Site characterization by seismic dilatometer (SDMT) in the city of L’Aquila

Paola Monaco,* Gianfranco Totani,** Sara Amoroso,*** Ferdinando Totani,**** Diego Marchetti*****

Sommario

This paper presents a review of results obtained by a large number of seismic dilatometer tests (SDMT) carried out in the area of L’Aquila (central Italy), after the April 6, 2009 earthquake. Due to the characteristics of the soils (mostly coarse-grained, non-penetrable materials), SDMT measurements were generally performed in backfilled boreholes, using the technique briefly described; in these conditions only the shear wave velocity VS, without the other DMT parameters, was measured. The test results illustrated in the paper include: (a) SDMT typical results obtained by the normal penetration procedure (in a limited number of sites, mostly silts); (b) VS-only profiles obtained by the backfilled borehole procedure; (c) comparisons of VS profiles obtained by SDMT and by other techniques (Down-Hole, Cross-Hole, surface waves tests); (d) comparisons of VS measured by SDMT and those estimated from mechanical DMT data. The VS profiles provided by SDMT, combined with the information obtained from geological data and from other investigations, including boreholes down to a maximum depth of 300 m in the city centre, have been used for the soil characterization in numerical seismic response analyses. An example is illustrated in the paper.

1. Introduction

The April 6, 2009, \(M_W = 6.3\) L’Aquila earthquake (central Italy) caused 309 victims, about 1,600 injured, 40,000 homeless and huge economic losses. The earthquake produced a heavy damage in the city of L’Aquila (MCS Intensity \(I = VIII-IX\)) and in several near villages (maximum MCS Intensity \(I = IX-X\) at Onna and Castelnuovo).

Subsequently the area of L’Aquila has been extensively investigated by several different geotechnical and geophysical testing techniques, involving numerous working groups [see e.g. MONACO et al., 2012; SANTUCCI DE MAGISTRIS et al., this journal].

This paper presents a review of results of site investigations carried out by the geotechnical research group of the University of L’Aquila in the period 2009-2012, including a large number of seismic dilatometer tests (SDMT). Some of these tests were carried out in the aftermath of the earthquake, as part of first-emergency field activities promoted by the Italian Department of Civil Protection, aimed at the geotechnical characterization of new temporary housing sites for the homeless people (C.A.S.E.) and at the seismic microzoning of the area of L’Aquila [MS–AQ WORKING GROUP, 2010]. In the following months, several seismic dilatometer tests were executed, both in the historic city centre and in suburban area of L’Aquila, as part of investigations planned to obtain input data for site seismic response analyses for design of restoration/retrofitting of important public buildings, severely damaged by the earthquake.

Additional investigations, promoted by the University of L’Aquila – CERFIS (Centre for Research and Education in Earthquake Engineering), include deep investigations in the city centre, in particular a 300 m deep borehole in Piazza Duomo and a 195 m deep borehole at the site of Madonna del Ponte [AMOROSO et al., 2010], aimed at investigating the soil profile down to the bedrock, on the basis of the known geology of the area.

The SDMT results presented in this paper, combined with geological information and data from other investigations, could possibly help in defining the soil characterization for numerical seismic response analyses in different areas of the city of L’Aquila.
2. Seismic dilatometer test (SDMT)

2.1 SDMT: standard penetration procedure

The seismic dilatometer (SDMT) is the combination of the mechanical flat dilatometer (DMT), introduced by Marchetti (1980), with an add-on seismic module for measuring the shear wave velocity $V_S$. First introduced by Hepton (1988), the SDMT was subsequently improved at Georgia Tech, Atlanta, USA [Martin and Mayne, 1997, 1998; Mayne et al., 1999]. A new SDMT system (Fig. 1) has been recently developed in Italy [Marchetti et al., 2008].

