

R. Bellotti, M. Jamiolkowski, D.C.F. Lo Presti and D.A. O'Neill

ANISOTROPY OF SMALL STRAIN STIFFNESS IN TICINO SAND

Geotechnique, 1996, Vol. 46, No. 1, pp. 115-131.

A series of comprehensive tests performed in a large calibration chamber and consisting of the propagation of seismic body waves in dry Ticino silica sand are presented. By virtue of the fact that both shear and constrained compression waves have been propagated in vertical, horizontal and oblique directions, five independent constants of the cross-anisotropic elasticity model of the test sand have been established. The tests have also made it possible to evaluate the influence of the structural (inherent) and stress induced anisotropy on the velocity of the propagated seismic body waves. Information concerning the influence of the principal effective stresses on the velocity of these waves is also given. The influence of the principal effective stresses on the velocity of these waves is also described.

D.C.F. Lo Presti

**VERIFICA DI STABILITA' DI UNA RAMPA IN TERRA
ARMATA: APPLICAZIONE ALLA PIRAMIDE DI CHEOPE
(Stability Analysis of a Reinforced Earth Ramp: the Cheope
Pyramid Case; in Italian)**

Atti dell'Accademia delle Scienze, Torino, Atti Scienze Fisiche, No. 130, pp. 95-109, Anno 1996.

La presente nota considera la stabilità di una rampa in mattoni crudi con elementi di rinforzo in legno di palma e stuoie di canna. Si presume che una simile struttura sia stata utilizzata per il sollevamento dei blocchi di pietra necessari alla costruzione delle Piramidi. L'esempio analizzato in particolare fa riferimento alla geometria delle grandi Piramidi. Si sono considerati tre differenti fenomeni di collasso: scivolamento dell'intera rampa lungo la superficie di appoggio, rottura locale della rampa all'estradosso, danno strutturale agli elementi di rinforzo in legno di palma. Le verifiche effettuate garantiscono la stabilità della struttura.

This note concerns the stability of a ramp obtained using clay bricks and reinforcements made up of palm wood and reed mat. It is supposed that such a structure was used during the construction of the Pyramids in order to transport the construction material. Cheope Pyramid is studied in detail. Three different kinds of failures were considered: global instability of the slope, local failure, structural damage of the reinforcing elements of the palm wood. The examined structure resulted to be safe.

O. Pallara, D.C.F. Lo Presti, M. Jamiolkowski e S. Pedroni

**CARATTERISTICHE DI DEFORMABILITA' DI DUE SABBIE
DA PROVE MONOTONE E CICLICHE**

Rivista Italiana di Geotecnica, 1998, Vol. XXXII, n. 1, pp. 61 - 80

Questo lavoro, frutto di una collaborazione tra l'ENEL CRIS. di Milano e il Politecnico di Torino, riporta i risultati di uno studio sperimentale riguardante le caratteristiche di deformabilità di due sabbie ricostituite in laboratorio.

I materiali utilizzati sono: la sabbia di Toyoura, che è prevalentemente quarzosa, e la sabbia carbonatica di Quiou con grani altamente frantumabili.

Per realizzare le indagini sperimentali si sono utilizzate due apparecchiature di laboratorio: una cella triassiale, con caratteristiche tali da poter determinare accuratamente la relazione sforzi deformazioni anche per piccoli livelli deformativi, ed un apparecchio di colonna risonante in grado di eseguire prove di taglio torsionale in condizioni di carico statico monotono e ciclico. Sia nel caso delle prove triassiali, che per le prove di colonna risonante e taglio torsionale è stato possibile determinare in modo affidabile la rigidezza dei provini anche per livelli deformativi molto piccoli pari a 10^{-3} %.

Le indagini sperimentali effettuate erano soprattutto tese a investigare l'influenza dei fattori sottoriportati sulla rigidezza di due sabbie aventi diversa mineralogia: stato del materiale (indice dei vuoti, tensioni di consolidazione); livello deformativo; storia tensionale; tipo di prova (triassiale, torsionale).

Inoltre la ricerca era tesa a valutare l'influenza degli errori di misura della deformazione assiale sulla rigidezza determinata in prove triassiali.

This paper shows the experimental results of a joint research between E.N.E.L C.R.I.S. of Milan and the Politecnico di Torino, which was aimed at investigating the deformation characteristics of two reconstituted sands.

The tested soils were: quartz Toyoura sand and carbonatic Quiou sand with high crushable grains.

Tests were performed by means of a triaxial apparatus and a Resonant Column/Torsional Shear apparatus. Both the apparatus allow the assessment of very small strains of about 10^{-3} %.

Tests were performed in order to investigate the influence of the following factors on the stiffness of two sands having different mineralogical composition: soil state (void ratio, pressures); strain level; stress-history; type of test (triaxial vs. torsional).

Moreover, the influence on the stiffness of possible experimental errors in the axial strain measurements during triaxial tests was also examined.

D.C.F. Lo Presti, M. Jamiolkowski, O. Pallara e A. Cavallaro

RATE AND CREEP EFFECT ON THE STIFFNESS OF SOILS

ASCE Convention, 10 - 14 Nov. 1996, Washington, Geotechnical Special Publication No. 61, pp 166- 180.

The shear modulus of two undisturbed Italian clays was measured in the laboratory by means of a Resonant Column/Torsional shear apparatus for a strain range of 0.0001 % up to 1 %. Three different kinds of tests were performed on hollow cylindrical specimens reconsolidated to the in situ geostatic stress: a) static monotonic loading tests at constant stress rate, b) cyclic loading tests at constant strain rate, c) Resonant Column tests. Moreover the small strain shear modulus G_o , determined at strain level less than 0.001% was measured during the drained creep following reconsolidation. The increase of G_o , with time during the drained creep was therefore assessed and compared with available correlations from literature. The data obtained from the above mentioned research activity enabled one to examine the influence of the strain rate, loading conditions (cyclic vs. monotonic) and strain level on the deformation moduli of the tested clays. It was possible to assess that the normalised curves (G/G_o vs. γ) are dependent on loading conditions and strain rate.

**C. Fretti, F. Froio, M. Jamiolkowski, D.C.F. Lo Presti, A. Olteanu
and S. Pedroni**

**DILATOMETER TESTS IN CALIBRATION CHAMBER:
STIFFNESS AND K_0 ASSESSMENT**

A VIII-a Conferinta Nationala De Geotehnica Si Fundatii, Iasi,
Romania 25-28 Septembrie 1996, Vol. I, pp. 85-94.

This paper analyses the Marchetti's dilatometer tests (DMT) performed in Calibration Chamber (CC) on reconstituted specimens of Ticino (TS) and Toyoura (TOS) sands. These tests were carried out to assess the capability of DMTs to determine the stiffness and the coefficient of earth pressure at rest K_0 of cohesionless deposits.

D.C.F. Lo Presti, A. Lazzari, V. Peisino e L. Vicentini

**DAMAGE TO THE ARTISTICAL PATRIMONY IN
PIEDMONT DUE TO THE NOVEMBER 1994 FLOOD**

Arrigo Croce Memorial Symposium, Geotechnical Engineering for the Preservation of Monuments and Historic Sites, Napoli, Italy 3-4 October 1996, Balkema, Rotterdam, pp. 713-722.

From the 4th to the 6th November 1994, Piedmont (Italy) was affected by heavy floods which caused several deaths and more than 6.5 billion US dollars of damage to firms and civil buildings. The transport infrastructure was also heavily damaged. The flood was caused by peculiar meteorological conditions which have already occurred four times over the last century and another twice during this century. The majority of the observed casualties occurred because of river inundation and slope instability. Three different kinds of slope instability were observed: a) debris and mud flows, which mainly occurred in concurrence with the peak of the rainfall intensity. These instabilities evolved very quickly and caused the majority of deaths. The volume of soil that collapsed ranged from 10 to more than 500 cubic meters; b) translational sliding along planar surfaces. This kind of instability, which mainly affects schistose marls, concerned a very large volume of soil and was usually activated a day after the end of the rainfalls. The evolution of the phenomenon was quite quick; c) rotational failure, evolving in mud flow during heavy rainfalls.

Both old and new slope instabilities were activated by the heavy rainfalls.

The artistical patrimony was also damaged. Slope instabilities of first type damaged the Barolo fortress, the Castellinaldo Castle, the Corneliano and Barbaresco medieval towers and the medieval church of Brosso, among others.

This paper, after a brief description of the meteorological conditions which caused the flood and a brief analysis of the pluviometric data, describes the slope instabilities which damaged the above listed monuments. The countermeasures and repairs to the monuments are also considered.

D.C.F. Lo Presti, O. Pallara e A. Cavallaro

DAMPING RATIO OF SOILS FROM LABORATORY AND IN-SITU TESTS

Proc. of discussion special technical session on Earthquake Geotechnical Engineering, XIV ICSMFE, Hamburg, 6-12 Settembre 1997, Seismic Behaviour of Ground and Geotechnical Structures, Balkema, Rotterdam, pp. 391-400.

