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ABSTRACT: In order to determine dynamic parameters to use for seismic microzoning purposes in a new development area near Florence, the dynamic behaviour of the alluvial silty clays situated in the upper 60 m of the deposit was experimentally investigated using geophysical surveys and cyclic laboratory tests. Previous studies on the geotechnical properties of the clays of Florence revealed that, in spite of some similarities in a comparison with other coeval clays described in the literature this soil exhibits a few anomalies, as e.g. higher variations between field and laboratory shear waves velocities and remarkable differences in the coefficients of the empirical relations that link the shear modulus to other geotechnical parameters. Moreover, many current correlations from CPT and DMT tests resulted not valid. This peculiar behaviour cannot be explained in terms of cementation, because the carbonatic contents values, even if scattered, are practically normal. The objectives of the test program herein described were, therefore, as much to deepen our knowledge of the dynamic behaviour of the soil both in situ and in laboratory, at low and high strain level, as to find out the reasons for this different behaviour, by examining the possible influence of sample disturbance and of long-term effects, as well as of different geophysical survey techniques. The results of crosshole tests (CH), of spectral analysis of superficial waves surveys (SASW), of resonant column tests (RC) and of triaxial tests with measurement of shear and longitudinal wave velocities (V_{tl}), as well as the empirical relationships obtained between geotechnical parameters are analyzed and discussed.

1. INTRODUCTION

The present study illustrates the more significant results of an in situ and laboratory testing program, carried out to gather information about the dynamic behaviour of a deep cohesive deposit, located in the north-western part of Florence, representative of a large part of the silty clays forming the fluvial-lacustrine basin between Florence and Pistoia.
On the site, characterized by a medium seismic activity, a large-scale urban development project for the construction of a new residential settlement, having an extension of 2,6 km^2, was proposed. Many in situ and laboratory tests, including standard penetration tests (SPT), cone penetration tests (CPT and CPTU), Marchetti dilatometer tests (DMT) and borehole geophysical surveys with the cross-hole method (CH), were performed to evaluate the seismic response of the deposit. Even if the earthquakes foreseen in the area are not severe - a peak of acceleration below 0.15g is expected at the bedrock, with a 10% probability of exceedance, in a period of 50 years (Vannucchi et al., 1989; Crespellani et al., 1989c) - due to the high depth of the deposit, local amplification effects are to be foreseen.
The results of the geotechnical investigations and of the seismic studies up till now carried out to evaluate the local seismic response, have been illustrated in various papers (Vannucchi, 1987; Ghinelli and Vannucchi, 1988; Crespellani et al., 1989a, Crespellani et al., 1989b; Crespellani et al., 1989c; Vannucchi et al. 1989).

The objectives of the test program herein described were essentially 1. to deepen our knowledge of the homogenity of the deposit 2. to increase our understanding of the dynamic behaviour of the soil both in situ and in laboratory, at low and high strain levels 3. to find out the reasons for the different behaviour exhibited by Florence clays in comparison with other clays described in the literature, examining the possible influence of sample disturbance and of long-term effects, as well as of different geophysical survey techniques.
Therefore, in addition to standard static tests, the test program included in situ geophysical surveys with the SASW technique (Spectral Analysis Superficial Waves), laboratory cyclic tests employing the resonant column (RC), cyclic triaxial (CTX), the triaxial apparatus with measurement of shear and compression wave velocities by means of piezoelectrical crystals (V_{tl}). High-quality undisturbed specimens were obtained both with current sampling techniques and from cubic samples.
In reality, as will be demonstrated here as follows, the new experimental results, even though very profitable, explained only in part the discrepancies encountered between field and laboratory data and data in the literature. In fact, e.g. even removing sampling disturbance and aging effects, in situ shear wave values and shear modulus showed still remarkably higher results than those obtained in the laboratory.

2. SITE AND SOIL CONDITIONS

In the area investigated, the first 60m from the ground surface are constituted by alluvial brown silty clays with diffuse calcareous nodules, often alternated with layers and lenses of gravel in an abundant clayey-silty matrix; below, beyond 60 m grey-blue silty clays of lacustrine origin are encountered.
The deposition of these sediments occurred mainly in the Villafranchian Age. Successively, various tectonic events lifted the area around Florence, so that it is crossed by many faults and the substratum depth is highly variable (from 50 m to more than 400 m). At the site the bedrock is situated about 300 m. The ground surface is rather flat, and the water static level is at depths variable between 0.5 m and 2.2 m from the ground surface.
In recent years the site has been subjected to an extensive investigation program, which showed that the subsoil is relatively uniform and that the deposit can be considered 'uniformly nonhomogeneus'.
The geotechnical properties of the alluvial clays which form the object of the present study were experimentally investigated by means of 41 boreholes (in which 345 SPT were performed), 108 CPT, 6 CPTU, 72 DMT and laboratory tests on 77 samples (**Fig. 1**). On a representative site of the deposit two boreholes at a distance of 5 m were explored using the cross-hole method. The results of these investigations and of geotechnical interpretations of the data have been described in detail in various papers of some of the Authors (Vannucchi, 1987; Ghinelli and Vannucchi, 1988; Crespellani et al., 1989a, Crespellani et al., 1989b; Crespellani et al., 1989c; Vannucchi et al. 1989). Synthetically, these clays are generally slightly overconsolidated, consistent, not very compressible, nor swelling, of very low permeability, and present a high shear strength in undrained conditions and a brittle failure. Their average geotechnical characteristics, measured on a large number of undisturbed samples taken at the depth of between 1.5 m and 44.5 m, can be deduced from Table 1.