The seismic module (Fig. 1a) is a cylindrical element placed above the DMT blade, equipped with two receivers spaced 0.50 m. The shear wave source, located at the ground surface, is a pendulum hammer ($\approx 10$ kg) which hits horizontally a steel rectangular plate pressed vertically against the soil (by the weight of the truck) and oriented with its long axis parallel to the axis of the receivers, so that they can offer the highest sensitivity to the generated shear wave. The shear wave generated at the surface reaches first the upper receiver, then, after a certain delay, the lower receiver (Fig. 1b). The seismograms acquired by the two receivers, amplified and digitized at depth, are visualized on a PC in real time, and the time delay between the signals is determined immediately. $V_S$ is obtained as the ratio between the difference in distance between the source and the two receivers ($S_2 - S_1$) and the time delay between the arrivals of the impulse at the two receivers ($\Delta t$). $V_S$ measurements are typically taken every 0.50 m of depth (while the mechanical DMT readings are taken every 0.20 m).

The true-interval test configuration, with the two receivers, avoids possible inaccuracy in the determination of the “zero time” at the hammer impact, which is necessary if the one-receiver configuration is utilized. Moreover, the couple of seismograms recorded by the two receivers at a given test depth corresponds to the same hammer blow (i.e. same generated waves) and not to different blows in sequence, which are not necessarily identical. Hence the repeatability of $V_S$ measurements is considerably improved (observed $V_S$ repeatability $\approx 1\%$, i.e. a few m/s).

The determination of the time delay from SDMT seismograms, normally obtained using a cross-correlation algorithm, is generally well conditioned, being based on the waveform analysis of the two seismograms rather than relying on the first arrival time or specific single points in the seismogram. An example of seismograms obtained by SDMT – as recorded and re-phased according to the calculated delay – is shown in Fig. 1c.

$V_S$ measurements by SDMT have been validated by several comparisons with $V_S$ measured by other in situ techniques at various research sites, as reported by Marchetti et al. (2008). Besides $V_S$, the seismic dilatometer provides the parameters obtained by the classical flat dilatometer interpretation [Marchetti, 1980; Marchetti et al., 2001].

2.2 SDMT: backfilling procedure in non-penetrable soils

The SDMT procedure proves to be an effective, quick and cost-saving alternative to conventional Down-Hole tests in soft to firm soils (no need of holes with pipes to be grouted, operations requiring a few days pause before testing). A disadvantage of the SDMT is the impossibility of penetrating very hard soils. However a procedure for obtaining $V_S$ profiles – but not the other DMT parameters – in non-penetrable soils (e.g. in gravel, or even in rock)

---

**Fig. 1** – Seismic dilatometer test. (a) DMT blade and seismic module. (b) Schematic test layout. (c) Example of seismograms obtained by SDMT.

Fig. 1 – Prova con dilatometro sismico. (a) Lama DMT e modulo sismico. (b) Schema della prova. (c) Esempio di sismogrammi ottenuti da SDMT.
has been devised by TOTANI et al. (2009). The procedure is the following (Fig. 2):
1) a borehole is drilled to the required test depth;
2) the borehole is backfilled with sand;
3) the SDMT is inserted and advanced into the backfilled borehole in the usual way (e.g. by use of a penetrometer rig) and \( V_S \) measurements are taken every 0.50 m of depth; no DMT measurements – meaningless in the backfill soil – are taken in this case.

In this procedure the dilatometer acts only as a vehicle for inserting the seismic module. The method for measuring \( V_S \) is similar to a two-receiver Down-Hole test, except for the technique used to fix the receivers to the soil around the borehole (backfilling instead of casing) and for the insertion equipment.

The possibility of such \( V_S \) measurement descends from the fact that the wave travelpath from the surface to the upper and lower receiver includes a short path in the backfill which is assumed, in first approximation, to be of the same length (Fig. 2a), i.e. the time delay \( \Delta t \) does not change. Comparative tests at various sites where both the usual penetration procedure and the backfilling procedure were adoptable [TOTANI et al., 2009] indicate that \( V_S \) values obtained in the backfilled borehole are essentially coincident with the \( V_S \) obtained by penetrating the soil (Fig. 2b).