This paper considers the influence of N and ϕ on D of two undisturbed Italian clays and of three reconstituted granular soils. The experimental results were obtained in the laboratory by means of a Resonant Column/Torsional Shear apparatus.

Moreover, the damping ratio of reconstituted granular soils was determined, at small strains, from seismic tests performed in a large Calibration Chamber. The spectral ratio and the spectral slope methods were used for this purpose. Capability and limits of these methods are discussed in the light of the strong influence of test conditions on damping ratio even at very small strains.

Eventually the experimentally determined values of D are compared against those predicted by means of simple non-linear models incorporating the Masing rules.

D.C.F. Lo Presti, M. Maugeri, A. Cavallaro e O. Pallara

**SHEAR MODULUS AND DAMPING OF A STIFF MARINE
CLAY FROM IN SITU AND LABORATORY TESTS**

International Conference on Geotechnical Site Characterization, ISC
1998, Atlanta, Georgia, Balkema, Vol. 2, pp. 1293, 1300

This paper describes and compares the results of in situ and laboratory investigations which were carried out in order to determine the soil profile of the Saline di Augusta site (also Saline site), with special attention being paid to the variation of shear modulus and damping ratio with depth. The soil deposits at this site mainly consist of a medium stiff, overconsolidated ($OCR = 2.0$ to 6.0), Pleistocene marine clay with low to medium PI, overlaid by a 15 m thick Holocene silty clay stratum. The Saline site is located near the city of Augusta on the east coast of Sicily which is one of the most seismically active areas of Italy.

D.C.F. Lo Presti, M. Jamiolkowski, O. Pallara, A. Cavallaro e S. Pedroni

SHEAR MODULUS AND DAMPING OF SOILS

Géotechnique Symposium in Print, 1997, Vol. 47, No. 3, pp. 603-617.

The shear modulus (G) and damping ratio (D) of two natural clays and both siliceous and carbonatic pluvially deposited dry sands have been measured at the authors' laboratory by means of a Resonant-Column/Torsional-Shear apparatus for a strain range of 0.0001 % up to 1 %. Different kinds of tests were performed above all on hollow cylindrical specimens: a) monotonic loading torsional shear tests (MLTST) at constant stress rate, b) cyclic loading torsional shear tests (CLTST) at constant strain rate or at constant frequency and c) Resonant Column tests (RCT).

The results of the above tests enabled the authors to analyse the influence of strain level (γ), loading rate ($\dot{\gamma}$), number of loading cycles (N) and type of loading (monotonic or cyclic) on the measured values of G and D.

D.C.F. Lo Presti, A. Cavallaro e O. Pallara

**MODELLAZIONE DELLA NON LINEARITA' DEL LEGAME
SFORZI-DEFORMAZIONI DEI TERRENI IN PROBLEMI DI
SOLLECITAZIONE CICLICA**

8° Convegno Nazionale di Ingegneria Sismica, Taormina, Settembre
1997, Vol. 1, pp. 91-98.

La presente nota analizza criticamente la capacità di semplici modelli non lineari, basati sui criteri di Masing, di riprodurre i risultati di prove di taglio torsionale ciclico e monotono eseguite su argille naturali e sabbie ricostituite. Viene anche considerato un modello che introduce alcune modifiche significative al secondo criterio di Masing consentendo una rappresentazione più realistica della relazione sforzi-deformazioni a taglio dei terreni.

This paper critically analyses the capability of simple non-linear models based on the Masing rules, to fit the experimental stress-strain curves obtained from monotonic and cyclic loading torsional shear tests that were performed on two undisturbed clays and reconstituted sand. A model which modifies the second Masing rule providing more realistic fit of the experimental data is also considered.

D.C.F. Lo Presti, M. Maugeri, A. Cavallaro e O. Pallara

**RAPPORTO DI SMORZAMENTO DEI TERRENI DA PROVE
DI LABORATORIO**

8° Convegno Nazionale di Ingegneria Sismica, Taormina, Settembre
1997, Vol. 1, pp. 99-108.

Questo lavoro esamina l'influenza del numero di cicli e della velocità di deformazione sul rapporto di smorzamento di due argille naturali e tre sabbie ricostituite, per mezzo di un apparecchio di taglio torsionale-colonna risonante.

Dall'analisi dei risultati emerge chiaramente che il rapporto di smorzamento è in realtà una grandezza complessa che riflette fenomeni di diversa natura (non linearità, viscosità dello scheletro solido e viscosità del fluido interstiziale). Ciò comporta per il progettista, una particolare attenzione nella scelta dei valori di smorzamento da utilizzare in relazione al problema in esame.

This paper considers the influence of number of loading cycles and strain rate on the damping ratio of two undisturbed Italian clays and three reconstituted granular soils. The experimental results were obtained in the laboratory by means of a Resonant Column-Torsional Shear Apparatus. Due to the high variability of D , especially with frequency, it is extremely important when using linear equivalent methods to compute the seismic response of soil deposits to chose the most appropriate values of damping in relation to the examined problem.

D.C.F. Lo Presti e I. Puci

**DETERMINAZIONE DELLO SMORZAMENTO MEDIANTE
MISURE DI TIPO SISMICO IN CAMERA DI CALIBRAZIONE
SU TERRENI GRANULARI RICOSTITUITI**

8° Convegno Nazionale di Ingegneria Sismica, Taormina, Settembre 1997, Vol. 2, pp. 943-952.

La nota esamina criticamente la possibilità di determinare il rapporto di smorzamento dei terreni D da misure di propagazione di onde di volume eseguite in Camera di Calibrazione su diversi terreni granulari. In particolare sono stati esaminati i metodi cosiddetti del rapporto spettrale e della pendenza spettrale.

I valori di smorzamento ottenuti sono stati confrontati con quelli ricavati per i medesimi materiali da prove di laboratorio. I metodi considerati forniscono valori di D più elevati in confronto con quelli ricavati da prove di laboratorio.

Questa discrepanza può essere imputata alla dipendenza di D dalla frequenza e/o al fatto che la legge di attenuazione geometrica assunta non è in grado di rappresentare in modo realistico l'attenuazione con la distanza in un mezzo anisotropo

The paper critically analysed the capability of determining damping ratio D of granular soils from seismic tests performed in Calibration Chamber, by means of the so called spectral ratio and spectral slope methods.

The determined values of D are greater in comparison to those obtained from laboratory tests. As a possible explanation of such a discrepancy the following factors should be considered:

- frequency dependence of D , due to the viscosity of the pore fluid;
- need of a more complex law for geometric damping in anisotropic materials.

D.C.F. Lo Presti, O. Pallara, V. Fioravante e M. Jamiolkowski

ASSESSMENT OF QUASI-LINEAR MODELS FOR SANDS

Géotechnique, Pre-failure deformation of geomaterials, 1998, 363-372.

Appropriate modelling of the strain level dependency of soil stiffness is of great importance in order to correctly estimate the displacements of foundations under working load conditions. It is worthwhile remembering that soil deformations which mainly occur in the case of well designed foundations are within the range of 0.001% to 1%, therefore the assumed model should be able to reproduce stress-strain curves, above all in this interval. In the light of this observation, a review of quasi-linear stress-strain relationships has been made. This review includes the models recently proposed by Tatsuoka and Shibuya (1992), Fahey and Carter (1993) and Puzrin and Burland (1996), that overcome some intrinsic limitations of the conventional hyperbolic model (Cox 1850, Kondner 1963, Kondner and Zelasko 1963).

Model parameters were determined for a selected database of drained compression loading triaxial tests that refer to four sands with different mineralogical and physical characteristics. The sands were tested in a triaxial apparatus equipped with gauges for the local axial and radial strain measurements, so that the stress strain curve is accurately defined, especially in the strain interval of interest.

A parameter was introduced to evaluate the capacity of each model to fit the experimental results and especially those concerning the variation of Young's modulus with axial strain. An attempt was also made to find a correlation between the model parameters and test conditions (void ratio, consolidation stresses, consolidation stress-ratio, overconsolidation ratio). It was seen that the last two of these factors significantly affect the model parameters. It was also attempted to reproduce stress-strain curves obtained for different stress-paths using these correlations.

