

Comparative Study of Consolidation Parameters Derived by Oedometer Test and DMT Dissipation Test on Borrow Area Soil Samples used for Construction of Earthen Embankment Dam in Madhya Pradesh

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Abstract: The long-term stability and deformation of an earthen embankment dam are fundamentally linked to the consolidation parameters of the core and casing materials sourced from borrow areas. While the Oedometer test is the standard laboratory procedure for determining Consolidation parameters, the Marchetti Dilatometer (DMT) is traditionally an in-situ tool. This study explores the feasibility of conducting DMT dissipation tests within a controlled laboratory environment on compacted soil samples collected from borrow areas of proposed dam in Madhya Pradesh. By performing both Oedometer and DMT tests on reconstituted samples under identical conditions like compaction energy and moisture conditions, this paper evaluates the correlation between the horizontal coefficient of consolidation (C_h) as well as the vertical coefficient of consolidation (C_v). The results aim to calibrate DMT empirical correlations against benchmark laboratory data to improve the reliability of future in-situ testing during dam construction.

Key Words: Laboratory DMT, Oedometer Test, Earthen Dam, Borrow Area, Consolidation, Compacted Soil.

I. Introduction

The design of earthen embankment dams especially core portion of dam requires precise knowledge of the coefficient of consolidation (C_v) for estimating rate of subsequent crest settlement. Typically, this is obtained via Oedometer tests in laboratory. However, introduction of the Marchetti Dilatometer Test (DMT) (which is a field test) in a laboratory setting provides a unique opportunity to study soil behaviour under controlled lateral stress conditions.

In this research, soil samples from borrow areas of a proposed dam in Madhya Pradesh were reconstituted in the laboratory to simulate embankment conditions. By conducting DMT dissipation tests in a large-scale laboratory mould, one can directly compare "A-reading" decay curves with Oedometer results without the interference of field-scale heterogeneities.

II. Components of Earthen Dam

A non-homogeneous Earthen Embankment dam is divided into 2 main components, Clay core as an Impermeable barrier and Casing for clay core protection.

2.1. The Clay Core

It is the Central portion of the earthen dam, which acts as an impermeable barrier to stop the drainage of water in the reservoir through dam body. Clay core has low permeability. The consolidation of the core can continue for several years after the dam is finished. It is required to calculate the Coefficient of Consolidation (C_v) to predict the rate of settlement.

2.2. The Casing (Shell)

Casing is a thick outer layer that surround the core on both upstream and downstream faces. It provides structural stability by holding the core in place.

