*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*
*e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 22, Issue 2 Ser. I (Mar. –Apr. 2025), PP 86-91*
*www.iosrjournals.org*

# An Overview of Seismic Dilatometer Test (SDMT): Instrument, Principle, and Methodology for Advanced Geotechnical Site Characterization

Hemant Kumar Joshi[1], Satyajit Roy[2],Dr. Amardeep Singh[3], Dr. Manish Gupta[4],and Dr. R Chitra[4]
[1]*Scientist 'B', Central Soils and Materials Research Station (CSMRS), New Delhi, India*
[2]*Scientist 'C', Central Soils and Materials Research Station (CSMRS), New Delhi, India*
[3,4]*Scientist 'E', Central Soils and Materials Research Station (CSMRS), New Delhi, India*
[5]*Director, Central Soils and Materials Research Station (CSMRS), New Delhi, India*

***Abstract:*** *The Seismic Dilatometer Test (SDMT) has emerged as a reliable and efficient in-situ testing method for preliminary geotechnical site investigations/characterisation, particularly in regions prone to seismic activity. Combining the Flat Dilatometer Test (DMT) with seismic wave velocity measurements, the SDMT provides comprehensive data on soil stiffness, shear wave velocity, and constrained modulus. This paper offers an in-depth overview of the SDMT, discussing its instrument, working principle, and testing methodology. Emphasising its practical applications, the paper showcases its relevance in preliminary seismic site-specific studies, liquefaction potential assessment, and foundation design. Furthermore, the advantages of SDMT over conventional methods are outlined, along with a critical evaluation of its limitations. In the context of India's diverse geological conditions and increasing infrastructure development, the SDMT presents itself as a valuable tool for ensuring safe and resilient infrastructure. Prospects for the wider adoption of SDMT in India's geotechnical investigations are also explored.*

***Keywords:*** *Seismic dilatometer test, site investigations, geotechnical engineering*

## I. Introduction:

The need for accurate and reliable soil data in geotechnical engineering has led to the development of advanced in-situ testing methods. By adding shear wave velocity (Vs) readings, the Seismic Dilatometer Test (SDMT) is a novel approach that improves on the conventional Dilatometer Test (DMT). Both static and dynamic soil parameters that are necessary for seismic analysis and geotechnical design are provided by this integrated testing.The SDMT has been used in seismic site response analysis, foundation design, soil liquefaction assessment, and embankment stability evaluation.This paper provides a comprehensive overview of the SDMT, covering its working principles, equipment configuration, testing procedures, data interpretation, and case studies demonstrating its effectiveness.

## II. Equipment Configuration

The Seismic Dilatometer Test (SDMT) is an advanced in-situ testing method that combines the traditional Flat Dilatometer Test (DMT) with a seismic module to measure shear wave velocity (Vs). Here are the key components of SDMT equipment:

**2.1 Dilatometer Blade:** A stainless-steel blade (14 mm thick) with a flat, expandable steel membrane on one side, standard dimensions: 95 mm wide and 220 mm long designed to penetrate the soil up to the desired depth. Blade is equipped with a pressure sensing system for measuring lateral soil pressure.

**2.2 Seismic Module/Blade:** Positioned above the dilatometer blade, contains two horizontal geophones spaced 0.5 meters apart. Records the shear wave signals generated at the ground surface. Provides accurate determination of shear wave velocity (Vs).

**2.3 Pneumatic Control Unit:** Regulates gas or compressed air to inflate the membrane. Measures three pressures define below, connected to the blade via pneumatic tubing.

- $P_0$-Contact Pressure
- $P_1$- Pressure to deform the membrane
- $P_2$- - Pressure to retract the membrane

**2.4 Data Acquisition System:** Collects and stores data from the seismic module and pressure sensors. Equipped with real-time data visualization and processing software.

**2.5 Hammer and Strike Plate:** A metal hammer is used to generate shear waves by striking a plate or steel beam placed on the ground surface. The impact creates seismic waves that propagate through the soil.

**2.6 Cables and Connectors:** Electrical cables connect the seismic sensors and geophones to the data acquisition unit. Pneumatic tubing transmits air pressure from the control unit to the blade.