D.C.F. Lo Presti e M. Jamiolkowski

**DISCUSSION ON ESTIMATE OF ELASTIC SHEAR
MODULUS IN HOLOCENE SOIL DEPOSITS**

Soils and Foundations, 1998, Vol. 38, No. 1, 263-265

The authors are to be complimented on presenting and summarising well documented in situ and laboratory data concerning the "pseudo-elastic" shear modulus G_f . The writers, because of their own research, are greatly interested in the study of the factors which influence G_f and would like to contribute to the following points:

- a) influence of OCR on G_f*
- b) void ratio function*
- c) general equation*

M. Jamiolkowski, D.C.F. Lo Presti e F. Froio

DESIGN PARAMETERS OF GRANULAR SOILS FROM IN SITU TESTS

XI Europe-Danube Conference, Porec, May 1998, Proc. Balkema, pp. 65-94

The capability of in situ testing techniques to assess the mechanical properties of granular soils is here reviewed after a brief qualitative picture of the mechanical soil behaviour. Particular attention is paid to recent innovations and the capabilities of in situ testing methods to assess the relative density, stiffness and secant angle of shear resistance of coarse grained soils. In particular, the advantages and limitations of penetration, dilatometer, pressuremeter and seismic tests are critically reviewed.

**V. Fioravante, M. Jamiolkowski, D.C.F. Lo Presti, G. Manfredini
e S. Pedroni**

**ASSESSMENT OF COEFFICIENT OF EARTH PRESSURE AT
REST FROM SHEAR WAVE VELOCITY MEASUREMENTS**

Géotechnique, Vol. 48, No. 4, pp. 1-10.

The paper presents an attempt to evaluate the feasibility to predict the value of the coefficient of earth pressure at rest (K_0) of natural soil deposits on the basis of the measured velocities of the seismic shear waves. The experimental data presented have been obtained from seismic tests performed in the calibration chamber (CC) on laboratory prepared specimens of seven granular materials with grade ranging from fine sand to gravelly sand. The relationship between K_0 and shear wave velocity established by means of the CC results was used successfully to predict K_0 at two well documented sites where both Cross-Hole Seismic (CH) and Seismic Piezocone Penetration (SCPTU) tests are available.

D.C.F. Lo Presti, O. Pallara, A. Cavallaro e M. Maugeri

NON.LINEAR STRESS-STRAIN RELATIONS OF SOILS FOR CYCLIC LOADING

Proceedings of the 11th European Conference on Earthquake Engineering, 6-11 September 1998, Paris, Balkema, p 187.

This paper critically analyses the capability of Masing rules to represent the non-linear stress-strain relations of soils under cyclic loading. The analysis is performed in the light of the experimental results obtained from monotonic and cyclic loading torsional shear and resonant column tests performed on two undisturbed Italian clays and various reconstituted sands.

The second Masing rule implicitly assumes that cyclic and monotonic loading tests provide the same skeleton curve. This assumption is not confirmed by the experimental results shown in this paper.

For a given strain level the secant shear modulus from monotonic loading tests is smaller than the unload-reload shear modulus from cyclic loading tests. Moreover the loops originated by the second Masing rule are too large in comparison to those experimentally observed.

The model proposed by Tatsuoka and Kohata (1995) modifies the second Masing rule in order to overcome these intrinsic limits. This model is analysed and it seems to give more realistic prediction of the non-linear stress-strain relations of soils.

The original formulation of the Masing rules assumes stable cycles and disregards the possible occurrence of cyclic hardening or cyclic degradation.

The cyclic hardening is experimentally observed in dry sand for shear strain level greater than about 0.01 %. Cyclic degradation is typical of clays. The strain level at which this phenomena is triggered seems to depend on soil plasticity because of the rate dependent behaviour of clays.

I. Puci e D.C.F. Lo Presti

DAMPING MEASUREMENT OF RECONSTITUTED GRANULAR SOILS IN CALIBRATION CHAMBER BY MEANS OF SEISMIC TESTS

Proceedings of the 11th European Conference on Earthquake Engineering, 6-11 September 1998, Paris, Balkema, p 206.

This paper analyses the results of seismic tests performed in a large Calibration Chamber (CC) in order to determine the damping ratio of seven different granular soils by means of the spectral ratio and spectral slope methods. Seismic measurements were performed with arrays of three miniature geophones, using the geophone located at one end of the arrays as a source and the other two as receivers. The damping ratio values were determined by analysing the traces of shear waves propagating along the horizontal direction with particle motion in the vertical direction (S_{hv}) and those propagating in the vertical direction with particle motion in the horizontal direction (S_{vh}). These shear waves practically corresponds to those generated during Cross hole (CH) and Down Hole (DH) tests, respectively. It is reasonable to assume that the seismic tests in CC simulate CH and DH tests performed in ideal conditions: i) ideal coupling between soil and geophone, ii) homogeneous soil, iii) well known boundary conditions, soil density and imposed stresses. Seismic measurements were performed in the CC of Ismes at Bergamo which houses 1.5 m height and 1.2 m diameter specimens. Soil sample were reconstituted by means of pluvial deposition in air. During formation of the specimens, the pluviation process was interrupted at a pre-established elevation in order to place on the specimen surface several miniature cylindrical geophones. The specimen was saturated with deaired water after formation. The source geophone was excited by means of a 50 V peak-to-peak sine wave with frequencies of 2000 and 3000 Hz for P and S waves respectively. Typical lengths of the travel path between two receivers ranged from 45 to 60 cm. The above conditions minimise the so called "near field" effects. The CC specimens were subjected to stepwise loading with stress increments for σ_1 of 25-50 kPa with σ_1 corresponding to either σ_v or σ_h depending on the chosen path. The seismic tests were performed, at the end of each consolidation step, by generating the groups of body waves and measuring their velocities. These waveforms have been pre-processed by means of a cosine bell filter before their use for damping determination. The damping ratio obtained from seismic tests in the CC were compared with those obtained in the laboratory on soil element from cyclic loading torsional shear tests or Resonant Column tests. The paper tries to explain

the observed differences and to improve the capability of the seismic tests in predicting the damping ratio of soils.

P. Negro, G. Verzeletti, J. Molina, S. Pedretti, D. Lo Presti e S. Pedroni

LARGE-SCALE GEOTECHNICAL EXPERIMENTS ON SOIL-FOUNDATION INTERACTION (TRISEE TASK 3)

Special Publication No. I.98.73, European Commission, Joint Research Centre, Ispra (VA), Italy.

This report provides: 1) a general description of the experimental work carried out at the ELSA laboratory (JRC Ispra) in the framework of the activities of the research project TRISEE (3D Site Effects of Soil-Foundation Interaction in Earthquake and Vibration Risk Evaluation), funded by the European Commission under the Environment and Climate Programme, Contract n° ENV4-CT96-0254; 2) the necessary post processing of the test results and the comparative analysis, from the point of view of the assessment of the permanent deformations and the ultimate bearing capacity for the soil-foundation system.

The large dynamic interaction experiments were designed to investigate the non-linear interaction between shallow foundations of building structures and the supporting soil during strong seismic loading. A shallow foundation resting on cohesionless soil of known properties and excited by a time varying horizontal force and moment, which simulate the inertial forces transmitted to the foundation by the superstructure, was considered. The wave propagation effects in the soil were neglected with respect to the dynamic structural inertia forces transmitted by the foundation.

The results of this program will be used to improve the current design practice and to validate non-linear constitutive models implemented in the numerical tools developed as a part of the activities of TRISEE (AHNSE codes), or in other codes.

Two large size tests were envisaged with two different soil relative densities (about 45 and 85 %). The tests were intended as representative of high density and low density soil conditions respectively for the practical design of shallow foundation.

D.C.F. Lo Presti, M. Barla, G. Barla, O. Pallara, A. Plescia e A. Grigore

DEVELOPMENT AND USE OF A TRIAXIAL CELL FOR SOFT ROCKS

The Geotechnics of Hard Soils-Soft Rocks, Napoli 12-14 Ottobre 1998, Balkema, Vol. 1, pp. 259-265.

The stiffness of sedimentary soft rocks was determined by means of compression loading triaxial tests. These tests were performed on two different kinds of sedimentary soft rocks: i) specimens retrieved from a Miocene (23 million years) geologic formation (S. Raffaele Cimena, Italy) which consists mainly of clay shales interbedded with sandstones and ii) specimens of mudstone from Sagamihara (Japan) (Kim et al. 1994, Hayano et al. 1997). The Sagamihara sedimentary soft mudstone have been deposited in the late Pliocene to the early Pleistocene epochs. These deposits of mudstone are well cemented and most of them are unweathered and continuous (Hayano et al. 1997). The tests were performed with a specially devised triaxial apparatus (Hayano et al. 1997, Tatsuoka 1988) having the following peculiar characteristics: i) very low apparatus compliance; ii) accurate, local measurements for the axial and radial strains; iii) high resolution of the actuator; iv) sliding mechanism at bottom of pedestal.

D.C.F. Lo Presti and M. Jamiolkowski

**DISCUSSION ON "SPT-N-VALUE AND S-WAVE VELOCITY
FOR GRAVELLY SOILS WITH DIFFERENT GRAIN SIZE
DISTRIBUTION**

Soils and Foundations, 1999, Vol. 39, No. 2, pp. 142-144.