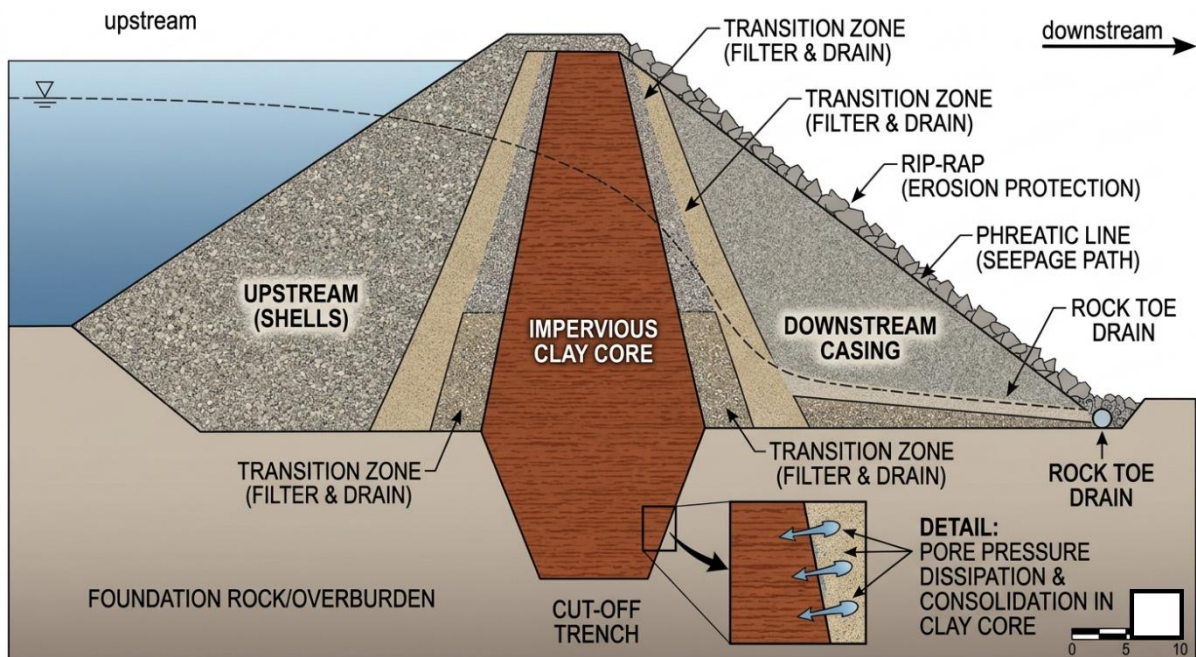


Fig-1: Sectional View of Earthen Embankment Dam

III. Borrow area for Earthen Dam

The borrow area is the off-site location where the specific clay for the core is excavated. For a core to function properly, the borrow material must have enough plasticity to ensure it remains impermeable. In present investigation, samples have been collected from the borrow areas to study their Index and Engineering properties. The soil samples collected from these borrow areas typically consists of CH and CI type of soils. Optimum moisture content and Maximum dry density of these soils were determined by laboratory proctor compaction tests and results are presented in table-1.

IV. Experimental Setup

The research used soil sourced from borrow areas designated for an earthen dam project in Madhya Pradesh.

- Testing Mould: A specialized large-scale laboratory Mould was used to house the compacted specimen, providing sufficient boundary distance to prevent interference during the insertion of the DMT blade to determine C_h .
- Sample Preparation: Soil was processed and compacted at Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) derived by proctor compaction test.
- Nitrogen Gas Cylinder, DMT Control Unit, DMT blade, System to record pressure and time values.
- Oedometer Consolidation testing Equipment is Used to determine C_v .



Fig-2: Lab Flat Dilatometer Test Setup



Fig-3: Oedometer Consolidation Test Setup

V. Estimate of Geotechnical Parameters

5.1 Marchetti Flat Dilatometer (DMT)

DMT blade should be first calibrated for ΔA and ΔB values, Then the DMT blade was inserted into the laboratory-compacted soil at a constant rate. After reaching the desired depth dissipation tests were performed by monitoring the decay of the total stress on the membrane (A-reading) over time. The Log-time vs pressure graph was plotted to determine the T_{flex} value as shown in fig:5.

- **Horizontal Consolidation (C_h):** Estimated from the T_{flex} value derived from the dissipation curve.

$$C_h = 7/T_{flex}$$

	SYMBOL	PARAMETER NAME	FORMULA /DESCRIPTION
Field Readings	A	First Reading	Membrane lift-off pressure
	B	Second Reading	Pressure for 1.1 mm membrane expansion
	C	Third Reading	Membrane closing pressure
	ΔA	Membrane Calibration (A in free air)	Suction as positive pressure
Corrected Readings	ΔB	Membrane Calibration (B in free air)	Inflation as positive pressure
	[T, A]	Dissipation Test Readings	A-readings with time (at specific depth)
	P_0	Corrected First Reading	$P_0 = 1.05 (A + \Delta A) - 0.05 (B - \Delta B)$
	P_1	Corrected Second Reading	$P_1 = B - \Delta B$
Intermediate Parameters	P_2	Corrected Third Reading	$P_2 = C + \Delta A$
	I_D	Material Index	$I_D = (P_1 - P_0) / (P_0 - U_0)$
	K_D	Horizontal Stress Index	$K_D = (P_0 - U_0) / \sigma'_{v0}$
	E_D	Dilatometer Modulus	$E_D = 34.7 (P_1 - P_0)$
	U_D	Pore Pressure Index	$U_D = (P_2 - U_0) / (P_0 - U_0)$
	T_{flex}	Dissipation Flex Point	
Interpreted Geotechnical Parameters	γ	Unit weight	see unit weight chart
	K_0	Earth Pressure Coefficient	$K_{0, DMT} = (K_D / 1.5)^{0.47} - 0.6$ $I_D \leq 1.2$
	OCR	Overconsolidation Ratio	$OCR_{DMT} = (0.5 K_D)^{1.56}$ $I_D \leq 1.2$
	S_u	Undrained Shear Strength	$S_{u, DMT} = 0.22 \sigma'_{v0} (0.5 K_D)^{1.25}$ $I_D \leq 1.2$
	Φ	Friction Angle	$\Phi_{DMT} = 28 + 14.6 \log K_D - 2.1 \log^3 K_D$ $I_D > 1.8$
	M	Vertical Drained Constrained Modulus	$M_{DMT} = R_M E_D$ If $(I_D \leq 0.6)$ $R_M = 0.14 + 2.36 \log K_D$ If $(I_D \geq 3)$ $R_M = 0.5 + 2 \log K_D$ If $(0.6 < I_D < 3)$ $R_M = R_{M0} + (2.5 - R_{M0}) \log K_D$ $R_{M0} = 0.14 + 0.15 (I_D + 0.6)$ If $(K_D > 10)$ $R_M = 0.32 + 2.18 \log K_D$ If $(R_M < 0.85)$ set $R_M = 0.85$
	C_h	Coefficient of Consolidation	$C_{h, DMT} = 7 \text{ cm}^2 / T_{flex}$
	K_h	Coefficient of Permeability	$K_{h, DMT} = C_{h, DMT} \gamma_w / M_{DMT}$ ($M_{DMT} \approx K_D M_{DMT}$)
	U_0	Equilibrium Pore Pressure	$U_0 \approx P_2$ for drained layers only

