Rapid Water Content Measurement for Processed Asphalt Planings

O. I. Ogwuda
School of the Built Environment, Heriot-Watt University, Dubai Campus, Dubai, United Arab Emirates

D. Niedźwiecki
Zakład Realizacyjno-Projektowy Obiektów Ochrony Ekologicznej "EKO-PAR" Spółka z o.o, Kraków, Poland

ABSTRACT: A rapid field technique for evaluating water content of processed asphalt planings has been developed. The need for developing a rapid water content measurement technique has arisen from a technology programme (partly sponsored by the UK Government), in which a commercially viable novel process for road asphalt planings has been established. Integral to the process is the addition of water and the ability to rapidly and reliably determine the water content during production, stockpiling and transportation of the processed asphalt planings. Various techniques exist for measuring water content, but these are generally applicable for aggregates and soil. This paper appraises the various techniques for measuring water content and proposes techniques that would be most suited for asphalt planings. The standard methods of measuring moisture content can be time consuming and are not suitable for routine field production, sampling, stockpiles and transportation. Experimental work has been undertaken for those techniques that are deemed most suited for processed asphalt planings and the results are presented. A fast and reliable method of measuring water content for processed asphalt planings was determined to be a portable probe that is simple to use by operators, is reliable and is safe.

KEY WORDS: Asphalt planings, water content, moisture measurement.

1 INTRODUCTION

Roads are the largest national asset of any country and the provision and maintenance of this asset is a hugely significant undertaking. Roads are the main form of land transport in many countries and often carry more than 80 percent of passenger-km and over 50 percent of freight ton-km in a country. Thus, roads are important to the national economy and provide vital links to vast regional, urban, local and rural areas (World Bank 2009). Developed countries need to maintain their road networks for continued economic growth while developing countries are building their road networks to reach standards similar to developed countries. Developing countries are also looking to create a national network of roadways, but they are looking to include much more sustainable construction. They have the opportunity to lead with a form of construction that will cascade to what are now 4th world countries - developed countries of the future.

Since the oil crisis in the 1980s, the cost of energy, bitumen and aggregates has risen. For this reason, wide-ranging research and development work has been undertaken to reduce costs of road building and maintenance. Part of the research and development work involves the use of alternative materials - recycled and secondary materials. These materials have been proven to be feasible in many cases, with some alternative materials outperforming primary materials (de Urbina and Goumans 2003, Dhir et al. 2002, Dhir et al. 2003, Edwards 2003, Eighmy 2003, Goumans et al. 1997, Goumans et al. 1994, Hansen 1992, Lauritzen 1994, OECD 1997, Sherwood 2001, The Highways Agency et al. 2005, Woolley et al. 2000).

An increasing amount of vehicular traffic on roads means designing, building and maintaining roads after years of use. The most frequent wear and tear usually occurs with the road surfacing, which is exposed to weather effects and vehicle loading. Hence, the road surfacing must be restored at adequate intervals and in good time. Generally, asphalt planers are used to “plane off” of the road surface to produce asphalt planings, containing bitumen and aggregates. Asphalt planings, obtained by milling road surfacing, is one of the most common arisings from road construction and maintenance activities.

There are two main techniques (hot and cold) for production of new asphalt mixtures using asphalt planings. However, as entrapped water within asphalt mixtures is detrimental to the performance of asphalt pavements, both techniques require strict control of water, in primary aggregates and/or added recycled asphalt planings.

An alternative and novel process for the use of asphalt planings has been developed from a UK government sponsored technology programme, in which a commercially viable novel process for road asphalt planings has been established (Technology Strategy Board (UK) 2007). The process involves controlled utilization of water in the production of low energy high performance re-engineered asphalt planings that requires no additional primary materials. Hence, a rapid on-site technique for determining water content is integral to the process.

The standard methods of measuring moisture content can be time consuming and are not suitable for routine field production, sampling, stockpiles and transportation. This paper appraises various techniques for measuring water content and proposes a technique that would be suitable for asphalt planings.

