analyses have been done assuming as many artificial accelerograms. The choice of these accelerograms follows the criteria of the quoted Eurocode, saving the random variability of the main features of real earthquakes, so to apply a Monte Carlo process of probabilistic investigation of structural performance. The computed responses have been quantified on the base of the overstrength behaviour parameter, for which a statistical evaluation has been done. Some additional considerations are pre-

sented about the suitability of the analytical model used in computations, about the representativeness of the random set of ground motion simulations and about the design provisions of Eurocode 8. In particular the comparison of the responses coming from different arrangement of joint connections (rigid or hinged) shows that the dissipation of energy is not a question of number of dissipation zones, but it is a question of total structural volume involved in dissipation: few larger zones may dissipate the same amount of energy of many smaller zones. This deny the discriminations set by the first version 1994 of Eurocode 8 to some type of one storey precast structures.

KEY WORDS: seismic response; design reliability; concrete structures; simulation; artificial earthquakes.

Paper No. 2644

RV1

Biondini F., Toniolo G., Tsionis G.

DESIGN RELIABILITY OF CAST-IN-SITU AND PRECAST CONCRETE FRAMES UNDER RECORDED EARTHQUAKES

Studi e Ricerche, Scuola di Specializzazione per le Costruzioni in Cemento Armato, Politecnico di Milano, Vol. 22, 2001, pp. 51-72.

The paper deals with the behaviour classification of concrete structures, both cast-in-situ and precast, with reference mainly to frame systems as defined in Eurocode 8. This classification is related to the ductility resources of the different types of structures and to the consequent capacity of energy dissipation. With the aim to check the value given by Eurocode 8 to frame systems, a number of dynamic analyses has been made on the base of an analytical model taken from previous works and already verified by testing. For the analyses, a set of recorded accelerograms has been used, computing the structural response for any of them with intensities increasing up to collapse. The set of data obtained from the analyses has been elaborated to try a reliable evaluation of safety and check the design rules of Eurocode 8. The results allow to deny some assumptions taken for granted about precast structures and to suggest proper corrections.

KEY WORDS: seismic behaviour; design reliability; concrete structures; recorded earthquakes.

Bolzon G., Fedele R., Maier G.

PARAMETER IDENTIFICATION OF A COHESIVE CRACK MODEL BY KALMAN FILTER

Computer Methods in Applied Mechanics and Engineering, Vol. 191, pp. 2847-2871, 2002.

The Kalman filter (KF) methodology is apt to solve parameter identification (inverse) problems in a statistical context, through a sequence of estimations, which starts from an a priori estimation by an "expert" (Bayesian approach) and exploits a time-stepping flow of experimental data until convergence is empirically ascertained. Such methodology is here adopted for the identification of the material parameters, together with their uncertainties, in a mode I cohesive crack model, on the basis of experimental data generated by wedge-splitting tests on concrete specimens. The simulation of the experiments is based on the assumptions of a piecewise-linear cohesive model with four parameters to identify on the crack path, and of linear elasticity elsewhere. In view of regularly progressive fracture processes, the discrete crack model and, consequently, the overall finite element analysis, are formulated as linear complementarity problems. This mathematical construct is exploited to obtain the sensitivity matrix, key ingredient of the KF extended to nonlinear inverse problems, in a computationally convenient closed form. Various issues peculiar of KF identification in the present mechanical context are critically discussed in the light of the numerical solutions achieved.

KEY WORDS: quasi-brittle fracture; cohesive crack models; parameter identification; Kalman filter.

Bolzon G., Ghilotti D., Maier G.

STRENGTH OF PERIODIC ELASTIC-BRITTLE COMPOSITES EVALUATED THROUGH HOMOGENIZATION AND PARAMETER IDENTIFICATION

European Journal of Mechanics A/Solids, Vol. 21, pp. 355-378, 2002.

Reference is made herein to the elastic-brittle behavior of unidirectional E-glass-fiber epoxy-matrix composites of potential use in offshore technology. In view of engineering analyses of structural components, an anisotropic constitutive model in average stresses and strains is selected, centered on an elastic stiffness tensor and on an elastic limit locus and a yield locus in the average stress space (the latter defines the homogenized material strength). These loci are here described according to the popular Tsai-Wu model, and to a trigonometric model characterized by a user-chosen number of parameters as proposed by Labossière and Neale. The identification of the coefficients in the analytical expressions of both loci is performed by solving a mathematical programming problem, apt to

minimize a norm which quantifies the discrepancy between the elastic limit or the peak stress computed by micromechanical homogenization (or defined by experimental data, if available) on one side and the relevant predictions (as functions of those coefficients) by the macroscopic model on the other side. The selection of the radial paths in the average stress or average strain space, based herein on the mathematical theory of regular polytopes, turns out to be crucial factor for the cost-effectiveness of the parameter identification process. The proposed methodology is discussed by means of examples related to practical engineering situations.

KEY WORDS: composites; homogenisation; parameter identification.

Paper No. 2647

CV2

Calvetti F.

EXPERIMENTAL MEASURE OF TENSILE STRENGTH OF MARBLE SPECIMENS (in Italian)

Atti dell'Incontro Annuale dei Ricercatori di Geotecnica (IARG 2002), Napoli, June 19-21, 2002 (CD ROM).

The tensile strength of natural building stones (Carrara and Dionysos marble) is measured by means of bending tests (three and four point bending tests). The well known scale effect is investigated by performing tests on specimen with different size. Test results are interpreted with the guiding help of local measurements of strain. Strain gages and a particular laser interferometry technique (ESPI) are used for this purpose.

KEY WORDS. natural building stones; bending tests; tensile strength; scale effect; laser interferometry.

Paper No. 2648

CV2

Calvetti F., Tamagnini C., Viggiani G.

INCREMENTAL BEHAVIOUR OF SOILS: MICROMECHANICAL APPROACH (in Italian)

Atti dell'Incontro Annuale dei Ricercatori di Geotecnica (IARG 2002), Napoli, June 19-21, 2002 (CD ROM).

The incremental behavior of granular materials is investigated by numerically simulating stress probing experiments on a 3D Distinct Element model. Various initial states are considered, differing as for stress and previous loading history. The results obtained when the material is loaded in axisymmetric conditions starting from a virgin state show that classical plasticity with single potential is able to describe the incremental behavior quite satisfactorily. On the contrary,

stress probing from a preloaded state, or in the deviatoric plane, indicate major deviations of observed response from the paradigm of both classical and Bounding Surface plasticity.

KEY WORDS. granular materials; incremental behaviour; micro-mechanics; distinct element method; strain response envelopes; constitutive models.

Paper No. 2649

CV1

Calvetti F., Tamagnini C., Viggiani G.

ON THE INCREMENTAL BEHAVIOUR OF GRANULAR SOILS

Proc. 8th Int. Symp. on 'Numerical Models in Geomechanics' (NUMOG VIII), G.N. Pande and S. Pietruszczak (Eds.), Swets & Zeitlinger, Lisse, 2002, pp, 3-9.

The incremental behaviour of granular materials is characterised by strong non-linearity. This evidence turns into a relevant requirement for the definition of a proper constitutive model. An accurate experimental characterisation of the incremental behaviour is recommended. In substitution of experiments, discrete particle methods can be employed. Calvetti et al. (2002) discussed the reliability of a 3D Distinct Element model as a substitute for real granular materials by reproducing experimental results presented by Royis & Doanh (1998). Calvetti et al. (2002) also studied the incremental behaviour of the numerical model under axisymmetric conditions. In this paper, the same numerical model is subjected to a series of stress probes in the deviatoric plane. The results clearly show that single mechanism plasticity theories are unable to describe all the features of the observed behaviour. An adequate interpretation of the incremental behaviour of granular soils, as illustrated throughout the paper, would then require more advanced constitutive approaches.

KEY WORDS. granular materials; incremental behaviour; micro-mechanics; distinct element method; strain response envelopes; constitutive models.

Paper No. 2650

CV1

Cardani G., Tedeschi C., Binda L., Baronio G.

CRYSTALLISATION TEST ON TREATED BRICK/STONE MASONRY SPECIMENS FOR DAMAGE EVALUATION

Proc. 9th Int. Conf. on 'Durability of Building Materials', Brisbane, (AUS), March 17-20, 2002 (CD ROM).

It is known that water-proof and consolidant surface treatments cannot be carried out in presence of soluble salts due to the possible formation of cryptoefflorescences causing detachment of the treated parts. An European Community (EC) contract was developed aimed to establish the maximum salt content below

which the surface treatment do not fail. A large number of crystallisation tests was carried out on single components (bricks and stones) and on masonry wall-ettes treated with a water repellent and a consolidant. Different types of salt solutions and different salt concentrations were used. The test was carried out according to RILEM recommendations; the long term damage caused by the salts was measured by visual inspection, photographic survey and laser profilometer. The laser device allows for measurements along chosen profiles on the surface masonry: it is so possible to quantify with the variation of the profile depth over time, the loss of surface material. This value has been used as a suitable parameter describing the time and extent of the material deterioration process.

KEY WORDS: durability; brick and stone masonry; crystallisation test; surface treatments. .

Paper No. 2651

CV1

Cardani G., Tedeschi C., Binda L., Baronio G.

LABORATORY INVESTIGATION ON THE DURABILITY OF JOINT RE-POINTING IN BRICK MASONRY DAMAGED BY SALT CRYSTALLISATION

Proc. 6th Int. Masonry Conf., London, November 4-6, 2002, No. 9, pp. 65-72.

Efflorescence and crypto-efflorescence due to crystallisation of soluble salts in the walls are one of the most frequent causes of damage to facing brick-masonry in the Mediterranean countries. Mortar joints are the mostly affected in the case of historic masonries. When only rain penetration remains the cause of moisture, effective repair can be carried out by re-pointing. Nevertheless there might be the possibility that non-compatible mortars are chosen and/or that the workmanship is very poor. Under the frame of a EC Contract (CEE ENV4-Ct98-706), a series of crystallisation tests was carried out, according to RILEM Recommendations, on brick masonry specimens to control the effect of different re-pointing mortars. The long term damage caused by the salts was detected by visual inspection, photographic survey and measured by a laser profilometer. In addition the bond between the re-pointing and the bricks was also detected by a special application of the bond wrench test.

KEY WORDS: masonry decay; salt crystallization; laboratory tests.

Carvelli V., De Angelis D., Poggi C., Puoti R.

EFFECTS OF MANUFACTURING TECHNIQUES ON THE MECHANICAL PROPERTIES OF COMPOSITE LAMINATES

Key Engineering Materials, Vol. 221, pp. 109-120, 2002.

An experimental investigation was carried out on composite laminates to detect the influence of the manufacturing effects on the mechanical properties. The paper presents the results of tensile tests on composite laminates produced with different manufacturing techniques (Bag Moulding, Resin Transfer Moulding, Vacuum Assisted Resin Transfer Moulding, Curing by Electron Beam Irradiation). Both unidirectional and roving fabric laminates made with four types of reinforcing fibers (Carbon, Glass, Aramid and PVA) were tested.

KEY WORDS: fiber reinforced composites; manufacturing techniques; mechanical properties.

Carvelli V., Poggi C.

STEEL CORD-RUBBER COMPOSITES: MECHANICAL PROPERTIES BY A NUMERICAL HOMOGENIZATION METHOD

Proc. 5th World Congress on Computational Mechanics (WCCM V), Wien (A), July 7-12, 2002, H.A. Mang, F.G. Rammerstorfer and J. Eberhardsteiner (Eds.), Vienna University of Technology Pub., on-line publication (<http://wccm.tuwien.ac.at>).

In this paper a numerical micromechanical method for the determination of the mechanical properties of steel cord-rubber composites is presented. The approach is based on the finite element method assuming a periodic distribution of the reinforcements in the composite. The theoretical concepts of the homogenization theory for periodic media are exploited. The determination of the global (or macroscopic) mechanical behaviour of the heterogeneous material is reduced to the analysis of a Representative Volume (RV). The numerical predictions are validated against experimental investigations on single and multi-layers specimens. Different steel cords, having a wide range of orientation, and two types of rubber are considered.

KEY WORDS: steel cord-rubber composites; homogenization; mechanical properties; finite elements.

Carvelli V., Poggi C.

TWO-SCALE MODELING FOR FAILURE ANALYSIS OF TEXTILE COMPOSITES

Proc. Int. Symp. on Textile Composites (TEXCOMP 6), Philadelphia (USA), September 11-13, 2002 (CD ROM).

A two-scale homogenization technique is presented to evaluate the mechanical properties of woven textile composites. The numerical approach is founded on the main assumption of periodic distribution of the reinforcements in the composite at two different scale. The first scale concerns the warp and weft yarns while the second regards a representative volume of the woven textile laminate with homogenized yarns. The main aim is to predict the macroscopic behavior until failure of textile composites. The procedure is validated against experimental results.

KEY WORDS: homogenization; textile composite; failure analysis.

Casolo S.

IN-PLANE DYNAMICS OF MASONRY WALLS BY RIGID ELEMENTS: ELASTIC BEHAVIOUR AND MICRO - STRUCTURE EFFECTS

Proc. 3rd Joint Conference of Italian Group of Computational Mechanics and Ibero-Latin American Association of Computational Methods in Engineering (GIMC2002), Giulianova (I), June 24-26, 2002 (CD ROM).

A rigid element approach is proposed for the formulation of a simplified model of the in-plane behaviour of a composite material with 'masonry-like' periodic texture. The model consists of plane quadrilateral elements connected to each other by two normal springs and one shear spring. These connections are defined by imposing the elastic energy equivalence, with the aim to account for some of the micro-structure effects. To do this, the two normal springs of each connecting side are placed at a certain distance in order to reproduce the in-plane bending stiffness, while the polarity effects of the micro-structure are partially reproduced by assigning different stiffness to the two adjacent sides' shear springs. These effects become significant in the case of large difference of the elastic stiffness of the constituents, as it is the case of masonry walls subjected to seismic loadings that heavily degrade the mortar joints. The study of these aspects is worth in view of a subsequent non-linear formulation of this simplified model that takes into account also the mechanical degradation of the materials.

KEY WORDS: masonry; micro-structure; rigid elements.

Castellanza R., Nova R., Tamagnini C.

MECHANICAL EFFECTS OF CHEMICAL DEGRADATION OF BONDED GEOMATERIALS IN BOUNDARY VALUE PROBLEMS

Rev. Fran. Génie Civil, Vol. 6, No. 6, pp. 1169-1192.

The paper presents a constitutive approach to describe the effects of rock weathering processes in boundary value problems. The term rock weathering is used to refer to a number of chemical and physical phenomena that continuously transform a rock mass into a granular soil. From an engineering point of view rock weathering can be interpreted as a generalised decay of the mechanical properties of the original material. It acts at a constitutive level essentially by reducing the strength of the bonds joining the grains together. Such a material degradation can occur in a time scale which is comparable to the average life of engineering structures. Weathering can induce subsidence on shallow foundations resting on soft rocks layers or it can be crucial for what concerns the stability of slopes or abandoned underground mines. In the first part of the paper, it is shown how the progressive destruction of the intergranular bonds due to weathering has been modelled satisfactorily by extending a strain hardening elastoplastic model. Such a model has been corroborated by means of special oedometer tests on soft rock specimens in which a progressive chemical debonding has been induced through the exposition of the rock to a uniform flow of an acid solution. In the second part of the work, three different boundary value problems in which weathering effects cannot be neglected are presented. The numerical analyses performed with the proposed constitutive model refer to: i) the weathering-induced subsidence of a circular foundation; ii) the stability of a slope subject to weathering from the ground surface; and, iii) the effects of the progressive collapse of pillars in an abandoned underground mine.

KEY WORDS: bonded soils; elastoplasticity; numerical modelling; mines; weathering.

Castellanza R., Nova R., Tamagnini C.

WEATHERING INDUCED SUBSIDENCE OF A CIRCULAR FOUNDATION

Proc. 8th Int. Symp. on 'Numerical Models in Geomechanics' (NUMOG VIII), G.N. Pande and S. Pietruszczak (Eds.), Swets & Zeitlinger, Lisse, 2002, pp. 407-413.