3. SDMT results in the area of L’Aquila

3.1 SDMT test sites

Fig. 3a shows the location of the sites investigated by SDMT in the area of L’Aquila after the April 6, 2009 earthquake. The detail in Fig. 3b shows the location of the SDMT test sites in the city centre, which includes most of the historical heritage and several old masonry buildings, heavily damaged by the earthquake.

The complex geological setting of the L’Aquila basin is extensively described in MS–AQ WORKING GROUP (2010). A basic description can also be found in SANTUCCI DE MAGISTRIS et al. (this journal).

In the city centre (see the schematic geological section in Fig. 4) the upper portion of the subsoil is constituted by the deposit known as “Brecce dell’Aquila”, composed of fine to coarse calcareous fragments of variable size (mostly of some centime-
tres) embedded in sandy or silty matrix (Fig. 5), characterized by highly variable cementation and mechanical properties. The breccias, about 80-100 m thick, lay on fine- to medium-grained, mostly silty lacustrine deposits of average thickness ≈ 250-270 m, placed on the limestone bedrock. Gravimetric investigations [MS–AQ WORKING GROUP, 2010] have indicated that in the city centre the bedrock is located below 300 m depth. This indication has been confirmed directly by deep core-destructive boreholes executed to a maximum depth of 300 m in Piazza Duomo and to 195 m at the site of Madonna del Ponte [AMOROSO et al., 2010; Fig. 6]. Only in the latter site, located at an elevation 100 m lower than Piazza Duomo, the bedrock was encountered at a local depth of 192 m, i.e. at an absolute elevation of 425 m a.s.l.

Whenever possible, in soils ranging from clay to silty sand (silt in the majority of the cases), the seismic

Fig. 4 – Schematic geological section across L’Aquila city centre [modified after MS–AQ WORKING GROUP, 2010], showing the position of deep investigations promoted by University of L’Aquila – CERFIS.

Fig. 4 – Sezione geologica schematica attraverso il centro storico dell’Aquila [modificata a partire da MS–AQ WORKING GROUP, 2010], con indicazione della posizione delle indagini profonde eseguite per conto di Università dell’Aquila – CERFIS.

Fig. 5 – Typical composition and grain size distribution of the breccias.

Fig. 5 – Composizione e distribuzione granulometrica tipiche delle breccie.

Fig. 6 – Schematic stratigraphic profiles reconstructed from two deep boreholes at the sites of Piazza Duomo (300 m) and Madonna del Ponte (195 m), L’Aquila [after AMOROSO et al., 2010].

Fig. 6 – Profili stratigrafici schematici ricostruiti attraverso due sondaggi profondi a Piazza Duomo (300 m) e Madonna del Ponte (195 m) [da Amoroso et al., 2010].
dilatometer tests were carried out by the classical penetration procedure. However, due to the characteristics of the soils commonly encountered in the area of L’Aquila (mostly coarse-grained, non-penetrable soils), particularly in the city centre, generally $V_S$-only measurements were performed by use of the SDMT seismic module in backfilled boreholes, according to the TOTANI et al. (2009) procedure previously described.

### 3.2. SDMT results by the penetration procedure

Figs 7 to 11 show SDMT results obtained at various sites investigated by the standard penetration procedure, in fine- to medium-grained soils. The soils, mostly composed of silts or silty sands, belong to the Pleistocene lacustrine deposits which fill the bottom of the L’Aquila basin.

The typical graphical SDMT output in Figs 7 to 11 displays the profile of $V_S$ as well as the profiles of four basic DMT parameters: the material index $I_D$ (indicating soil type), the constrained modulus $M$, the undrained shear strength $c_u$ (in clay) and the horizontal stress index $K_D$ (related to OCR), calculated with usual DMT interpretation formulae [MARCHETTI, 1980; MARCHETTI et al., 2001].

The SDMT results shown in Figs 7, 8 and 9 were obtained at three C.A.S.E. sites (Cese di Preturo, Pi-
The diagrams on the right show the comparison between the $V_S$ profiles obtained by SDMT, Down-Hole (Polo Geologico) and MASW (Politecnico di Torino). DH and MASW data from MS–AQ WORKING GROUP (2010); see also SANTUCCI DE MAGISTRIS et al. (this journal).