The authors present a great number of high quality experimental data concerning the shear wave velocity (V_s) and the SPT N-value of reconstituted gravels which were tested in a Calibration Chamber. Data interpretation shows several interesting features, such as the influence of grading on the void ratio function and a new correlation between V_s and N. In particular, the authors show that, for a given level of the consolidation pressure, different kinds of granular soils exhibit the same V_s and N values at the maximum void ratio. However, the writers would like to have some more details concerning the experiments in order to better evaluate the relevance of the findings. Moreover the writers would like to compare their own data to those of the authors. Thus, the discussion deals with the following points:

- a) Request for additional information*
- b) Comparison between authors' and writers' data*

A. Cavallaro, D.C.F. Lo Presti, M. Maugeri and O. Pallara

STRAIN RATE EFFECT ON STIFFNESS AND DAMPING OF CLAYS

Italian Geotechnical Review, 1998, Vol. XXXII, n. 4, pp. 30-49.

This paper describes the results of a laboratory study which was carried out in order to determine the stress-strain behaviour of two Italian clays (Augusta and Pisa clays), with special attention being paid to the variation of stiffness parameters and damping ratio with strain rate. The experimental study was carried out using a Resonant Column/Torsional Shear apparatus and a triaxial cell. Monotonic loading torsional shear tests (MLTST), cyclic loading torsional shear tests (CLTST, Resonant Column tests (RCT) and monotonic compression loading triaxial tests (TX) were performed on specimens of Augusta and Pisa clays. The obtained results showed a little influence of strain rate on stiffness parameters in the small strain range. While the stiffness parameters for medium and large strains are strongly influenced by the strain rate. The measured damping ratio values resulted to be influenced by strain rate much more than stiffness. A comparison of the stress-strain curves obtained from monotonic and cyclic tests allowed one to verify the effectiveness of a modified second Masing rule (Tatsuoka et al. 1993).

**V. Fioravante, M. Jamiolkowski, D.C.F. Lo Presti, G. Manfredini
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**ASSESSMENT OF COEFFICIENT OF EARTH PRESSURE AT
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The paper presents an attempt to evaluate the feasibility to predict the value of the coefficient of earth pressure at rest (K_0) of natural soil deposits on the basis of the measured velocities of the seismic shear waves. The experimental data presented have been obtained from seismic tests performed in the calibration chamber (CC) on laboratory prepared specimens of seven granular materials with grade ranging from fine sand to gravelly sand. The relationship between K_0 and shear wave velocity established by means of the CC results was used successfully to predict K_0 at two well documented sites where both Cross-Hole Seismic (CH) and Seismic Piezocone Penetration (SCPTU) tests are available.

F. Tatsuoka, R. Jardine, D.C.F. Lo Presti, H. Di Benedetto e T. Kodaka

TESTING AND CHARACTERISING PRE-FAILURE DEFORMATION PROPERTIES OF GEOMATERIALS

Theme Lecture Session 1, XIV ICSMFE, Hamburg September 1997, Balkema, Vol. 4, pp. 2129-2164.

Recent developments in the characterisation of geomaterial prefailure deformation properties are reviewed, focusing on the data required to predict ground deformations and structural displacements at working loads. Descriptions are given of the deformation characteristics developed at very small to intermediate strains of a variety of geomaterials, in testing using modern laboratory and field techniques. The relationships between static and dynamic experiments, between laboratory and field techniques, and between testing and field full-scale behaviour are discussed. Important features that are highlighted include: kinematic yielding, effects of recent stress-time history, anisotropy, structuration and destructuration, non-linearity by strain and pressure and effects of cyclic loading. Careful distinctions are made between elastic, plastic and viscous properties.

D.C.F. Lo Presti

**STRESS-STRAIN BEHAVIOUR OF UNDISTURBED CLAYS
IN THE LABOTRATORY**

Panel Discussion Session 1.1, XIV ICSMFE, Hamburg September 1997, Balkema, Vol. 4, pp. 2183-2186.

This Panel presentation concerns the stiffness assessment of undisturbed clays in the laboratory and summarises the research activity undertaken at the writers' University over the last five years. the main purpose of this research was to define reliable test procedures in order to determine the stiffness of geomaterials to be used for settlement analysis under working loading conditions.

D.C.F. Lo Presti

**COMPORTAMENTO DEI TERRENI IN CONDIZIONI
DINAMICHE E CICLICHE**

Ingegneria Geotecnica nelle aree sismiche. 1999, CISM, Udine, pp:
109-146

Il presente lavoro analizza i recenti sviluppi riguardanti la determinazione delle caratteristiche sforzi-deformazioni dei terreni con particolare attenzione ai parametri necessari per l'analisi della risposta sismica di un deposito di terreno e per gli studi di interazione dinamica terreno-struttura. Vengono presi in considerazione i risultati ottenuti mediante recenti tecniche di indagine in laboratorio e in sito. Il lavoro descrive le caratteristiche di deformabilità a piccole e medie deformazioni ed i fenomeni di degradazione ciclica a grandi deformazioni per un'ampia varietà di terreni.

A. Cavallaro, D.C.F. Lo Presti, M. Maugeri e O. Pallara

**A CASE-STUDY (THE SAINT NICOLÒ CATHEDRAL) FOR
DYNAMIC CHARACTERIZATION OF SOIL FROM IN SITU
AND LABORATORY TESTS**

Earthquake Resistant Engineering Structures II. 1999, pp: 769-778.

The Saint Nicolò Cathedral of Noto was damaged by a post-seismic structural collapse on March 13th 1996 and is now under repair and restoration. The city of Noto is located near Siracusa on the east coast of Sicily and actually is object of a seismic microzonation (level II) study. Assessment of the seismic risk of Saint Nicolò Cathedral by means of analytical computation is also under way. To this end, in situ and laboratory investigations have been carried out in order to determine the soil profile with special attention being paid to the variation shear modulus and damping ratio with depth. This paper is aimed at providing information about the Saint Nicolò Cathedral site characterisation for seismic analysis.

D.C.F. Lo Presti, A. Cavallaro, M. Maugeri e O. Pallara

**NON LINEAR STRESS-STRAIN MODELLING OF
GEOMATERIALS UNDER STABLE AND UNSTABLE
CYCLIC LOADING.**

Proceedings of the 2nd International Conference on Earthquake Geotechnical Engineering, Lisbona 21-25 June 1999, Balkema, Vol. 1, pp. 29-34.

The paper shows that a modified 2nd Masing rule is capable of well reproducing the experimental stress-strain curve of natural clays during cyclic loading. The modified 2nd Masing rule assumes that the scale amplification factor for the unload-reload branches (n) is not necessarily equal to two as postulated by the original 2nd Masing rule. In particular, it was found that $n=6$ in the case of stable cycles. When degradation phenomena occur, n decreases. The limited experimental data did not allow the authors to determine the dependence of n on shear strain (γ) and number of loading cycles (N). On the other hand the degradation parameter (t) proposed by Idriss et al. (1978) was computed according to the procedure suggested by Lin & Chen (1991). The values of t resulted to be much higher than those available in literature.

D.C.F. Lo Presti, O. Pallara, A. Cavallaro e M. Jamiolkowski

INFLUENCE OF RECONSOLIDATION TECHNIQUES AND STRAIN RATE ON THE STIFFNESS OF UNDISTURBED CLAYS FROM TRIAXIAL TESTS

Geotechnical Testing Journal, GTJODJ, Vol. 22, No. 3, September 1999, pp. 211-225.

This paper concerns the stiffness assessment of undisturbed clays from triaxial tests. The paper summarises the research activity undertaken at the authors' Universities over the last five years by means of triaxial cells equipped with local gauges for axial and radial strain measurements and with piezoceramic bender elements for the measurement of the propagation velocity of differently polarised shear waves. The main purpose of this research was to define reliable test procedures in order to determine the stiffness of geomaterials to be used for settlement analysis under working load conditions. In particular the paper deals with four different topics: i) evaluation of sample disturbance by means of different methods, ii) assessment of the reconsolidation techniques which minimise the sample disturbance effects, iii) influence of strain rate on the stiffness of undisturbed clays iv) stiffness anisotropy of undisturbed clays at small strains.

D.C.F. Lo Presti, O. Pallara, M. Jamiolkowski e A. Cavallaro

**ANISOTROPY OF SMALL STRAIN STIFFNESS OF
UNDISTURBED AND RECONSTITUTED CLAYS**

Proc. of 2nd Int. Symposium on Pre-Failure Deformation Characteristics of Geomaterials, Torino 27-30 September 1999, Balkema, Vol. 1, pp. 3-10.

