Compacted landfill quality based on DMT

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ABSTRACT

For the last 25 years we have been using DMT tests to check the quality of landfill compaction. In several situations of large areas subject to earthmoving, significant pathologies were observed associated with the occurrence of settlements, determined by poor compaction of landfills. These settlements affect the internal floors of buildings, external floors, and sometimes the foundations also. With the intense use of the DMT test as an usual geotechnical investigation practice, it was possible to group the results of these tests, separating them into cases of good, average, and bad behavior. With these systematic observations, it was possible to adapt the traditional graphical representation proposed by Silvano Marchetti and David Crapps, relating the material index "Id" with the dilatometer modulus "Ed", creating regions that represent well-compacted landfills, those with medium compaction and poorly compacted landfills. This system makes it easy to predict the settlement behavior of compacted landfills and represents an appropriate method for checking the quality of compaction.

Keywords: DMT; compacted fill; compaction control; quality of compaction.

1. Introduction

DMT has been widely used around the world as an in-situ investigation tool for obtaining geotechnical soil parameters, being used in Brazil for at least 25 years.

In Brazilian practice, the DMT test has been employed as an additional method for site investigation, complementing traditional Standard Penetration Test (SPT) percussion drillings, which remain as the main geotechnical investigation technique in the country.

Practical applications of the test encompass various geotechnical engineering issues, such as: subsurface stratigraphic identification; prediction of settlements of various types of foundations; assessment of soil strength and deformability and evaluation of the quality of landfill compaction.

This study focuses on the latter application, aiming to bring a contribution of the potential of the DMT test for this purpose, drawing on experience gained from tests conducted on various fills located in the Metropolitan Region of São Paulo (MRSP) and neighboring cities.

2. Initial considerations

Although the test technique was developed by Prof. Silvano Marchetti in the 1970s (Marchetti 1975), its commercial application in Brazil only began in the late 1990s, after the Damasco Penna Geotechnical Engineering firm acquired the first equipment in 1997 and initiated practical investigations in engineering projects.

The equipment and test characteristics are as presented in (Marchetti 1980) and (Marchetti et al. 2001), with applications and discussions on knowledge indicated in (Schmertmann 1986), (Robertson, Davies, and Campanella 1987), (Lutenegger 1988), (Lunne, Lacasse, and Rad 1989), (Lunne, Robertson, and Powell 1997), (Coutinho, Bello, and Pereira 2006), (Cruz, Devincenzi, and Fonseca 2006), (Giacheti et al. 2006), (Mayne 2006), and (Marchetti 2015).

There has been an intensification of DMT test usage in logistics sites located in MRSP and neighboring cities since 2015, when several warehouses built on large landfill areas exhibited poor performance, with manifestations of settlements and cracks in the internal floors of storage areas, excessive deformations in yards and external streets, as well as settlements in foundation piles in some cases.

Studies carried out on these sites confirmed the initial hypotheses which diagnosed the pathologies, associating the occurrence of settlements with the poor compaction of the fills constructed at the investigated sites.

Examples of pathologies that occurred at these sites and records of settlements obtained with instrumentation are indicated in Fig. 1 to Fig. 3.

Figure 1. Crack observed on the inside concrete floor.

Figure 2. Displacements observed on the external asphalt pavement.

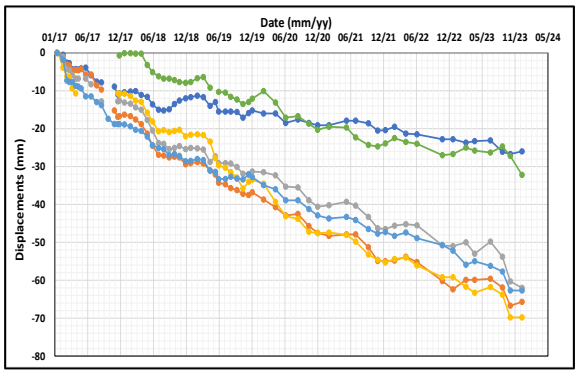

Figure 3. Settlements measured by geotechnical instrumentation.

In all these sites, the damages were quite significant. The association of these damages with landfill compaction deficiencies exposed a fragility in the earthwork construction process and, primarily, in the quality control used in most works with these same characteristics.