**2.7 Software:** Dedicated software analyses the raw pressure and seismic data. Provides plots of $V_s$ profiles, pressure readings, and calculated soil parameters.

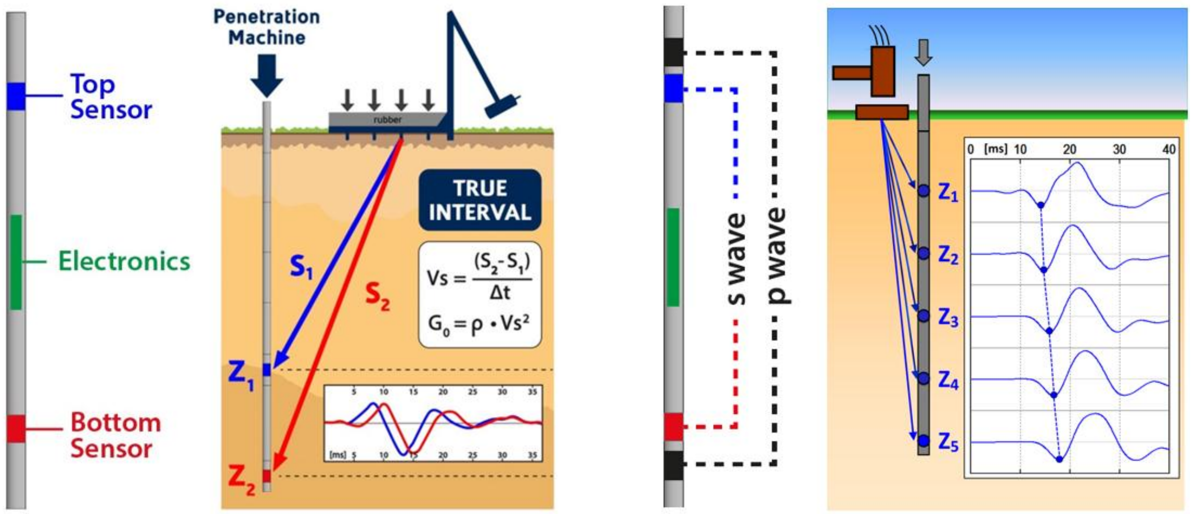


Figure-1: SDMT test layout

This integrated system allows SDMT to provide both geotechnical parameters (e.g., $E_D$, $K_D$, and $E_s$) and seismic properties (e.g., Vs) in a single test. Let me know if you need detailed specifications or operational guidelines for any component.

## III. Principle of Seismic Dilatometer Test (SDMT)

The Seismic Dilatometer Test (SDMT) is an in-situ geotechnical testing method that combines the functionalities of the Flat Dilatometer Test (DMT) with seismic wave velocity measurements. It is widely used for evaluating soil stiffness, determining small-strain shear modulus, and characterizing subsurface conditions for geotechnical and seismic site classification purposes.

### 3.1 Dilatometer Test (DMT):

The dilatometer consists of a stainless-steel blade with a flat, expandable membrane on one side.It is pushed into the ground using a penetration rig, typically to depths of up to 30 m or more.The membrane is expanded by applying gas pressure, and two pressures are measured:
From these pressures, soil parameters such as lateral stress, soil modulus, and strength properties are estimated.