2 WATER CONTENT IN PROCESSED ASPHALT PLANINGS

Water, which can be present as vapour, liquid or ice, is necessary for many processes in construction. However, it can be undesirable and a source of defects and disasters. Water deteriorates bitumen-aggregate bonds which reduces mixture strength and stiffness. In some processes water content determination is essential. One of these processes is the novel process for asphalt planings which requires strict control to create satisfactory material properties during production, transportation and placement. Hence, it is particularly important to determine water content of the asphalt planings.

3 METHODS FOR DETERMINING WATER CONTENT

This section describes common methods for determining water content in soils and aggregates, which could potentially be used with asphalt planings.

3.1 Ventilated Oven

The ventilated oven is the most common method for determining water content in various materials, such as soils and aggregates. This method generally gives reliable results and is used as a standard in many countries. The ventilated oven is often used to compare and validate results obtained from other water content moisture measurement techniques. The principle of water content determination is based on measurement of the loss of water after drying samples (at approximately 100°C) for a period of time, usually 24 hours (British

Standards Institution 2008). The drying temperature is not suitable for asphalt mixtures and for routine control purposes 24 hours may not be practicable.

There are usually no major health and safety issues with using the ventilated oven. The oven does require an external power source which may make it impracticable for use on site.

3.2 Speedy Moisture Tester

This method uses a speedy moisture tester (Figure 1) to determine water content in various materials. It provides very quick readings of moisture content which can be read directly from the specially calibrated gauge. It is a lightweight and portable device and can be used to determine in situ water content. The speedy moisture tester is designed to measure water content in soils, aggregates, dusts and powders.

Figure 1: Speedy moisture tester

Water content is determined by chemical reaction between free water in the sample and the reagent (calcium carbide) in the sealed pressure vessel. The result of the reaction is acetylene gas which generates pressure (British Standards Institution 1990). The more free water the sample contains the more acetylene gas that is produced. The pressure in the vessel is proportional to the amount of the water in the sample. The pressure is measured by the calibrated gauge which displays water content as a percentage of wet mass.

The speedy gives quick water content readings (takes approximately four minutes to get a reading from the start of the test). The method can be used to determine in-situ water content for a wide range of materials and does not require an external power source. This method can be a suitable alternative to the ventilated oven, where drying may cause vaporizing of materials – other than water e.g. volatiles in asphalt mixtures – that can give rise to misleading water results. Relatively small amounts of sample material (up to 40 g) can be tested, which limits the maximum particle size of the sample (20 mm). Health and safety issues need to be taken into consideration as calcium carbide reagent combined with water produces a potentially explosive and highly flammable gas (acetylene).

3.3 Portable Probe

The portable probe (Figure 2) is a versatile hand-held device designed to measure water content in various granular materials such as soils and aggregates. The device uses electrical conductivity to determine instant measurements of water content of bulk material samples. The tip of the sensor generates the high frequency electrical field between the fins of the sensor. The change in the field, which is affected by the presence of water, is converted to water content. The higher the water content the stronger the signal generated by the sensor.

As the portable probe is designed to be used on site for bulk material, sampling is usually not required and large quantities of material can be tested relatively quickly. The probe does not require any external power source and health and safety issues are not a major concern. Difficulties can arise with inserting the material in compacted material and coarse granular materials. Readings are based on electrical conductivity and highly conductive materials – other than water – can give misleading water content results.