This paper concerns the assessment of the elastic shear modulus G_o of reconstituted and undisturbed clays by means of seismic measurements performed during triaxial compression tests. The experiments were performed by means of a triaxial cell equipped with local gauges for axial and radial strain measurements and with piezoceramic bender elements for the measurement of the propagation velocity of differently polarised shear waves. The tests were performed on reconstituted specimens of Fujinomori (Japan) clay and on intact specimens of two Italian clays (Pisa and Augusta). Seismic tests were performed during saturation process, consolidation and shearing. These measurements allowed to determine the small strain shear modulus in the vertical and horizontal plane (G_{vh}, G_{hh}). In particular the paper deals with the following topics: i) assessment of the stiffness anisotropy at small strains, ii) assessment of the decay of G_o during shearing in order to define the sensitivity of this parameter to sample disturbance.

D.C.F. Lo Presti, M. Jamiolkowski, O. Pallara e M.L. Tordella

ASSESSMENT OF SAMPLE DISTURBANCE IN THE LABORATORY

Proc. of 2nd Int. Symposium on Pre-Failure Deformation Characteristics of Geomaterials, Torino 27-30 September 1999, Balkema, Vol. 1, pp. 11-19.

This paper concerns the assessment of sample disturbance in the laboratory by means of several methods. In particular, the degree of disturbance of Pisa clay was evaluated. Pisa clay samples were retrieved by means of Laval, Begemann and Osterberg samplers. Possible countermeasures for mitigating the negative effects of disturbance due to sampling and handling the soil specimens in the laboratory are also considered. The following reconsolidation techniques have been compared to evaluate possible beneficial effects: i) dry vs. wet setting ii) reproducing in the laboratory a known stress-history. Undisturbed Pisa and Augusta clay and reconstituted Fujinomori clay samples were used to assess the effectiveness of such procedures.

M. Barla, G. Barla, D.C.F. Lo Presti, O. Pallara e N. Vandebussche

STIFFNESS OF SOFT ROCKS FROM LABORATORY TESTS

Proc. of 2nd Int. Symposium on Pre-Failure Deformation Characteristics of Geomaterials, Torino 27-30 September 1999, Balkema, Vol. 1, pp. 43-50.

The stress-strain-strength properties of various soft rocks have been evaluated by means of tests performed with a specially devised triaxial apparatus having the following characteristics: i) very low compliance; ii) accurate local measurements for the axial and radial strains; iii) high resolution of the actuator; iv) sliding mechanism at the bottom of the pedestal. The samples tested were taken from two sedimentary soft rocks: i) Miocene silty marl interbedded with sandstone (S. Raffaele Cimena, Italy) and ii) late Pliocene to early Pleistocene mudstone (Sagamihara, Japan), well cemented and mostly unweathered and continuous. Moreover, two tests were performed on specimens of highly tectonised carbonatic Breccia (Giaglione Site, Italy). In particular, the following aspects have been considered: i) the influence of CaCO₃ content on strength and stiffness in the case of S. Raffaele Cimena sandstone; ii) the importance of local strain measurements; iii) the importance of end capping; iv) the comparison of the stiffness inferred from in situ and laboratory tests, as well as from rock mass rating systems in the case of carbonatic Breccia.

A. Cavallaro, M. Maugeri, D.C.F. Lo Presti e O. Pallara

**CHARACTERISING SHEAR MODULUS AND DAMPING
FROM IN SITU AND LABORATORY TESTS FOR THE
SEISMIC AREA OF CATANIA**

Proc. of 2nd Int. Symposium on Pre-Failure Deformation
Characteristics of Geomaterials, Torino 27-30 September 1999,
Balkema, Vol. 1, pp. 51-58.

The paper shows the dynamic characterisation of three different sites of the city of Catania which is one of the most seismically active areas of Italy. The results of in situ and laboratory investigations are described and compared. Moreover, normalised laws are proposed to consider shear modulus decay and damping ratio increase with strain level. Special attention is paid to the variation of shear modulus and damping ratio with strain level and depth. The deposit under consideration consist of different type of soils and represnt the geotechnical variability in the municipal area of Catania.

A. Cavallaro, M. Maugeri, D.C.F. Lo Presti e O. Pallara

**STRAIN RATE EFFECTS ON THE YOUNG MODULUS OF
AUGUSTA CLAY**

Proc. of 2nd Int. Symposium on Pre-Failure Deformation Characteristics of Geomaterials, Torino 27-30 September 1999, Balkema, Vol. 1, pp. 353-340.

An experimental study was carried out using a triaxial cell in order to determine the undrained stress-strain behaviour of Augusta clay, with special attention being paid to the dependence of Young modulus on strain rate. A particular attention was paid to the stiffness assessment at small strains, for which the deformation of specimen in triaxial compression was measured locally over the central part with an accuracy of the strain measurement of about 0.001 %. The results obtained showed in the small strain range a little influence of strain rate on Young modulus. The results obtained from triaxial tests were compared to those obtained from monotonic loading torsional shear tests (MLTST) performed in undrained conditions. Rate effects were evaluated by means of an empirical parameter. The rate dependence of the pore pressure increase in undrained monotonic, triaxial compression tests and MLTST was carefully examined.

M. Jamiolkowski, D.C.F. Lo Presti, I. Puci, P. Negro, G. Verzeletti, J.F. Molina, E. Faccioli, S. Pedretti, S. Pedroni e P. Morabito

LARGE SCALE GEOTECHNICAL EXPERIMENTS ON SOIL-FOUNDATION INTERACTION

Proc. of 2nd Int. Symposium on Pre-Failure Deformation Characteristics of Geomaterials, Torino 27-30 September 1999, Balkema, Vol. 1, pp. 749-758.

This paper describes two large-scale load tests performed on a square rigid foundation, 1 m by side, resting on a sand bed 4.6 by 4.6 m in plan and 3 m deep. Two samples of Ticino sand were reconstituted at two different relative densities ($D_r \cong 45$ and 85 %). In the case of the low-density sample a maximum vertical pressure of about 100 kPa was applied. For the high-density sample the maximum vertical pressure was equal to about 300 kPa. The observed settlements have been compared to those inferred from conventional computation methods (Schmertmann 1970). The load displacement curves were used to determine the soil stiffness. The obtained values were compared to those inferred from plate load tests performed in Calibration Chamber on a circular, rigid, deep foundation resting on reconstituted Ticino sand samples (Ghionna et al. 1994).

D.C.F. Lo Presti, S. Pedroni e F. Froio

RIGIDEZZA DEI TERRENI A GRANA GROSSA DA PROVE TRIASSIALI ESEGUITE IN UNA CELLA DI GRANDI DIMENSIONI

XX Convegno Nazionale di Geotecnica, Parma 22-25 Settembre 1999, Pàtron Editore Bologna, pp. 149-153.

La caratterizzazione meccanica dei materiali a grana grossa che trovano un diverso impiego nell'Ingegneria Civile (materiale di fondo per pavimentazioni stradali flessibili, massicciate ferroviarie, rockfill, ecc.) richiede appropriate tecniche sperimentali. Questa nota descrive una cella triassiale in grado di alloggiare un provino con diametro di 300 mm e rapporto altezza diametro pari a 2 e che è stata sviluppata nell'ambito di una collaborazione di ricerca tra l'ENEL PIS di Milano e il Politecnico di Torino. Le caratteristiche principali di questa cella triassiale vengono confrontate con altre apparecchiature simili. L'apparecchiatura è stata utilizzata per eseguire delle prove di compressione triassiale di tipo CID su alcune sabbie e su un ghiaietto. Il confronto tra i risultati relativi alle sabbie e quelli del ghiaietto ha consentito di verificare che i parametri delle correlazioni empiriche normalmente utilizzati per le sabbie non sono del tutto adeguati nel caso delle ghiaie. In particolare è emerso, nel caso delle ghiaie, una più pronunciata non linearità ed una maggiore influenza dell'indice dei vuoti sul modulo iniziale

A. Cavallaro, D.C.F. Lo Presti, M. Maugeri e O. Pallara

**CARATTERISTICHE DI DEFORMABILITÀ DEI TERRENI
DA PROVE DILATOMETRICHE: ANALISI CRITICA DELLE
CORRELAZIONI ESISTENTI**

XX Convegno Nazionale di Geotecnica, Parma 22-25 Settembre 1999,
Pàtron Editore Bologna, pp. 47-53.

La determinazione del profilo del modulo di taglio a piccole deformazioni G_0 risulta particolarmente importante negli studi di interazione terreno-struttura soprattutto in quelle aree ove è possibile il verificarsi di eventi sismici. Nel presente lavoro sono criticamente analizzate le correlazioni disponibili per la determinazione di G_0 da prove dilatometriche in sito. In particolare, si sono utilizzati i risultati di prove dilatometriche eseguite nel sito Le saline di Augusta per determinare, con le correlazioni disponibili in letteratura, il profilo di G_0 . I valori così ottenuti sono stati confrontati da quelli ricavati da prove Cross-hole in sito e da prove di colonna risonante e taglio torsionale eseguite in laboratorio su campioni indisturbati prelevati con campionatori Osterberg e Shelby.