Table 1 - Main properties of Florence alluvial clays

	w (%)	wl (%)	wp (%)	Ip (%)	gamma KN/m^3	Gs (-)	eo (-)	OCR (-)	Cc (-)	Cs (-)	cu (KPa)
MV	23.2	55.2	23.1	32.1	20.5	2.74	0.62	1.67	.214	.058	143
SD	4.2	6.5	2.7	6.4	0.6	0.04	0.10	0.65	.052	.025	59

3. PREVIOUS INVESTIGATION RESULTS

From the analysis of the field and laboratory results, and by comparing the geotechnical behaviour of the clays of Florence with that of other clays, some conclusions on the peculiarities of the Florence clays have been drawn (Crespellani et al., 1989a, Crespellani et al., 1989b; Crespellani et al., 1989c; Vannucchi et al. 1989):

1. By comparing CPT, DMT and laboratory data, the following behaviour was observed (Crespellani et al., 1989a). As concerns soil classification, both CPT and DMT offered estimates in good agreement with laboratory data. Instead, the OCR-values from CPT and DMT, even if quite comparable with each other, are completely out of scale in comparison to the laboratory values, ranging from more than 10 up to 100, whereas the oedometric values vary from 1.5 to 7 (the OCR distribution is strongly asymmetric; cfr Crespellani et al., 1989b). Consequently, the estimates of K_o obtained from CPT and DMT, even if consistent with each other, are decidedly higher (K_o = 1,5 - 4) than those measured in the oedometric tests with measurement of K_o (K_o = 0.7 - 1.1). The laboratory measures and CPT estimates of oedometric modulus (M) - obtained with the relationship of Mitchell and Gardner (1975) - are in good agreement, but are strongly inconsistent with the values obtained with DMT. Instead, all direct and indirect estimates of the undrained strength (CPT, DMT and undrained triaxial tests) are, practically speaking, comparable and satisfactory.
As the empirical correlations linking the various parameters are valid only for uncemented soils, the first hypothesis advanced was that carbonatic contents were high; but the numerous measures performed showed that the carbonatic content values, even if rather scattered, are, practically speaking, within the norm, and cannot be considered the only element responsible for the invalidity of usual-type correlations.
2. From comparisons of CH with SPT, CPT and DMT results, a general trend was observed . As can be noted in **Table 2**, the correlations valid for the site are generally always comparable with those reported in the literature; but also, the most reliable correlations obtained for other sites (including a few relationships valid for sands and gravels) always underestimate the dynamic stiffness of the deposit. For example, as shown in **Fig. 2**, the straight lines 1 and 2, obtained with data from the site (respectively, collecting only the data of the area investigated and the data from nearby areas), are definitely in a higher position compared to the lines obtained for other sites. The relationships included in the hatched area were specified in **Table 3** (Crespellani et al., 1989b).
3. Preliminary attempts to compare some laboratory dynamic tests (RC, V_{t1}) with in situ values observed by CH surveys (Crespellani et al., 1989c), indicated Go(situ)/Go(lab) ratios between 3 and 7, considerably higher than those generally obtained.

Table 2. Some empirical correlations between in situ parameters obtained for the Florence clays having as an equation:
$Y = aX^b$
r = correlation coefficient

Y	X	a	b	r
V_s(m/s)	N_{spt}	83.3	0.471	0.499
V_s(m/s)	z(m)	252.4	0.237	0.690
Go(MPa)	N_{spt}	14.2	0.942	0.499
Go(MPa)	sigma'-m(MPa)	25.7	0.573	0.663

4. TEST PROGRAMME

The results of the previous investigations, which revealed some contrasting features, suggested performing a new test programme in order to deepen our understanding of the in situ and laboratory behaviour of the clays of Florence and to study the influence of a few factors, such as aging and sample disturbance, as well as to assess the spatial variability of dynamic characteristics within the deposit.
A program of additional in situ and laboratory tests was then studied such as to allow the following crossed comparisons between:

a) Go values obtained with different in situ and laboratory equipment;
b) dynamic parameters and other geotechnical parameters;
c) empirical relations valid for the site and for other cohesive deposits.

4.1 In situ surveys with the SASW method

Since the area to be investigated is very large, the SASW method (Spectral Analysis Superficial Waves) was considered to be a suitable solution, for the following reasons 1) its cost-effectiveness 2) the possibility that it gives of controlling homogeneity of the deposit 3) its successful recent applications.
The SASW method is a relatively new in situ testing seismic technique for determining shear wave velocity profiles at soil sites, using the dispersive nature of the superficial waves (Rayleigh) in layered media. The theoretical fundamentals have been explained in detail in many papers, and various geotechnical applications have been recently presented (Nazarian and Stokoe, 1986).
The shear modulus values estimated from SASW testing are comparable to those deduced from CH. On the site in question, 6 locations, some of them rather distant, were chosen for performance of the SASW tests; two of the lines explored, orthogonal to each other, were chosen in such a way as to cross the boheroles where the cross-hole tests were performed. In this way it was possible to make a direct control of the effectiveness of the SASW tests. The depth investigated was 30 m, and a bulldozer was employed as the source at low frequencies (< 3Hz).
The resulting shear wave velocity profiles are compared with the CH profile in **Fig. 3**. This comparison indicates that, as the SASW tests were performed in locations greatly distant from each other, the difference between the shear wave velocity profiles in the deposit is limited and confirms the result of previous investigations, i.e. that the deposit can be considered 'uniformly nonhomogeneous'.