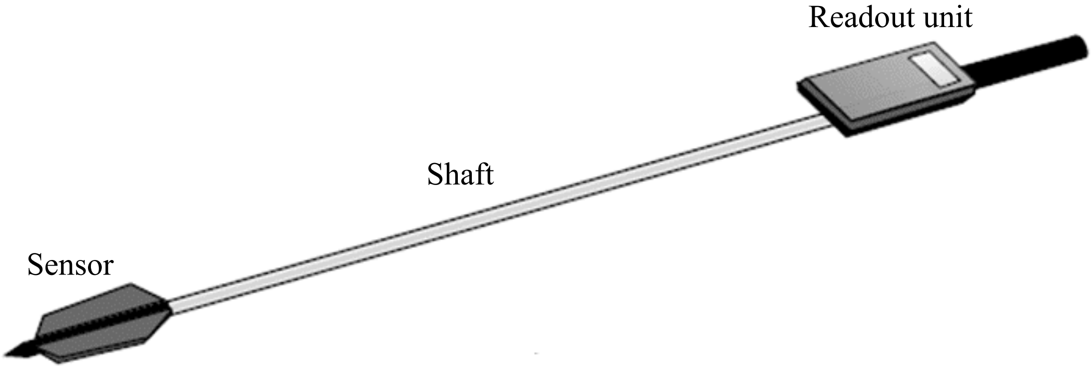

Figure 2: Portable probe schematic

3.4 Microwave Oven

The microwave oven is a rapid method for determining water content and the principle of operation is similar to ventilated ovens (British Standards Institution 1990). This method generally gives similar results to these obtained using conventional ventilated ovens and can be used for site control purpose. With the microwave oven, there is the possibility of overheating of samples resulting in misleading water content measurements. The overheating may be controlled by change in power setting and/or drying time. Hence, the test protocol should be appropriate for the material.

Some materials such as flints, slag and some calcareous aggregates have a tendency to shatter and drying in the microwave oven is not advised. Materials such as high organic soils, pulverized fuel ash, colliery spoils and soils containing coal, oils or other contaminations are also not suitable as they may ignite and burn during microwave drying. Soils and aggregates containing metallic materials can cause arcing in the oven by reflecting the microwaves.

There are health and safety precautions which must be strictly adhered to in using the microwave oven. The microwave oven requires an external power supply, which may be impracticable in certain on-site applications.

3.5 Alcohol Burning

Alcohol burning method is one of the oldest methods used for rapid determination of water content in soils and aggregates (Bouyoucos 1928). The alcohol method is based on measurement of the loss in mass of samples after burning with alcohol (methanol). This method can only be used with non-flammable materials, such as soils and aggregate. However, materials containing flammable components or contaminations which can be burned off during the test may give misleading water content results. Alcohol burning can be used on site and does not require a power supply. Alcohol burning is rarely used as there are much safer available techniques.

3.6 Summary of Test Methods

Considering the pros and cons of each method the ventilated oven, the speedy moisture tester and portable probe appear to be the most appropriate for the rapid evaluation of water content of asphalt planings. They provide quick water content measurements and can be used on site, however the ventilated oven needs a source of power supply to be used on site. These three methods are relatively safe and do not require a high degree of specialisation and skills to operate. These methods are also considered more appropriate because there is relatively lower risk of overheating the samples and losing the volatiles, which can give misleading results for asphalt planings. Taking these issues into consideration, the ventilated oven, the speedy moisture tester and portable probe were selected for laboratory testing and evaluation for water content.

4 LABORATORY WORK

Five different gradings (batches) of asphalt planings covering the range of typical asphalt planings were tested for water content. These typical gradings were determined over an 18-month period from samples of asphalt planings obtained from stockpiles of asphalt planings located near the City of Edinburgh, Scotland. The grading curves for these materials are shown in Figure 3. The average of these gradings was classified as *Material 1*. *Material 2* (approximately 150 kg) was obtained at a different time to *Material 1*. The gradings for *Material 1* and *Material 2* are shown in Figure 4.