The paper presents a numerical analysis of the effects of weathering on a circular flexible foundation, resting on a soft rock layer. Due to its high initial shear strength, the response of the rock upon loading is elastic. The load is then kept constant, while degradation takes place from the top surface of the layer downwards, gradually losing some of its aggressive capacity with depth; the artificial weathering profile has been chosen according to natural weathering profiles. In

the framework of the theory of elastoplasticity with strain-hardening, weathering can be interpreted as a non-mechanical debonding process which induces a progressive shrinkage of the initial elastic domain of the soft rock. Consequently the initial shear strength is reduced and the response becomes elastoplastic from a certain point onwards. Settlements are therefore induced at constant applied loading, and a marked stress redistribution occurs. In particular the deviator stress is strongly reduced beneath the foundation base, while the hydrostatic component increases.

KEY WORDS: bonded soils; elastoplasticity; foundations; numerical modelling; weathering.

Paper No. 2658

CV1

Chesi C., Compagnoni M., Parisi M.A., Pergalani F., Petrini V.

SEISMIC RISK ANALYSIS OF HISTORICAL TOWN CENTERS: THE ROLE OF LOCAL EFFECTS AND VULNERABILITY OF INTERACTING BUILDINGS

Proc. 7th U.S. National Conference on Earthquake Engineering (7NCEE), Boston, Mass. (USA), July 21-25, 2002 (CD ROM).

The work proposed here deals with the evaluation of seismic risk for historical town centers, that are characterized by old, traditional buildings, often connected to form street rows. The seismic protection of these centers is a critical issue in many European countries. An effective evaluation of seismic risk, which is generally defined as the convolution of seismic hazard, vulnerability, and value, must rely on a multidisciplinary approach. The work proposed here focuses on two points, that are prior in interest and now under study: the evaluation of local effects and the consequences of structural interaction on vulnerability.

KEY WORDS: seismic risk; urban centers.

Paper No. 2659

CV1

Chesi C., Parisi M.A.

DYNAMIC BEHAVIOUR OF AN ICE HOCKEY STICK

in 'Structural Dynamics – EURO DYN 2002', H. Grundmann and G.I. Schuëller (Eds.), A.A. Balkema (Lisse), 2002, pp. 613-618.

The work proposed here deals with the determination of the interaction forces between an ice hockey player and the stick, which may be modelled as a beam on flexible supports. An extensive experimental study is the base of an analytical interpretation model.

KEY WORDS: structural dynamics; interaction forces; sport physiology; dynamic testing.

Paper No. 2660

CV2

Ciccotelli S., Coronelli D.

SAFETY EVALUATION FOR EXISTING R/C STRUCTURES (in Italian)

Proc. 14th Conf. of the Building Technicians Board (CTE), Mantua (I), November 7-9, 2002, Vol. 1, pp. 111-119.

The assessment of existing R/C structures is carried out at the Ultimate Limit State in bending, considering the effects of the damage caused by bar corrosion, in the evaluation of both the design strength and actions. Deterioration is introduced by considering the cross-section reduction, and modified material models including steel-concrete bond, within a non-linear analysis code. This allows some modifications to the traditional elastic analysis methods with bending-moment redistribution, and to the equations for the evaluation of the ultimate bending capacity. An example is proposed, to show the application of the procedure to the ultimate state of continuous beams. This rather general solution allows the drawing of interesting conclusions regarding safety assessment and failure modes of existing structures.

KEY WORDS: structural safety; reinforced concrete; corrosion; finite elements; structural analysis.

Paper No. 2661

RV1

Cividini A.

A LABORATORY INVESTIGATION ON THE BEHAVIOUR OF REINFORCED SAND SAMPLES UNDER PLANE STRAIN AND TRIAXIAL CONDITIONS

Soils & Foundations, Vol. 42, No. 4, pp. 23-39, 2002.

An experimental study on the behaviour of re-constituted samples of sand reinforced with geotextile layers is presented using standard triaxial and plane strain tests. After describing the main features of the plane strain device and of the data acquisition system, details are provided on the procedure developed for preparing plane strain samples containing inclined reinforcements with respect to the principal stress directions. Comments are also made on the influence of preparation procedure on the overall behaviour observed during loading. Finally, the results of the experimental investigation are described with reference to standard triaxial tests with horizontal reinforcements, and to plane strain tests with horizontal and inclined reinforcements. The study complements data already available in the literature, for the development of constitutive laws applicable to numerical analysis of reinforced earth structures.

KEY WORDS: plane-strain test; reinforced sand; inclined geotextile layers; sample preparation procedure.

Paper No. 2662

CV1

Cividini A.

REINFORCED SAND PARAMETERS FROM PLANE STRAIN COMPRESSION TESTS

Proc. 5th European Conference on Numerical Methods in Geotechnical Engineering (NUMGE'02), Paris (F), September 4-6, 2002, pp. 45-50.

The numerical modelling is discussed of plane strain compression tests on sand samples reinforced with geotextile layers. The experimental investigation includes samples containing horizontal reinforcements, as well as specimens with geotextiles layers inclined with respect to the vertical loading direction. Both “inhomogeneous” and “homogeneous” finite element schemes were adopted in the calculations. The comparison between the experimental data and the results of analyses permits drawing some conclusions on the influence of the mechanical properties of the geotextiles on the overall behaviour of the reinforced samples. Some comments are also presented on the accuracy of the adopted constitutive laws in modeling the stress-strain relationship of the tested “composite” material.

KEY WORDS: plane strain tests; reinforced earth structures; finite element analysis.

Paper No. 2663

RV1

Cocchetti G., Maier G.

A SHAKEDOWN THEOREM IN POROPLASTIC DYNAMICS

Rendiconti dell'Accademia Nazionale dei Lincei - Meccanica dei Solidi, Serie IX, Vol. 13, pp. 43-53, 2002.

The constitutive model assumed in this note is poroplastic two-phase (solid-fluid) with full saturation and stable in Drucker's sense. A solid or structure of this material is considered, subjected to dynamic external actions, in particular periodic or intermittent, in a small deformation regime. A sufficient condition and a necessary one are established, by a “static” approach, for shakedown (or adaptation), namely for boundedness in time of the cumulative dissipated energy.

KEY WORDS: poroplasticity; shakedown; dynamics.

Cocchetti G., Maier G., Shen X.P.

PIECEWISE LINEAR MODELS FOR INTERFACES AND MIXED MODE COHESIVE CRACKS

Computer Modeling in Engineering & Sciences, Vol. 3, pp. 279-298, 2002.

Interface models mean here relationships between displacement jumps and tractions across a locus of displacement discontinuities. Frictional contact and quasi-brittle fracture interpreted by cohesive crack models are typical mechanical situations concerned by the present unifying approach. Plastic-softening multi-dissipative interface models are studied in piecewise linear formats, i.e. assuming linearity for yield functions, plastic potentials and relationships between static and kinematic internal variables. The properties and the pros and cons of such simplified models in a variety of formulations (fully non-holonomic in rates, holonomic and in finite steps), all mathematically described as linear complementarity problems, are comparatively investigated in view of overall analyses of structures (like e.g. concrete dams) which include joints and/or are exposed to quasi-brittle fracture processes.

KEY WORDS: interface and joint models; piecewise linearisation; time-integration.

Cocchetti G., Perego U.

ADAPTIVE BACKWARD-DIFFERENCE TIME-STEPPING PROCEDURE FOR FINITE ELEMENT HARDENING ELEASTOPLASTICITY

Proc. 3rd Joint Conference of Italian Group of Computational Mechanics and Ibero-Latin American Association of Computational Methods in Engineering (GIMC2002), Giulianova (I), June 24-26, 2002 (CD ROM).

The present contribution is intended to provide the conceptual basis for a self-adaptive time-marching strategy by defining a mechanically founded estimate of the error involved in the time-integration. Showing that the total work performed at a material point in a time-step according to an Euler forward integration scheme is always larger than the exact work, an error measure is defined related to the difference between the maximum and minimum total work. The effectiveness of the proposed estimate and its convergence are tested on simple cases where the analytical solution is available.

KEY WORDS: error estimation; plasticity; backward-difference.

Cocchetti G., Perego U.

ESTIMATION OF TIME-STEP INTEGRATION ERROR FOR ELASTOPLASTIC MODELS

Proc. 5th World Congress on Computational Mechanics (WCCM V), Wien (A), July 7-12, 2002, H.A. Mang, F.G. Rammerstorfer and J. Eberhardsteiner (Eds.), Vienna University of Technology Pub., on-line publication (<http://wccm.tuwien.ac.at>).

The finite element analysis of elastoplastic structures requires in general a time-stepping procedure. The integration of the constitutive law within each time-step is carried out by numerical integration. The error associated to the numerical integration depends on the degree of nonlinearity of the structural response in the considered time-step and can be used as an indicator to adaptively tune the size of the time-step. A simple estimate of the integration error associated to a backward-difference scheme for elastoplastic models with hardening is derived. It is shown that the proposed estimate is a rigorous upper bound on the error in the case of assigned constant strain rate. The estimator is validated by application to the analytical solution of a perfectly plastic material model.

KEY WORDS: error estimation; plasticity; backward-difference.

Cocchetti G., Zavelani Rossi A.

FINITE ELEMENT ANALYSIS OF NON-LINEAR PLANE PROBLEMS BASED ON FULLY EQUILIBRATED STRESS FIELDS

Proc. 5th World Congress on Computational Mechanics (WCCM V), Wien (A), July 7-12, 2002, H.A. Mang, F.G. Rammerstorfer and J. Eberhardsteiner (Eds.), Vienna University of Technology Pub., on-line publication (<http://wccm.tuwien.ac.at>).

Stress analysis of plane problems is generally performed by means of the "displacement" approach of the finite element (FE) method, in which the unknowns are represented by a set of piece-wise continuous displacement functions and the stress field, obtained through the compatibility and constitutive laws, does not conform to local equilibrium. The alternative version based upon the assumption of fully equilibrated stress fields is seldom adopted. The formulation here presented is intended to analyse plane stress (or plane strain) elastic-plastic structures with full respect of equilibrium by the stress fields. Specifically, reference is made to limit analysis. Equilibrium equations are implicitly satisfied and the problem is formulated only in terms of redundant stress components (the so called "redundants"). The peculiarities of the method are briefly addressed and a classical example is solved.

KEY WORDS: equilibrium fields; stress functions; finite elements; limit analysis.

Comi C., Mariani S., Perego U.

FROM LOCALIZED DAMAGE TO DISCRETE COHESIVE CRACK PROPAGATION IN NONLOCAL CONTINUA

Proc. 5th World Congress on Computational Mechanics (WCCM V), Wien (A), July 7-12, 2002, H.A. Mang, F.G. Rammerstorfer and J. Eberhardsteiner (Eds.), Vienna University of Technology Pub., 14 pp.

A methodology for finite element analyses of quasi-brittle structures up to failure is proposed. The damage process leading to diffuse micro-cracking followed by damage localization and eventually to coalescence and macro-cracks propagation is analyzed in a first stage making use of a continuum nonlocal damage model and in a second stage by a cohesive crack model. The question of the proper time and location for the occurrence of the transition from the first to the second stage is addressed. In particular, a critical damage and direction for the initiation of the discrete crack are proposed. The cohesive crack law to be used for the initiating displacement discontinuity is defined on the basis of energetic considerations.

KEY WORDS: damage; nonlocal regularization; finite elements; cohesive crack.

Comi C., Mariani S., Perego U.

ON THE TRANSITION FROM CONTINUUM NONLOCAL DAMAGE TO QUASI-BRITTLE DISCRETE CRACK MODELS

Proc. 3rd Joint Conference of Italian Group of Computational Mechanics and Ibero-Latin American Association of Computational Methods in Engineering (GIMC2002), Giulianova (I), June 24-26, 2002, 10 pp. (CD ROM).

A finite element strategy for the analysis of damage processes in quasi-brittle materials up to the inception and propagation of a main crack is proposed. In a first stage, the structure is treated as a nonlocal continuum with developing micro-cracking that leads to a diffuse state of damage. Subsequently, a macro-crack is assumed to nucleate inside the damaged zone and to propagate according to the evolution of damage ahead of its tip. In this work, the transition from damage to crack propagation is governed by the attainment of a critical damage value, which is in turn linked to the ratio between the current localization bandwidth and the local characteristic dimension of finite elements. Furthermore, a cohesive traction vs displacement discontinuity relation is deduced from the continuum damage model on the basis of equivalence of specific energy dissipation.

KEY WORDS: damage; nonlocal continua; finite elements; cohesive crack.

Corigliano A.

ELASTO-PLASTIC INTERFACE LAW FOR NON-HOMOGENEOUS MATERIALS: FORMULATION, SENSITIVITY ANALYSIS, PARAMETER IDENTIFICATION

Proc. IUTAM Symp. on 'Analytical and Computational Fracture Mechanics of Non-Homogeneous Materials', B.L. Karihaloo (Ed.), Kluwer Acad. Pub., pp. 233-242, 2002.

In the present paper the possibility to use the extended Kalman filter for parameter identification, coupled with a sensitivity analysis based on the Direct Differentiation Method (DDM) is verified. The parameter identification of an interface model is considered. An elasto-plastic interface model is formulated and a backward-difference time integration procedure is used in order to derive explicit expressions for the time-step response. Explicit formulae at the level of the interface are derived for the application of the DDM for sensitivity analysis and examples of sensitivity are presented. The performance of the identification procedure is checked through a numerical example.

KEY WORDS: interface models; elasto-plasticity; parameter identification; Kalman filter; sensitivity analysis.

Corigliano A.

PARAMETER IDENTIFICATION OF INTERFACE LAWS

Proc. 5th World Congress on Computational Mechanics (WCCM V), Wien (A), July 7-12, 2002, H.A. Mang, F.G. Rammerstorfer and J. Eberhardsteiner (Eds.), Vienna University of Technology Pub., 18 pp. (CD ROM).

An Extended Kalman Filter (EKF) approach is applied in the present paper to the purpose of identifying interface model parameters and estimating the state of a dynamic structural system. A structural system space-discretised by means of Finite Elements (FE) is considered; the system can have a nonlinear irreversible constitutive law and can contain interfaces which obey nonlinear irreversible interface laws. Time discretisation with the Forward Euler explicit algorithm is adopted in order to easily obtain the time-discretised state equations of the system in terms of nodal displacements and velocities. The EKF is then applied by defining a state vector containing nodal displacements, nodal velocities and constitutive models parameters. The Jacobian of the state equation with respect to the state variable vector is explicitly computed and the EKF procedure is numerically tested with the study of a one-dimensional bar subject to impact loading.

KEY WORDS: Kalman filter; parameter identification; interface models; dynamic structural response.

Paper No. 2672

RV1

Corigliano A., Mariani S.

IDENTIFICATION OF A CONSTITUTIVE MODEL FOR THE SIMULATION OF TIME-DEPENDENT INTERLAMINAR DEBONDING PROCESSES IN COMPOSITES

Computer Methods in Applied Mechanics and Engineering, Vol. 191, pp. 1861-1894, 2002.

Time-dependent interlaminar debonding processes in polymer-based laminates are studied in this paper. A visco-plastic constitutive law is introduced to model the behaviour of the resin-enriched interfaces between adjacent plies; details concerning the formulation and the finite element implementation of the interface law are given. To calibrate the model, namely to identify model parameters, a fully numerical approach is proposed: this approach is centred on the extended Kalman filter and on an approximate methodology to compute the sensitivity of the structural response to model parameters. First, results are presented concerning parameter identification at the constitutive level; at this stage numerical results are compared with pseudo-experimental data in order to assess the capability of the proposed approach to identify each model parameter that affects the nonlinear branch of the interface behaviour. Hence, results of the identification procedure for finite element simulations of delamination growth in standard tests are discussed.

KEY WORDS: delamination; interface models; visco-plasticity; parameter identification: Kalman filter.

Paper No. 2673

CV1

Corigliano A., Mariani S.

PARAMETER IDENTIFICATION OF INTERFACE MODELS FOR DELAMINATION ANALYSIS IN THE PRESENCE OF DYNAMIC LOADING

Proc. 3rd Joint Conference of Italian Group of Computational Mechanics and Ibero-Latin American Association of Computational Methods in Engineering (GIMC2002), Giulianova (I), June 24-26, 2002, 10 pp. (CD ROM).