For this reason, some developers decided to adhere to the guidelines and technical specifications of the geotechnical earthwork projects, adopting stricter practices regarding the production of compacted landfills.

An exemplary case that highlights this paradigm shift in relation to the production of well compacted landfills is presented in (Penna et al. 2021). In that work, the authors presented data from a logistics site located in the city of Cajamar, involving a large-scale earthwork (1,000,000 m³ of compacted landfill), executed following good earthwork construction practices and with additional rigor regarding landfill compaction quality controls.

Other similar sites located in the cities of Cajamar and Embu das Artes were also executed with high rigor in landfill compaction quality control procedures.

Contrary to what was observed in the first sites mentioned, these new sites have shown very satisfactory behavior of the landfills, as well as the structures implemented on them.

It is important to note that DMT tests were intensively conducted in these new sites, forming part of the compaction control process for landfills that exhibit superior quality and highly satisfactory behaviors.

3. Proposed approach

With the intensified application of geotechnical investigation practices using DMT in the works of important landfills with very different geotechnical conditions (landfills with poor compaction and well-compacted landfills), it was possible to build a database of these tests results, associated with the behavior of the landfills observed in the field.

The data used for this approach were the intermediate parameters of the material index (I_D) and the dilatometric modulus (E_D), defined in (Marchetti 1980).

Silvano Marchetti and David Crapps (Marchetti and Crapps 1981) presented a chart for soil classification and specific weight estimation by relating the values of I_D and E_D, as indicated in Fig. 4.

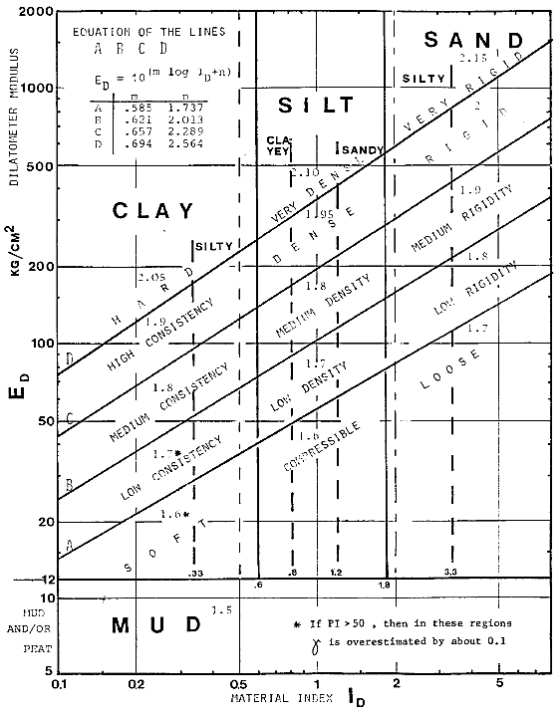

Figure 4. Chart for estimating soil type and specific weight for soil.

The authors included soil consistency and compactness states in the chart, which is highly applicable for the procedure presented in this work, since the goal is to evaluate the level of soil densification achieved with earthwork compaction operations in the field.

It is reasonable to expect that DMT tests performed on well-compacted landfills will result in pairs of I_D x E_D values corresponding to the highest states of consistency and compactness of that material.

This hypothesis was initially tested with the data obtained from the work presented in (Penna et al. 2021). The result of this test can be seen in Fig. 5.

Subsequently, the other sites with well-compacted landfills mentioned in the previous chapter were also tested and the results were equivalent to those in Fig. 5, with a concentration of points in the ranges of materials with higher consistencies and compactness.