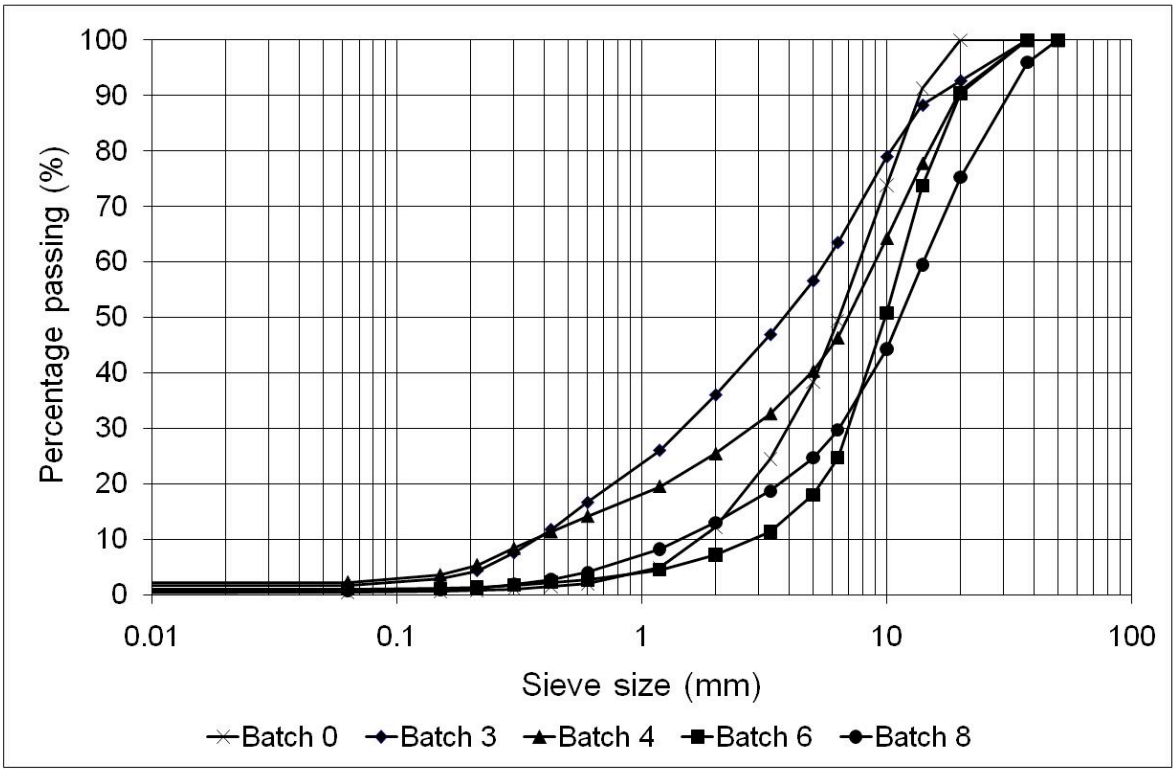

Figure 3: Grading curves for first set of asphalt planings

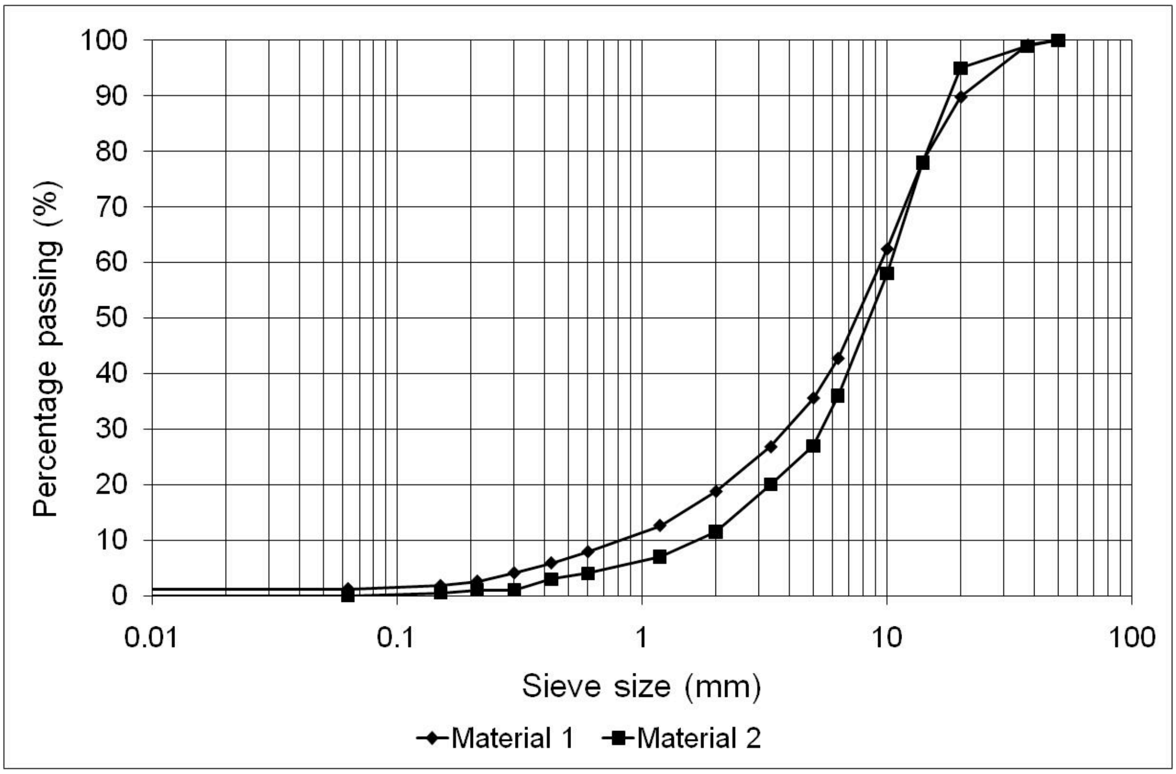

Figure 4: Grading curves for *Material 1* and *Material 2*

The laboratory work determined average water content in the asphalt planings (*Material 1* and *Material 2*) using the speedy moisture tester, the portable probe and the ventilated oven. The laboratory work was undertaken in main stages, as follows:

(i) Establishing a process for oven-drying asphalt planings (to 0% water content)
(ii) Reduction of samples
(iii) Oven-drying asphalt planings using established process
(iv) Water content evaluation

A process for oven-drying asphalt planings to 0% water content was established and the optimum temperature for oven-drying was determined to be 35°C (Niedźwiecki 2008). Sub-samples from *Material 1* and *Material 2* were prepared and then dried to 0% water content using the established process for oven-drying the asphalt planings (Niedźwiecki 2008). Actual water content (by dry mass (0% water content)) was calculated at 0, 2, 4, 6, 8 and 10% and water was added to the oven-dried asphalt planings to produce two sets of sub-samples (*Material 1* and *Material 2*) at the actual water contents.

Two portable probes (used by two different organisations) were calibrated in accordance with the manufacturer's instruction (Niedźwiecki 2008). 