An Extended Kalman Filter (EKF) approach is applied in the present paper to the purpose of identifying interface model parameters in the presence of dynamic loading conditions. An elastic structural system space-discretised by means of Finite Elements (FE) is considered; the system can contain interfaces which obey nonlinear irreversible interface laws. Time discretisation with the Forward Euler

explicit algorithm is adopted in order to obtain the time discretised state equations of the system in terms of nodal displacements and velocities. The EKF is then applied by defining a state vector containing nodal displacements, nodal velocities and interface model parameters. The EKF procedure is numerically tested with the study of a one-degree of freedom system and a one-dimensional bar subject to impact loading.

KEY WORDS: layered composites; delamination; interface models; dynamics; parameter identification; extended Kalman filter.

Paper No. 2674

CV1

Corigliano A., Mariani S., Pandolfi A.

RATE-DEPENDENT INTERFACE MODELS AND DYNAMIC DELAMINATION PROCESSES

Proc. 3rd Joint Conference of Italian Group of Computational Mechanics and Ibero-Latin American Association of Computational Methods in Engineering (GIMC2002), Giulianova (I), June 24-26, 2002, 8 pp. (CD ROM).

Experimental observations of damage in polymer-matrix composites under dynamic loading (e.g. delamination as consequence of impact) show that the global behavior of the material can strongly depend on loading rate. A reliable constitutive model for polymer-matrix composites should be able to correctly reproduce the observed rate effects. Purpose of the present study is to single out basic features of cohesive models to correctly simulate rate dependent fracture processes. Analytical and numerical results are presented with reference to a spallation problem in a originally undamaged linear elastic isotropic material. The spalling crack forms on a cohesive interface where the softening depends on the velocity of the damage process (i.e. the opening displacement rate). Among the obtained results, it is shown that rate dependent cohesive models are able to capture the variation of the fracture energy with the speed of the pulse wave impinging upon the spalling surface.

KEY WORDS: interface models; dynamics; time-dependency; spalling.

Corigliano A., Perego U.

NUMERICAL EVALUATION OF RESIDUAL STRESSES IN HIGH SPEED TRAIN WHEELS

Proc. Workshop on 'Rolling Contact Fatigue', Brescia (I) November 15, 2002, pp. 163-170.

In this paper, a procedure for the numerical evaluation of the residual stresses in the bulk material in the proximity of the rail contact region for a train wheel is synthetically described. The computed residual stresses are then compared to the residual stresses measured in the course of a separate experimental campaign on real train wheels by means of a diffractometric technique. The finite element model proved suitable for being used in subsequent estimates of the wheel rolling contact fatigue life by means of high cycle fatigue criteria.

KEY WORDS: rolling contact fatigue; elasto-plasticity; residual stresses; shakedown analysis.

Coronelli D.

ASSESSMENT OF THE RESIDUAL BOND STRENGTH IN CORRODED BARS

Proc. Int. Conf. on 'Bond in Concrete – from Research to Standards', G.L. Balasz, P. Bartos, J. Cairns and A. Borosnyoi (Eds.), Budapest (H), November 20-22, 2002, pp. 190-198.

Testing and modelling of bond in corroded bars in R/C are discussed in order to work out the indicators of bond conditions in a deteriorating structure. The opening of the first corrosion cracks (primary cracking) is shown not to jeopardize bond capacity, and the effects of the cover cracking in bending are examined, together with the through-splitting of the cover; both are shown to correspond to a final cracking stage, that starts bond deterioration. In this phase, the degradation of the interface properties is taken into account, together with the reduction of bar rib height and inclination; also the role of the stirrups is discussed, in relation to the cross-section losses of the selfsame corroding transverse steel. These elements are used to introduce a new strategy to assess the residual bond capacity, using a simplified version of a previously developed model. Analytical expressions are proposed to evaluate bond strength in the different stages of the deterioration process. Some hints are suggested to identify the regions in R/C beams that are more prone to become critical because of the progress of the environmental attack and of the loading of the structure.

KEY WORDS: bond strength; corrosion; cracking; structural safety assessment.

Coronelli D.

CORROSION CRACKING AND BOND STRENGTH MODELLING FOR CORRODED BARS IN REINFORCED CONCRETE

ACI Struct. J., Vol. 99, No. 3, pp. 267-276, 2002.

A model for the prediction of bond strength is proposed with reference to corroded bars. Different confinement situations are considered, and the role of the interface pressure caused by bar expansion is studied. With reference to the ultimate bond stress (bond ultimate capacity), the model is shown to reproduce very well some of the most documented test results available in the literature. Initial bond increase and the final bond deterioration are also modelled, and the residual bond at corrosion levels beyond cover cracking is shown to remain substantial, on condition that sufficient confinement is provided by the stirrups. Finally the model makes it possible to study bond mechanics under both mechanical and environmental actions, as required by the assessment of safety in existing deteriorated structures.

KEY WORDS: concrete; corrosion; anchorage; cracking; bond; assessment.

Paper No. 2678

Corradi L., Panzeri N.

A TRIANGULAR FINITE ELEMENT FOR THE STUDY OF THE POST-CRITICAL BEHAVIOR OF SHELLS

Proc. 6th Int. Conf. on 'Computational Structures Technology', Prague, September 4-6, 2002 (CD ROM).

The numerical solution of the limit analysis problem has experienced a growing interest in recent years. Methods developed in this context can be employed also to obtain indications on the structural response subsequent to collapse, which is required in several situations, such as for shells employed as shock absorbers or energy dissipators. The procedure is known as *sequential limit analysis* and, as its name suggests, is based on a sequence of limit analysis solutions referring to progressively updated configurations. In this paper, the limit analysis procedure proposed in [6] is employed to this purpose in conjunction with the TRIC shell element developed by Argyris and coworkers in [16], which is modified to some extent to adapt to the rigid-plastic context. Some examples show the effectiveness and the accuracy of the method, which compares well with results obtained from complete, although computationally demanding, incremental elastic-plastic approaches.

KEY WORDS: post-collapse behavior; sequential limit analysis; shells.

di Prisco C., Nova R., Sibilìa A.

ANALYSIS OF SOIL-STRUCTURE INTERACTION OF TOWERS UNDER CYCLIC LOADING

Proc. 8th Int. Symp. on 'Numerical Models in Geomechanics' (NUMOG VIII), G.N. Pande and S. Pietruszczak (Eds.), Swets & Zeitlinger, Lisse, 2002, pp. 637-642.

The aim of the paper is the modelling of the interaction of the foundation of a tower structure with the soil underneath. It is assumed that the motion of the tower is constrained by a set of uncoupled viscous dampers and by a macroelement connecting external actions on the foundation with its displacements and rotation. The constitutive law of such macroelement is formulated within the framework of strainhardening elastoplasticity. To account for cyclic loading effects, it is assumed that irreversible displacements occur even within a conveniently defined boundary surface. These can be calculated by means of a mapping rule, establishing a correspondence between a stress point within the boundary surface and an image point on it. Comparisons between predicted results and experimental data on various model tests in quasi-static conditions are illustrated. An example of calculation of displacements and rotation of a chimney subjected to the dynamic action of a strong wind is eventually presented. It is shown that with this method it is possible to describe in a realistic way hysteresis, ratcheting and subsequent shake down of the foundation.

KEY WORDS: cyclic loading; elastoplasticity; foundations; numerical modelling; soil-structure interaction.

di Prisco C., Imposimato S.

STATIC LIQUEFACTION OF A SATURATED LOOSE SAND STRATUM

International Journal of Solids and Structures, Vol. 39, pp. 3523-3541, 2002.

The ideal case of an infinite horizontal, homogeneous oedometrically consolidated saturated loose sand stratum, sheared in displacement controlled conditions is numerically analysed. The phenomenon of the stratum liquefaction, which is due to both the material mechanical instability and the water presence within pores, is discussed. The numerical results have been obtained by means of a spatial one dimension finite difference numerical code within which both the local and the non local versions of the same elasto-viscoplastic constitutive model are implemented. Both pore water and shear strain wave propagation within the soil layer is described.

KEY WORDS: loose sand; liquefaction; numerical analyses; elasto-viscoplastic constitutive model.

di Prisco C., Imposimato S., Aifantis E.C.

A VISCO-PLASTIC CONSTITUTIVE MODEL FOR GRANULAR SOILS MODIFIED ACCORDING TO NON-LOCAL AND GRADIENT APPROACHES

Int. J. Num. Anal. Meth. Geomech. Vol. 26, pp. 121-138, 2002.

An already available non-associated elastic-viscoplastic constitutive model with anisotropic strain hardening is modified in order to describe both the constitutive parameter dependency on relative density and the spatio-temporal evolution of strain localisation. To achieve this latter goal, two distinct but similar approaches are introduced: one inspired by the gradient theory and one by the nonlocal theory. A one-dimensional case concerning a simple shear test for a non-homogeneous infinitely long dense sand specimen is numerically discussed and a finite difference scheme is employed for this purpose. The results obtained by following the two different approaches are critically analysed and compared.

KEY WORDS: granular material; stability and bifurcation; finite differences; elastic-viscoplastic material.

di Prisco M., Ferrara L., Meftah F., Pamin J., de Borst R., Mazars J., Reynouard J.M.

MIXED MODE FRACTURE IN PLAIN AND REINFORCED CONCRETE: SOME RESULTS ON BENCHMARK TESTS

Int. J. of Fracture, Vol. 103, pp. 127-148, 2000.

Three different models for concrete based on local and non-local approaches have been adopted to investigate the mechanical behaviour of plain and reinforced concrete when undergoing mixed-mode fracture. The purpose of the research is to understand the results of some benchmark tests, to compare the models with each other and with experiments, and to estimate the reliability of the modelling. To create a sound basis for comparison, the discretization, the boundary conditions and the material data are considered, when possible, as unified parameters for the different models in each benchmark test.

KEY WORDS: mixed-mode fracture: shear; dowel action; notched specimens; path-dependence; smeared cracks; (non)local models; damage; plasticity.

Faccioli E., Paolucci R.

ENGINEERING ASSESSMENT OF SEISMIC HAZARD AND LONG PERIOD GROUND MOTIONS AT THE BOLU VIADUCT SITE FOLLOWING THE NOVEMBER 1999 EARTHQUAKE

Journal of Seismology, Vol. 6, pp. 307-327, 2002.

The Mw 7.1 earthquake of November 12, 1999 severely damaged a 2.5 km long viaduct on a stretch under construction of the Istanbul-Ankara motorway, 18 km W of Bolu. The fault rupture crossed the viaduct with an observed offset close to 1.5 m; the viaduct deck suffered large permanent displacements with respect to the piers but did not collapse. Seismic hazard at the site appears to be governed by characteristic earthquakes occurring every few hundred years both on the Düzce fault and on the main stretch of North Anatolian fault (NAF). Smaller active faults near the site also contribute to the hazard. We investigate how a reliable design response spectrum of displacement can be constructed for the viaduct site using both probabilistic and deterministic tools. After checking the applicability of known attenuation relations against recorded data, we illustrate a hazard analysis that incorporates a characteristic earthquake model for the relevant faults, and accounts for statistical directivity effects on the Düzce fault. Constant-risk response spectra up to 3 s are thus obtained for different return periods. Synthetic motions at the site are generated next, using a known source model, in order to explore the features of the displacement response spectrum at vibration periods in the range between 1s and 6 s, in which the dominant response of the viaduct deck, uncoupled from the piers, occurs. A discussion of results follows.

KEY WORDS: 1999 Turkey earthquakes; seismic hazard; characteristic earthquake; long period ground motion; numerical simulation; displacement response spectrum; source directivity; bridge retrofitting.

Failla C., Toniolo G., Ferrara L.

DESIGN CRITERIA FOR STRUCTURAL USE OF FIBRE-REINFORCED CONCRETE IN PRESTRESSED PRECAST ROOF ELEMENTS

Proc. 5th RILEM Symp. on Fibre Reinforced Concretes (BEFIB 2000), Lyon (F), September 13-15, 2000, P. Rossi and G. Chanvillard (Eds.), pp. 253-262.

The paper presents the results of a research on technological aspects and on design criteria for structural application of FRC. This application refers to large precast roof elements to be produced with industrial processes. First of all the concreting technology has been set-up through an initial experimentation which allowed to achieve a very good homogeneity of the material. Design criteria derive from the improvement of previous experiences available in literature as well

as from specific tests and their proper interpretation. Steel fibres are assumed as substitutive of the welded mesh, for local transverse bending of flanges, and of the stirrups in the webs, for the main longitudinal shear. Fibres are also assumed as integrative reinforcement for the main longitudinal bending, in addition to pretensioned strands. Tests have been made on samples of thin plates for the characterization of the material and on some full scale prototypes. The results of the research have been finally applied to the construction of a first experimental building which is now finished and in service.

KEY WORDS: fibre reinforced concretes; roof elements; design criteria; type tests.

Paper No. 2685

CV1

Failla C., Toniolo G., Ferrara L.

**STRUCTURAL DESIGN OF PRESTRESSED PRECAST ROOF ELEMENTS
MADE WITH STEEL FIBRE REINFORCED CONCRETE**

Proc. Int. Conf. BIBM 2002, Istanbul, May 1-4, 2002 (CD ROM).

The criteria for a design assisted by testing are presented referring to thin walled precast elements for long span roofings produced with steel fibre-reinforced concrete (SFRC) in factory permanent plant. The design is based on proper preliminary tests for the identification of material properties, followed by calculations in which the tensile contribution of SFRC, due to its high toughness, is properly taken into account. The setting out of a reliable production process which ensures a good material homogeneity with an uniform distribution of fibres allowed for a structural use of SFRC. The traditional welded mesh reinforcement for transverse flexure and shear has been replaced by fibres. The post-peak tensile strength of SFRC has been taken into account also for the midspan flexural resistance in the longitudinal direction, considering its contribution as integrative of the principal one given by the pretensioned tendons. Proper full scale load tests on some prototypes have been made in order to verify the design model. The application of this type of elements in some industrial buildings is finally shown.

KEY WORDS: prestressed roof elements; plain concrete; fibre reinforced concrete; design by testing; design criteria; type tests.

Fatica G., Floris C.

RANDOM VIBRATION OF COULOMB OSCILLATORS SUBJECTED TO SUPPORT MOTION WITH A NON-GAUSSIAN MOMENT CLOSURE METHOD*Mechanics of Structures and Machines, Vol. 30, No. 3, pp. 381-410, 2002.*

The response of one-degree-of-freedom systems with frictional devices (Coulomb oscillators) undergoing Gaussian support motion (earthquake) is investigated by adopting a moment equation approach in the context of Itô's calculus. Such equations contain expectations of the signum function of the velocity. In order to evaluate them, the joint probability density function of the variables is expanded in a truncated series of modified Hermite polynomials, which allows the computation of the response moments. The truncation is equivalent to neglecting the Hermite moments of the variables beyond a given order. Starting from the response moments so calculated, approximate marginal and joint PDF, mean upcrossing rate functions, and the largest value distributions can be constructed. Viceversa, the estimates of the response correlations require the evaluation of a first order differential system, which too is written by using Itô's rule. The results of the applications compare well with the simulation, and show that the assumption of Gaussian response is unacceptable and non conservative.

KEY WORDS: frictional (Coulomb) stochastic oscillators; Itô's calculus; moment equation approach; non-Gaussian closure.

Fatica G., Floris C., Sandrelli M.

COMPUTER ALGEBRA FOR RANDOM VIBRATION ANALYSIS*Proc. 8th Int. Conf. on 'Structural Safety and Reliability' (ICOSSAR 2001), Newport Beach, CA (USA), June 17-22, 2001 (CD ROM).*

The problem of the computation of the response statistical moments of multidimensional linear dynamic systems excited by polynomial forms of filtered Gaussian processes is concerned by the view point of the numerical evaluation of the stationary solution. It is shown that the application of Itô's calculus rules for writing the equations giving the response moments can be automatized. This operation is easier and straightforward if a symbolic manipulator is used, but in this way the computing times are larger. Viceversa, if the same operations are performed by a computer program written in FORTRAN language, the time for computation is considerably reduced. A numerical example regarding a two-degree-of-freedom system proves the previous statement.