Table 3. Relashionships Vs versus N_{spt} for different soils
$Vs = a\ N_{spt}^{\ b}$ (MPa)
r = correlation coefficient

N. Authors (cfr. Crespellani et al.,1989b)	a	b	r	Soil
1. Crespellani et al.(1989b)	83.3	0.471	0.499	Clay
2. Crespellani et al.(1989b)	71.5	0.535	0.500	Clay
3. Seed (1983)	55.0	0.500	-	-
4. Maugeri (1983)	48.0	0.550	-	Clay
5. Muzzi (1983)	102.0	0.292	-	Clay
6. Imai (1977)	91.2	0.400	-	All
7. Imai et al.(1982)	97.0	0.314	0.868	All
8. Imai et al.(1982)	107.0	0.274	0.721	Clay
9. Imai et al.(1982)	87.8	0.292	0.690	Sand
10. Imai et al.(1982)	75.4	0.351	0.791	Gravel
11. Imai et al.(1982)	128.0	0.257	0.712	Clay
12. Imai et al.(1982)	110.0	0.285	0.714	Sand
13. Imai et al.(1982)	136.0	0.246	0.550	Gravel
14. Otha & Goto (1978)	85.6	0.340	0.726	Clay
15. Otha & Goto (1978)	93.1	0.249	0.787	Clay
16. Otha & Goto (1978)	134.8	0.249	0.787	Clay
17. Sykora et al.(1983)	100.0	0.300	-	Sand
18. Muzzi (1984)	80.6	0.331	-	Sand
19. Ohsaki and Iwasaki (1973)	81.4	0.340	-	All
20. Ohsaki and Iwasaki (1973)	56.0	0.500	-	Sand

4.2 Laboratory testing

Seven undisturbed samples, two of them from large cubic samples, were tested under dynamic and static loading. The samples were drawn from the CH boreholes (or close to them) at such depths that the dependence of dynamic properties on depth z could be investigated, and laboratory results could be compared with in situ seismic records.
The physical characteristics of the soils tested are shown in **Table 4**. It may be seen that there is practically no difference between the samples, except that in the samples in the upper part of the deposit the clay fraction and plasticity are higher. Their properties are also in good agreement with the values of Table 1, measured on samples recovered from many boreholes within the deposit.
Standard RC tests, resonant column tests with time effects measurements, measurements of shear wave velocity by means of piezoelectric crystals and cyclic triaxial tests were performed on the samples. Static tests, such as UU triaxial (TX UU), triaxial with isotropically consolidated (TX CIU) and K_o consolidated (TX CK_oU), edometric (EdoIL) and oedometric with measurement of K_o (EdoILK_o) were also carried out.
The RC test device used in the investigation was the fixed-free Stokoe's type ; the sample measured 3 cm in diameter and 7.6 cm in height.

5. LABORATORY RESULTS

The main results of the V_{tl} and RC tests are presented in **Tables 5 and 6**. The values of the dynamic parameters and the empirical relationships obtained will be discussed separately.

5.1. Shear modulus

a) Correlations Go - sigma'-c
As can be seen in **Tables 5** and **6**, the Go values obtained in RC and V_{tl} tests at the same confining pressures are in close agreement, even if the test conditions are different.
The correlation Go - sigma'-c obtained for the clays of Florence has clearly the form Go = K sigma'-c^n.
The experimental values of the K and n coefficients of each sample tested, as well as the values obtained for all the samples together, are shown in **Table 7**. In **Fig. 4** the regression straight line is plotted in a log scale referring to all measurements.
In **Fig. 5** the exponent n has been correlated to

Table 4 - Physical properties of the samples

N. (-)	S/C (-)	z (m)	gamma (KN/m3)	w (%)	w_l (%)	w_p (%)	I_p (%)	Gs (-)	CCM (%)	%<74micr (%)	Gr. (%)	Sa. (%)	Si. (%)	Cl. (%)	A=Ip/CF (-)
1	1cub	3.15	19.7	26	67.5	19.5	48	2.761	2.5	92	5	4	30	61	0.79
2	2cub	3.15	19.7	25.5	68.1	19.6	48.5	2.748	TR.	96	3	3	33	61	0.80
3	SS1/1	6.35	20.8	21.5	63.1	17	46.1	ND	11.5	61	36	5	22	37	1.25
4	5/1	6.65	20.1	24	66.7	18.9	47.8	2.774	ND	100	0	0	34	65	0.74
5	SS2/1	16.85	20.8	21	49.5	16.3	33.2	2.75	TR	96	0	6	46	48	0.69
6	4/1	21.35	20.8	21	53	17.7	35.3	2.762	11.5	84	4	13	35	47	0.75
7	4/2	33.25	20.9	21	50.1	16.3	33.8	2.756	24.0	89	6	7	41	46	0.73

