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Research to evaluate the effect of humidity on the resilient modulus of soils using laboratory experiments

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KEYWORDS

Resilient
Modulus
Soils

ABSTRACT

When designing pavement structures according to AASHTO 1993, the Resilient Modulus (M_R) is the most important characteristic of the soils. There are many factors that effect on the resilient modulus of soils and one of those factors is humidity. This paper presents some experimental research results in the laboratory in Vietnam for determining the effect of humidity on the resilient modulus of soils according to AASHTO T307

1. Introduction

The Resilient Modulus describes the mechanical response of a pavement base or subgrade to the applied cyclic (traffic) load, and, hence it is considered to be an essential parameter for pavement design. By knowing the resilient modulus for the subgrade soil and the pavement material, the structural behavior of the pavement against traffic loading can be ascertained. The Resilient Modulus is the ratio between the applied stress and the recoverable axial strain (figure 1). The resilient modulus can be expressed as: $M_R = \frac{\sigma_d}{\varepsilon_r}$. According to AASHTO T307, the M_R is measured on the Cyclic triaxial test with repeated loads to a cylindrical sample.

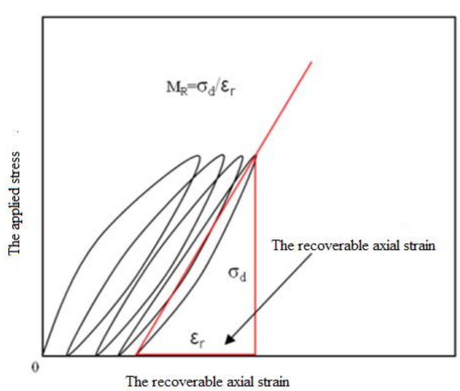

Figure 1. The Resilient Modulus (M_R).

The resilient modulus of soils significantly affects the operating characteristics of the pavement [1]. It is an important material characteristic used in pavement structural design according to AASHTO 1993 [2]. Many experimental studies determining the Resilient Modulus (M_R) of soils have been carried out in the laboratory using the Cyclic triaxial test with repeated loads [4, 5, 6, 7-11].

Many studies around the world have shown that the Resilient Modulus of soils decreases when humidity increases or the degree of saturation increases (Butalia et al 2003; Heydinger 2003; Huang 2001; anh Titi et al 2006). Drumm et al. (1997) found that the resilient modulus decreased with increasing degree of saturation for soil samples compacted at maximum dry volume. Hossain (2008, 2010) found that humidity affects the resilient modulus value of soil samples, the trend can be seen that the resilient modulus is lower when the sample has a higher degree of saturation.

This paper presents some results of laboratory experiments to determine the influence of a humidity on the Resilient Modulus (M_R) of soils according to AASHTO.T307 in Vietnam.

2. Experimental test

2.1. Materials

The material in this experiment is soil that used for the uper subgrade layer on highway QL45- Mai Son. This soil was taken in Xuan Hai, Thach Thanh, Thanh Hoa. Soil samples were tested in the laboratory to determine the following criteria: Particle composition, liquid limit, plastic limit, plasticity index, flat particle content, Los Angeles abrasion degree, ES index and CBR index. The results of testing the physical and mechanical properties of the soil sample are given in Table 1, the results satisfy the technical requirements. According to AASHTO M145, the soil belongs to group A-2-7.

2.2. Experimental process

To evaluate the influence of humidity on the Resilient Modulus (M_R) of the soil test sample, the research team changed the moisture of sample equal to the optimal moisture (determined in section 2.1) OMC ±2 %. The cylindrical test sample has a diameter of 100mm and a height of 200mm (figure 2). To cast 3 groups of samples, each group has 6 samples. The research team used the UTM machine at the Institute of Transport Science and Technology to determine the Resilient Modulus (M_R) of the soil test sample according to AASHTO T307.

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Table 1. Physical and mechanical criterias of experimental soil.

No	Physical and mechanical criterias	Symbol	Units	Experimental results	Technical requirements	Testing standards
1	Sieve size (mm)			% passing sieve		TCVN 4198-95
	50	-	%	100		
	25	-	%	93.3		
	19	-	%	82.8		
	9.5	-	%	65.5		
	4.75	-	%	61.7		
	2.0		%	49.0		
	1.0		%	40.1		
	0.425		%	33.6		
	0.25		%	29.5		
	0.10		%	22.0		
2	maximum dry density	γ_{cmax}	g/cm^3	2.106	-	TCVN 12790:2020 (PP I-D)
3	OMC	W_o	%	13.3	-	
4	liquid limit	W_L	%	42.6	≤ 50	TCVN 4197-2012
5	plasticity index	Ip	%	15.4	≤ 20	
6	CBR index at K = 98%	CBR	%	32.9	≥ 6	TCVN 12792:2020
7	Organic matter content	-	%	0.70	≤ 10	AASHTO T267

2.3. Experimental process

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Figure 2. The cylindrical test sample.