D.C.F. Lo Presti, A. Cavallaro, M. Maugeri, O. Pallara e F. Ionescu

MODELLING OF HARDENING AND DEGRADATION BEHAVIOUR OF CLAYS AND SANDS DURING CYCLIC LOADING

12WCEE, Auckland 30 Jan. to 4 Feb. 2000, paper No. 1849/5/A

It is demonstrated that the stress-strain response in both undrained and drained cyclic loading conditions is of the hardening type until the shear strain is smaller than the so called volumetric threshold. On the contrary, beyond this limit, degradation phenomena occur. In this paper, the possibility of modelling the hardening and degradation behaviour of clays and sands with a simple law is examined. In particular, the case of one-dimensional loading is considered. Experimental data on reconstituted Toyoura sand specimens and undisturbed specimens of three Italian clays (Pisa, Augusta and Catania) have been used

A. Cavallaro., D.C.F. Lo Presti e M. Maugeri

**DYNAMIC GEOTECHNICAL CHARACTERIZATION OF
SOILS SUBJECTED TO UMBRIA AND MARCHES
EARTHQUAKE**

12WCEE, Auckland 30 Jan. to 4 Feb. 2000, paper No. 2509/10/A/ST3

The Umbria and Marches regions, in central Italy, were severely damaged by the seismic sequence initiated on September 26, 1997. After that event, Local Authorities, GNDT and Servizio Sismico Nazionale (SSN) have promoted and supported some Grade 3 microzonation studies in those areas, in order to reduce the seismic risk and to rationalise the land use. A Grade 3 seismic microzonation of the city of Fabriano is under way. This paper presents the results of in situ and laboratory investigations performed in typical deposits of Fabriano area with the main purpose of obtaining representative shear modulus and damping ratio profiles.

T. Crespellani, D.C.F. Lo Presti, C. Madiati e G. Vannucchi

INFLUENCE OF SOIL DYNAMIC PARAMETERS ON SEISMIC RESPONSE OF A SITE AT FABRIANO, ITALY

12WCEE, Auckland 30 Jan. to 4 Feb. 2000, Paper No. 2499/10/A/ST3

Dynamic parameters play an important role in evaluating the seismic response of soil deposits. However, they are affected by many uncertainties associated with the natural variability of soils, sampling techniques, laboratory testing procedures, sensing devices, instrumental biases, operators, etc. Therefore, choosing the 'best values' is generally a complex problem of decision-making. In this paper, the problem of the influence on seismic response of the uncertainties connected with laboratory testing equipment and procedures used in measurement of damping ratio is considered. Reference is made to the evaluation of site effects in a cohesive deposit in the town of Fabriano, Italy, which was damaged by the Umbro-Marchigian seismic sequence that initiated on September 26, 1997

C.G. Lai, D.C.F. Lo Presti, O. Pallara e G.J. Rix

**MISURA SIMULTANEA DEL MODULO DI TAGLIO E
DELLO SMORZAMENTO INTRINSECO DEI TERRENI A
PICCOLE DEFORMAZIONI**

Atti 9° Convegno Nazionale "L'Ingegneria Sismica in Italia", Torino
20-23 Settembre 1999. ANIDIS (formato CD)

Evidenze sperimentali mostrano che un campione di terreno sottoposto a sollecitazioni cicliche esibisce sia capacità di immagazzinare energia di deformazione sia di dissiparla. Il fenomeno di dissipazione avviene anche a livelli molto bassi di deformazione, al di sotto della soglia di deformazione lineare ciclica. Da un punto di vista fenomenologico tale tipo di comportamento meccanico può venire convenientemente descritto dalla teoria della viscoelasticità. Un risultato importante previsto da questa teoria è la dipendenza funzionale tra la velocità di propagazione delle onde di volume e i coefficienti di smorzamento. Tale dipendenza ha importanti implicazioni sulla determinazione sperimentale di questi parametri, tra cui il fatto che essi dovrebbero essere determinati simultaneamente, sebbene nella prassi, essi siano misurati in modo completamente indipendente. In questo articolo gli autori propongono una nuova procedura sperimentale dove la velocità di propagazione delle onde di taglio e lo smorzamento intrinseco dei terreni sono misurati simultaneamente attraverso prove in laboratorio di colonna risonante

D.C.F. Lo Presti, I. Puci, O. Pallara, R. Maniscalco e S. Pedroni

EXPERIMENTAL LABORATORY DETERMINATION OF THE STEADY STATE OF SANDS

Soils and Foundations, Vol. 40, No. 1, February 2000, pp: 113-122.

Some experimental problems encountered when determining Steady-State (SS) or Phase Transformation (PT) envelopes and their projections in the state diagram are studied; 1) accurate assessment of the void ratio (e) at the end of the consolidation process; 2) the effects due to the membrane compliance; 3) effectiveness of lubrication ends and 4) influence of specimen slenderness on the lateral strain uniformity.

The specimen's dimensions after its formation were continuously monitored by measuring axial and radial strains locally. Both conventional undrained triaxial tests and constant volume tests with continuous correction for the membrane penetration effects were performed at constant cell pressure using loose saturated Toyoura sand.

The adopted lubrication system worked effectively up to an axial strain of 4 % for specimens with a height to diameter ratio of $H/D=2$, while for $H/D=1$ lateral strains were uniform until the end of the tests ($\varepsilon_a = 25\%$).

The SS and PT envelope and their projection in the state diagram (SS or PT line) were established based on results from 29 tests. The condition which triggers the softening behaviour, i.e. the so called Critical Stress Ratio (CSR) envelope was also determined. The test results showed the importance of careful control of the test factors mentioned above determining the undrained behaviour of saturated very loose sand under truly constant conditions.

L. Gabrielaitis, M. Jamiolkowski, D. Lo Presti e I. Puci

OPERATIONAL SAND STIFFNESS FROM LARGE SCALE LOAD TESTS ON RECONSTITUTED SAND BEDS.

Baltic Geotechnics IX 2000, Pärnu, Estonia 9-12 May 2000. Estonian Geotechnical Society. Published by Akadeemia Trükk, Niine, 10414 Tallinn, Estonia. pp: 84-91, paper 1.14

This paper is aimed at obtaining the operational sand stiffness from two large-scale load tests performed on a square rigid foundation, 1 m side, resting on a sand bed 4.6 by 4.6 m in plan and 3 m deep. Two samples of Ticino sand were reconstituted at two different relative densities ($D_r \cong 45$ and 85 %). In the case of the low-density sample a maximum vertical pressure of about 100 kPa was applied. For the high-density sample the maximum vertical pressure was equal to about 300 kPa. The observed settlements have been compared to those inferred from a conventional computation methods. Particular attention was devoted to the analysis of creep deformations. The load displacement curves were used to determine the operational soil stiffness. The obtained values were compared to those inferred from plate load tests performed in Calibration Chamber on a circular, rigid, deep foundation resting on reconstituted Ticino sand samples (Ghionna et al. 1994).

S. Foti, D.C.F. Lo Presti e O. Pallara

INDAGINI GEOTECNICHE PER LA VALUTAZIONE DEGLI EFFETTI LOCALI DEI TERREMOTI A CASTELNUOVO GARFAGNANA

Atti Convegno GeoBen 2000, Geological and Geotechnical Influences in the Preservation of Historical and Cultural Heritage. Torino 7-9 Giugno. pp: 501-510

Nella salvaguardia del patrimonio storico-monumentale nazionale, l'adeguamento sismico ha un ruolo fondamentale e pertanto una accurata valutazione degli effetti locali dei terremoti è il necessario presupposto per gli interventi in tutte le regioni a rischio. In tale contesto, la caratterizzazione geotecnica dei depositi costituisce un elemento fondamentale, per la corretta modellazione numerica degli eventi sismici. L'effettuazione di prove in sito e prove di laboratorio è un requisito necessario per una modellazione che riesca a tenere debitamente in conto gli effetti della non-linearità dei terreni.

Il progetto Valutazione degli Effetti Locali, avviato dalla Regione Toscana per la definizione del rischio sismico nei comuni della Garfagnana e della Lunigiana, prevede una fase di caratterizzazione dei geo-materiali relativamente accurata in relazione all'estensione dei territori da indagare, al fine di ottenere una base dati sufficiente per una corretta modellazione. Nel presente lavoro si riportano i risultati relativi a prove geotecniche in sito e di laboratorio eseguite nel comune di Castelnuovo in Garfagnana.

In the safeguard of the Italian National Heritage, the aspects related to the seismic retrofit are of great importance, considering the high degree of seismic risk. In this view an accurate evaluation of the possible local seismic effects is necessary. For this purpose, geotechnical characterisation of soil deposits plays a major role in the numerical modelling. In situ and laboratory tests are both necessary for a correct modelling of the non-linear behaviour of soils.