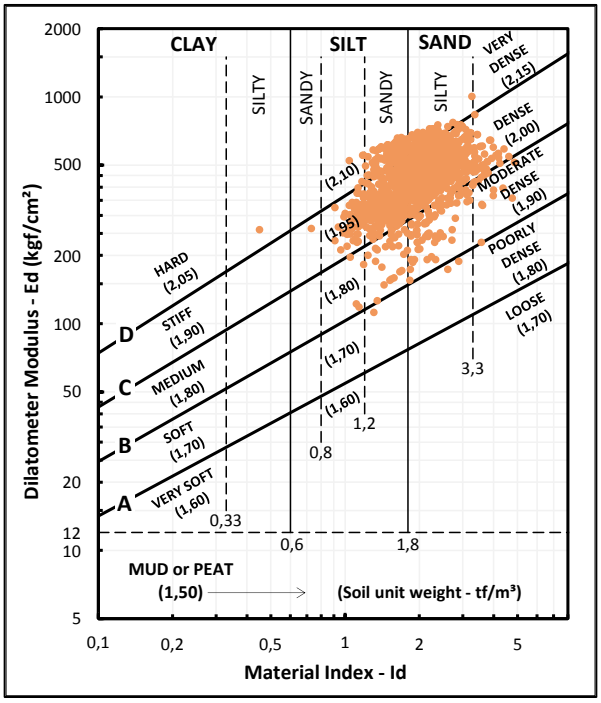

Figure 5. Results of DMT tests on a very well-compacted landfill mentioned in (Penna et al. 2021).

After these initial findings, the pairs of I_D x E_D values from DMT tests of the landfills with poor compaction were also plotted on the same chart, resulting in a cloud of scattered points and a strong occurrence in the ranges of soft and poorly compacted materials, as indicated in Fig. 6, which groups together data from sites with the pathologies mentioned in the previous chapter.

Following this approach, the I_D x E_D values of DMT tests conducted on conventional landfills were plotted, where compaction and quality control conditions of the earthworks were not differentiators of the project, i.e., a median condition between the previous extreme limits. In addition, no pathologies associated with the behavior of the landfills were registered in these sites.

The plotted points of this supplementary verification are indicated in Fig. 7.

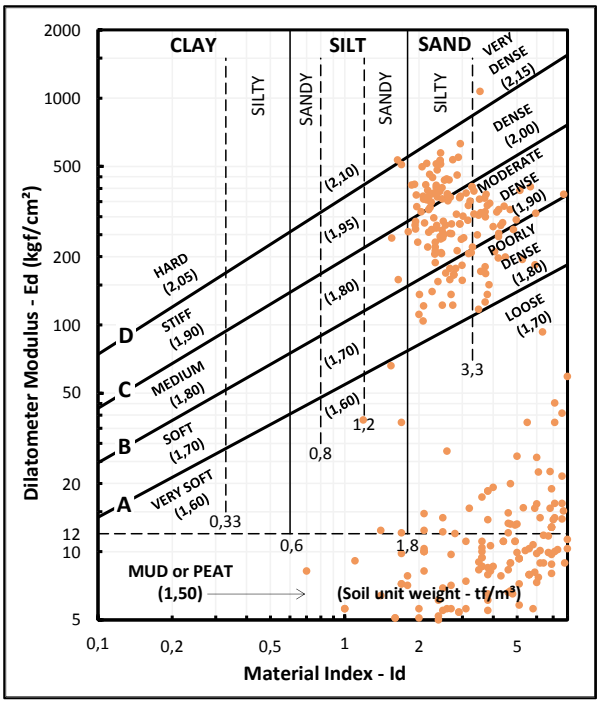

Figure 6. Results of DMT tests on landfills with compaction deficiencies

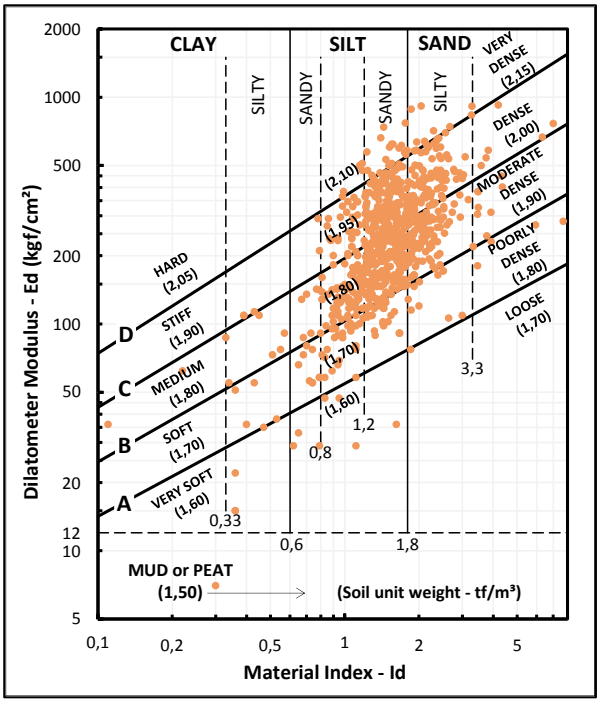

Figure 7. Results of DMT tests on landfills with median compaction quality.