KEY WORDS: stochastic dynamics; Itô's calculus; moment equation approach; computer algebra; FORTRAN; symbolic manipulators.

Fedele R., Bolzon G., Maier M., Whelan M.

IDENTIFICATION OF LOCAL (PHASE) PARAMETERS IN HETEROGENEOUS MEDIA

Proc. 3rd Joint Conference of Italian Group of Computational Mechanics and Ibero-Latin American Association of Computational Methods in Engineering (GIMC2002), Giulianova (I), June 24-26, 2002, 9 pp. (CD ROM).

Purpose of this study is to develop a methodology to characterize local constitutive models in periodic heterogeneous media, when only global experimental measurements are available. This approach has been applied to the identification of constitutive parameters for metals. The behaviour of an heterogeneous periodic medium, consisting of a metal-matrix with voids as inclusions, has been simulated by means of finite element and homogenization techniques. Both statistical and deterministic parameter identification algorithms have been employed. A correlation index has been used in order to quantitatively compare computed and experimental displacement fields.

KEY WORDS: composites; local constitutive models; parameter identification.

Felicetti R., Gambarova P.G., Silva M., Vimercati M.

THERMAL DIFFUSIVITY AND RESIDUAL STRENGTH OF HIGH-PERFORMANCE LIGHT-WEIGHT CONCRETE EXPOSED TO HIGH TEMPERATURE

Proc. 6th Int. Symposium on the Utilization of HSC/HPC, Leipzig (D), June 17-19, 2002, Vol. 2, pp. 935-948.

See also: **THERMAL AND MECHANICAL PROPERTIES OF LIGHT-WEIGHT HIGH-PERFORMANCE CONCRETE EXPOSED TO HIGH TEMPERATURE** (in Italian)

Proc. 14th Conf. of the Building Technicians Board (CTE), Mantua (I), November 7-9, 2002, pp. 181-188.

The extensive studies devoted so far to normal-strength light-weight aggregate concrete (LWAC or LWC) have exhaustively clarified its behavior. However, the introduction of high-strength light-weight aggregate concrete (HPLWAC or HPLWC), containing such hydraulically-active components as microsilica and fly ash, raises some concerns, for instance about the behavior at high temperature and after cooling. Whether HPLWC is more temperature-sensitive than LWC and ordinary normal-strength concrete (NSC) is still an open question. To investigate the temperature-induced mechanical damage in a mixed-aggregate, silica-fume HPLWC, a systematic research program is in progress at Milan University of Technology. Three concrete mixes (NSC, C30; LWC, LC 40; and HPLWC,

LC 60), five temperature levels (20, 105, 250, 500 and 750°C), one thermal state (after cooling), three nominally-equal tests for each case (for repeatability) have been planned, bringing the total number of the specimens to 45. At the same time the thermal diffusivity of the materials has been evaluated up to 750°C. The first results show that HPLWC is somewhat more temperature-sensitive than LWC, but its reduced thermal diffusivity may be favorable to the integrity of fire-exposed R/C structures.

KEY WORDS: concrete compressive strength; high-performance concrete; high temperature; light-weight concrete; normal-strength concrete; residual.

Paper No. 2690

CV1

Ferrara L., di Prisco M.

A NON-LOCAL APPROACH WITH EVOLUTIONARY INTERNAL LENGTH FOR THE ANALYSIS OF MODE I FRACTURE PROCESSES IN CONCRETE

Proc. 15th ASCE Engineering Mechanics Conference, (EM2002) New York, NY (USA), June 2-5, 2002 (CD ROM).

A non-local approach with an “evolutionary internal length” is here proposed and implemented in the formulation of the “*Crush-Crack*” non-local damage model. The internal length is actually made evolving with the damage from its initial value, which is correlated to the material characteristic length. The evolution laws of the internal length with damage have been calibrated, mainly with reference to the value that such a length has to assume at complete breakage of the material (damage equal to one), in order to not retrieve the drawbacks of a local analysis. The calibration of such a law and of the whole set of model parameters is performed on both 1D and 2D benchmarks in uniaxial tension, taking a Normal Strength Concrete as a reference. The reliability of the proposed approach is finally checked with reference to experimental results from direct tension tests.

KEY WORDS: damage; non-local models; evolutionary characteristic length; mode I fracture.

Ferrara L., di Prisco M.

THREE- VS. FOUR-POINT BEND TESTS: A NUMERICAL INVESTIGATION ON PLAIN CONCRETE

Studi e Ricerche, Scuola di Specializzazione per le Costruzioni in Cemento Armato, Politecnico di Milano, Vol. 22, 2001, pp. 73-119.

In this paper the Three-Point-Bend (3PB) and the Four-Point Bend (4PB) tests are extensively examined with reference to plain concrete. The investigation is based on several numerical analyses performed using a non-local damage model already successfully employed in reproducing mode I fracture process in concrete. This research was needed in the framework of UNI and RILEM Technical Commissions, bound to select a test for the characterisation of mechanical properties in tension of Steel Fibre Reinforced Concrete (SFRC). The test has to emphasize the fibre contribution in mode I fracture behaviour with respect to what the same plain concrete matrix offers. Different reasons moved the Commissions to consider as standard bending test two different notched specimen geometries, furthermore characterized by two different notch depths. The Italian Committee (UNI) chose the 4PB and the International Committee (RILEM) the 3PB. The final purpose of this work is hence to compare these two bending test-geometries with reference to peak load, energy-release contributions, crack-tip and mouth opening displacements, deflections, regarding as variables the notch depth, the load position, the specimen size and the concrete class. The influence of defects was not taken into account, because only the choice of the specimen geometry was debated. It has been found that the values of both Crack Tip Opening Displacements (CTOD) and deflections at the peak load are almost independent of specimen geometry and testing variables and are weakly dependent on concrete strength. A semi-empirical relationship between crack-opening displacement and deflection is also proposed in order to simplify the test set-up as much as possible.

KEY WORDS: plain concrete; material properties; tensile strength; identification; bending tests; notch sensitivity; size effect; fracture energy; kinematic control parameters.

Ferrara L., Failla C., Signorini S., Sonzogni F.

INFLUENCE OF VISCOSITY ENHANCING ADMIXTURES ON FIBRE DISTRIBUTION IN STEEL FIBRE REINFORCED CONCRETES (in Italian)

Proc. 14th Conf. of the Building Technicians Board (CTE), Mantua (I), November 7-9, 2002, pp. 47-58.

Relevant studies have been carried out in these last years about the replacement of conventional shear reinforcement with metallic fibres in reinforced concrete structural elements. The efficacy of this technology, and hence the possibility of reliably implementing it in the production processes of a pre-cast factory, clearly depends on the possibility of achieving a homogenous and uniform distribution of fibres, reducing the influence of castings and vibration. An unproper design and placement of the fresh mix may lead to segregation of larger particles and of fibres thus limiting the possibilities for a structural use of fibre reinforced concrete. This work presents the results of a research program aimed at evaluating the influence of viscosity enhancing admixtures (VEA) on the fibre distribution in Steel Fibre Reinforced Concrete (SFRC) elements. First of all their influence has been investigated with reference to fibre distribution along casting direction in cylinder specimens. As a further step of the investigation small-scale prototypes have been cast with the same mixes previously tested and the distribution of fibres, as influenced by the mix-design of concrete, has been evaluated along the thickness and the cross-section as well as along the longitudinal axis of the prototypes. Results are really promising in sight of structural applications. In this framework some full-scale prototypes have been cast with the "optimum" mix, as came out from previously said experiments, and the repeatability of results previously obtained has been checked with reference to them.

KEY WORDS: fibre reinforced concrete; fibre distribution; viscosity enhancing admixtures; self-compacting high performance concretes; pre-stressed thin-walled roof elements.

Ferrara L., Gettu R.

NON-LOCAL DAMAGE ANALYSIS OF THREE-POINT BENDING TESTS ON SFRC NOTCHED BEAMS

Proc. 5th RILEM Symp. on Fibre Reinforced Concretes (BEFIB 2000), Lyon (F), September 13-15, 2000, P. Rossi and G. Chanvillard (Eds.), pp. 357-368.

A non-local damage model, together with a suitable constitutive model for steel-fiber reinforced concrete, is here employed for the numerical analysis of three point bending tests on beams of different sizes and made with concretes incorporating different fiber contents. numerical computations are instrumental for as-

sessing the capabilities of the proposed modelling tool for the analysis of a typical mode I fracture problem in fiber reinforced cement based composites, highlighting its benefits and pointing out its limits, as well as for having a better insight into the reliability of the flexural test as a tool for the identification of material properties.

KEY WORDS: non-local damage; constitutive model; fiber reinforced cement.

Paper No. 2694

CV1

Ferrara L., Gettu R.

SIZE EFFECT IN SPLITTING TESTS ON PLAIN AND FIBER REINFORCED CONCRETE: A NON-LOCAL DAMAGE ANALYSIS

Proc. 4th Int. Conf. on 'Fracture Mechanics of Concrete Structures' (FraMCoS4), Cachan (F), May 31-June 4, 2001, R. de Borst et al. (Eds.), pp. 677-694.

Recent splitting-tension tests on plain and steel fiber reinforced concrete have shown that, besides the existence of a size effect that depends on the relative width of the loading area, the deformations due to the splitting and compression (including the consequent wedge development) can be uncoupled through tests of whole and previously-halved discs. In order to have a better insight into the problem, experiments have been analyzed through a non-local damage model. The material properties were first identified using three-point bending test data from geometrically-similar notched beams. Numerical analyses of the splitting tests, both in the traditional and modified test configurations, were then performed with a two-fold purpose. On one hand, it aims at a better understanding of the splitting test, as well as the reliability of jointly using the two types of tests for obtaining the fracture parameters for both plain and fiber concretes. On the other hand, the applicability of the proposed modeling tool is thoroughly checked.

KEY WORDS: plain and fibre reinforced concrete; splitting tests; non-local damage; testing variables; boundary conditions; size effect.

Paper No. 2695

CV2

Ferrara L., Toniolo G.

STATISTICAL QUALITY CONTROL OF CONCRETE: RELIABILITY AND SAFETY FACTORS (in Italian)

Proc. 13th Conf. of the Building Technicians Board (CTE), Pisa (I), November 9-11, 2000, pp. 543-552.

The paper presents the results of three years of continuing statistical controls performed on three families of concretes corresponding to as many production lines

of LARCO-ASTORI factory in Carvico. Controls follow the criteria of recently published Italian Instructions CNR 10025/98. Besides showing the standard form for the recording of test results, together with the graphs showing the time-trend of strength parameters, some significant practical information drawn from the procedure are highlighted, which allow for timely adjustments of production processes. Controls show that, due to the improvement of equipments and mainly of the instruments governing the dosage of the single constituent materials, the quality of concretes coming out from a prefabrication factory remains almost constant, shortly spread and with limited seasonal fluctuations. On the basis of the fundamental reliability criteria of structural analysis, it is finally shown that partial factors can be reduced, for the same safety level, or that a higher safety level can be attained, for the same partial factors.

KEY WORDS: reliability; partial safety factors; concrete strength; quality control.

Paper No. 2696

RV1

Floris C., De Iseppi L.

STOCHASTIC ALONG-WIND RESPONSE OF NONLINEAR STRUCTURES TO QUADRATIC WIND PRESSURE

Wind and Structures, Vol. 5, No.5, pp. 423-440, 2002.

The effects of the nonlinear (quadratic) term in wind pressure has been analyzed in many papers with reference to linear structural models. The present paper addresses the problem of the response of nonlinear structures to stochastic nonlinear wind pressure. Adopting a single-degree-of-freedom structural model with polynomial nonlinearity, the solution is obtained by means of the moment equation approach in the context of Itô's stochastic differential calculus. To do so, wind turbulence is idealized as the output of a linear filter excited by a Gaussian white noise. Response statistical moments are computed for both the equivalent linear system and the actual nonlinear one. In the second case, since the moment equations form an infinite hierarchy, a suitable iterative procedure is used to close it. The numerical analyses regard a Duffing oscillator, and the results compare well with Monte Carlo simulation.

KEY WORDS: quadratic wind pressure; nonlinear structures; wind response; Itô's calculus; moment equation approach; iterative closure method.

Floris C., Pulega R.

STOCHASTIC RESPONSE OF OFFSHORE STRUCTURES VIA STATISTICAL CUBICIZATION

Meccanica, Vol. 37, No.1, pp. 15-32, 2002.

This paper deals with the stochastic response of single-degree-of-freedom structures with polynomial restoring force excited by random Morison's forces with mean current. The problem is recast by expressing the excitation by means of a cubic polynomial of the wave elevation, which in turn is assumed as a stationary zero-mean Gaussian process, whose spectral density is given by the output of a cascade of two second order linear filters having a Gaussian white noise as primary excitation. Thus, Itô's stochastic differential calculus becomes applicable, and the solution is pursued with a moment equation approach by using a suitable closure scheme. The results of the applications compare well with digital simulation.

KEY WORDS: offshore structures; Itô's calculus; moment equation approach; stochastic dynamics.

Frangi A.

FRACTURE PROPAGATION IN 3D BY THE SYMMETRIC BOUNDARY ELEMENT METHOD

International Journal of Fracture, Vol. 116, pp. 313-330. 2002.

The numerical simulation of fatigue crack propagation in 3D linear elastic bodies is addressed. The symmetric Galerkin BEM is employed, thus drastically reducing the remeshing work compared to what is needed by domain formulations. The propagation algorithm adopted has been implemented into a fully automated numerical code and utilized to analyze two examples concerning surface breaking cracks.

KEY WORDS: asymptotic expansions; BEM; elastic fracture mechanics; fracture propagation.

Frangi A., Novati G.

BEM-FEM COUPLING FOR FRACTURE MECHANICS APPLICATIONS

Proc. 5th World Congress on Computational Mechanics (WCCM V), Wien (A), July 7-12, 2002, H.A. Mang, F.G. Rammerstorfer and J. Eberhardsteiner (Eds.), Vienna University of Technology Pub., on-line publication (<http://wccm.tuwien.ac.at>), 10 pp.

Attention is focused on the implementation of a coupled BEM-FEM procedure preserving the following features: i) symmetric final system matrix; ii) weak interface coupling of tractions; iii) independent modelling of interface displacements allowing to tune discretization according to the different features of the FEM and BEM procedures employed. The code developed is used to simulate two examples of 3D linear-elastic fracture and fracture propagation.

KEY WORDS: BEM; 3D fracture mechanics; BEM-FEM coupling.

Paper No. 2700

Frangi A., Novati G.

FRACTURE MECHANICS IN 3D BY A COUPLED FE-BE APPROACH

Proc. IABEM 2002 Symposium, Austin, TX (USA), May 28-30, 2002, S.A. Kinnas (Ed.), 9 pp. (CD ROM).

The analysis of linear elastic fracture mechanics problems in three dimensions is addressed via a symmetric coupled BEM-FEM procedure. The code developed is used to simulate two classical benchmarks of 3D linear-elastic fracture and comparisons are presented with available BEM and FEM solutions.

KEY WORDS: BEM; 3D fracture mechanics; BEM-FEM coupling.

Paper No. 2701

Frangi A., Novati G., Springhetti R., Rovizzi M.

3D FRACTURE ANALYSIS BY THE SYMMETRIC GALERKIN BEM

Computational Mechanics, Vol. 28, pp. 220-232, 2002.

The subject of this paper is the formulation and the implementation of the symmetric Galerkin BEM for three-dimensional linear elastic fracture mechanics problems. A regularized version of the displacement and traction equations in weak form is adopted and the integration techniques utilized for the evaluation of the double surface integrals appearing in the discretized equations are detailed. By using quadratic isoparametric quadrilateral and triangular elements, some ex-

ample crack problems are solved to assess the efficiency and robustness of the method.

KEY WORDS: variational BEM; linear elastic fracture mechanics; singular integrals.

Paper No. 2702

CV1

Garavaglia E., Cardani G., Binda L.

APPLICATION OF A PROBABILISTIC MODEL FOR THE PREDICTION OF THE DECAY DUE TO SALT CRYSTALLISATION OF MASONRY BUILDING MATERIALS

Proc. Int. Conf. 9th on 'Durability of Building Materials', Brisbane (AUS), March 17-20, 2002 (CD ROM).