The Tuscany local government has started a comprehensive project for the evaluation of site effects in the territories of Garfagnana and Lunigiana, which are under its authority. Such a project requires an accurate characterisation of geo-materials in the whole zone interested by the study, in the view of having sufficient data for a correct modelling of seismic events.

This paper reports the results of a series of geotechnical tests, both in situ and in the laboratory, that have been conducted for the characterisation of the soil deposits in the town of Castelnuovo Garfagnana.

D.C.F. Lo Presti, C. Lai, A. Camelliti e T. Crespellani

ANALISI NON LINEARE DELLA RISPOSTA SISMICA DEI TERRENI

Atti Convegno GeoBen 2000, Geological and Geotechnical Influences in the Preservation of Historical and Cultural Heritage. Torino 7-9 Giugno. pp 601-612.

Questo articolo ha per oggetto lo sviluppo di un codice di calcolo per la determinazione della risposta sismica locale di un deposito di terreno in condizioni di sollecitazione monodimensionale e nell'ipotesi di un comportamento costitutivo dei terreni di tipo non-lineare (ONDA). La non linearità è stata modellata assumendo 1) una curva "scheletro" finalizzata a descrivere il comportamento sforzi-deformazioni di primo carico, e 2) una "legge" che consenta di modellare il comportamento di scarico-ricarico al persistere dell'eccitazione sismica (KRAMER 1996). La curva scheletro è ottenibile da prove sperimentali quasi statiche e monotone. Per quel che concerne la legge per modellare i cicli di scarico-ricarico, una scelta comunemente usata è quella della regola di Masing (MASING 1926) per cui i rami dei cicli di scarico e ricarica della curva sforzi-deformazioni sono assunti omotetici alla curva di primo carico con un fattore di scala (n) uguale a 2. In questo lavoro, i cicli di scarico-ricarico sono stati modellati con il 2° Criterio di Masing modificato (TATSUOKA et al. 1993) dall'assunzione di un fattore di scala (n) non necessariamente uguale a 2. In particolare valori di (n) maggiori di 2 sono utilizzati per modellare un comportamento di tipo incrudente (incrudimento ciclico) mentre i valori di n possono risultare persino minori di 2 per nel caso di comportamento di tipo rammollente (degradazione ciclica del materiale). ONDA pertanto, offre la possibilità di determinare le deformazioni permanenti che si sviluppano a seguito dell'eccitazione sismica e quindi di modellare la degradazione ciclica del materiale.

ONDA ed il codice di calcolo di tipo lineare equivalente SHAKE (SCHNABEL et al. 1972) sono stati utilizzati per valutare la risposta sismica locale nell'abitato di Fabriano. Le differenze ottenute con i due metodi di analisi vengono attentamente discusse.

This paper describes a newly developed computer code for performing one-dimensional, non-linear dynamic analysis (ONDA) of soil deposits. Non-linearity is modelled by assuming 1) a "backbone" curve to describe the initial loading stress-strain behaviour, and 2) a "rule" for modelling the unloading-reloading behaviour as the seismic excitation progresses (KRAMER 1996). The backbone curve can be obtained from quasi-static monotonic loading tests. Concerning the rule to model the unloading-reloading soil behaviour a

common choice is the so-called “Masing rule” (MASING 1926) by which it is assumed that the unload-reload branches of the stress-strain curve have the same shape of first loading curve with a scale factor (n) equal to 2. In this work the 2^o Masing rule has been modified by assuming a factor (n) not necessarily equal to 2 (TATSUOKA et al. 1993). In particular, in case of cyclic hardening, n will be greater than 2, while in the case of cyclic softening n can become even smaller than 2. ONDA gives then the possibility of computing permanent strains that are developed during seismic excitation and hence of taking into account the phenomenon of material degradation.

ONDA and the equivalent linear code SHAKE (SCHNABEL et al. 1972) have been used to evaluate the seismic response at Fabriano. Differences between the results obtained by ONDA and SHAKE are discussed in detail.

**M. Ferrini, V. Petrini, D. Lo Presti, I. Puci, L. Luzi, F. Pergalani,
e P. Signanini**

**NUMERICAL MODELLING FOR THE EVALUATION OF
SEISMIC RESPONSE AT CASTELNUOVO GARFAGNANA IN
CENTRAL ITALY**

XV ICSMGE, Istanbul 27-31 August 2001, Special Volume of TC4,
Lessons Learned from Recent Strong Earthquakes. pp 149-154.

ABSTRACT: This paper mainly focuses on the evaluation of the seismic response in the town of Castelnuovo Garfagnana. It represents the conclusive part of a multidisciplinary work that includes geological, geophysical and geotechnical investigations and the evaluation of the expected strong ground motion at the bedrock. Several computer codes have been used to compare 1D and 2D approaches and to evaluate, for the 1D case only, the effect of non-linear vs. linear-equivalent stress-strain soil models.

The main objectives of this paper are i) to point out capabilities and limitations of different models and ii) to provide the local authorities with a tool for land use planning, building construction and retrofitting of pre-existing structures.

The results are expressed as response spectra and amplification coefficients for two representative geologic cross-sections in the territory of Castelnuovo Garfagnana.

E. Calosi, M. Ferrini, A. Cancelli, S. Foti, D. Lo Presti, O. Pallara, G. D'Amato Avanzi, A. Pochini, A. Puccinelli, L. Luzi, M. Rainone e P. Signanini

GEOLOGICAL AND GEOTECHNICAL INVESTIGATIONS FOR THE SEISMIC RESPONSE ANALYSIS AT CASTELNUOVO GARFAGNANA IN CENTRAL ITALY

XV ICSMGE, Istanbul 27-31 August 2001, Special Volume of TC4, Lessons Learned from Recent Strong Earthquakes. pp 141-148.

ABSTRACT: The Tuscany regional government (Regione Toscana) has started a comprehensive project for the evaluation of site effects in about 60 municipalities, located in the territories of Garfagnana and Lunigiana (Ferrini et al. 2000). For this purpose a multidisciplinary task force is working in order to assess the elastic response spectra taking into account both topographic and stratigraphic amplifications. The main objective is to provide a tool for land use planning, design of new structures and retrofitting of the existing ones. Such activity has been completed for Castelnuovo Garfagnana, that is a town of about 6500 inhabitants with a territory of about 28 square Km.

This paper mainly focuses on the geological, geophysical and geotechnical investigations concerning the town of Castelnuovo Garfagnana. The results are summarised with special attention to the following aspects:

- interplay between geological, geophysical and geotechnical investigations;
- comparison among different geophysical testing methods (Down-Hole, SASW-fk, Seismic refraction);
- comparison among different laboratory tests (Monotonic and cyclic triaxial tests, resonant column tests, cyclic torsional shear tests);
- assessment of the input parameters for seismic analysis, from the experimental results;
- creation of an integrated database.

The main objectives of this paper are i) to point out capabilities and limitations of different in situ and laboratory testing methods and ii) to provide enough information on a well-documented case history. The results of seismic analysis at Castelnuovo Garfagnana are reported in a companion paper.

A.Cavallaro, V. Fioravante, G. Lanzo, D. Lo Presti, Oronzo Pallara S. Rampello, A. d'Onofrio, F. Santucci de Magistris e F. Silvestri

REPORT ON THE CURRENT SITUATION OF LABORATORY STRESS-STRAIN TESTING OF GEOMATERIALS IN ITALY AND ITS USE IN PRACTICE

XV ICSMGE, Istanbul 27-31 August 2001, Special Volume of TC29, Advanced Laboratory stress-strain testing of geomaterials. pp 15-44.

ABSTRACT: Laboratory testing for routine geotechnical design in Italy is mainly based on the results of oedometer, triaxial and direct shear tests. These tests provide compressibility, undrained shear strength and shear strength characteristics generally used in simplified design procedures. The undrained shear strength and/or shear strength parameters are inferred from UU or CU triaxial compression tests performed on specimens 38 mm in diameter and $H/D \approx 2$. The shear strength parameters are also inferred from direct shear tests performed under drained conditions.

A booklet prepared by the Italian Geotechnical Society (AGI, 1994) suggests the procedures recommended for laboratory tests such as: grain size analysis, oedometer, direct shear and triaxial tests. Anyway, none of these suggested methods deal with the assessment of the stress-strain relationship of geomaterials. In a separate booklet (AGI, 1977) recommendations are provided in order to:

- program geotechnical investigations
- retrieve soil samples
- draw stratigraphic and geotechnical logging
- install piezometers
- determine in situ soil permeability
- perform in situ tests (CPT, SPT and FVT)

The above mentioned documents are written in Italian and mainly follow the recommendations of the International Society (ISSMGE). Associations of commercial laboratories (ALGI) and contractors (ANISIG) also guarantee that laboratory and in situ tests (including sampling and borehole logging) are carried out according to the AGI recommendations.