The results of these tests, entrusted by the Italian Department of Civil Protection, are included in MS–AQ WORKING GROUP (2010). It can be observed that the $V_S$ profiles obtained by SDMT are generally in satisfactory agreement with the $V_S$ profiles obtained by Down-Hole and MASW.

Other SDMT results obtained by the penetration procedure are illustrated in Fig. 10 (Santa Rufina, Roio) and in Fig. 11 (Ponte Rasarolo). In the latter site, located near the Aterno riverside, liquefaction and lateral spreading phenomena were triggered by the April 6, 2009 earthquake, as detected by AYDAN et al. (2009). Another case of liquefaction triggered by the earthquake main shock at Vittorito ($\approx$ 45 km far from the epicentre), and analyzed by use of SDMT results, was presented by MONACO et al. (2011a).

In general, at all sites investigated by the penetration procedure the maximum testing depth (lim-
3.3. \( V_S \) measurements by the backfilling procedure in non-penetrable soils

Figs 12 to 24 show the profiles of \( V_S \) obtained by use of the SDMT seismic module in backfilled boreholes (no DMT parameters), in non-penetrable soils, at various sites in the area of L’Aquila.

In particular, Figs 12 to 19 show the \( V_S \) profiles and the schematic stratigraphic profiles at various sites in the city centre (see location in Fig. 3b). At all the sites the upper portion of the subsoil belongs to the “Brecce dell’Aquila” formation. It can be noted that the values of \( V_S \) in the breccias (down to a maximum depth of 74 m at Palazzo Camponeschi, Fig. 12) are mostly 600-1000 m/s or higher, generally increasing with depth. It is supposed that the observed dispersion of the measured \( V_S \) could possibly reflect some variability in grain size distribution, cementation and/or mechanical properties typical of this material. This assumption relies on “visual experience” rather than on comparisons with experimental results of in situ or laboratory tests. On the other hand, since the breccias typically include calcareous fragments of up to some centimetres of size, irregularly embedded in the sandy-silty matrix (see example in Fig. 5), it is extremely difficult to characterize this material by any in situ method other than geophysical methods, and laboratory testing is precluded by the difficulty of sampling.

Fine-grained residual soils, locally known as “Terre rosse” (red soils), are frequently encountered in the upper ≈ 8 to 15 m of breccias, particularly in...
the Southern part of the city centre. The $V_S$ values measured in the “Terre rosse” are typically $\approx 400$ m/s (see e.g. Figs 17 and 18). Lower values ($V_S \approx 200-300$ m/s) have been locally measured in shallow filling materials (in several cases man-made fills discovered in the city centre are supposed to originate from disposal of rubble of masonry buildings destroyed in past earthquakes, namely in the 1703 earthquake).

The lacustrine silty deposit underlying the “Brecce dell’Aquila” was investigated by SDMT at the site of Fontana 99 Cannelle, located at an elevation $\approx 90$ m lower than Piazza Duomo, near the South-Western border of the city centre (see Fig. 4). Here the thickness of the breccias reduces to 15-20 m or less (Fig. 19). The backfilling procedure permitted to obtain SDMT measurements down to a depth of 133 m. Below $\approx 100$ m depth the signal/noise ratio of the SDMT seismograms was too low to permit the $V_S$ determination by the usual interpretation. In this case $V_S$ was obtained using the “stacking” technique, consisting of summing up the signals recorded by the receivers at the same depth and in the same conditions (in this way the energy of the signal is summed,
while the energy of the noise, having a zero mean value, remains about the same). In the same Fig. 19, the profile of $V_S$ measured by a Cross-Hole test (CH) in a site nearby is reported. The CH test, carried out by Cardarelli and Cerbato (2010), was performed down to a depth of 78 m at the site of Madonna del Ponte, where the same lacustrine deposit is outcropping, at about 500 m distance and $\approx 15$ m lower elevation with respect to Fontana 99 Cannelle. Accounting for the different elevation of the two sites, the $V_S$ measured by SDMT, mostly ranging between 400 and 600-700 m/s, are in reasonable agreement with those obtained by Cross-Hole at Madonna del Ponte.