An attempt has been made within an EU Contract, to establish the maximum salt content, below which the surface treatments do not fail. Crystallisation tests were carried out on treated and untreated brick and limestone masonry specimens. Salt solutions with two low concentrations of sodium sulphate were inserted in masonry wallets treated with a water based water repellent and a consolidant. On the basis of the recorded experimental data, a suitable damage parameter describing the material deterioration process has been chosen. The parameter assumed is the loss of surface material at each measurement. The measurements have been made through a laser device along chosen profiles on the masonry surface. The deterioration process could be interpreted as a stochastic process $L(t, \mathbf{I})$, function of time t and damage \mathbf{I} , where \mathbf{I} is considered a random variable (r.v.) because of experimental evidence. In this way, for different damage levels $\bar{\mathbf{I}}$ it is possible to build the fragility curve for each $\bar{\mathbf{I}}$. A fragility curve describes the probability of reaching or exceeding a given damage $\bar{\mathbf{I}}$ over time. By using this approach the magnitude of the expected damage over time and the occurrence time of it can be predicted. The results will allow for the investigation on the durability of materials with respect to the treatment used and on the decay process of single and composite materials.

KEY WORDS: salt crystallisation; masonry decay process; stochastic processes; fragility curves.

Garavaglia E., Cardani G., Binda L.

A PROBABILISTIC MODEL TO PREDICT THE DURABILITY OF SURFACE TREATMENTS

Int. Journal for Restoration of Buildings and Monuments, Vol. 8, No. 2/3, pp. 233-254, 2002.

Surface treatments, such as hydrophobization, of brick and stone-facing walls should generally be avoided in the presence of soluble salts due to the possible formation of cryptoefflorescence. A research carried out within an EC contract aims to establish the maximum salt content below which surface treatments do not fail. Crystallisation tests were carried out on treated and non-treated masonry units made with different materials, such as stone and brick. Increasing salt percentages were used in order to find the allowable salt content for successful treatments. In order to compare the results, a suitable damage parameter describing the material deterioration process had to be chosen. The selected parameter was the surface material loss at each measurement carried out with a laser device along chosen profiles on the sample surface.

KEY WORDS: probabilistic mode; masonry durability; stochastic model.

Garavaglia E., Lubelli B., Binda L.

TWO DIFFERENT STOCHASTIC APPROACHES MODELLING THE DECAY PROCESS OF MASONRY SURFACES OVER TIME

Materials and Structures, Vol. 35, No. 248, pp. 246-256, 2002.

On February 2000 a delegation from the Politecnico of Milan visited the My Son archaeological site. The aim of the visit was to detect by visual inspection the state of damage of the temples after the war destruction and the damage effects due to the environment. Several of the buildings which are so much interesting for Vietnam and for the world Cultural Heritage show structural damage and material decay. The structural damages have been photographed and a first interpretation of the damages was given; moreover also the material decay was surveyed and samples of biological growth were taken. Bricks, assemblages and mortars in the interior of the walls were sampled and brought to DIS, Politecnico of Milan to carry out a preliminary characterisation. Chemical, physical, petrographic and other optical analyses and mechanical tests. The peculiar technique of construction of My Son walls, together with the bonding material used for the joints seems to be very interesting not only for historic masonry walls but even for the today masonry construction. A research programme is proposed in order to have a confirmation of the preliminary tests results and prepare data for a future design for conservation.

KEY WORDS: laboratory test; mortar; brick; characterization .

Paper No. 2705

SA1

Garavaglia E., Lubelli B., Binda L.

A PROBABILISTIC APPROACH MODELLING THE DETERIORATION PROCESS OF MASONRY SUBJECTED TO AGGRESSIVE ENVIRONMENT OVER TIME (in Italian)

in 'Il Progetto di Conservazione: linee metodologiche per le analisi preliminari, l'intervento, il controllo di efficacia', S. Pesenti (Ed.), Alinea, par. 2.6, pp. 164-173, 2001.

During their service life, the structures that are subjected to an aggressive environment may suffer degradation of their component materials. The deterioration of material due to environmental attacks affects also the masonry. The main attacks for masonry are the natural frost–defrost cycles. In presence of moisture and/or capillary rise these cycles can produce crystallisation of water or salts inside the component materials (bricks or stones and mortar). As a consequence, the loss of surface material can happen. Along the time this decay can compromise the reliability of the structural element's cross section. The time to release this deterioration is not known. But, in a planning of maintenance and/or repair, the knowledge of this time could be useful. In the last years the research has been oriented on the development of a model able to quantify the time of reaching different significant damage levels. The great randomness connected with the realisation of critical environmental attacks suggests approaching the study of the deterioration of the building materials under a probabilistic point of view. Therefore, the deterioration process $L(t)$ over time has been defined as a stochastic process of the random variable (r.v.) \mathbf{I} , where \mathbf{I} is the loss of surface material. Following this approach the deterioration process as been treated as a reliability problem. This has led to the building of fragility curves able to describe the probability of reaching given damage levels over time. In this paper the operative guidelines, describing the use of the procedure proposed, are defined. To better explain the probabilistic model, the procedure has been applied, step by step, on stone full-scale models. Each step of application and the results obtained are commented by an operative point of view.

KEY WORDS: masonry deterioration; stochastic models; fragility curves; operative guidelines.

Garavaglia E., Pavani R.

TWO STOCHASTIC APPROACHES TO INVESTIGATE RELIABILITY OF BUILDING MATERIALS OVER TIME

Proc. 8th Int. Conf. on 'Structural Safety and Reliability' (ICOSSAR 2001), Newport Beach, CA (USA), June 17-22, 2001, 9 pp. (CD ROM).

The great randomness involved in the masonry decay phenomenon, due to environmental attacks, suggests studying it from a probabilistic point of view. Here, the study of evolution of the stone masonry decay has been carried out applying two different approaches on experimental data collected on on-site models. Results are very close, therefore the choice of the approach appears depending on the available data and the monitoring time only.

KEY WORDS: masonry decay; reliability problems; probabilistic approaches.

Gentile C., Saisi A., Binda L.

DYNAMIC INVESTIGATION OF A HISTORIC MASONRY BELL TOWER

Proc. 6th Int. Masonry Conf., London, November 4-6, 2002, No. 9, pp. 192-199.

The dynamic characteristics of a historic masonry bell tower are investigated using full-scale testing and finite element analysis. The Tower, about 74m high, is adjacent to the Cathedral of Monza (Italy) and exhibits major cracks on the western and eastern load-bearing walls. The experimental program includes ambient vibration tests of the Tower; full details on the experimental procedures, instrumentation and data analysis techniques are given. In the theoretical study, vibration modes were determined by using a 3D finite element model. The comparison between measured and predicted modal parameters was then used to verify the assumptions adopted in formulating the model. Specifically, a good match between theoretical and experimental modal parameters was reached for relatively low stiffness ratios of the model in the zones of the Tower which were most damaged.

KEY WORDS: masonry decay; dynamic investigation; bell tower; numerical model.

Lualdi M., Zanzi L.

GPR INVESTIGATIONS TO RECONSTRUCT THE GEOMETRY OF THE WOODEN STRUCTURES IN HISTORICAL BUILDINGS

Proc. 9th Int. Conf. on 'Ground Penetrating Radar' (GPR2002), April 29-May 2, 2002, Santa Barbara, CA (USA), pp. 63-67.

GPR applications to historical buildings have been cautiously increasing in recent years. The investigation of the wooden structural elements in historical buildings is essential to plan the restoration works. We discuss three case histories where 2D and 3D GPR surveys were executed to solve problems posed by restorers. The first survey was carried out to locate the beams of a wooden floor in a two hundred years old house in Pescate (Italy). The second survey was carried out in a stone masonry house of the 19th century in Lecco (Italy) to investigate the beam-wall connection. The third survey was carried out in a five hundred years old church in Busto Arsizio (Italy) to detect all the wooden elements. In this case some beams were totally hidden inside the brick and stone walls.

KEY WORDS: historical buildings; wooden structures; beams; NDT; GPR.

Lubelli B., Garavaglia E., Binda L., Baronio G.

DAMAGE EXTENT AND DISTRIBUTION IN MASONRY SURFACES SUBJECTED TO SALT CRYSTALLIZATION DUE TO MOISTURE MOVEMENTS

Proc. 5th Int. Symp. on the Conservation of Monuments in the Mediterranean Basin, April 5-8, 2000, Seville (E), pp. 191-201.

In 1990, some full-scale models were built and subjected to salt crystallisation by causing rising damp from the soil in order to study on site the decay of the masonry surface. Some of the models were treated with consolidants and/or water repellents. On site investigation techniques were applied to study the behaviour of the treated masonry: visual and photographic inspection, core and powder drilling, thermography, laser profilographer. The laser profilographer is a device to evaluate the masonry decay by measuring the surface loss of material; this loss starts from the external surface and proceeds forward the interior along the time. A stochastic mathematical approach is proposed by the authors to interpret the profilographer data recorded on treated and untreated surface. The aim of this approach is to obtain information on the durability of masonry material over time and/or on the prediction of a given damage level. This analysis is useful in the planning of maintenance and repair strategies.

KEY WORDS: environmental attack; masonry; stochastic mode; surface treatments.

Maier G., Carvelli V.

A KINEMATIC METHOD FOR SHAKEDOWN AND LIMIT ANALYSIS OF PERIODIC HETEROGENEOUS MEDIA

in 'Inelastic Behaviour of Structures under Variable Repeated Loads: Direct Analysis Methods', D. Weichert and G. Maier (Eds.), Springer Verlag, Wien, 2002, pp. 115-132.

In this Chapter the kinematic (second, Koiter's) shakedown theorem is applied to the representative volume of periodic heterogeneous media with Huber-Mises local plastic behavior. The adopted formulation of shakedown analysis is based on periodicity boundary conditions, conventional finite element modeling and penalization enforcement of plastic incompressibility. A cost-effective iterative solution procedure is discussed and computationally tested. Numerical tests and engineering applications are presented with reference to perforated plates and metal-matrix unidirectional fiber-reinforced composites.

KEY WORDS: composite; shakedown; limit analysis.

Maier G., Cocchetti G.

FUNDAMENTALS OF DIRECT METHODS IN POROPLASTICITY

in 'Inelastic Behaviour of Structures under Variable Repeated Loads', D. Weichert and G. Maier (Eds.), Springer Verlag, Wien, 2002, pp. 91-113.

A nonlinear initial-boundary-value coupled problem, central to poroplasticity, is formulated under the hypotheses of small deformations, quasi-static regime, full saturation, linear Darcy diffusion law and piecewise-linearized stable and hardening poroplastic material model. After a preliminary nonconventional multifield (mixed) finite element modelling, shakedown and upper bound theorems are presented and discussed, numerically tested and applied to dam engineering situations using commercial linear and quadratic programming solvers. Limitations of the presented methodology and future prospects are discussed in the conclusions.

KEY WORDS: poroplasticity; shakedown; bounds.

Malerba P.G.

TOOLS FOR CONCEPTUAL DESIGN OF STRUCTURES

Proc. 2nd Int. Conf. on 'Advances in Structural Engineering and Mechanics' (ASEM'02), Busan (South Korea), August 21-23, 2002 (CD ROM).

A relevant part of Mechanics of the last century had been focussed on solving, both from theoretical and methodological point of view, problems of structural analysis. These efforts contributed in supporting the design of important and critical structural realisations in many engineering fields and induced the technicians to new and challenging projects. However, the design activity, in its development, uses the analysis only as a tool. When the design starts, there isn't anything to analyse, because the structure has still to be defined. What the conception of a structure requires, is something completely different and involves few and clear criteria in order to choose the shape of the structure, how to distribute the restraints, the stiffness, the prestressing and how to collect into a unitary proposal different and frequently conflicting aspects. Thus, instead of to the analysis, the first phase of a design process is clearly oriented to a structural synthesis. Useful tools for this synthesis may be the structural optimisation and some of the skills offered by the artificial intelligence methods.

KEY WORDS: conceptual design; optimization techniques, evolutionary structural optimization; biological growth; bridge design.

Martinelli L.

NUMERICAL SIMULATION OF CYCLIC TESTS OF R/C SHEAR WALLS

Proc. 12th European Conference on Earthquake Engineering (12th ECEE), London (UK), September 9-13, 2002, Paper Ref. 600 (CD ROM).

This paper aims to better define the protection level offered by the Eurocode 8 provisions with respect to the cyclic behaviour of R/C shear walls. Within this framework accurate, and at the same time as simple as possible, numerical models of the non linear behaviour of shear walls are necessary to carry out a sufficient amount of parametric analyses. To assess the performance of a recent column fibre finite element well documented experimental cyclic tests, performed on simple shear walls designed to comply with different ductility requirements, were numerically simulated. The element is based on Timoshenko's beam theory and accounts for shear-flexure interaction, a feature which might be of some relevance for the problem at hand. Shear resistance is obtained by modelling the principal resisting mechanisms. Shear and flexural behaviour are related to each other by means of suitable kinematics assumptions. This element differs from standard fibre beam elements since the principal direction of the compressive

stress (direction of the fibres) is rotated to account for the contribution to shear due to arch action. Results of the experimental-numerical comparison are given in terms of the hysteretic behaviour of the structure. The good agreement with the experimental results suggests that the element is suitable for future modelling of complete structural systems.

KEY WORDS: shear wall; numerical simulation; cyclic shear; fibre beam; non-linear behavior.

Paper No. 2714

CV1

Martinelli L., Gattulli V., Vestroni F.

NONLINEAR BEHAVIOUR OF A SUSPENDED CABLE UNDER STATIONARY AND NON-STATIONARY LOADING

in 'Structural Dynamics – EUROLYN 2002', H. Grundmann and G.I. Schuëller (Eds.), A.A. Balkema (Lisse), 2002, Vol. 2, pp. 893-898.

In cables, time-varying forces cause large amplitude oscillations involving mainly the low modes. The contribution of higher modes may arise due to either internal coupling phenomena or peculiar spatial distribution of the loading. Using analytical reduced models and finite element models, the paper explores the relevance of the modal interactions in both planar and spatial response to harmonical inplane excitation and to out-of-plane wind turbulence with its spatial distribution.

KEY WORDS: cables; non-linear dynamics; modal coupling; wind excitation.

Paper No. 2715

RV1

Meda A., Gambarova P.G., Bonomi M.

HIGH-PERFORMANCE CONCRETE IN FIRE-EXPOSED R/C SECTIONS

ACI Structural Journal, Vol. 99, No. 3, pp. 277-287, 2002.

The ultimate behavior of reinforced HPC structures at high temperatures is still not fully understood, but the increasing number of important HPC structures at a risk of fire requires further studies, either at high temperatures or after cooling. Here, the ultimate behavior of 3 different R/C square sections subjected to an eccentric axial force is investigated with reference to a typical high-performance concrete and to several fire durations. In addition to the M-N envelopes of the undamaged sections, those at high temperatures (i.e during a fire) and after cooling are worked out. Comparisons are made with NSC sections having the same size or the same ultimate capacity, as well as with HPC sections characterized by different bar arrangements or protected by a cementitious lining, and a few "performance indicators" are introduced to describe the marked reduction of

the failure envelopes. The main findings are: the sections can still be analysed by limiting their effective area to a critical isothermal line (lower than in NSC); thin insulating layers are sufficient to minimize the greater HPC sensitivity to high temperatures; and different bar arrangements have marginal effects on section performance, except in the case of pure bending. Summing up, HPC sections are more temperature-sensitive than NSC sections, but not as much as one might expect.

KEY WORDS: fire protection; fire resistance; fire tests; high-performance; high temperatures; R/C columns; R/C section design.

Paper No. 2716

RV1

Miquel A., Bromblet P., Vergès-Belmin V., Binda L., Baronio G., De Witte E., De Clercq H., Van Hees R., Brocken H.

EXPERIMENTS ON THE COMPATIBILITY OF A POLYSILOXANE TREATMENT WITH SUBSTRATES LOADED WITH SODIUM SULPHATE: INFLUENCE OF THE PHYSICAL PROPERTIES OF SUBSTRATES ON THE SALT CONTENT LIMIT

Int. Journal for Restoration of Buildings and Monuments, Vol. 8, No. 2/3, pp. 271-292, 2002.