15 kg each of *Material 1* and *Material 2* were tested for water content and the results are presented in Table 1. The materials and water contents used for the 'speedy' test were the same as that used for the portable probe. Samples were prepared in accordance with published standards and the test results are shown as Table 2 (British Standards Institution 1990, Niedźwiecki 2008). The materials and water contents used for the samples dried using a ventilated oven were the same as that used for the portable probe. Samples were prepared in accordance with published standards and the test results are shown as Table 3 (British Standards Institution 1990, Niedźwiecki 2008).

Table 1: Water content laboratory test results from the portable probe

Actual Water Content (%)	Measured water content (%)			
	Material 1		*Material 2*	
	Probe 1	**Probe 2**	**Probe 1**	**Probe 2**
0	0.00	0.00	0.18	0.02
2	3.69	2.89	2.32	2.34
4	6.58	5.65	4.66	5.80
6	7.35	7.23	5.74	6.20
8	10.49	9.70	8.68	8.20
10	11.31	10.82	9.50	9.24

Table 2: Water content laboratory test results from the Speedy moisture tester

Actual Water Content (%)	Measured water content (%)	
	Material 1	*Material 2*
0	0.00	0.00
2	2.70	1.37
4	5.41	3.84
6	8.03	5.74
8	8.77	7.52
10	12.80	12.13

Table 3: Water content laboratory test results from drying samples in a ventilated oven

Actual Water Content (%)	Measured water content (%)	
	Material 1	*Material 2*
0	0.24	0.16
2	2.00	1.77
4	3.97	3.69
6	5.49	5.22
8	7.46	6.04
10	8.37	9.02

Figure 5 and Figure 6 shows the correlation between the actual and measured water content for all test methods.