From the systematic observation of these forms of distribution of I_D x E_D values on the Marchetti and Crapps chart, associated with the behavior of the landfills in the field, it was possible to adjust regions on a graphical scale to classify the results of DMT tests on well-compacted, moderately compacted or inadequately compacted landfills.

This proposal is indicated in Fig. 8.

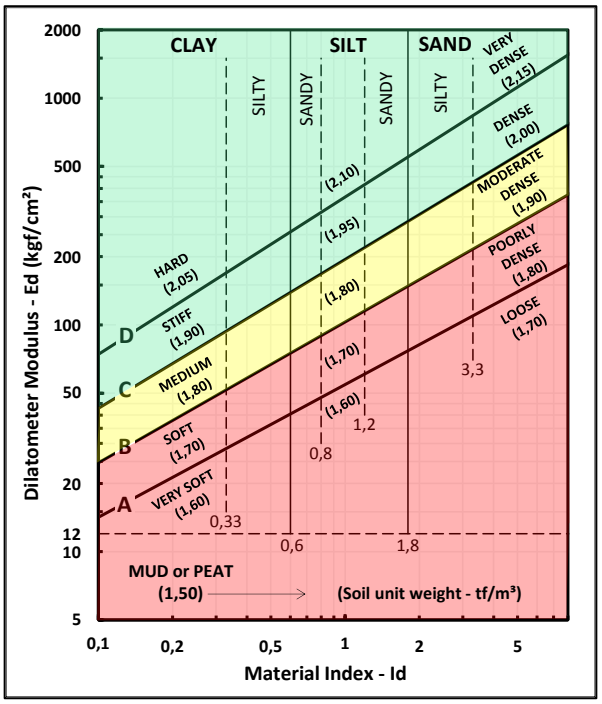

Figure 8. Graphical scale pattern for regionalization of landfill compaction quality.

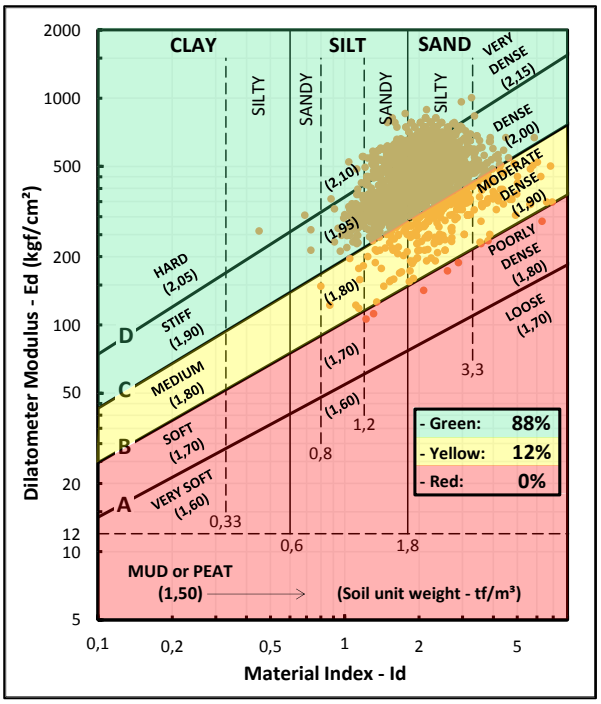

Figure 9. Results of DMT tests in well-compacted landfills in the MRSP.

In this chart, the green region represents adequately compacted landfills, the yellow region represents moderately compacted landfills and the red region represents inadequately compacted landfills.

Furthermore, with this regionalization, the interpretation of DMT test results for classifying the quality of a landfill becomes visually clear.