Figs 20 to 23 show the profiles of $V_S$ obtained by SDMT in backfilled boreholes at various sites located in the western suburban area of L’Aquila (see Fig. 3a), in the densely populated districts of Coppito (San Salvatore Hospital, Fig. 20), Pile (Sant’Antonio, Fig. 21), Cansatessa (Via Solaria, Fig. 22) and Pettino (Via Sila Persichelli, Fig. 23). These recently developed residential/commercial districts, generally composed of 3-6 storey reinforced concrete frame buildings, were considerably damaged by the earthquake. The sites investigated in this area are mostly characterized by the presence of coarse-grained soils (calcareous gravel in sandy-silty matrix or sand). The $V_S$ values measured at the above sites generally range between 400-600 m/s and more than 1000 m/s, increasing with depth.

In Fig. 22 the profile of $V_S$ obtained by SDMT is compared to the $V_S$ profile obtained by surface waves tests (MASW) carried out at the same site by IAMC-CNR [MS–AQ Working Group, 2010]; the two $V_S$ profiles show to be in good agreement between 12.5 m and 17 m depth, while they differ substantially above 12.5 m and below 17 m depth, where the average $V_S$ from SDMT is about 20% lower than $V_S$ from MASW.

At the site of Via Sila Persichelli, Pettino (Fig. 23), characterized by the presence of an upper soft silty clay layer overlying stiff gravel, the profiles of $V_S$ obtained by SDMT 1 and SDMT 3 clearly identified a contrast of shear wave velocity between the upper soft clay layer ($V_S \approx 300$ m/s) and the lower gravel layer ($V_S \approx 600-900$ m/s) at about 15-17 m depth; this velocity contrast is a potential source of local amplification of the ground motion. In SDMT 2 $V_S$ increases with depth down to about 23-24 m, when the gravel layer is encountered. Such difference in the
Fig. 20 – Profiles of $V_S$ measured by SDMT in 8 backfilled boreholes and schematic stratigraphy at the site of San Salvatore Hospital (Coppito), L’Aquila.

Fig. 21 – Profiles of $V_S$ measured by SDMT in a backfilled borehole and schematic stratigraphy at the site of Sant’Antonio (Pile), L’Aquila.

$V_S$ profiles at the same site reflect the variability in thickness of the upper soft clay layer (colluvial sediments filling the bottom of buried valleys), which typically in the Pettino area may range from zero, or a few metres, to 20-25 m even within a short distance.

Fig. 24 shows the profiles of $V_S$ obtained by SDMT in two backfilled boreholes at the site of the Fac-
Other SDMT results, obtained as part of investigations aimed at the characterization of sites of strong motion stations (part of the Italian Strong Motion Accelerometric Network – RAN) in the area of L’Aquila, are reported elsewhere [e.g. LANZO et al., 2011].

3.4 Evaluation of $V_s$ from mechanical DMT data

In addition to the recent SDMT investigations previously described, the results of several mechanical DMTs carried out in the past in the area of L’Aquila were collected for the seismic microzonation of Engineering of the University of L’Aquila (Monteluco di Roio), located at only $\approx 500$ m distance from the April 6, 2009 earthquake main shock epicentre (see Fig. 3a) and severely damaged by the earthquake.

Other SDMT results, obtained as part of investigations aimed at the characterization of sites of

![Fig. 22 – Profile of $V_s$ measured by SDMT in a backfilled borehole, $V_s$ measured by MASW [IAMC-CNR, MS–AQ WORKING GROUP, 2010] and schematic stratigraphy at the site of Via Solaria (Cansatessa), L’Aquila.](image1)

![Fig. 23 – Profiles of $V_s$ measured by SDMT in 3 backfilled boreholes and schematic stratigraphy at the site of Via Sila Persichelli (Pettino), L’Aquila.](image2)

![Fig. 24 – Profiles of $V_s$ measured by SDMT in 2 backfilled boreholes and schematic stratigraphy at the site of Monteluco di Roio – Faculty of Engineering, L’Aquila.](image3)