Within the framework of an EC program on the compatibility of salt with surface treatments (COST), crystallization tests were carried out on 20 different substrates (limestone, sandstone, brick, tuffeau, tuff and plaster) treated with a polysiloxane (Rhodia H224) or untreated. First, the samples were treated with the hydrophobic agent and the impregnation depth and product consumption were measured. Crystallization tests were carried out for each material using various initial salt contents. Both visual examination of the damage and weighing of loose materials (stone and salt) collected after the test (mass loss) were undertaken to provide qualitative and quantitative test evaluations. The influence of the protective treatment on the observed deterioration depends on the type of substrate. In general, treated samples result in worse spalling or flaking than that observed for untreated specimens. The treatment modifies the way the substrate dries and prevents surface efflorescence formation. But as salts crystallise deeper within the porous network, the treated material suffers other degradation phenomena and eventually, more damage. For each type of substrate, the tests enabled to determine a salt limit content, i.e., the highest sodium sulphate content for which no damage was observed during the crystallization test. No clear correlation could be established between any given parameter of the studied substrates, such as mechanical strength, porosity, capillarity, etc. and the salt limit content or the intensity of the observed deterioration. Finally, an attempt was made to analyse the results by means of a statistical approach. Parameters used were the physical properties of substrates, their nature (limestone, sandstone, brick...), the impregnation depth and product consumption, damage intensity, the salt content limit and the time of damage appearance.

KEY WORDS: treatment compatibility; polysiloxane treatment; crystallization test; maintenance.

Paper No. 2717

RV1

Modena C., Valluzzi M.R., Tongini Foli R., Binda L.

DESIGN CHOICES AND INTERVENTION TECHNIQUES FOR REPAIRING AND STRENGTHENING OF THE MONZA CATHEDRAL BELL-TOWER

Construction Building Materials, Vol. 16, No. 7, pp. 385-395, 2002.

A presentation is given of the fundamental design choices and of the selection of the most appropriate materials and techniques which have been made for strengthening the Monza Cathedral bell-tower, based on investigation and structural assessment carried out prior to and during the design process. The results of the experimental and numerical investigation will first be given in order to explain the reasons for the design choice.

KEY WORDS: bell-tower; brick masonry; strengthening; creep; confinement repair.

Paper No. 2718

RV1

Modena C., Valluzzi M.R., Tongini Folli R., Binda L.

BUILDING CIVIL STRUCTURES AND MASONRY STRUCTURES

Construction Building Materials, Special Issue, Vol. 16, No. 7, pp. 377-378, 2002.

For a special issue on Day 3 of Construction and Building Materials Journal, the Editors made a selection of papers concerning the research on new and traditional repair techniques applied to masonry, timber and concrete structures. A short presentation of the proposed papers is given.

KEY WORDS: masonry structures; timber structures; concrete structures; NDT for investigation.

Mota A., Klug W.S., Ortiz M., Pandolfi A.

FINITE ELEMENT SIMULATION OF FIREARM INJURY TO THE HUMAN CRANEUM (in Spanish)

Proc. 2nd Int. Congress on 'Métodos Numéricos en Ingeniería y Ciencias Aplicadas', E. Oñate, F. Zárata, G. Ayala, S. Botello and M.A. Morales (Eds.), Guanajuato (Mexico), January 17-19, 2002.

We present a finite element simulation of human skull wounds due to a firearm projectile collision. The simulation reproduces the ballistic penetration of the skull through an entrance wound, since a complete model including the brain is still in development. The time integration is achieved by using the explicit version of the Newmark time stepping algorithm. The choice is related to the involved time scale and to the possibility to easily include the contact forces into the model. The contact between projectile and skull is accounted for by a non-smooth contact algorithm. This is able to simulate contact between surfaces containing corners and edges. Fracture and fragmentation are modeled with cohesive elements, introduced into the finite element model only when the cracks start to propagate. The numerical results are compared with forensic data on firearm wounds of human skulls.

KEY WORDS: contact; fracture; fragmentation.

Mota A., Klug W., Ortiz M., Pandolfi A.

SIMULATION OF FIREARM INJURY TO THE HUMAN CRANIUM

Proc. of the EnginSoft Conference and User's Meeting, Stezzano (I), WEB, October 3-4, 2002 (CD ROM).

A computational model of a projectile hitting a human parietal bone is used for an advanced and realistic physics-based simulation of firearm injuries to the cranium. We account for the true physics of the collision and explicitly reproduce the propagation of fracture, the formation and the spreading of bone fragments. We compare the images of the numerical results with statistic data available from forensic science.

KEY WORDS: contact; fragmentation; high speed impact; bone damage.

Mourad S.A., Casolo S.

SEISMIC DAMAGE SCENARIO FOR THE MEDIEVAL TOWER OF SAFITA, SYRIA AND PROPOSED URGENT INTERVENTION

Proc. 7th U.S. National Conference on Earthquake Engineering (7NCEE), Boston, Mass. (USA), July 21-25, 2002 (CD ROM).

Constructed in the eleventh century, the Safita Tower represents an important monument that has witnessed a significant part of the history of the area. Following its construction, the building was subjected to several damaging events, including strong earthquakes and battles. The current status of the structure is extremely deteriorated, with several major cracks, nonuniform repairs, and deteriorated materials. In the absence of detailed documentation of the damages and repair records, the task of assessment of the structural condition of the building becomes more challenging. A preliminary assessment of the building was performed by data collection, historical study, field observations and damage survey. Based on the study, an urgent intervention plan is proposed for the Tower. A system of steel ties at three levels is recommended to confine the building and restrain the Tower walls from out-of-plane deformations. The emergency intervention is believed necessary to ensure the structural stability and integrity of the monument and should be given priority before any detailed analyses and/or investigations.

KEY WORDS: masonry power; structural intervention; seismic loading.

Mulas M.G., Gentile C.

THE ANALYSIS OF NON-LINEAR DYNAMIC RESPONSE FOR SEISMIC DAMAGE ASSESSMENT

in 'Structural Dynamics – EURO DYN 2002', H. Grundmann and G.I. Schuëller (Eds.), A.A. Balkema (Lisse), 2002, Vol. 2, pp. 847-852.

Under a strong earthquake, structures are prone to suffer a major damage. Objective of this paper, concerning RC plane frames, is to determine a numerical procedure to summarise structural damage in a concise way, based on the evaluation of structural stiffness/flexibility through modal properties. In fact, these can take into account both the extension of damage throughout the structure and the intensity of damage itself in different locations. Modal properties are determined in two ways: a) from a standard modal analysis, based on the results of a linearisation procedure, here proposed, of the non-linear behaviour of a prototype frame, as determined in non-linear dynamic analyses; b) from an identification procedure applied on the numerical output of the non-linear analyses. The results of the two procedures are qualitatively in good agreement, match

well the physical response of the frame, and allow for the determination of flexibility - based damage indicators.

KEY WORDS: seismic damage assessment; non linear seismic analysis; identification procedure; modal properties; flexibility-based damage indicators.

Paper No. 2723

CV1

Mulas M.G., Martinez-Rueda J.E.

NON-INVASIVE PASSIVE CONTROL OF STEEL MRFS WITH ROTATIONAL FRICTION DEVICES

Proc. ATC-17-2 Seminar on 'Response Modification Technologies for Performance-Based Seismic Design', Los Angeles, May 30-31, 2002, pp. 201-212.

The efficiency of a passive control technique is analyzed in the case of the seismic retrofitting of a steel moment-resisting frame (MRF). A significant part of the energy input by the earthquake is dissipated through rotational friction devices, located around beam-column joint zones where inelastic behavior is expected. An experimental cyclic test has validated the hysteretic restoring force model of the device, which has been adopted to numerically model the device in a computer code for the nonlinear analysis of steel MRFS. As an example of application, a frame designed by Tsai and Popov in 1988 is analyzed; the positive effect of retrofitting, for both the serviceability and the ultimate limit state (SLS and ULS), is measured by the reduction in local and global ductility requirements.

KEY WORDS: non-invasive passive control; moment resisting steel frames; hysteretic friction devices; seismic retrofitting; non linear seismic analysis.

Paper No. 2724

CV1

Nova R.

MODELLING OF SOIL BEHAVIOUR: FROM MICRO-MECHANICAL ANALYSIS TO MACROSCOPIC DESCRIPTION

in 'Modeling and mechanics of granular and porous materials', G. Capriz, V.N. Ghionna and P. Giovine (Eds.), Birkhauser, pp. 85-127, 2002.

A qualitative micro-mechanical analysis is used for highlighting the important phenomena occurring within a soil specimen and as a guideline for the formulation of a macroscopic model of soil behaviour. Elementary considerations on friction and grain interlocking will lead first to the formulation of an elastic plastic model with isotropic hardening or softening. A key role will be played in this respect by the experimental relationship between stress obliquity and dilatancy and by the hardening rule relating the variation of the size of the elastic domain

with plastic strains. The micro-mechanical analysis suggests further that the dilation angle is less than the friction angle. The macroscopic counterpart of this phenomenon is the non-associativeness of the plastic flow rule. The experimental data illustrating this feature will be presented and discussed. Non associativeness of the flow rule has far reaching consequences. It will be shown in fact that unstable specimen responses are possible, even in the hardening regime. Special cases of such instabilities are the so-called static liquefaction phenomenon in undrained tests on sands and the occurrence of shear banding in plane strain tests. An extended model which takes induced anisotropy into account will be presented next. The introduction of a time and length scales in the macroscopic constitutive model helps in regularising the numerical response in initial boundary value problems. Finally the problems related to the description of soil behaviour at small strains and in unloading-reloading will be briefly discussed.

KEY WORDS: elastoplasticity; hardening and softening; instability.

Paper No. 2725

SA2

Nova R.

TREATMENT OF GEOTECHNICAL ULTIMATE LIMIT STATES BY THE THEORY OF PLASTICITY

in: 'Geotechnical Engineering Handbook – Vol. 1: Fundamentals', U. Smolczyk (Ed.), Ernst & Sohn, pp. 313-352, 2002.

The fundamental theorems of limit analysis for standard and non-standard materials are proven. The combined use of the static and kinematic theorems is shown for the case of the bearing capacity of a strip foundation on a purely cohesive soil. The use of a Tresca failure condition for determining the limit height of an excavation is criticised. An elastoplastic method, based on the concept of generalised stress and strain variables, for determining the settlement and rotation of a foundation under an eccentric and inclined load is eventually presented.

KEY WORDS: elastoplasticity; excavations and slopes; foundations; limit analysis; standard and non-standard materials.

Novati G., Frangi A.

SYMMETRIC GALERKIN BEM IN 3D ELASTICITY: COMPUTATIONAL ASPECTS AND APPLICATIONS TO FRACTURE MECHANICS

in: *'Selected Topics in Boundary Integral formulations for Solids and Fluids' (CISM Courses and Lectures No. 433)*, V. Kompis (Ed.), Springer-Verlag, Wien, pp. 181-207, 2002.

The formulation of the symmetric Galerkin BEM for 3D elastic fracture mechanics problems and some relevant computational aspects are presented in this paper; the method is employed for the evaluation of stress intensity factors and for the modeling of fatigue crack growth. In the latter context a propagation algorithm has been developed and implemented into a fully automated numerical code which is used to analyze two example problems concerning the fatigue growth of surface breaking cracks.

KEY WORDS: variational BEM; linear elastic fracture mechanics; fracture propagation.

Pandolfi A., Kane C., Marsden J.E., Ortiz M.

TIME-DISCRETIZED VARIATIONAL FORMULATION OF NONSMOOTH FRICTIONAL CONTACT

International Journal for Numerical Methods in Engineering, Vol. 53, No. 4, pp. 1801-1829, 2002.

The present work extends the nonsmooth contact class of algorithms introduced by Kane et al. (1999) to the case of friction. The formulation specifically addresses contact geometries, e.g., involving multiple collisions between tightly packed nonsmooth bodies, for which neither normals nor gap functions can be properly defined. A key aspect of the approach is that the incremental displacements follow from a *minimum* principle. The objective function comprises terms which account for inertia, strain energy, contact, friction and external forcing. The Euler-Lagrange equations corresponding to this extended variational principle are shown to be consistent with the equations of motion of solids in frictional contact. In addition to its value as a basis for formulating numerical algorithms, the variational framework offers theoretical advantages as regards the selection of trajectories in cases of non-uniqueness. We present numerical and analytical examples which demonstrate the good momentum and energy conservation characteristics of the numerical algorithms, as well as the ability of the approach to account for stick and slip conditions.

KEY WORDS: nonsmooth frictional ; incremental variational formulation; time stepping algorithms; closest point projection; nonsmooth analysis.

Paper No. 2728

RV1

Pandolfi A., Ortiz M.

AN EFFICIENT ADAPTIVE PROCEDURE FOR THREE-DIMENSIONAL FRAGMENTATION SIMULATIONS

Engineering with Computers, Vol. 18, No. 2, pp. 148-159, 2002.

We present a simple set of data structures, and a collection of methods for constructing and updating the structures, designed to support the use of cohesive elements in simulations of fracture and fragmentation. Initially all interior faces in the triangulation are perfectly coherent, i.e., conforming in the usual finite element sense. Cohesive elements are inserted adaptively at interior faces, when the effective traction acting on those faces reaches the cohesive strength of the material. The insertion of cohesive elements changes the geometry of the boundary and, frequently, the topology of the model as well. The data structures and methods presented here are straightforward to implement and enable the efficient tracking of complex fracture and fragmentation processes. The efficiency and versatility of the approach is demonstrated with the aid of two examples of application to dynamic fracture.

KEY WORDS: fragmentation; fracture; topological changes adaptive remeshing; cohesive elements; 3D finite elements.

Paper No. 2729

RV2

Panzeri N, Poggi C.

NUMERICAL AND EXPERIMENTAL ANALYSES FOR THE DETERMINATION OF THE LOAD-BEARING CAPACITY OF METAL STRUTS IN ACCORDANCE WITH THE UNI-EN 1065 STANDARD (in Italian)

Costruzioni Metalliche, No. 5, 2002.

The European EN 1065 standard, recently incorporated and published by UNI in its Italian version, requires only notification of its adoption before being given the status of a national standard. It supplies the guidelines for the design and construction of telescopic steel struts and lays down the requirements for the classification of the struts on the basis of their geometric characteristics and load-bearing capacity. This paper presents and comments on the principles of the UNI-EN 1065 standard, with particular reference to the techniques used to carry out the experimental tests and numerical analyses recommended for the determination of the characteristic resistance of the strut. As an example of the application of the standard, the paper also presents and discusses the results obtained

from a series of struts analysed and experimented on by the authors in the Material Test Laboratory of the Polytechnic of Milan.

KEY WORDS: EN 1065; props; safety; experimental tests; numerical analyses.

Paper No. 2730

RV1

Paolucci R.

AMPLIFICATION OF EARTHQUAKE GROUND MOTION BY STEEP TOPOGRAPHIC IRREGULARITIES

Earthquake Engineering & Structural Dynamics, Vol. 31, pp. 1831-1853, 2002.

The problem of amplification of seismic waves by surface topographic irregularities is addressed through analytical and numerical investigations. First, a closed-form expression for estimating the fundamental vibration frequency of homogeneous triangular mountains is obtained, using Rayleigh's method. Subsequently, numerical modelling based on the spectral element approximation is used to study the 3D seismic response of several real steep topographic irregularities excited by vertically propagating plane S-waves. A topographic amplification factor is obtained for each case, by a suitable average of the ratio of acceleration response spectra of output vs. input motion. The 3D amplification factors are then compared with those derived by 2D analyses as well as with the topographic factors recommended in Eurocode 8 for seismic design.

KEY WORDS: topographic site effects; seismic wave propagation; Rayleigh's method; spectral method; 3D numerical simulations.

Paper No. 2731

CV1

Paolucci R., Rimoldi A.

SEISMIC AMPLIFICATION FOR 3D STEEP TOPOGRAPHIC IRREGULARITIES

Proc. 12th European Conference on Earthquake Engineering (12th ECEE), London (UK), September 9-13, 2002, paper No. 87 (CD ROM).