A comprehensive review of AGI recommendations on both in situ and laboratory tests is currently in progress. The reviewed version will closely refer to the principles addressed by Parts 2 and 3 of Eurocode 7 (Geotechnical design).

The Italian Ministry of Public Work (MLLPP) has recently established that Geotechnical Laboratories in Italy should guarantee some requirements and should follow given standards in performing laboratory and in situ tests on soils and rocks

(MLLPP, 1999). According to the MLLPP the AGI recommendations will become mandatory. For those tests not considered by AGI it is suggested to follow the international standards such as ASTM, ISRM recommendations and BS 1377 - 5930.

Advanced stress-strain testing is in practice required only for special projects such as microzonation studies and/or design of very important infrastructures especially in seismic areas.

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LOW-STRAIN STIFFNESS AND MATERIAL DAMPING RATIO COUPLING IN SOILS.

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ABSTRACT: Experimental evidence shows that soils subjected to dynamic excitations have both the ability to store and to dissipate strain energy. The phenomenon of energy dissipation takes place even at very small strain levels, below the so-called linear cyclic threshold shear strain. During low-strain harmonic oscillations, mechanical energy is exchanged between the loading apparatus and a soil specimen. Because this energy exchange takes place in a *finite* amount of time (which is called the *relaxation time*), stress and strain are out of phase and energy is dissipated during the process of cyclic loading. This type of material behaviour, where the phenomenon of energy dissipation takes place over a finite amount of time can be conveniently described from a phenomenological point of view by the theory of viscoelasticity. It is an experimental fact in soils that at strain levels below the linear cyclic threshold shear strain, phenomena of *instantaneous* energy dissipation do not take place or if they do they are negligible. An important result predicted by the linear theory of viscoelasticity, is the functional dependence between the velocity of propagation of body waves and material-damping ratio. The coupling existing between these two important parameters is a consequence of material dispersion, a phenomenon by which the velocity of propagation of mechanical disturbances in dissipative media is frequency dependent. Viscoelastic materials, and hence soils subjected to low-strain harmonic excitations, are inherently dispersive. A corollary of the functional dependence of the velocity of propagation of body waves upon material damping ratio is that a correct procedure for the experimental measurement of these parameters should determine them simultaneously and at the same frequency of excitation. However, it is a common practice in laboratory measurements to determine V_S and D_S separately. In this article the authors present a new experimental procedure to be conducted with the resonant column apparatus where the shear wave velocity and shear-damping ratio are determined simultaneously. Since these parameters are determined at specific frequencies of excitation, the proposed method is also well suited to investigate the frequency dependence laws of these important soil parameters. The novel procedure, which offers a re-interpretation of the resonant column test, has been applied in a series of experiments using both remoulded and undisturbed clay specimens. The paper shows the results

obtained and compare them with those determined with conventional techniques.

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THE DEGRADATION BEHAVIOUR OF FABRIANO SOIL DURING CYCLIC LOADING.

Italian Geotechnical Review, Vol. XXXV, No. 2, pp. 107-117.

When the shear strain is higher than the so called volumetric threshold, degradation phenomena occur. In this paper the possibility of modelling the degradation behaviour of Fabriano soil with a simple law is examined. The study shows that the modified 2nd Masing Rule (Masing 1926, Tatsuoka et al. 1993) is capable of well reproducing the experimental stress strain curve of natural clays during cyclic loading. The modified 2nd Masing rule assumes that the scale amplification factor for unload-reload branches (n) is not necessarily equal to 2 as postulated by the original 2nd Masing rule. In particular it was found that $n=6$ in the case of stable cycles. When degradation phenomena occur, n decreases. The limited experimental data did not allow the authors to determine the dependence of n on shear strain and number of loading cycles. On the other hand, the degradation parameter (t) proposed by Idriss et al. (1978) was computed according to the procedure suggested by Lin and Chen (1991). The values of t resulted to be much higher than those available in literature.

The results obtained for fabriano soil have been compared with others data available in literature and in particular with the results obtained for undisturbed Augusta, Catania, Pisa clays and reconstituted Toyoura sand (Cavallaro 1997, Lo Presti et al. 1998, Ionescu 1999, Lo Presti et al. 2000).

Lo Presti D.C.F. e Puci I.

**IMPIEGO DELLE PROVE PENETROMETRICHE
DINAMICHE PER LA CARATTERIZZAZIONE MECCANICA
DEI TERRENI**

XVIII Ciclo di Conferenze di Geotecnica di Torino

La presente nota descrive le prove penetrometriche dinamiche a punta aperta come la Standard Penetration Test (SPT) ed a punta chiusa come la Standard Cone Penetration Test (SCPT). Negli anni più recenti la sigla SCPT è stata utilizzata per designare una particolare prova penetrometrica statica (Seismic Cone Penetration Test), cosicché nel proseguimento la prova penetrometrica dinamica a punta chiusa sarà designata con la sigla DP (Dynamic Probing) in accordo con la terminologia adottata dal Technical Committee on Penetration Testing dell'International Society of Soil Mechanics and Geotechnical Engineering – ISSMGE (Stefanoff et al. 1988). In particolare, per entrambe le metodologie di prova, saranno descritte le attrezzature (molto brevemente), le modalità di esecuzione (confrontando i diversi standards) ed i metodi di interpretazione al fine di pervenire alla caratterizzazione dei depositi ed alla definizione dei parametri di progetto. Quest'ultimo aspetto sarà trattato ponendo particolare attenzione al caso dei depositi ghiaiosi.

In una precedente edizione delle Conferenze di Geotecnica di Torino lo stesso argomento era stato trattato nei lavori di Bruzzi e Cestari (1983) e Pasqualini (1983) che rappresentano punti di riferimento fondamentali per quel che concerne la letteratura tecnica in lingua italiana su tale argomento. Un altro lavoro in lingua italiana riguardante le attrezzature e le modalità di prova è quello di Cestari (1990).

Lo scopo delle prove penetrometriche dinamiche è quello di determinare il numero di colpi (N_{SPT}, N_{30}, N_{20}) necessari ad infiggere, per una data profondità (tipicamente 300 mm), un tubo campionatore o una punta chiusa di dimensioni standard mediante battitura. La prova SPT può essere effettuata in fori di sondaggio, oppure in fori appositamente eseguiti. Tale requisito non risulta invece necessario per la prova DP che in tal senso risulta economicamente vantaggiosa, tuttavia, al fine di evitare l'attrito laterale sulla batteria delle aste, è necessario eseguire la prova utilizzando dei tubi di rivestimento.

Le prove vengono preferibilmente eseguite in terreni granulari (sabbie e ghiaie). Tuttavia è possibile realizzarle in qualsiasi terreno sciolto ed anche nel caso di alcune rocce tenere. Unicamente in presenza di grossi elementi lapidei, questa tipologia di prova perde di significato.

I valori misurati nel corso della prova consentono una stima qualitativa della consistenza del terreno. Inoltre è possibile stimare mediante correlazioni empiriche i seguenti parametri:

- la densità relativa (D_R), l'angolo di resistenza al taglio (ϕ') e la resistenza alla liquefazione (τ_1 / σ'_{vo}) dei terreni granulari;
- il modulo di taglio a piccole deformazioni (G_o);
- la resistenza al taglio non drenata c_u di terreni a grana fine e rocce tenere.

E' anche diffuso l'impiego diretto dei risultati delle prove per il calcolo dei cedimenti delle fondazioni superficiali in sabbia (Burland e Burbridge, 1984, Berardi e Lancellotta, 1991) e per il calcolo della capacità portante dei pali di fondazione. Tale impiego è basato sull'esperienza locale oppure su un'estensione di metodi che utilizzano i risultati delle prove penetrometriche statiche (CPT). In questo secondo caso, è necessario utilizzare delle correlazioni empiriche tra q_c ed N_{SPT} . Nella presente nota vengono illustrate e commentate le correlazioni empiriche utilizzate per la determinazione dei parametri sopra indicati e vengono brevemente riassunti e commentati i metodi che utilizzano direttamente i risultati delle prove penetrometriche dinamiche per la verifica delle fondazioni superficiali e profonde.

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INNOVATION IN SOIL TESTING

IS Torino 99, Theme Lecture, Balkema, Vol. II, pp:1027-1076.

This paper describes the experimental determination of the stress-strain properties and stiffness of geomaterials in the pre-failure range. In particular, the following aspects are described in detail: i) importance of accurate measurements of stress and strain in laboratory tests, ii) assessment in the laboratory of sample disturbance, iii) development of appropriate laboratory reconsolidation techniques to minimise the effects of sampling disturbance and iv) use of seismic tests to obtain reference stiffness (E_o , G_o) and damping ratio (D_o) values.