![Fig. 25 – Ratio $G_0 / M_{DMT}$ vs. $K_D$ (OCR) for various soil types [MONACO et al., 2009].](image4)
These results were used to obtain rough estimates of $V_S$, at sites where it had not been measured [see MONACO et al. (2012); SANTUCCI DE MAGISTRIS et al. (this journal)], by use of the correlations in Fig. 25. Such correlations were established considering that the SDMT (by the standard penetration procedure) provides routinely, at each test depth, both the small strain shear modulus $G_0$ (obtained as $G_0 = \rho V_S^2$) and the working strain constrained modulus $M_{DMT}$. The latter is obtained from the usual DMT interpretation. The effectiveness of the $M_{DMT}$ estimation has been proved by the good agreement observed in a large number of well documented comparisons between measured and DMT-predicted settlements or moduli [MONACO et al., 2006; MARCHETTI et al., 2008].

The experimental relationship between $G_0$ and $M_{DMT}$ is illustrated in the diagram in Fig. 25, where the ratio $G_0 / M_{DMT}$ is plotted vs. the DMT horizontal stress index $K_D$ (related to OCR): the values of $G_0$ and $M_{DMT}$ are derived by SDMT results at 34 different sites, in a variety of soil types [MONACO et al., 2009].

The comparisons shown in Fig. 26 indicate a good agreement between the profiles of $V_S$ measured directly by SDMT (solid line) and $V_S$ estimated from mechanical DMT data (dashed line) obtained in the same SDMT test, using the correlations in Fig. 25, at

---

**Fig. 26** – Comparison of profiles of $V_S$ measured by SDMT and estimated from DMT data at six sites in the area of L’Aquila.

**Fig. 26** – Confronto tra profili di $V_S$ misurati con SDMT e stimati da dati della prova DMT in sei siti nell’area dell’Aquila.
six sites in the area of L'Aquila where SDMT was performed using the penetration procedure. The relative error, calculated as $(V_S^{\text{measured}} - V_S^{\text{estimated}}) / V_S^{\text{measured}}$, is about 20% on average.

4. Use of $V_S$ from SDMT for soil characterization in site seismic response analyses

The $V_S$ profiles obtained by SDMT, combined with geological information and data obtained from other investigations, have been used for the soil characterization in seismic response analyses of various sites, located both in L'Aquila city centre and in the surrounding area [MONACO et al., 2011b; MONACO et al., 2011c; FERRARO et al., this journal]. The results of these analyses, in agreement with previous studies [e.g. MAUGERI et al., 2011; MS–AQ WORKING GROUP, 2010], confirm that site effects played an important role in the observed non-uniform damage distribution due to the April 6, 2009 earthquake.

As an example, Fig. 27 illustrates the shear wave velocity profile defined for the seismic response analysis at the site of Palazzo Camponeschi (see location in Figs 3b and 4). As typical of the city centre, the subsoil is characterized by an inversion of the shear wave velocity with depth, at the transition from the upper 80 m thick breccias ($V_S \approx 800-1000$ m/s) to the underlying lacustrine silts ($V_S \approx 600-700$ m/s); the bedrock (geological and seismic) is found at 350 m depth. The profile of $V_S$ in the breccias was defined as an average of five $V_S$ profiles obtained by SDMT in backfilled boreholes to 74 m depth (Fig. 12). In the lower lacustrine silts, in absence of direct measurements, the profile of $V_S$ was estimated as a function of depth or stress level by experimental relationships [CHIARA, 2001; CRESPELLANI et al., 1989]. Such $V_S$ profile was found in reasonable agreement with $V_S$ measured by SDMT and by Cross-Hole at Fontana 99 Cannelle and Madonna del Ponte (Fig. 19), where the same lacustrine formation is encountered at shallow depths. The limestone bedrock was characterized by $V_S = 1250$ m/s, derived from a Cross-Hole test performed at the site of the strong motion station AQV (a few km West of the city centre), where the bedrock was found at $\approx 50$ m depth [DI CAPUA et al., 2009]. Additional information on the input data and the results of the seismic response analysis at Palazzo Camponeschi can be found in MONACO et al. (2011b).