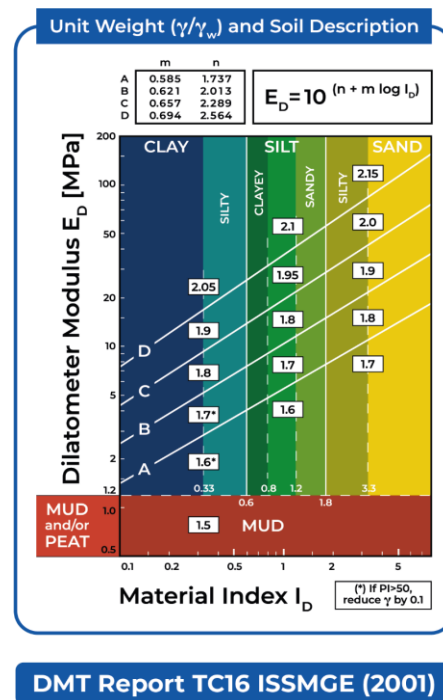


Fig-4: DMT Data Reduction Formulae

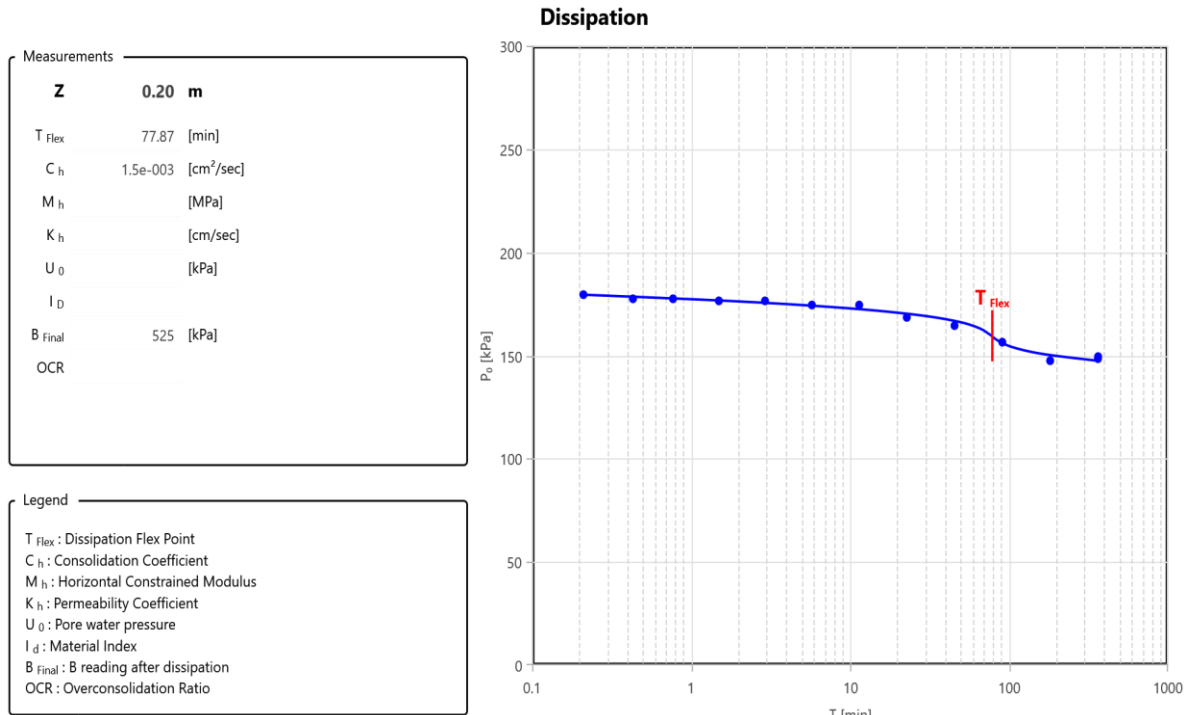


Fig-5: T_{flex} Graph from DMT Dissipation Test to determine T_{flex} and C_h

5.2 Oedometer Consolidation Test

Laboratory parameters were derived from samples collected from the borrow areas and compacted to the target Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) derived by Standard proctor compaction test. The vertical coefficient of consolidation (C_v) was determined following standard incremental loading procedures (IS 2720 Part 15).