CCM = carbonatic and magnesic content

Table 5 - V_{tl} results

N. (-)	z (m)	sigma'-c (MPa)	V_s (m/s)	V_l (m/s)	Go (MPa)
1/1	3.15	0.00	160.7	-	50.5
1/2	3.15	0.052	187.3	1894	69.8
4/1	6.84	0.00	192.4	-	76.3
4/2	6.84	0.20	218.2	1750	99.2
5/1	16.83	0.00	227.8	-	110.2
5/2	16.83	0.06	278.6	709	164.8
5/3	16.83	0.12	281.7	1727	168.5
5/4	16.83	0.19	283.3	1727	170.5
7/1	33.14	0.00	187.6	1842	75
7/2	33.14	0.12	218.8	1873	102
7/3	33.14	0.24	223.7	1880	106.7
7/4	33.14	0.35	226.2	1883	109.1
7/5	33.41	0.35	236.7	1827	119.6

I_p and even if the correlation is low, nevertheless it seems possible to hypothesize the existence of a link between them. **Table 8** compare the coefficients obtained for the site with analogous coefficients found by other Authors, and indicates the comparability of experimental results obtained for the Florence clays.

b) Correlation Go-e
The relationship between Go and the void ratio e, shown in **Fig. 6**, exhibits, as can be expected, a greater scattering than the relationship Go-sigma'-c. Nevertheless, the trend of the experimental data is clearly linear in the semilog scale.

c) Time effects
The time dependence of shear modulus at low strain levels was studied in the laboratory in the sample N. 2, confined at a pressure of 0,2 MPa and held at this pressure for a period of two weeks. **Fig. 7** shows the effect of confinement time on shear modulus. As is well known, long-term effects are generally expressed by two coefficients I_G and N_G, respectively, representing the change in shear modulus for a logarithmic cycle of time and this same quantity normalized with respect to Go, conventionally measured after 1000 min of confinement. The purpose of the normalization is to remove the influence of confining pressure. The values of these parameters obtained for the sample tested are:

$$I_G = 7.239 \text{ MPa}$$
$$G_{1000} = 79.00 \text{ MPa}$$
$$N_G = 9.162 \text{ \%}$$

Table 6 - RC tests results

N. (-)	z (m)	sigma-c (Mpa)	e (-)	Go (MPa)
1/1	3.15	0.06	0.753	62.7
1/2	3.15	0.1	0.746	69.3
1/3	3.15	0.2	0.728	85.9
1/4	3.15	0.6	0.684	138.4
1/5	3.15	0.1	0.772	81.4
2/1	3.15	0.06	0.738	56.5
2/2	3.15	0.1	0.732	64.5
2/3	3.15	0.2	0.719	88.5
4/1	6.69	0.09	0.678	78.1
4/2	6.69	0.13	0.678	81.2
4/3	6.69	0.19	0.677	90.4
4/4	6.69	0.29	0.668	103.1
5/1	16.94	0.13	0.61	74.6
5/2	16.94	0.19	0.594	84.7
5/3	16.94	0.23	0.573	92.7
5/4	16.94	0.3	0.543	106.3
6/1	21.61	0.16	0.582	94.1
6/2	21.61	0.23	0.563	105.5
6/3	21.61	0.35	0.511	132.3
7/1	33.25	0.28	0.582	96.6
7/2	33.25	0.35	0.552	105.1
7/3	33.25	0.45	0.509	120.4

Table 7 - K and n coefficients of the relationship
$Go = K \text{ sigma'-c}^n$ (MPa)
obtained for the samples tested
r = correlation coefficient

N. (-)	I_p (%)	K (-)	n (-)	r (-)
1	48	159.6	0.350	0.989
2	48.5	159.9	0.378	0.989
4	47.8	137.0	0.243	0.981
5	33.2	173.9	0.421	0.992
6	35.3	206.7	0.438	0.989
7	33.8	173.6	0.466	0.994
All	-	162.3	0.351	0.945

Table 8 - Coefficients of the relationship
$Go = K(\text{sigma'-c})^n$ (MPa)
obtained for different cohesive deposits

Authors	k	n	r	Clays
Present paper	162.2	0.352	0.945	Florence
Pane and Burghignoli (1988)	173	0.840	-	Fucino
Carrubba and Maugeri (1988)	160	0.120	-	Calabritto
Carrubba and Maugeri (1988)	57.7	0.362	0.998	Catania

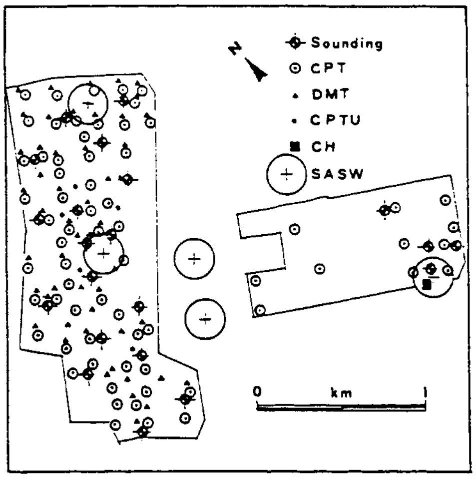

Fig. 1 - Map of soundings and in situ tests

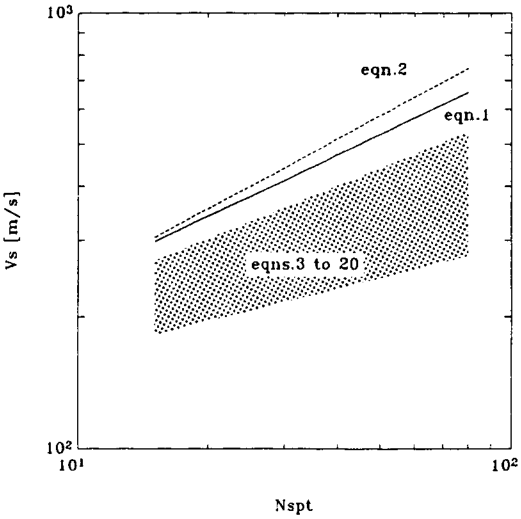

Fig. 2 - V_s versus N_{spt}. Comparison of correlations obtained for different sites (Table 3): $V_s = a\ N_{spt}^{\ b}$ (m/sec)