Landfills with a higher concentration of points in the green region are well-compacted landfills, where no pathologies resulting from their behavior are expected. On the other hand, landfills with higher concentration of points in the red region are landfills with poor compaction, thus serving as a trigger for the manifestation of pathologies.

4. Results

The database of DMT tests carried out on landfills in the MRSP and neighboring cities was used to feed the adjusted classification chart, the results of which are presented in Fig. 9 to 11.

Fig. 9 shows the results obtained from well-compacted landfills, with over 85% of points in the green region. Fig. 10 displays the results from moderately compacted landfills, with around 50% of the points in the yellow region, along with a significant presence of points in the green region. Fig. 11 shows the results of landfills with poor compaction, with over 85% of points in the red region.

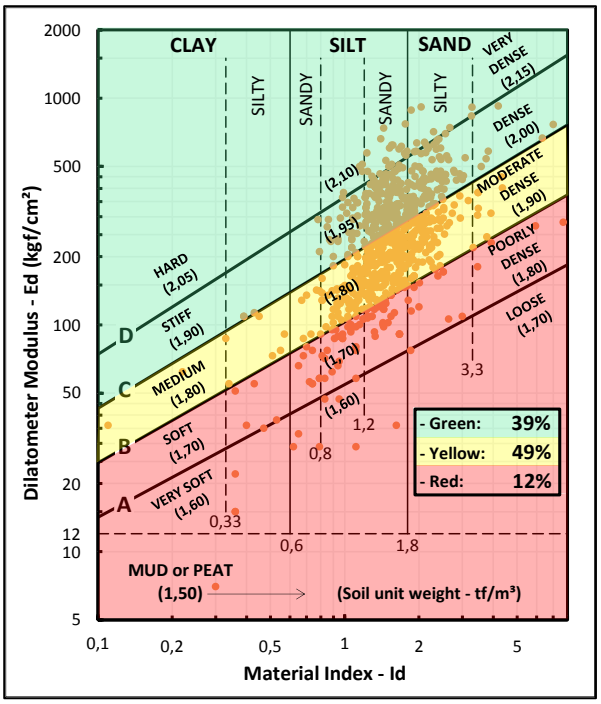

Figure 10. Results of DMT tests in moderately compacted landfills in the MRSP

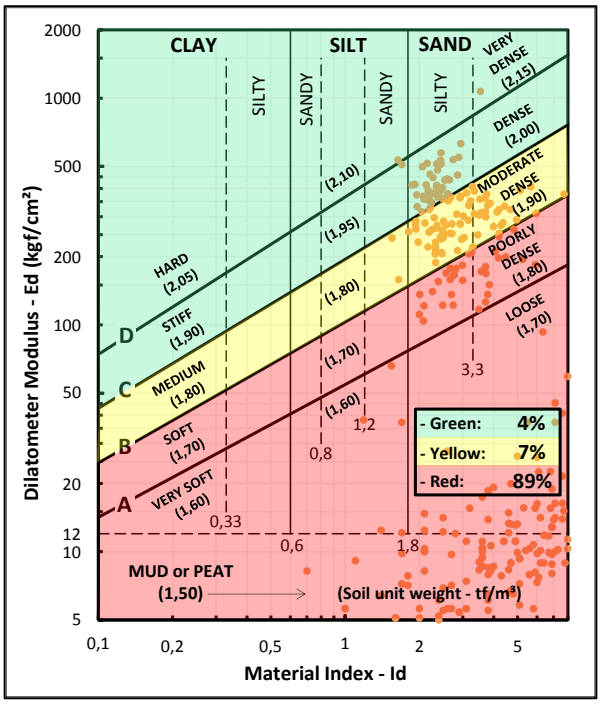

Figure 11. Results of DMT tests in poorly compacted landfills in the MRSP

5. Conclusions

The increasingly intensified application and practice of geotechnical investigation using DMT have led to the development of this empirical approach for verifying the compaction quality of landfills, resulting in a simple and effective method.

The extension of the application of this method to landfills located in other regions may fuel new and timely discussions for the improvement of the methodology suggested in this work.

Acknowledgements

The authors express their gratitude to Damasco Penna Geotechnical Engineering for providing the test data to produce this work, as well as to Ana Beatriz Alcantara, geologist from Damasco Penna, for translating the article into English.

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