The Log-time vs Settlement graph was plotted to determine the t₅₀ value as shown in Fig-6. The value of Vertical Coefficient of Consolidation was determined by below Equation.

$$C_v = 0.197 * d^2 / t_{50}$$

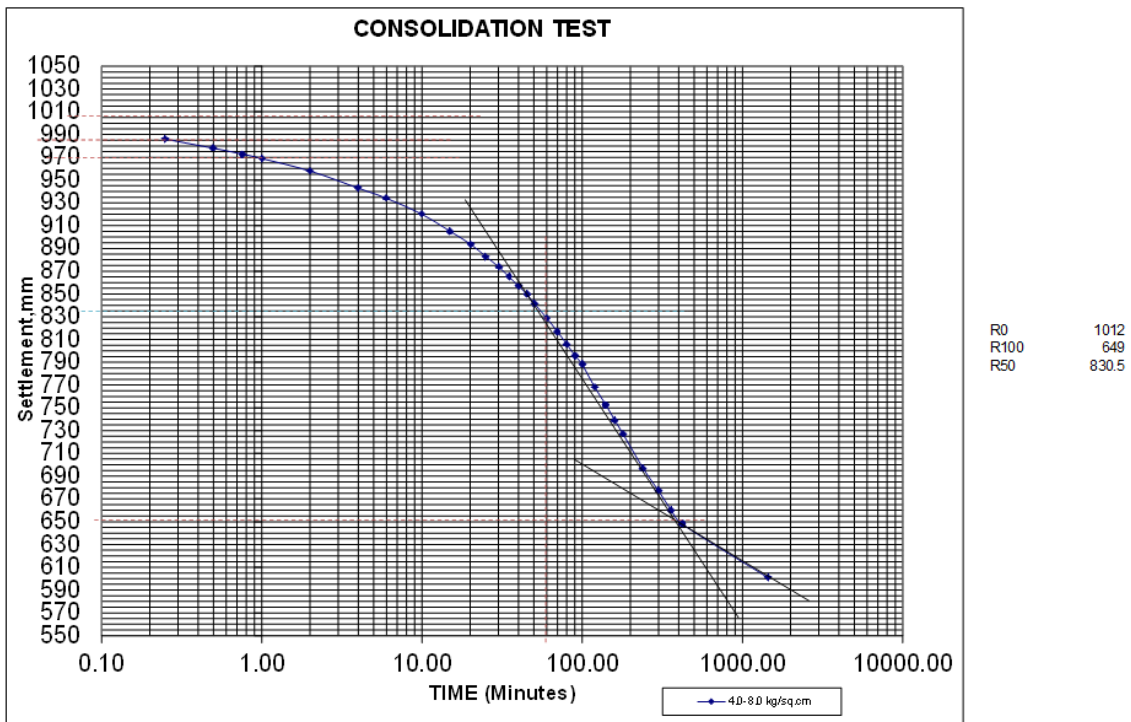


Fig-6: Oedometer log-Time vs Settlement graph to determine t₅₀ and C_v

VI. Results and Analysis

The table below compares the parameters derived from the two laboratory-based methods.

Table-1: Comparison of parameters obtained by Oedometer and Lab-DMT

Borrow Area Sample	OMC (%)	MDD (g/cc)	Coefficient of Consolidation C_v (cm ² /sec)	Lab-DMT C_h (cm ² /sec)	Correlation factor (C_h/C_v)
Sample-1	21.0	1.630	1.23×10^{-4}	1.5×10^{-3}	12.1
Sample-2	19.5	1.637	2.18×10^{-4}	1.9×10^{-3}	8.7
Sample-3	17.9	1.780	2.03×10^{-4}	1.8×10^{-3}	8.8
Sample-4	18.8	1.670	1.92×10^{-4}	1.8×10^{-3}	9.3
Sample-5	20.5	1.646	2.23×10^{-4}	2.0×10^{-3}	8.9
Sample-6	20.5	1.610	1.85×10^{-4}	1.8×10^{-3}	9.7

Analysis of the data indicates that the Lab-DMT yields C_h values that are consistently higher than the C_v from Oedometer tests, likely due to the different drainage path orientations and the lateral stress state imposed by the DMT blade.

VII. Conclusions

The laboratory application of the DMT on compacted borrow area samples proved successful in characterizing consolidation behaviour. Key findings include:

- a) **Correlation Reliability:** The laboratory DMT provides a controlled baseline for C_h which can be used to calibrate field equipment data for the Madhya Pradesh region. The values of C_h by DMT Dissipation test are approximately 10 times that of the values of C_v by Oedometer Consolidation test.
- b) **Insertion Effects:** Even in a laboratory setting, the displacement caused by the DMT blade influences the initial pore pressure, which must be accounted for when comparing to Oedometer results.
- c) **Future Application:** This comparative study validates that DMT correlations can be effectively used to monitor the quality of compacted clay cores in earthen dams.

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