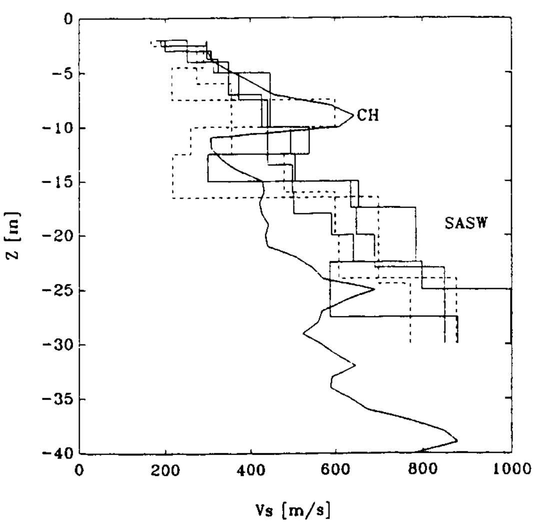

Fig. 3 - Comparison of shear velocity profiles from CH and SASW tests

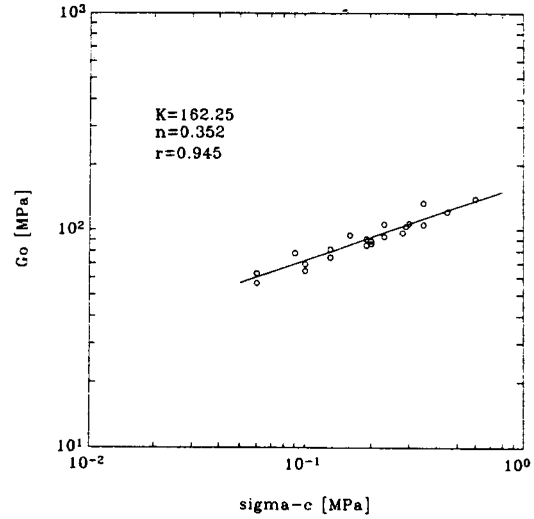

Fig. 4 - Shear modulus at low strain level versus confining pressure

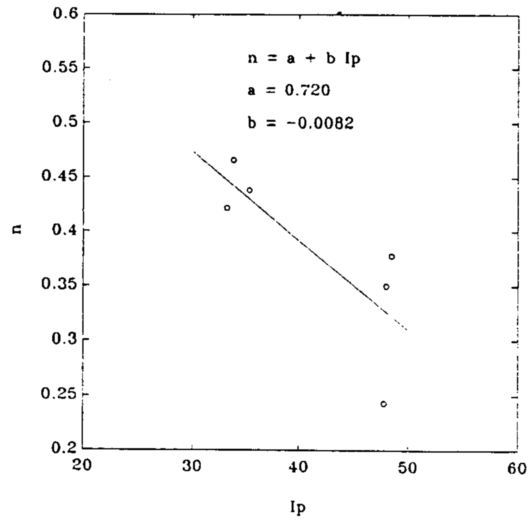

Fig. 5 - Influence of I_p on n-coefficient

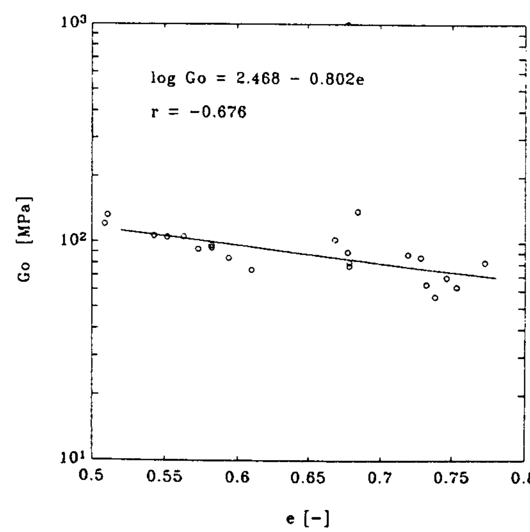

Fig. 6 - Shear modulus at low strain level versus void ratio

The coefficient N_{Vs}, analogous with N_G when shear velocity is considered rather than G, was also evaluated. For the sample tested this value is:

$$N_{Vs} = 4.65 \%$$

By applying to the sample examined the empirical correlations proposed by Anderson and Woods (1976)

$$N_{Vs} = \exp(-0.35 \log D_{50} + 1.1)$$
$$N_{Vs} = \exp(1.7 - 0.25 Su + 0.37 e)$$