5 DATA ANALYSIS

Over a range of water contents (0 to 10%) all measurement techniques give good correlation (greater than 0.95), with the ventilated oven giving the highest correlation for *Material 1* and the portable probe (probe 2) giving the highest correlation for *Material 2*. The portable probe tends to give higher measured water content relative to actual water content, while the ventilated oven tends to give lower measured values compared to actual values. The speedy moisture tester gives relatively higher measured water content for *Material 1* (and lower measured water content for *Material 2*) relative to actual water content.

For each water content, the ventilated oven tends to give measured water content values that are relatively close to the actual water content. For all techniques, the least spread in water content values is at 0% (*Material 1* and *Material 2*), followed by 6% for *Material 2*.

The greatest spread in water content values is at 10% for *Material 1*. With *Material 1*, there is a tendency for greater variance between actual and measured water content as water content increases, but this occurrence is not clearly evident with *Material 2*.

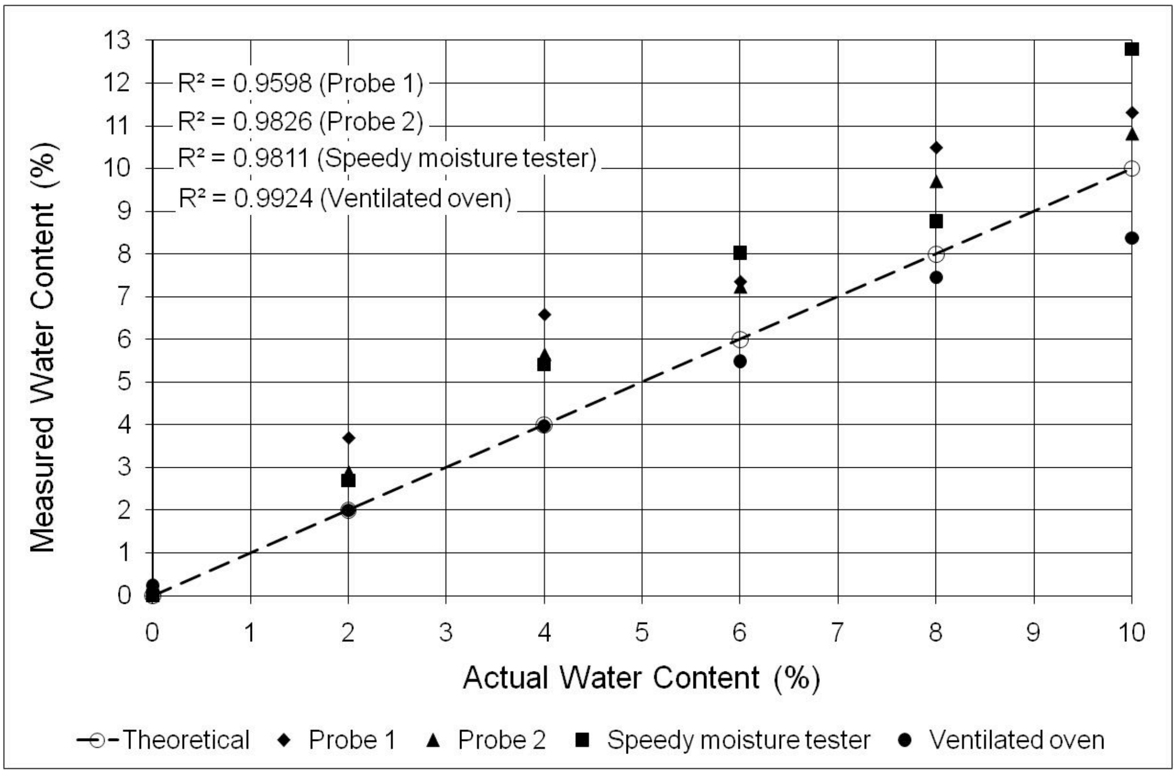

Figure 5: Correlation between the actual and measured water content for *Material 1*