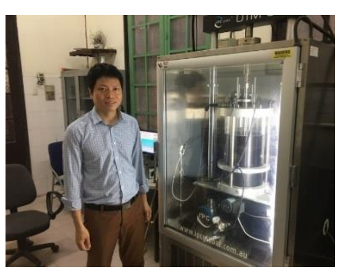

Figure 3. The UTM machine.

3. Experimental results and discussion

3.1. The experimental results

The test results of the Resilient Modulus (M_R) of samples at different humidity levels according to AASHTO T307 are given in Table 2 and Figure 4.

Table 2. The test results of the Resilient Modulus (M_R) of samples at different humidity levels.

No	Humidity (%)	Samples	M_R (MPa)
1	OMC-2	1	123.34
	OMC-2	2	121.46
	OMC-2	3	126.67
	OMC-2	4	128.11
	OMC-2	5	130.33
	OMC-2	6	132.24
2	OMC	1	121.63
	OMC	2	118.18
	OMC	3	115.34
	OMC	4	109.18
	OMC	5	108.76
	OMC	6	119.15
3	OMC+2	1	93.22
	OMC+2	2	91.11
	OMC+2	3	96.68
	OMC+2	4	95.29
	OMC+2	5	90.58

No	Humidity (%)	Samples	M_R (MPa)
	OMC+2	6	85.18

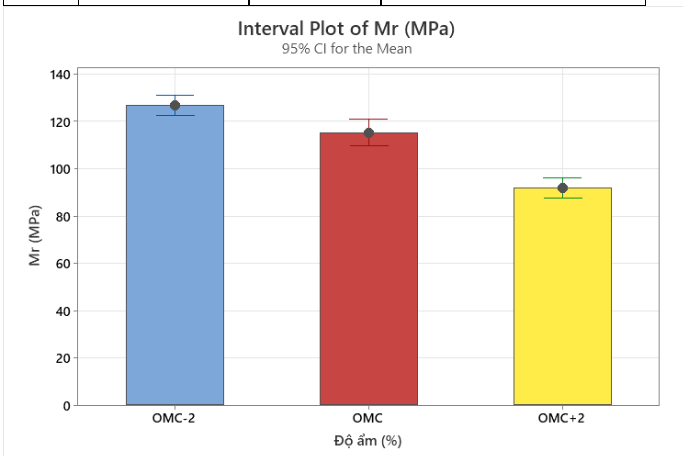

Figure 4. The test results of the Resilient Modulus (M_R) of samples at different humidity levels.

3.2. To analyze and evaluate experimental results

From the experimental results in table 3 and figure 4, the research team conducted statistical analysis with Minitab software, using ANOVA analysis of variance to analyze and evaluate the experimental results.

3.2.1. Evaluate the number of samples in the sample group

With a number of repetitions of 6 samples/group of samples, the Minitab test determined a difference detection level of 1.18 standard deviations with $\alpha = 0.05$ and Power = 0.8.

3.2.2. Statistical analysis of experimental results

Check that the data are all according to normal distribution, p-value > 0.05 as shown in Figure 5.

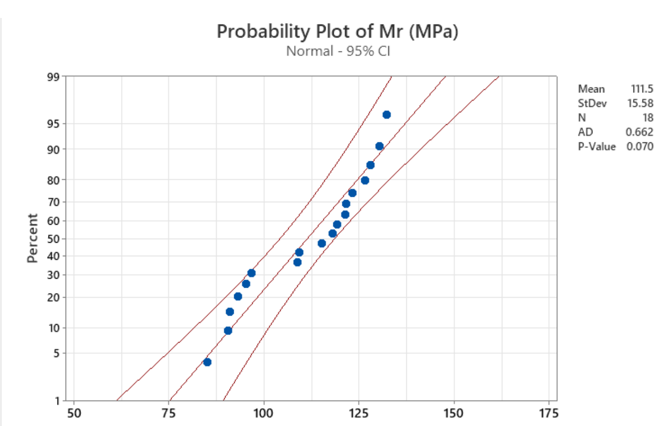

Figure 5. Check the normal distribution of the experimental results.