(being D_{50} and Su, respectively, the diameter at 50% and the undrained strength), the following estimates of N_{Vs} were obtained:

$$N_{Vs} = 8.99 \%$$
$$N_{Vs} = 6.16 \%$$

As shown in **Figg. 8** and **9**, the values obtained are consistent with those more frequently observed. In the same figures, the dependence of I_G, and the relative independence of N_G, on confining pressure can also be seen.

d) Strain dependence of G
The dependence of shear modulus from the amplitude of strain level for all the samples tested can be observed in **Fig. 10**. In the same figure the strain dependence of the Florence clays is compared with that of other cohesive deposits. This comparison shows that the Florence clays fall in an approximately central position. The threshold level may be evaluated about 3×10^{-3} percent.
Fig. 11 shows that either a Hardin and Drnevich relationship, in the form modified by Yokota et al. (1981)

$$G/Go = 1/ (1 + alpha * gamma^{beta})$$

(with alpha and beta empirical coefficients) or Ramberg-Osgood model

$$gamma = tau/Go + C (tau/Go)^R$$

can be used to fit the data.
Both curves reveal a close agreement and diverge only for the strain levels above 5×10^{-2} %.
The alpha and beta coefficients of the hyperbolic model obtained for the Florence clays are compared with those of other sites in **Table 9**.

5.2 Damping ratio

The values of the damping ratios, measured in RC tests following the Amplitude Decay Method, are shown in **Fig. 12**. The damping ratios obtained were related to shear modulus by means of the equation

$$D = D_{max} \exp (lambda\ G/Go)$$

The experimental values of these coefficients are reported in **Table 10**, and, by way of example, are compared with values obtained for the Catania clays.
As concerns long-term time effects on damping, in **Fig. 13** a decrease can be observed in the damping ratio of 0.375 % for a logarithmic cycle of time, a value in good agreement with those generally observed (Marcuson and Wahls, 1978)

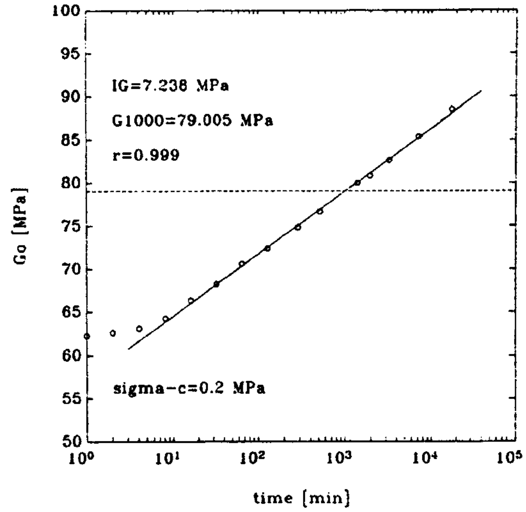

Fig. 7 - Time dipendence of G_o

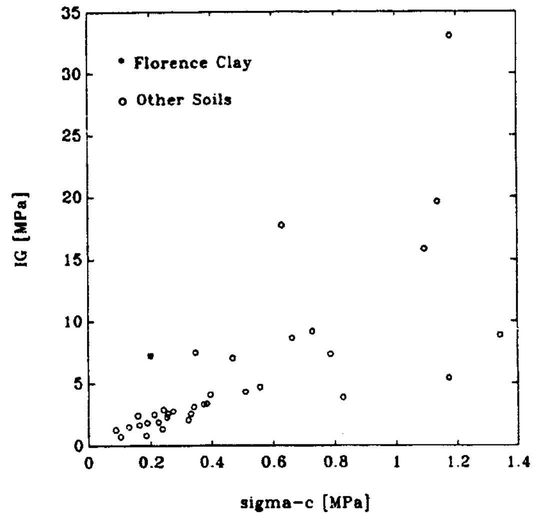

Fig. 8 - Values of I_G versus sigma'-c at different sites

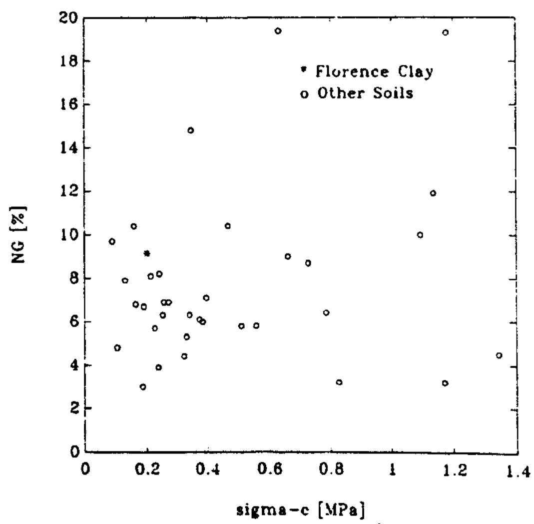

Fig. 9 - Values of N_G versus sigma'-c at different sites

Table 9 - The alpha and beta coefficients obtained for various clays

Authors	alpha	beta
Present paper	45.833	1.405
Seed and Idriss (1970)	30.258	0.696
Stokoe and Lodde (1978)	15.080	0.962
Saada and Macky (1985)	35.010	1.530
Carruba and Maugeri (1988)	7.150	1.233
Pane and Burghignoli (1988)	11.850	1.328

Table 10 - D_{max} and lambda values

Authors	D_{max}	lambda
Present paper	23.056	-2.179
Carrubba and Maugeri (1988)	28.12	-2.500