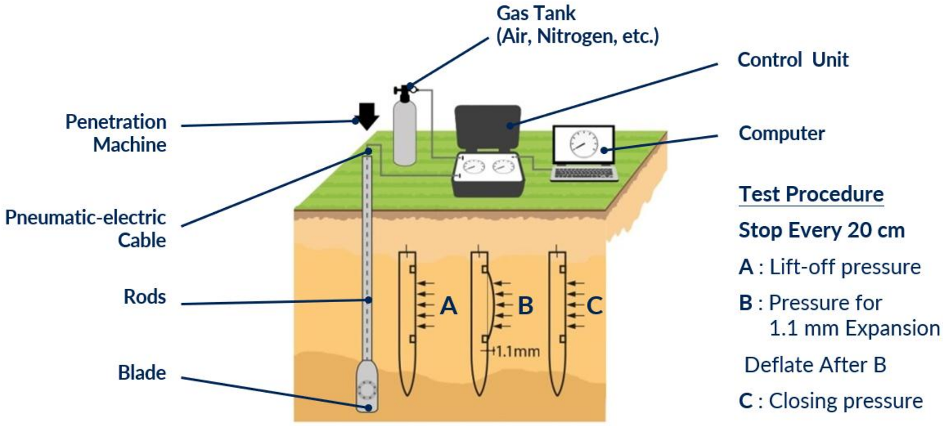


Figure-3: DMT Test Layout

### 3.1.1 Data Interpretation and Parameters:

The interpretation of SDMT results involves using both the mechanical response from the **Dilatometer Test (DMT)** and the seismic wave velocity data. These data points provide valuable insights into soil behaviour, stress conditions, and dynamic properties.

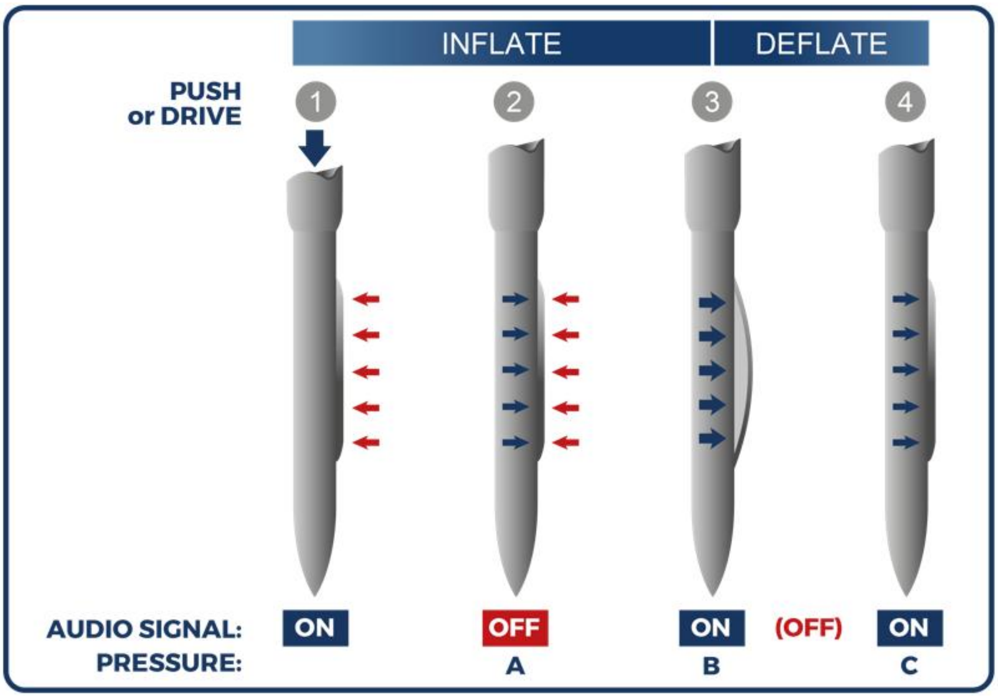


Figure-2: DMT Test Sequence A, B and C Readings

### 3.1.2 Parameters from the Dilatometer Test (DMT)

The DMT provides three primary readings:

- **$P_0$**: Contact Pressure (when the membrane just touches the soil)
- **$P_1$**: Expansion Pressure (when the membrane is expanded 1.1 mm)
- **$P_2$**: Closing Pressure (when the membrane is deflated, usually not always measured)

From these readings, the following parameters are interpreted:

**a. Material Index ($I_D$)**

Indicates soil type and behaviour (clay, silt, sand, or mixed).

$$I_D = \frac{P_1 - P_0}{P_0 - P_a}$$

Where:

- $I_D$= Material Index (dimensionless)
- $P_a$ = Atmospheric pressure (kPa)
- $I_D$< 0.1 → Clay
- $I_D$> 1.8 → Sand
- 0.1≤ $I_D$ ≤1.80→ Silt or mixed soil

**b. Horizontal Stress Index ($K_D$)**

Estimates the in-situ horizontal stress and lateral earth pressure.

