Methods for Assessing Density of Low Plasticity High Permeability Materials

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Abstract

Good quality embankment materials are required to maintain smooth-riding pavements. Adequate moisture control and uniform compaction are required for a quality embankment. The current test process (modified Proctor compaction test) for density ratio determination is poor at achieving repeatability of the results for cohesionless soils. This affects the quality control certification of these types of civil works and limits their application. The objective of compaction is to achieve a high density by expelling water and air from the soil matrix to achieve an increase in stiffness and density, thereby reducing the failure risk of post-construction settlement. A method of determining the maximum and minimum density for cohesionless sands for embankments and subgrades in road construction through a vibrating table has been studied. Both the test procedures and results are to be compared and empirical relations are determined by conducting a set of experiments. Four different cohesionless sand sample materials have been tested using two methods of to determine the level of compaction, modified proctor & vibratory table methods. Corresponding PSD (particle size distribution) curves have been studied to confirm the material classification. The final objective is to develop test methods that will be quicker and produce more technically reliable (repeatability) outcomes for a reasonable range of non-plastic material types.

1. Introduction

Compaction is the densification of soils by a mechanical process. Dry density determination of non-plastic (cohesionless), poorly graded sands is an ongoing challenge that results in poor and sometimes imprecise MMDD (modified maximum dry density) vs OMC (optimum moisture content) curves being produced. The potential cause of this phenomenon could be that water is squeezed out of the sample during testing around and above the optimum moisture content, leading to ill-defined curves. The most economical and abundant fill material in the Perth metropolitan area is typically poorly graded sands. It is important that these soils should possess good quality compaction characteristics for long-term purposes. Due to poor repeatability issues, many human potentials (technician hours) have also been affected. The objective of compaction is to achieve an adequate density of the founding soils to ensure the post-construction settlements are small and the bearing capacity of the soils is achieved. The water used for compaction aids the compaction process and increases the density achieved. This moisture helps the granular particles move to achieve a closer packing level, which improves the strength characteristics (internal friction angle) of soils, resulting in decreases in compressibility and permeability.

The main objective of this research is to develop a more repeatable and lower-cost test method to ensure quality compliance certification by determining the maximum dry density for cohesionless soils. This new approach should be simpler than the current MMDD method and less prone to error with consistent repeatability.

This research project seeks to improve the quality of test results, it is difficult to predict the direct financial merit due to this project. As the new apparatus has been purchased, the initial capital cost may be higher. It is estimated that the methodology will reduce the testing time and thereby the technician hours assigned to testing. Over the next decade, this project will increase confidence in the use of cohesionless materials as fill materials, reduce technician time and laboratory procedures and improve the quality of reporting for the pavement engineers. This also improves the reputation of Main Roads WA as an example for other road agencies in adopting more resilient tests.

2. Process

The soil forms the basis and the foundation of every structure. Accurate tests are needed to verify the engineering properties of the founding soils, safety and reliability. The Modified proctor compaction test plays a vital role in ascertaining the structure such as pavements' strength and durability. The modified proctor compaction test helps to variate the connection between the soil moisture content and the dry density. Table 1 shows test procedures and their corresponding Australian Standards.

Experiments	**Description**	**AS Standards**	**MRWA Standards**
Particle Size Distribution (PSD)	Sieving and Decantation method	AS1152	WA115.1-2019
Soil Compaction and density test	Determination of dry density/moisture content using modified compactive effort	AS1289.5.2.1:2017	WA133.1
	Determination of minimum and maximum dry density of a cohesionless material – Standard method	AS1289.5.5.1:1998	Not available

Table 1 Australian and Main Roads WA Standards Reference Numbers

Pertaining to the sample type and testing methods, there are four soils identified as illustrated in Table 2. As this research is focusing on the MMDD vs OMC and Minimum and Maximum Density testing methodologies, the comparison and procedures for these tests have been described here.

Sample type	Picture	Supply	PSD	Soil Particle density	MMDD	Vibrating table
Bassendean Sand		Tonkin Highway	1	1	5	5
Red sand		Manufactured sand	1	1	5	5
Yellow sand		Bunnings	1	1	5	5
White sand		Welshpool	1	1	5	5

Table 2 Samples & Testing plans

2.1 Test methods

There are two test methods that are being compared in this research study. The Modified proctor and vibrating table (including loose pouring by funnel) methods are explained as below.