5. Conclusions

A large number of seismic dilatometer tests were carried out in the area of L'Aquila following the April 6, 2009 earthquake. The SDMT results provided useful data for the geotechnical characterization of new temporary housing sites (C.A.S.E.), for the seismic microzonation of the area and for site seismic response analyses aimed at design of restoration/retrofitting of important public buildings, particularly in the historic centre of L'Aquila.

Due to the characteristics of the soils generally encountered in the area of L'Aquila, mostly coarse-grained, the seismic dilatometer tests were performed by the normal penetration procedure only in a limited number of sites. However the backfilled borehole procedure permitted to obtain $V_S$ profiles of use of the SDMT seismic module – likewise a two-receiver Down-Hole test – also in non-penetrable soils, at several sites both in the city centre and in the suburban area of L'Aquila. In some cases the backfilling procedure permitted to obtain $V_S$ measurements down to unusually large depths ($\approx 70$ to 130 m), by use of the “stacking” technique for interpreting the SDMT seismograms in case of low signal/noise ratio.

The $V_S$ profiles obtained by SDMT were found generally in acceptable agreement with the $V_S$ profiles obtained by other in-hole techniques (Down-Hole, Cross-Hole), while the agreement with the $V_S$ profiles obtained by surface wave tests in some cases is less satisfactory.

As a general rule, it is obviously advisable to directly measure $V_S$. However, if only mechanical DMT results are available (e.g. from past investigations),
rough estimates of $V_s$ (from $G_0$) can be obtained by correlation with mechanical DMT data.

The $V_s$ profiles obtained by SDMT, combined with geological information and data obtained from other investigations, have been used to define the soil model for numerical seismic response analyses of sites located both in L’Aquila city centre and in the suburban area, characterized by substantially different subsoil conditions.

References


CHIARA N. (2001) – Investigation of Small-Strain Shear Stiffness Measured in Field and Laboratory Geotechnical Studies. MS Thesis, Department of Civil Engineering, University of Texas at Austin.


FERRARO A., GRASSO S., MAUGERI M., TOTANI F. – Site response analysis in the southern part of the historic centre of L’Aquila. Rivista Italiana di Geotecnica, Special Issue “Aspetti geotecnici del terremoto del 6 aprile 2009 in Abruzzo”.


ing, Special Issue: L’Aquila Earthquake: Seismic Sequence of 6th April 2009, Abruzzo, Italy, (9)1, pp. 231-261, Springer.


Caratterizzazione in sito con dilatometro sismico (SDMT) nella città dell’Aquila

Sommario

Questo articolo presenta una rassegna di risultati ottenuti da un gran numero di prove con dilatometro sismico (SDMT) eseguite nell’area dell’Aquila dopo il terremoto del 6 Aprile 2009. Date le caratteristiche dei terreni comunemente incontrati in quest’area (prevalentemente a grana grossa, non penetrabili), generalmente le prove SDMT sono state eseguite all’interno di fori riempiti di sabbia, per cui è stato possibile misurare solo la velocità di propagazione delle onde di taglio $V_S$ e non gli altri parametri DMT. I risultati sperimentali illustrati in questo articolo comprendono: (a) risultati SDMT ottenuti con la normale tecnica di penetrazione (in un numero limitato di siti, prevalentemente a grana grossa); (b) profili della sola $V_S$ ottenuti con la tecnica del riempimento di fori; (c) confronti tra profili di $V_S$ ottenuti da SDMT e da altre prove (Down-Hole, Cross-Hole, analisi di onde di superficie); (d) confronti tra $V_S$ misurata da SDMT e stimata da risultati della prova DMT meccanica. I profili di $V_S$ forniti dalla prova SDMT, combinati con informazioni di natura geologica e dati di altre indagini, comprendenti sondaggi profondi fino a 300 m nel centro storico, sono stati utilizzati per la caratterizzazione geotecnica in analisi di risposta sismica locale.