$$K_D = \frac{P_0 - P_a}{\sigma_v'}$$

Where:

- $K_D$ = Horizontal Stress Index
- $\sigma_v'$= Effective vertical stress (kPa)

**c. Dilatometer Modulus ($E_D$)**

Provides a measure of soil stiffness and is used for settlement analysis.

$$E_D = 34.7(P_1 - P_0)$$

***d.*** **Undrained Shear Strength ($S_u$)** ***(For Clays)***

$$S_u = 0.22\ (P_0 - P_a)$$

**e. Over consolidation Ratio (OCR)** ***(For Clays)***

$$OCR = \ (0.5K_D)^{1.56}$$

**f. Coefficient of Earth Pressure at Rest ($K_0$)**

$$K_0 = \left({}^{K_D}/_{1.5}\right)^{0.47} - 0.6$$

**3.2 Seismic Test (S-Wave Measurement)**:

The SDMT blade is equipped with geophones (usually two horizontal geophones) to measure shear wave (S-wave) propagation.A seismic source, typically a hammer striking a steel beam, generates seismic waves at the surface.The waves travel through the ground and are detected by the geophones.The time taken for the shear waves to travel between two sensors (spaced 0.5 to 1.0 m apart) is recorded using a data acquisition system.The shear wave velocity (Vs) is calculated using the formula:

$$V_s = \frac{L}{\Delta t}$$

Where,
$V_s$= Shear wave velocity (m/s)
L = Distance between geophones (m)
$\Delta t$ = Time difference between arrivals (s)

**3.2.1 Parameters from Seismic Test (S-Wave Measurement)**

a. **Shear Wave Velocity (Vs)**: Provides small-strain shear modulus ($G_0$),

$$G_0 = \rho {V_s}^2$$

Where,
$G_0$ = Small-strain shear modulus (Pa)
ρ= Soil density (kg/m³)

**b. Poisson's Ratio (ν)**

If compression wave velocity ($V_p$) is also available:

$$v = \frac{{V_p}^2 - 2{V_s}^2}{2({V_p}^2 - {V_s}^2)}$$

**c. Constrained Modulus (M):** Evaluated from DMT data for settlement analysis.

$$M = \frac{E_D}{1 - v^2}$$

The SDMT's combined capability of determining both mechanical properties and seismic wave velocities makes it an efficient and reliable tool for geotechnical site characterization, particularly for seismic site response analysis and liquefaction assessment.

## IV. Applications of SDMT

The Seismic Dilatometer Test (SDMT**)** is a powerful in-situ testing method that provides valuable geotechnical and seismic data for a variety of applications.

**a.** Geotechnical **Site Characterization**

- Provides detailed insights into soil strata, stiffness, and in-situ stress condition.
- Help to identify soft, loose, or problematic soil strata below foundations.
- Useful for determining soil parameters for design and settlement of foundation

**b. Seismic Site Classification**

- SDMT measures **shear wave velocity (Vs)** to classify sites as per seismic design codes like **IS 1893** and **NEHRP**.
- Provides essential data for estimating seismic loads and designing earthquake-resistant infrastructure.

**c. Liquefaction Assessment**

- Assesses the potential for **soil liquefaction** during earthquakes using shear wave velocity and empirical correlations.
- Used in seismic hazard evaluations for critical infrastructure like dams, bridges, and industrial facilities.

**d. Small-Strain Stiffness Estimation**

- The **small-strain shear modulus (G0)** calculated from SDMT is essential for dynamic analysis and seismic site response studies.
- Provides reliable data for **soil-structure interaction**modeling and ground motion analysis.

**e. Earth Pressure and Slope Stability Analysis**

- The **Horizontal Stress Index (KD)** from SDMT helps estimate in-situ earth pressures.
- Useful for designing **retaining walls**, embankments, and assessing **slope stability**.

**f. Settlement Analysis and Foundation Design**

- The **Dilatometer Modulus (ED)** is used to predict soil settlement and assess the load-bearing capacity of foundations.
- Facilitates the design of **shallow and deep foundations** with improved accuracy.