6. FIELD AND LABORATORY RESULTS

The field and laboratory shear modulus values at low strains are compared in **Fig. 14**. The plots refer to the borehole investigated by CH, coinciding with the intersection of the two orthogonal lines explored with SASW tests. By observing this figure , it can be seen that:

1. As concerns field values of the shear modulus obtained by CH and SASW procedures, there is relatively good agreement between the two seismic surveys. This result confirms the overall reliability of the SASW. Nevertheless, as the significant soil volumes explored by SASW are considerably greater than those of CH, the results of the two procedures must inevitably be different in a non-homogeneous deposit. In fact, the SASW test offers averaged information, which does not reflect the local effect of the small lenses of gravel and sand, diffuse in the deposit, as, instead, the CH test does. So, on the sites where these lenses are crossed by the CH, the CH values are considerably greater than with the SASW; whereas, where they are not encountered by the CH, the SASW gives higher values, because if certainly encounters a few lenses along its way.

The comparison of the two SASW tests gives satisfactory results up to about 17 m; after 17 m, there is a remarkable difference between the two corresponding plots.

2. It can be seen that the Go laboratory values are considerably distant from Go in situ profiles; moreover, they are, practically speaking, constant with the depth, whereas in situ measured values both from CH and SASW testing definitely increase with depth. It must be noted that the laboratory Go values were reported at the same confining pressure in situ, employing the respective empirical relationships of Table 7 for each sample.

In **Table 11** the values of the ratios R(Go) = Go,situ/Go,lab are shown. The Go,situ values of Table 11 were computed as average values between the Go values from CH and the mean value of SASW measures.

The lower values of R(Go) correspond to specimens recovered from cubic samples, but it does not seem possible to conclude that sample disturbance is mainly responsible for the divergence in field and in situ measurements.

3. Finally, various direct and indirect estimates of the K_o coefficient were obtained from the in situ and laboratory tests performed. The va-

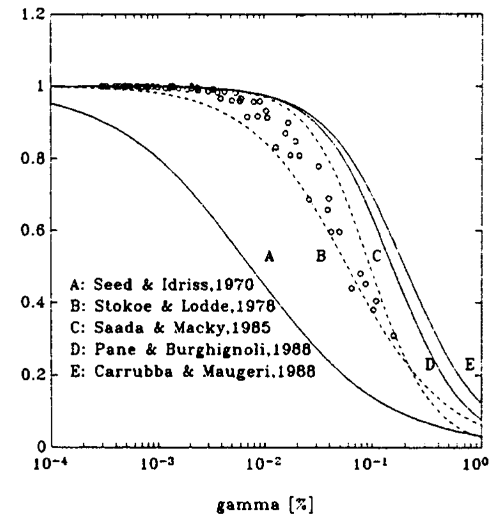

Fig. 10 - Strain dependence of shear modulus

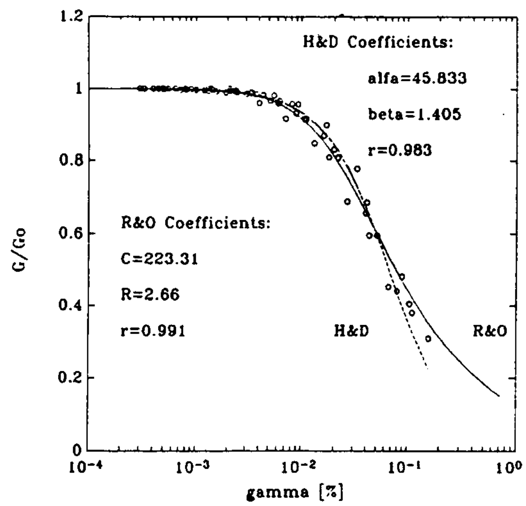

Fig. 11 - Fitting of Hardin & Drnevich and Ramberg & Osgood relationships to experimental data

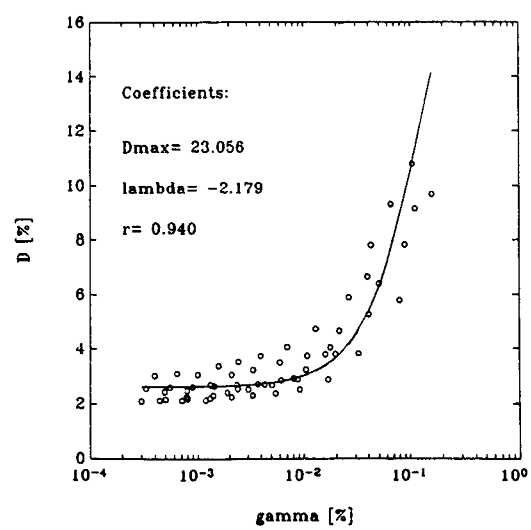

Fig. 12 - Strain dependence of damping ratio

Table 11 - Comparison of field and laboratory shear modulus

N. (-)	z (m)	Go,lab (MPa)	Go,situ (MPa)	R(Go)
1	3.15	54.8	175.5	3.20
2	3.15	54.8	175.5	3.20
3	6.35	66.0	303.7	4.60
4	6.65	66.9	323.7	4.84
5	16.85	89.2	542.8	6.09
6	21.35	96.3	728.3	7.56
7	33.25	111.7	1117.1	10.00

lues are compared in **Fig. 15**. The agreement between K_o values from the CH, EdoIlK_o and EdoIl tests is rather good, iven if the last values, as empirically estimated, are more scattered.