2.1.1 Procedure for modified proctor test (AS1289.5.2.1:2017)

1. Weigh the mould with base plate attached to the nearest 1g and record the weight. Attach the extension collar with the mould. Compact the moist soil into the mould in five layers of approximately equal mass, each layer being given 25 blows, with the help of 4.9 kg rammer, dropped from a height of 450mm above the soil. The blows must be distributed uniformly over the surface of each layer. The operator shall ensure that the tube of the rammer is kept clear of soil so that the rammer always falls freely.
2. Weigh the mould with the compacted soil to the nearest 1g and record this weight.
3. Remove the compacted soil from the mould and place it on the mixing tray. Determine the water content of a representative sample of the specimen. Record the moisture content.
4. The remainder of the soil shall be broken up, by adding a suitable increment of water to the soil. The total number of determinations made shall be at least five, and the moisture contents should be such that the optimum moisture content, at which the maximum dry density occurs, is within that range.

Loose pouring using a funnel will be used for minimum dry density and vibratory compaction will be used for maximum dry density.

2.1.2 Procedure for minimum dry density by dry placement (AS1289.5.5.1:1998)

1. Determine the mass of the mould and all further mass determinations to the nearest 0.1 percent .
2. Fill the mould to overflowing by placing the material as loosely as possible using the funnel device. When placing the by pouring funnel, all the sand to a steady flow so that the free fall is not more than 20mm in a spiral motion from outside towards the centre.
3. Levelling off the material by steel straightedge and repeat again steps (1) and (2). Determine the mass of the material m_s. Use the lowest value.

2.1.3 Procedure for maximum dry density by wet placement (AS1289.5.5.1:1998)

1. Mix the saturated soil in a tray and transfer it to the mould by means of a scoop.
2. Attach the mould assembly to the vibrating table and vibrate the mould during filling to overflowing. Adjust the amplitude as required to avoid boiling and continue the vibration for 5 minutes.
3. Lower the surcharge and vibrate the loaded specimen for 10 minutes.
4. Carefully remove the contents of the mould into suitable tray and dry to constant mass in an oven at 105 to 110 degree C.
5. Determine the mass (m_s)of the dry material.

3. Results and Discussion

3.1 Particle Size Distribution curve (Selection criteria for cohesionless soils)

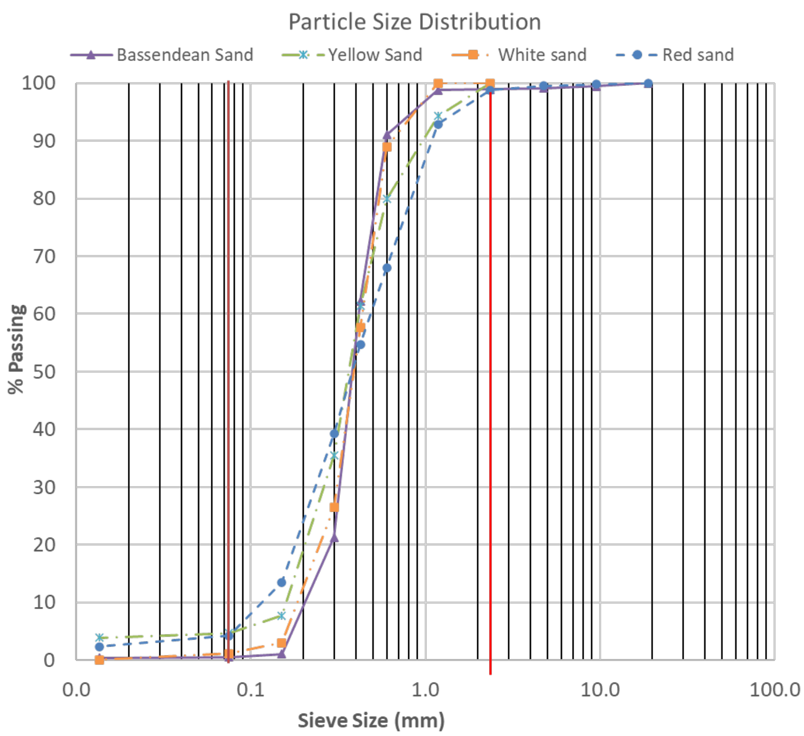

Figure 1 Particle Size Distribution curves

3.2 Maximum Dry Density vs Optimum moisture content (for Yellow sand)

The results of the modified proctor test in Figure 2 show that MMDD was obtained from experiments for the yellow sand. As per the project brief, the results from the graph are inconsistent showing double hump, it is evident from Table 3 that the obtained MMDD data is consistent for the given sample. The same has been observed for the remaining samples as well.