**g. Ground Improvement Monitoring**

- SDMT is widely used for **pre- and post-improvement assessments** in ground stabilization projects.
- Evaluates the effectiveness of methods such as **vibro-compaction**, **grouting**, and **stone columns** by comparing shear wave velocity before and after treatment.

These applications highlight the SDMT's versatility in providing both static and dynamic soil properties, making it a valuable tool for geotechnical investigations and seismic site evaluations.

## V. Advantages and Limitations

### 5.1 Advantages

- **Combined Geotechnical and Geophysical Data:** SDMT provides both mechanical properties and seismic wave velocity, offering a more comprehensive understanding of soil behaviour.
- **Accurate Seismic Measurements:** The dual-receiver system ensures precise shear wave velocity (Vs) measurements, which are critical for seismic site classification.
- **Rapid Data Acquisition:** Both DMT and seismic data can be obtained in a single sounding, reducing testing time and costs.
- **Reliable Soil Stiffness Assessment:** It provides reliable measurements of soil stiffness at small strains, essential for geotechnical and earthquake engineering applications.
- **Liquefaction Evaluation:** The test provides parameters necessary for evaluating the liquefaction potential of soil deposits.

### 5.2 Limitations

- **Specialized Equipment and Training:** Conducting SDMT requires specific instruments and experienced personnel, making it less accessible in remote regions.
- **Limited in Very Dense Soils:** Penetration may be difficult in dense gravelly soils or highly cemented materials, potentially affecting data acquisition.
- **Depth Constraints:** Although SDMT can typically reach depths of up to 50 meters, deeper investigations may require alternative geophysical methods.
- **Higher Costs:** Compared to conventional tests like SPT and CPT, the SDMT can be relatively expensive due to its dual data acquisition system.
- **Membrane Durability:** The thin membrane used in the DMT phase can sometimes be prone to damage in abrasive soils, impacting the accuracy of results.

## VI. Relevance in the Indian Context

India, with its vast and geologically diverse terrain, faces significant challenges in geotechnical site characterisation. SDMT has shown immense potential for application in seismic-prone regions such as the Himalayan belt, Gujarat, and the Northeastern states. Its capability to assess liquefaction potential and classify seismic sites makes it particularly valuable for infrastructure development in earthquake-sensitive zones. Furthermore, SDMT provides reliable data for large-scale projects like metro rail systems, dams, and highways, ensuring safer and more cost-effective construction practices. Adopting SDMT as a standard geotechnical investigation tool in India could enhance the resilience of infrastructure against seismic events.

## VII. Conclusions

The Seismic Dilatometer Test (SDMT) is a versatile and reliable tool for geotechnical site characterisation. Its ability to provide both mechanical and seismic data makes it invaluable for seismic hazard assessment, foundation design, and ground improvement studies. The SDMT's capacity to evaluate soil stiffness, shear wave velocity, and constrained modulus enables geotechnical engineers to make informed design decisions, ensuring safe and cost-effective infrastructure development. Additionally, the test's application in liquefaction potential assessment and seismic site classification further underscores its importance in earthquake-prone regions. With advancements in technology and increasing demand for comprehensive site investigations, the SDMT is expected to play a pivotal role in geotechnical engineering practices worldwide, particularly in the Indian context where seismic risks and infrastructure expansion demand robust geotechnical data.

## References

[1]. Marchetti, S. (1980). "In Situ Tests by Flat Dilatometer."
[2]. Totani, G., et al. (1998). "Seismic Dilatometer Test (SDMT) for Geotechnical Site Characterization."
[3]. Robertson, P. K. (2009). "Interpretation of In-Situ Tests in Geotechnical Practice."
[4]. Ashford, S. A., & Sitar, N. (2002). "Seismic Site Response from In-Situ Tests."
[5]. Mayne, P. W. (2007). "In-Situ Test Evaluations for Geotechnical Site Characterization."
[6]. Lancellotta, R. (2008). "Geotechnical Engineering."
[7]. Schnaid, F. (2009). "In-Situ Testing in Geomechanics."
[8]. Silvestri, F., & Viggiani, G. M. B. (2012). "Applications of SDMT in Geotechnical Earthquake Engineering."
[9]. Jefferies, M., & Been, K. (2015). "Soil Liquefaction: A Critical State Approach."