In this paper the results of several 3D numerical analyses of seismic wave propagation in steep topographic irregularities are presented. Namely, 4 real configurations have been selected from the Italian geological context, where the steepness of site topography make significant site amplification effects during earthquakes highly probable. After evaluation of numerical transfer functions and convolution with a significant number of real accelerograms, the response spectrum of each synthetic accelerogram at the mountain surface was calculated, together with the ratio $r(T)$ with respect to the response spectrum of the input motion. The variation with period T of such ratio is small, so that a single, period-independent, topographic amplification factor F was calculated as the average

value of $r(T)$. The value of F was found to be in reasonable agreement with that recommended by Eurocode8, for topographic profiles elongated in one direction ("2D configurations"), while in the case of steep isolated hills the F factor is significantly higher.

KEY WORDS: 3D topographic site effects; amplification of seismic waves; spectral method; Eurocode8.

Paper No. 2732

CV1

Parisi M.A.

CONSERVATION OF TIMBER STRUCTURES IN SEISMIC AREAS: STRENGTHENING ACCORDING TO EUROCODE 8 (in Italian, with summary in German)

Atti del Convegno Italo-Germanico X Bauschau-Lignomec 'Progettare la durabilità – Dauerhaftigkeit als Planungskriterium', Bolzano/Bozen (I), February 17, 2001, pp. 109-126.

In seismic areas, the problem of extending the life of traditional timber structures concerns primarily their conservation. Indeed, the tendency is to substitute old timber roof structures with new materials and renovated structural layouts. In order to preserve traditional structures, it is necessary to identify their deficiencies and point out suitable criteria for their strengthening. International seismic codes, that summarize critically knowledge and experience in design and building behavior, are an authoritative reference. In this work, the fundamental principles and rules concerning design and upgrading of timber structures in the Eurocode 8 are described and discussed, with special reference to traditional structures.

KEY WORDS: seismic behavior; design codes; Eurocodes; timber structures; strengthening.

Paper No. 2733

RV1

Parisi M.A., Piazza M.

SEISMIC BEHAVIOR AND RETROFITTING OF JOINTS IN TRADITIONAL TIMBER ROOF STRUCTURES

Soil Dynamics and Earthquake Engineering, Vol. 22, pp. 1183-1191, 2002.

The seismic quality of traditional timber structures, as those supporting roofs in old buildings, mostly depends on the condition of their connections. A research program has investigated the behavior of old timber joints and examined retrofitting criteria. The main parameters affecting the mechanical behavior of the connection have been singled out and their effects quantified by means of experimentation and numerical analysis. A synthetic model of the cyclic behavior

has been formulated, implemented in a finite element format, and used in the analysis of timber structures in seismic conditions. The model has been verified with full-scale experimentation on a roof truss. Different reinforcing methods have been compared on the basis of experimental observation and calculated structural response. The study has shown that a satisfactory post-elastic response, comparable to that of new structures, may be reached for suitably retrofitted structures.

KEY WORDS: seismic behavior; timber structures; retrofitting; experimental testing.

Paper No. 2734

RV1

Parisi M.A., Piazza M.

TRADITIONAL TIMBER JOINTS IN SEISMIC AREAS: CYCLIC BEHAVIOUR, NUMERICAL MODELLING, NORMATIVE REQUIREMENTS

European Earthquake Engineering, No. 1, pp. 40-49, 2002.

Traditional connections of timber structures are generally friction-based carpenter joints transmitting forces directly through pressure areas and offering a rotational semi-rigid behaviour. Timber structures with these connections are commonly used to support roofs of existing buildings. Seismic normative requirements for repair and strengthening prescribe that structural analyses to be performed for verifying the effect of proposed retrofitting designs be carried out with accurate modelling of the connections, possibly with experimental support. This paper proposes a model describing the cyclic semi-rigid behaviour of traditional joints in timber structures. The model, formulated and implemented in a finite element format, is based on the results of experimental and numerical studies on basic and retrofitted connections. The seismic analysis of a timber truss modelled with these joints indicates that traditional timber structures with suitably retrofitted connections may sustain appreciable post-elastic excursions, comparing positively, in terms of behaviour factors, with newly designed structural types.

KEY WORDS: cyclic behaviour; timber structures; seismic retrofitting; experimental testing.

Petrini V., Casolo S.

VULNERABILITY OF HISTORICAL AND MONUMENTAL BUILDINGS: SIGNIFICANT GROUND MOTION PARAMETERS AND EVALUATION OF THE SEISMIC PERFORMANCE

in: *'Innovative Approaches to Earthquake Engineering'*, G. Oliveto (Ed.), WIT Press, Chap. IV, pp. 203-228.

The evaluation of seismic risk of masonry monuments requires to study the combination of vulnerability and hazard. In fact, architecturally and historically important buildings need specific procedures for vulnerability assessment, since their responses to earthquakes often differ substantially from those of ordinary buildings. In addition, the hazard should also be described by specific measures of intensity of the seismic action, accounting for the particular seismic behaviour of such structures. In the present work, two structural typologies are considered, adopting ad hoc numerical models to perform non linear dynamic analyses. The out-of-plane behaviour of large masonry facades is studied adopting a rigid element model, while the slender masonry tower is modelled with a 3-D fibre model. A variety of different factors relating with the accelerogram records have been investigated for what regards their correlation with the damage indicators of the non linear models. In order to maximise the correlation, a specific combination of these factors should be defined for each structural typology. In the case of masonry facades, the root mean square of the acceleration multiplied by the significant duration proves to be a good measure of the destructiveness potential, while in the case of slender masonry towers, an effective intensity measure should combine both the characteristics of the horizontal and of the vertical components.

KEY WORDS: masonry; destructiveness potential; ground motion; rigid elements; fibre model.

Ronca P.

MODELS FOR STRUCTURAL ANCIENT VAULTS (in Italian)

in *'Il Progetto di Conservazione: linee metodologiche per le analisi preliminari, l'intervento, il controllo di efficacia'*, S. Pesenti (Ed.), Alinea, par. 2.4, pp. 140-150, 2001.

Consistent computational models for the analysis of the ancient masonry vaults have to face mostly two basic aspects: i) the uncertainties of the complex layout of the structural elements, ii) the uncertainties of the mechanical material behaviour. Vaulted roofs with several limitations in the height had to achieve their static requirements by means of different structural improvements, mostly de-

signed in the extrados part of the section of the vault. The so called “filling material” can no longer be considered to have minor roles. The paper underlines that analyses of the entire ancient vaults have to model accurately both the structural geometry of the “flanged” introdossal parts and the mechanical characteristic and non-linear behaviour of their material.

KEY WORDS: masonry vault; introdossal details; non-linear models.

Paper No. 2737

CV1

Song Y., Biondini, F., Bergman L.A.

EFFECT OF SURFACE IRREGULARITIES ON THE DYNAMIC RESPONSE OF BRIDGE-VEHICLE SYSTEMS

Proc. 15th Engineering Mechanics Division Conference of the American Society of Civil Engineers, New York (USA), June 2-5, 2002 (CD ROM).

In a careful investigation of the effects of bridge surface roughness on the dynamical response of bridge-vehicle systems, three important aspects should be addressed. First, the interactions between bridge and vehicles resulting from coupling and irregularities on the bridge surface should be accounted for; second, a good representation of bridge surface roughness is necessary; and, finally, the model of the bridge should be as realistic as possible. However, in most of the available literature on the subject, one or more of these elements is downplayed. In this paper, a Monte Carlo simulation technique is employed to study the related random vibration problem. The irregularities in the bridge surface are modeled as a stationary, zero mean Gaussian process with a specified power spectral density (PSD), from which sample functions are generated by Shinozuka's method. To model a slab-girder bridge, a finite element formulation is used, in which the interaction dynamics between bridge and vehicles can be considered accurately. “Moving mass” and “moving oscillator” solutions are obtained. It is found that the “moving mass” simulation does not give reasonable results and that the distribution of Dynamic Amplification Factors (DAF) from the moving oscillator solution can be described well by a double log-normal probability distribution.

KEY WORDS: bridge-vehicle interaction; surface roughness; dynamical response analysis; Monte Carlo simulation.

Sterpi D.

INFLUENCE OF THE KINEMATIC TESTING CONDITIONS ON THE MECHANICAL RESPONSE OF A SAND

in: 'Geotechnology Compendium I', Elsevier Science, 2002, pp. 45-64.

The influence of the laboratory testing conditions on the mechanical characterization of a compacted sand is investigated on the basis of standard triaxial and of plane strain compression tests. The two sets of experimental results lead to the independent calibration of two constitutive models. In fact, while the triaxial tests suggest a perfectly plastic behaviour for the sand, the plane strain results show marked strain softening effects, in particular for the denser samples or for high values of the confining pressure. The perfectly plastic and the strain softening models are then applied to the stability analysis of a cantilever sheet pile. The numerical results permit to draw some conclusions on the effect that the material model, chosen and calibrated on the basis of a particular laboratory test, could have on the predicted performance of geotechnical structures.

KEY WORDS: plane strain tests; strain softening; retaining structure; finite element analysis; compacted sand.

Paper No. 2739

Sterpi D.

ON THE STABILITY OF THE EXCAVATION FACE IN STRAIN SOFTENING SOILS (in Italian)

Atti dell'Incontro Annuale dei Ricercatori di Geotecnica (IARG 2002), Napoli, June 19-21, 2002 (CD ROM).

For underground shallow openings, in dense cohesionless soils, a gradual loss of confining pressure at the excavation face is simulated by a series of three-dimensional Finite Element analyses. The soil behaviour is elastic plastic with loss of shear strength consequent to the localization of shear plastic deformations. The results show the influence of both the softening behaviour and the excavation cross section shape on the collapse mechanism and on the value of the confining pressure corresponding to the onset of the failure.

KEY WORDS: finite element analysis; strain softening; tunnels; excavation face.

Stucchi E., Mirabella F., Barchi M., Merlini S., Zanzi L., Mazzotti A.

CHARACTERISATION OF SEISMOGENIC FAULTS BY MEANS OF REFLECTION SEISMIC SURVEYS. A CASE STUDY IN THE COLFIORITO AREA: 1997 UMBRIA-MARCHE EARTHQUAKES

Proc. 64th Meeting of European Association of Geoscientists and Engineers, May 27-30, Florence, E-48, 4 pp. (CD ROM).

Earthquake seismology and reflection seismology, although sharing the same fundamental principles on wave propagation and common physical bases, have been rarely used jointly to study the seismogenic structures of the upper crust. To this end, a research project has been recently launched in which several disciplines, reflection seismic, seismology, magnetotelluric, structural geology and geochemistry, are integrated. The Colfiorito area, location of the 1997-1998 earthquakes, has been selected as the test site as it is particularly appropriate both for its historical relevance, for the abundance of recorded data and for the availability of information of different nature. In this paper we mainly illustrate the reflection seismic perspective, its potential in the reconstruction of the geometrical setting of the subsurface, the encountered problems and the first correlations with geological models and earthquake locations. Finally we point out the work ahead and we discuss the further possible methodological interactions between reflection seismology and earthquake seismology.

KEY WORDS: exploration seismics; seismogenic faults; earthquake seismology.

Tamagnini C., Castellanza R., Nova R.

A GENERALIZED BACKWARD EULER ALGORITHM FOR THE NUMERICAL INTEGRATION OF AN ISOTROPIC HARDENING ELASTOPLASTIC MODEL FOR MECHANICAL AND CHEMICAL DEGRADATION OF BONDED GEOMATERIALS

Int. J. Numer. Anal. Meth. Geomech., Vol. 26, No. 10, pp. 963-1004, 2002.

The mechanical behaviour of bonded geomaterials is described by means of an elastoplastic strainhardening model. The internal variables, taking into account the 'history' of the material, depend on the plastic strains experienced and on a conveniently defined scalar measure of damage induced by weathering and/or chemical degradation. For the sake of simplicity, it is assumed that only internal variables are affected by mechanical and chemical history of the material. Despite this simplifying assumption, it can be shown that many interesting phenomena exhibited by weathered bonded geomaterials can be successfully described. For instance, i) the transition from brittle to ductile behaviour with increasing pressure of a calcarenite with collapsing internal structure, ii) the com-

plex behaviour of chalk and other calcareous materials in oedometric tests, iii) the chemically induced variation of the stress and strain state of such kind of materials, are all phenomena that can be qualitatively reproduced. Several comparisons with experimental data show that the model can capture the observed behaviour also quantitatively.

KEY WORDS: bonded soils; elastoplasticity; numerical modelling; weathering.

Paper No. 2742

RV1

Tamagnini C., Castellanza R., Nova R.

IMPLICIT INTEGRATION OF CONSTITUTIVE EQUATIONS IN COMPUTATIONAL PLASTICITY

Rev. Fran. Génie Civil, Vol. 6, No. 6, pp. 1051-1067, 2002.

The paper discusses an extension of the now standard Generalized Backward Euler (GBE) algorithm to a general class of elastoplastic constitutive equations for geomaterials, characterized by mechanical and non-mechanical hardening mechanisms. The resulting integration scheme is well suited for the application to relatively complex, three-invariant yield surface and plastic potential functions. A closed form expression for the consistent tangent stiffness matrix is derived for the general case, extending the work of Tamagnini et al (2002a) for isotropic-hardening models. The application of the numerical procedure is discussed with reference to a constitutive model for chemical weathering of bonded geomaterials recently proposed by Tamagnini et al (2002b). Results from a series of numerical experiments are given to illustrate the accuracy and convergence properties of the algorithm.

KEY WORDS: bonded soils; elastoplasticity; numerical modelling; weathering.

Paper No. 2743

CV1

Tamagnini C., Castellanza R., Nova R.

NUMERICAL INTEGRATION OF ELASTOPLASTIC CONSTITUTIVE EQUATIONS FOR GEOMATERIALS WITH EXTENDED HARDENING RULES

Proc. 8th Int. Symp. on 'Numerical Models in Geomechanics' (NUMOG VIII), G.N. Pande and S. Pietruszczak (Eds.), Swets & Zeitlinger, Lisse, 2002, pp. 213-218.

The paper presents an extension of the classical Generalized Backward Euler (GBE) return mapping algorithm to a general class of elastoplastic constitutive equations for geomaterials characterized by both mechanical and non-mechanical hardening mechanisms. A key point of the proposed integration procedure is in the modification of the classical additive split of the evolution problem by extending the elastic predictor stage in order to account for non-

mechanical effects. Restriction to isotropic behavior allows to formulate the return mapping algorithm in the space of principal elastic strains. The resulting integration scheme is well suited for the application to relatively complex, three-invariant yield surface and plastic potential functions, and, remarkably, can be linearized in closed form. As an example, the application of the general procedure is discussed with reference to the constitutive model for chemical weathering of bonded geomaterials recently presented by Tamagnini et al 2002. A series of numerical experiments are given to illustrate the accuracy and convergence properties of the algorithm.

KEY WORDS: bonded soils; elastoplasticity; numerical modelling; weathering.

Paper No. 2744

CV1

Valente M., Chesi C.

ANALYTICAL STUDY OF THE CYCLIC BEHAVIOUR OF WELDED BEAM-TO-COLUMN JOINTS

Proc. 12th European Conference on Earthquake Engineering (12th ECEE), London (UK), September 9-13, 2002 (CD ROM).

Failures modes of steel welded moment connections which occurred during the Northridge and Kobe earthquake have been confirmed by numerous laboratory tests performed in the last years. Experimental evidence showed several types of cracks starting from the region between the beam flange and the column flange near the weld. Numerical analyses confirm that the beam flange region of the traditionally designed welded connections is overloaded and explain the recently observed connection failures. This analytical study developed with detailed finite element models indicate the presence of a triaxial state of stress near the weld at the center of the beam flange and a strain concentration near the root of the weld access hole as possible reasons of unexpected failures. Improved configurations of the access hole are studied with the intent to minimize the plastic strain demand and the potential for fracture. The role of the continuity plates in reducing the stress concentration and preventing premature fracture initiation is also highlighted.

KEY WORDS: welded connections; weld access hole; strain concentration; triaxial stress state; continuity plates.

Valluzzi M.R., Binda L., Modena C.