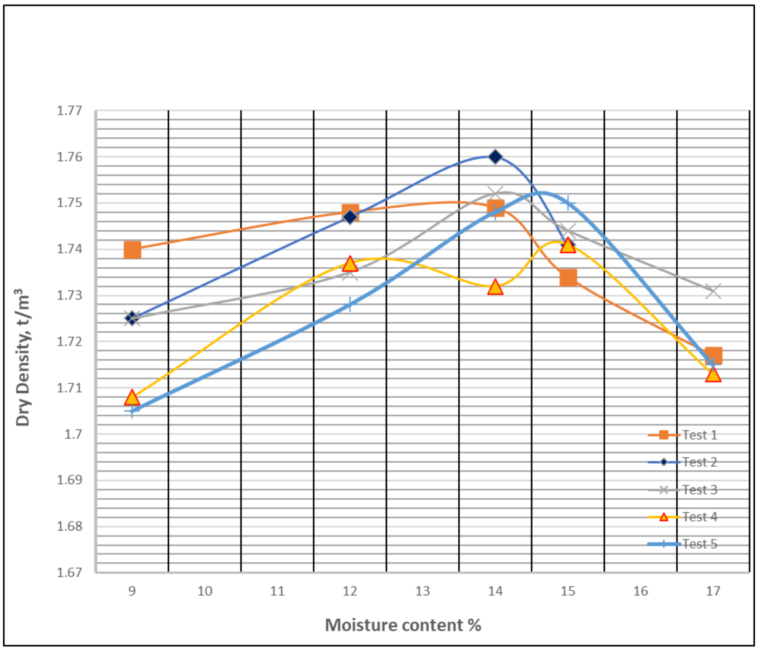

Figure 2 MDD vs OMC results (Yellow sand)

3.3 Maximum and Minimum Dry density (Yellow sand)

	Loose Pouring	Vibrating Table	MMDD
Test No	Min dry density (t/m^3)	Max dry density (t/m^3)	MDD from Mould (t/m^3)
1	1.45	1.816	1.75
2	1.443	1.811	1.766
3	1.435	1.820	1.752
4	1.438	1.824	1.742
5	1.439	1.835	1.752
Mean	1.441	1.821	1.7524
SD	0.004	0.008	0.008

Table 3 Min and Max Dry density - vibratory and funnel method (yellow sand)

Similarly, the vibrating table method along with the funneling method also produces more consistent and repeatable results as shown in Table 3. As the water content doesn't really have an impact on the field over the MMDD, it is considerable progress to this project leaning toward the vibrating table method.

All the remaining samples have been tested and all of them are showing a similar trend. Further analysis of data and its trend is being carried out with particle density tests. The fine content (75 microns or lesser) of all the samples remains at one percent except one which is 3%. The following Chart 1 has illustrated the relationship between the density index and density ratio.

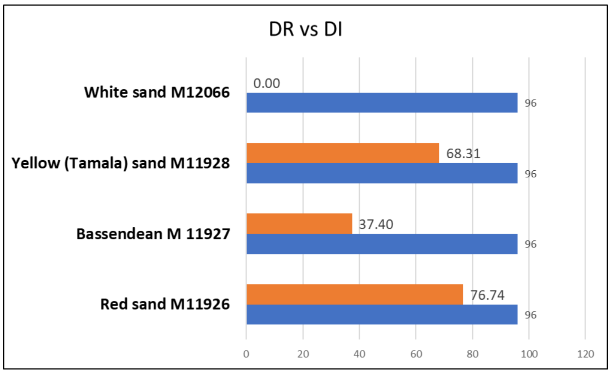

Chart 1 Density Index and Density ratio relationship

4. Conclusions and Future Work

It has been evident that the results of current MMDD vs OMC are inconsistent for non-plastic soils. On the other hand, the vibratory table method provides a reliable and consistent minimum and maximum density results for the same set of samples. During the remainder of the project period, the particle density test and the relationship between density index and density ratio will be studied.

However, further research about the fine content (more than 15%) materials and their suitability for this test method may be needed as an academic interest. These findings will help Main Roads WA to adopt the vibrating table method as one of its intrinsic test methods provided all the stakeholders and engineers accept this method as an alternative to current proctor tests depending on the ongoing effort to develop an empirical relationship between density ratio and density index.

5. Acknowledgements

The support of the Materials engineering division of Main Roads WA members including the Main Road engineers and laboratory technicians has been incredible throughout the experiment sessions. The scholar is expressing sincere thanks and appreciation for their efforts to support this project. Finally, the scholar is acknowledging and thankful to the CEED director Prof. Jeremy Leggoe and CEED coordinator Kimberlie Hancock, client mentors Phil Brittan and Simon Kenworthy-Groen, and academic supervisor Prof. Yuxia Hu and Colin Leek for providing continuous support and directions throughout the project period.

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