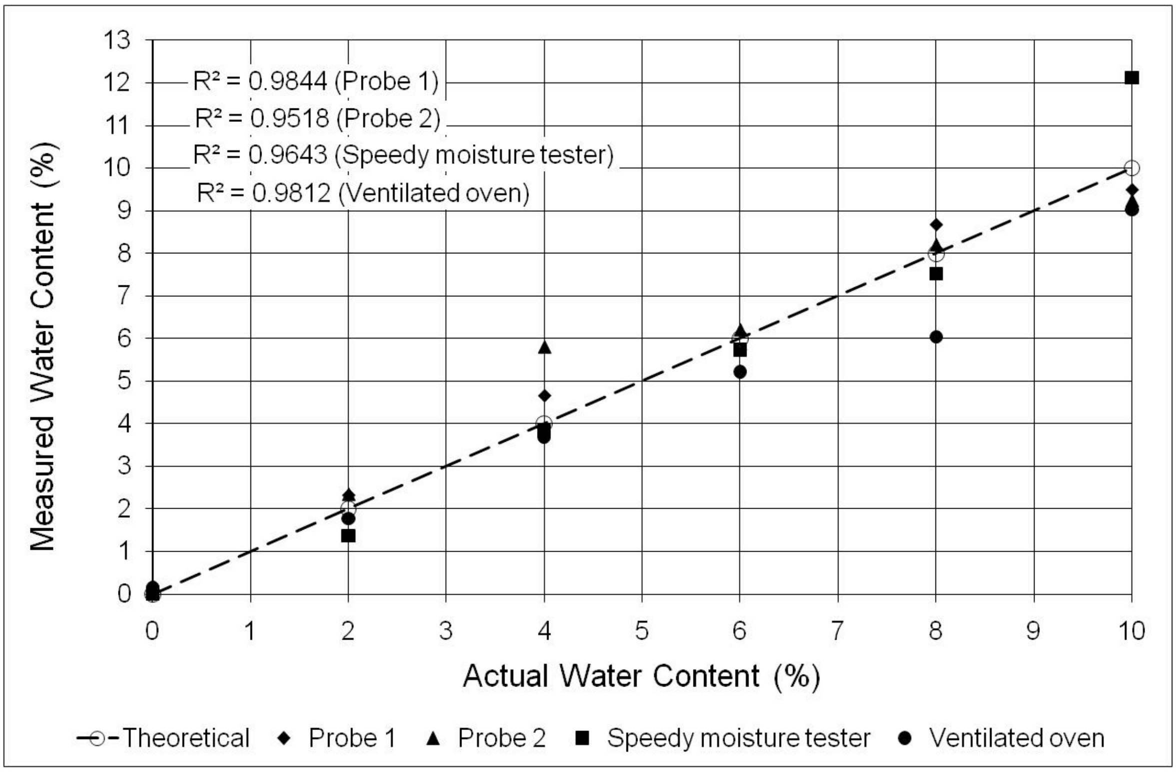

Figure 6: Correlation between the actual and measured water content for *Material 2*

6 CONCLUSIONS

A range of techniques for measuring water content of processed asphalt planings have been described and the most suited techniques for site application have been determined to be the ventilated oven, the portable probe and the speed moisture tester.

On the whole, the ventilated oven gives the better correlation between measured and actual water content, but issues still remain regarding its suitability for site applications – especially where rapid water content determinations are required.

The portable probe gives consistent relationships between measured and actual water content and is suitable for instant determination of water content on site. There are no significant health and safety issues and the probe does not require great skill to be used by site operatives.

The speedy moisture tester tends to give inconsistent relationships between measured and actual water content. The speedy moisture tester is portable, lightweight and gives instant water content readings (based on wet mass). However, there are limitations on material quantity and particle size that can be used with the test. There are also health and safety issues regarding the use of the flammable gas (acetylene).

All things considered, the portable probe is considered to be the most suitable device for fast, safe and reliable measurement of water content for processed asphalt planning for site operations.

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