EXPERIMENTAL AND ANALYTICAL STUDIES FOR THE CHOICE OF REPAIR TECHNIQUES APPLIED TO HISTORIC BUILDINGS

Materials and Structures, Vol. 35, pp. 285-292, 2002.

A study concerning the application of different repair techniques on damaged historic masonry buildings is presented. In particular, three techniques are considered: injections, jacketing, and repointing of bed joints reinforced by stainless steel wires. The results of an experimental research carried out in the last years on some study cases are shown. Laboratory and in situ tests are included and the interpretation of the mechanisms of failure by mechanical and numerical models is also given.

KEY WORDS: repair techniques; masonry; mechanical and numerical models.

Yu C., Pandolfi A., Coker D., Ortiz M., Rosakis A.

THREE-DIMENSIONAL MODELING OF INTERSONIC CRACK-GROWTH IN ASYMMETRICALLY LOADED UNIDIRECTIONAL COMPOSITE PLATES

Int. J. Solids Struct., Vol. 39, No. 25, pp. 6135-6157, 2002.

An anisotropic cohesive model of fracture is applied to the numerical simulation of Coker and Rosakis experiments (2001). In these experiments, a unidirectional graphite-epoxy composite plate was impacted with a projectile, resulting in an intersonic shear-dominated crack growth. The simulations account for explicit crack nucleation—through a self-adaptive remeshing procedure—crack closure and frictional sliding. The parameters used in the cohesive model are obtained from quasi-static fracture experiments, and successfully predict the dynamic fracture behavior. In keeping with the experiments, the calculations indicate that there is a preferred intersonic speed for locally steady-state growth of dynamic shear cracks, provided that sufficient energy is supplied to the crack tip. The calculations also show that the crack tip can attain speeds in the vicinity of the longitudinal wave speed in the direction of the fibers, if impacted at higher speeds. In addition, a double-shock which emanates from a finite size contact region behind the crack tip is observed in the simulations. The predicted double-shock structure of the near-tip fields is in close agreement with the experimental observations. The calculations additionally predict the presence of a string of surface hot spots which arise following the passage of the crack tip. The observed and computed hot spot structures agree both in geometry as well as in the magnitude of the temperature elevation. The analysis thus suggests intermittent friction as the origin of the experimentally observed hot spots.

KEY WORDS: 3D finite elements; anisotropic cohesive element; frictional contact; intersonic shear crack growth; unidirectional composites; self-adaptive remeshing.

Paper No. 2747

CV1

Zanzi L., Lualdi M

ATTENUATION TOMOGRAPHY ON HISTORICAL BUILDINGS THROUGH SPECTRAL ANALYSIS OF SONIC AND RADAR DATA

Proc. SAGEEP 2002, Las Vegas (USA), February 10-14, 2002, 10 pp. (CD ROM).

Sonic and radar investigations are frequently used in conjunction with other NDT techniques to assess the safety conditions of historical buildings, to understand the construction techniques and to locate internal in-homogeneities or hidden wood or metal elements. Both sonic and radar equipment can be used to produce tomographic sections that show the velocity map within a construction element like a wall or a pier. Radar data can be also processed by back-projecting the received energy in order to produce attenuation maps that can be interpreted to understand the absorption and scattering properties of the construction materials. Unfortunately, this method is not applicable to sonic data because sonic amplitudes are influenced by too many factors besides absorption. A promising alternative method consists of back-projecting the frequency downshift effect produced by absorption. The reliability of this approach is discussed for the specific application to historical buildings by presenting real data examples. The discussion shows the additional information that can be extracted from these sonic attenuation maps. By extending the approach to radar data, new attenuation maps can be obtained and compared to those derived from amplitude back-projection. Since the two inversion methods are based on the analysis of different effects produced by attenuation, i.e., frequency downshift and amplitude decay respectively, the attenuation maps are not necessarily equivalent and the analysis of similarities and differences can be quite useful to constrain the final interpretation of all the tomographic images.

KEY WORDS: GPR; sonic; tomography; attenuation; NDT; historical buildings.

Paper No. 2748

CV1

Zanzi L., Lualdi M., Braun H.M., Borisch W., Triltzsch G.

AN ULTRA HIGH FREQUENCY RADAR SENSOR FOR HUMANITARIAN DEMINING TESTED ON DIFFERENT SCENARIOS IN 3D IMAGING MODE

Proc. 9th Int. Conf. on 'Ground Penetrating Radar' (GPR2002), April 29-May 2, 2002, Santa Barbara, CA (USA), pp. 240-245.

A prototype of an ultra-high frequency radar system (2-6GHz) has been developed at the RST laboratory within the framework of the HOPE project funded by

the European Community and aimed at integrating three sensors (metal-detector, GPR and microwave radiometer) into a unique portable system for humanitarian demining. An advanced prototype of the GPR sensor assembled with the dual metal coil MD sensor has been recently tested at the outdoor facilities of the Joint Research Center in Ispra (Italy). The test field specifically prepared by JRC consists of a unique target scenario that is recreated under different type of soils and surface conditions. The target scenario includes different type of mines and false alarm targets like stone, wood, metallic or plastic objects. The dataset collected during this test are quite interesting for planning the future improvements of both the hardware and the software solutions. The data has been processed with a 3D imaging software specifically developed by the authors for the HOPE project. The preliminary results are encouraging for some scenarios whereas some others seem to be really demanding for the GPR sensor.

KEY WORDS: humanitarian demining; high-frequency radar; 3D imaging.

BOOKS

Book No. 1/02

LE2

Faccioli E., Paolucci R. (Editors)

SEISMIC ACTIONS

ECOEST2-ICONS Report No. 1, EC Contract No. fmrx-ct96-0022, published by Lneec, Lisbon (P), ISBN 972-49-1887-4, 96 pages, 2001.

The research performed under ICONS Task 1, i. e. «Seismic Actions», covers topics ranging from engineering seismology to dynamic soil-foundation interaction. This reflects the circumstance that while its predecessor project PREC 8 [Pre-normative research in support of Eurocode 8 (Faccioli and Paolucci 1996)] had been, by its very definition, explicitly tailored to some of the needs of the seismic Eurocode, ICONS is focused more in general on problems of design as well as of structural assessment and risk evaluation and reduction. Especially in Task 1, as it will shortly be seen, the work performed has a notable interdisciplinary flavour, as a possible indication that formulation of risk-reduction policies in earthquake-prone regions requires the support of a broad, articulated technical know-how. The Task 1 research deals with the following main subjects, each illustrated in a separate chapter of this report: 1. displacement response spectra for design; 2. influence of «complex» amplification effects on ground motion; 3. analysis of the seismic response of three-dimensional (3D) topographic features and its influence on earthquake-triggered landslides; 4. the effect of dynamic soil non-linearity and foundation uplift on the reduction of response spectrum ordinates.

KEY WORDS: displacement response spectra for design; complex site amplification effects; topographic site effects; non-linear soil-structure interaction.

TECHNICAL REPORTS

Technical Report No. 1/02

Baronio G., Binda L., Penazzi D., Tedeschi C.

DEEP REPOINTING AS STRENGTHENING TECHNIQUE IN SEISMIC AREAS

Maintenance of Pointing in Historic Building: Decay and Replacement, Contract No. EV-CT98-0706, Final Report to EC, paper 5.12, pp. 181-186, 2001.

A technique which is still subject of an ongoing experimental research applied to irregular stone masonry walls is described. The paper describes in detail the investigation carried out in situ and in laboratory to study the masonry morphology and components, the choice of compatible materials for re-pointing and the technique applied on site to a damaged wall. Finally the results obtained by mechanical tests comparing the shear strength of the wall before and after repair.

KEY WORDS: damage process; seismic area; reinforce technique.

Technical Report No. 2/02

Binda L., Baronio G., Tedeschi C., Cardani G.

IN SITU RESEARCH ON FULL SCALE MODELS

Salt Compatibility of Surface Treatments, Contract No. EV-CT98-0710, Final Report to EC, pp. 243-265, 2001.

Within the frame of the EC Contract SCOST, ENV4-CT98-0710 brick and stone full scale models built in Milan and already used for other EC and National Contracts were used to detect the effectiveness of some on site tests applied to study the effectiveness of surface treatments. The tests carried out before and after the treatments in different times from 1996 to 2001 were the following: Karsten tube, artificial rain, powder drilling.

KEY WORDS: treatment; salt; water absorption.

Technical Report No. 3/02

Binda L., Cardani G., D. Penazzi, Tedeschi C.

MECHANICAL RECURRENT DAMAGES REQUIRING DEEP REPOINTING

Maintenance of Pointing in Historic Building: Decay and Replacement, Contract N. EV-CT98-0706, Final Report to EC, paper 2.4, pp. 37-45, 2001.

A description of two types of damage to brick and stone masonry are described:

- 1) Failure due to high compressive stresses: this is the case of masonry towers. The phenomenon was for the first time taken into account for historic buildings after the collapse of the Civic Tower annexed to the Cathedral of Pavia (Italy). The collapse was attributed after a deep experimental work to the long term behaviour (creep) of masonry structures subjected to heavy compressive loads. Other towers in Italy and abroad were found affected by the same type of damage. The investigation procedure to recognise the presence of creep damage is suggested. The repair technique suggested in the case of brick or regular stone walls is deep reinforced repointing with stainless steel or FRP.
- 2) Failure of multiple leaf stone walls due to out of plane seismic loads: Most of the partial and total collapses of irregular stone masonry walls made with double leaf showed the separation of the leaves and the lack of connection between the stones. The failure took place also after repair by injection techniques and jacketing were applied. The repair of the two damages can be carried out by reinforced deep repointing (1) and by deep repointing with structural mortars (2).

KEY WORDS: masonry; damage process; flat-jack test; repointing.

Technical Report No. 4/02

Binda L., Cardani G., Tedeschi C.

LABORATORY MECHANICAL TESTS FOR THE EVALUATION OF THE MORTARS FOR RE-POINTING

Maintenance of Pointing in Historic Building: Decay and Replacement, Contract No. EV-CT98-0706, Final Report to EC, paper 5.8, pp. 143-197, 2001.

Within the frame of a EC Contract POINTING ENV4-CT98-706 with the aim to study the problem of repair of mortar joints by re-pointing with different types of mortars, different mechanical tests were applied to study the bond between new and old mortar, new mortar and brick/stone. The aim was to find a mechanical test reliable to control the effectiveness of re-pointing materials which were defined within the Contract as sacrificial in case of salt and frost decay. The tests applied were the following: splitting test (between old and new mortar), shear box test (between re-pointing and bricks or old and new mortar), bond wrench and modified bond wrench test (between re-pointing and brick or stone). All the applications were rather successful even if only the bond wrench can be used on site.

KEY WORDS: masonry; mortar; laboratory test; splitting test; bond wrench.

Technical Report No. 5/02

Binda L., Valluzzi M., Modena C., Tedeschi C.

DEEP REINFORCED REPOINTING AS REPAIR OF MASONRIES DAMAGED BY HEAVY DEAD LOADS,

Maintenance of Pointing in Historic Building: Decay and Replacement, Contract No. EV-CT98-0706, Final Report to EC, paper 5.13, pp. 187-193, 2001.

When a masonry wall is damaged by high compression stresses, the phenomenon can be detected by studying the crack pattern caused by the compression stresses. At the moment only few remedies are known to avoid the collapse: (i) reduce the load by partial demolition, (ii) confine the dilation of the material by adding confinements to the damaged structure. In the case of high towers there must be confinements by rods at each floor and local confinements by deep reinforced re-pointing which has been suggested and carried out by the authors. The local and the global strengthening technique applied to a case history is described together with the results of laboratory tests carried out on the effectiveness of the technique.

KEY WORDS: masonry decay; reinforce technique; site and laboratory investigation.

Technical Report No. 6/02

Cardani G., Garavaglia E., Binda L.

PROBABILISTIC MODEL FOR THE PREDICTION OF THE DECAY DUE TO SALT CRYSTALLISATION OF MASONRY BUILDINGS MATERIALS

Salt Compatibility of Surface Treatments, Contract No. EV-CT98-0710, Final Report to EC, pp. 281-300, 2001.

Within the frame of the EC Contract SCOST, ENV4-CT98-0710 crystallisation tests were carried out on masonry materials untreated and treated with commercial surface waterproof or consolidants (4 types of stones and 1 type of clay units). The aim was to find the maximum salt content allowable to obtain effective treatments. Three types of salt solutions were used with four different low percentages of salt concentration were used for the tests. In addition also brick and stone masonry specimens were submitted to the crystallisation test with two types of salt concentration, untreated and treated with two surface products. The decay was measured assuming as a parameter the loss of surface material during the test; the measurement was carried out through a laser device along chosen profiles on the material surface. The deterioration process was assumed as a stochastic process of the random variable (the surface loss). Defining significant thresholds of the damage value fragility curves were drawn describing the prob-

ability of reaching or exceeding a given threshold. By using this approach the magnitude of the expected damage over time as well as the occurrence time could be predicted.

KEY WORDS: maintenance; probabilistic model; salt crystallization; masonry.

Technical Report No. 7/02

Cardani G., Tedeschi C., Binda L., Baronio G.

CRYSTALLIZATION TESTS WITH WBW AND CST

Salt Compatibility of Surface Treatments, Contract No. EV-CT98-0710, Final Report to EC, pp. 163-177, 2001.

Within the frame of the EC Contract SCOST, ENV4-CT98-0710, crystallisation tests based on RILEM Recommendation were carried out on wallettes made with one type of brick and three types of stones treated with a water based water repellent (WBW) and a consolidant (CST). The salts used were: sodium sulphate and magnesium sulphate at different concentrations. Also untreated specimens were tested as reference. Three types of mortars were used to build the wallettes; some wallettes were also re-pointed. The damage was measured at different times from 0 to 8 months by a laser profilometer and calculated separately for the mortar joints and the units. The results were elaborated and a high influence of the presence of mortar joints on the behaviour of units was found compared to the damage found for the same units tested alone. Therefore the conclusion is that in order to test the effectiveness of a treatment on a masonry surface the ageing tests should be carried out on masonry wallettes.

KEY WORDS: laser profile; laboratory test; water repellent treatments.

Technical Report No. 8/02

Cardani G., Tedeschi C., Binda L., Baronio G.

INTERACTION OF WATER BASED WATER REPELLENT (WBW) TREATMENT WITH Na_2SO_4 , MgSO_4 AND NaCl

Salt Compatibility of Surface Treatments, Contract No. EV-CT98-0710, Final Report to EC, pp. 120-141, 2001.

Within the frame of the EC Contract SCOST, ENV4-CT98-0710, crystallisation tests using the RILEM Recommendation for wallettes were carried out on three types of stones and one type of bricks treated with a WBW (Water Based Water-repellent) using three types of salt concentration (1, 2.5 and 5%) in order to define a threshold of salt content above which the treatment has to be discouraged. The same number of specimens was also tested untreated as reference. All the specimens were tested with sodium sulphate, some specimens were also tested

with magnesium sulphate and sodium chloride. Before the test and treatment the materials were characterised by chemical, physical and mechanical tests. The damage was followed by photographic and visual inspection and measured by the use of a laser profilometer. The results are described in detail and elaborated according to the procedure used by all the partners in the EC Contract.

KEY WORDS: salt crystallization test; masonry decay; maintenance; water repellent.

Technical Report No. 9/02

Cardani G., Tedeschi C., Binda L., Baronio G.

LABORATORY CRYSTALLISATION TESTS FOR DAMAGE EVALUATION
Maintenance of Pointing in Historic Building: Decay and Replacement, Contract No. EV-CT98-0706, Final Report to EC, paper 5.3, pp. 99-107, 2001.

Crystallisation test were carried out on wallettes on which re-pointing of the joints with three types of mortars was applied. The tests were performed within the frame of a EC Contract POINTING ENV4-CT98-706 in order to study the durability of re-pointing to salt decay. Also wallettes with simply tooled bedding joints were tested in order to study the performance of the two techniques. The tests were carried out following the RILEM Recommendations. The results were showing a better performance of the pointing over the tooling and a better performance of the hydrated lime pointing over the hydrated lime cement pointing.

KEY WORDS: salt crystallization; masonry decay; laser profiler.

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