7. FIELD ADJUSTMENTS

Considering the objectives of the present research, that is, the evaluation of dynamic parameters to use for the microzoning of the area under question, some corrections for adjusting the cyclic laboratory shear modulus results to the equivalent field results were required. For predicting in situ G-gamma curves, four adjusted methods were employed (Stokoe, 1984):
a) Percentage Increase Method (P.I.M)
b) Arithmetic Increase Method (A.I.M.)
c) Linear Decrease Method (L.D.M.)
d) Combination Adjustment Method (C.A.M.)
Application of the four methods indicates great differences in the results; none of them can accurately predict the actual G-gamma curves. Nevertheless, the Combination Adjustment Method is generally believed to offer the best prediction. The resulting plots obtained referring to sample N. 4 are shown in **Fig. 16** by way of example.

8. CONCLUDING REMARKS

The in situ and laboratory testing experimental results, obtained with different procedures and equipment, confirmed the results of previous investigations, i.e the clays of Florence have a peculiar behaviour both under static and dynamic loading conditions.
The discrepancies encountered between field and laboratory dynamic parameters, considerably higher than for other coeval clays, were reaffirmed by the present additional testing program, even considering sampling disturbance and aging effects.

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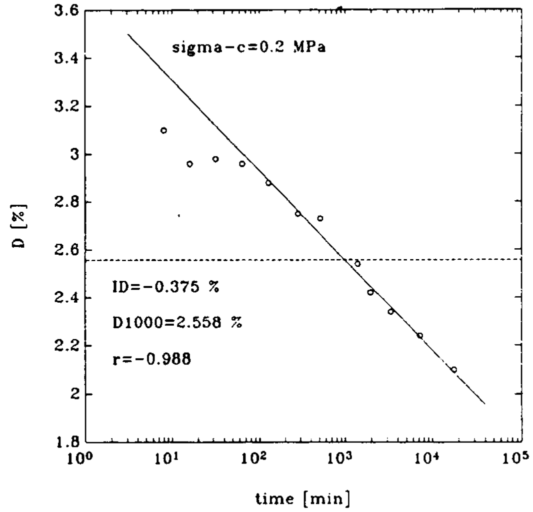

Fig. 13 - Time effects on damping ratio

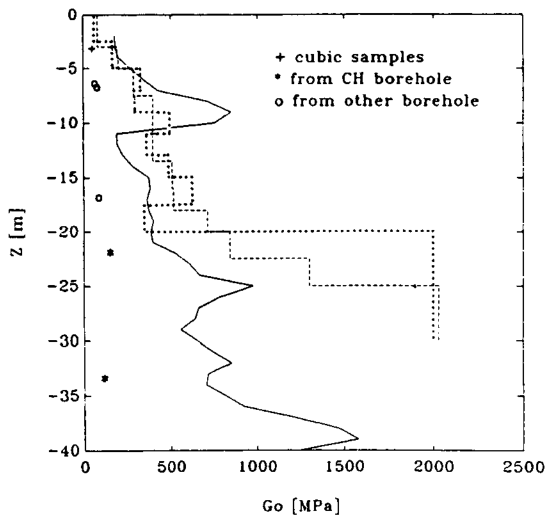

Fig. 14 - Field and laboratory shear modulus measurements

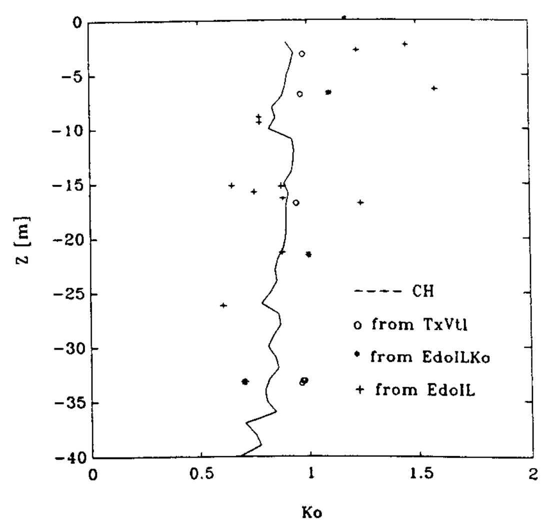

Fig. 15 - Measured and estimated K_o

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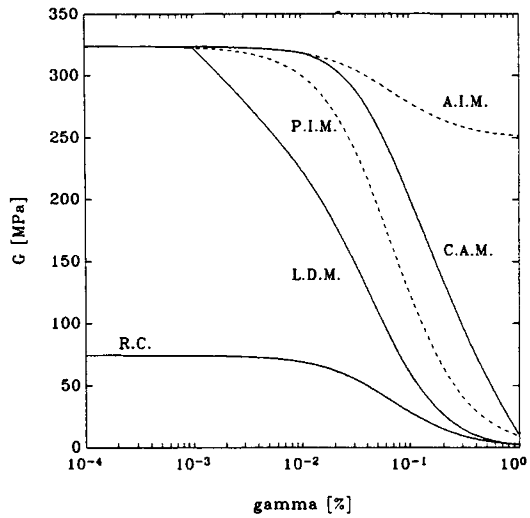

Fig. 16 - Prediction of field G-gamma curves using different methods

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