ANOVA analysis results give p value = 0.000 < 0.05 and R2dc = 91.46%. Thus, the humidity effect on the Resilient Modulus (M_R) has a statistically significant at $\alpha = 5$ %. Therefore, it can be concluded that: There is an influence of humidity on the Resilient Modulus (M_R).

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Độ ẩm (%)	2	3815.3	1907.66	92.04	0.000
Error	15	310.9	20.73		
Total	17	4126.2			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
4.55256	92.47%	91.46%	89.15%

Độ ẩm (%)	N	Mean	StDev	95% CI
OMC-2	6	127.03	4.10	(123.06, 130.99)
OMC	6	115.37	5.36	(111.41, 119.33)
OMC+2	6	92.01	4.09	(88.05, 95.97)

Tukey Pairwise Comparisons

Grouping Information Using the Tukey Method and 95 % Confidence

Humidity (%)	N	Mean	Grouping		
OMC-2	6	127.03	A		
OMC	6	115.37		B	
OMC+2	6	92.01			C

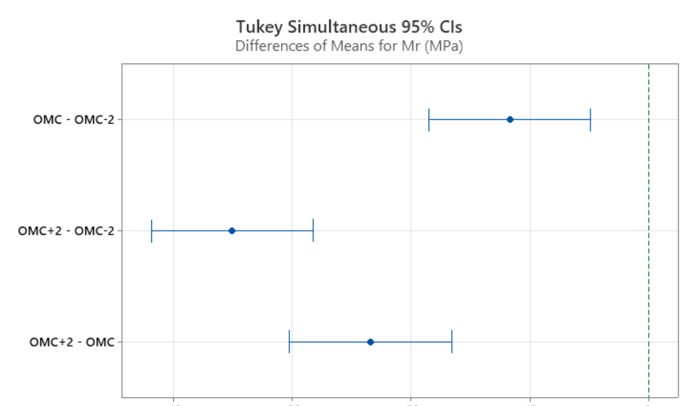

Figure 6. Tukey analysis of the influence of humidity on the Resilient Modulus (M_R) of soils.

The above analysis results show that: when humidity increases, the Resilient Modulus (M_R) decreases with statistical significance.

Figure 7 clearly shows that the Resilient Modulus (M_R) of the soil corresponding to the moisture OMC-2% is the highest, then comes M_R at OMC humidity and M_R at OMC + 2% humidity is the lowest.

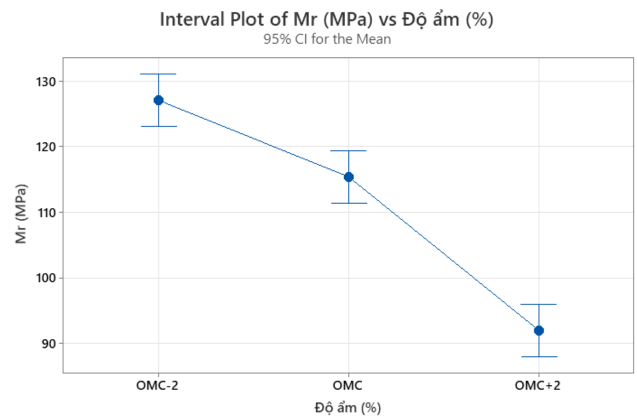

Figure 7. Graph of the Resilient Modulus (M_R) of soil according to moisture content.

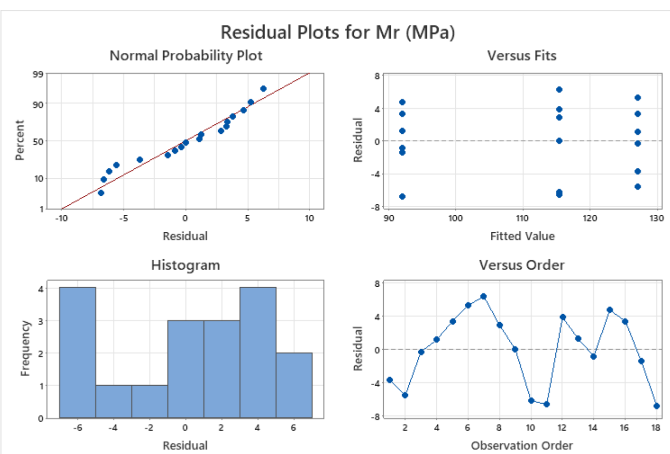

Figure 8. Analysis chart of residual plots for M_R according to humidity.

4. Conclution and recommendation

Through the results of theoretical and experimental research in the laboratory, the research team came up with a number of conclusions and recommendations as follows:

- In Vietnam's current conditions, it is possible to perform the experiments to determine the Resilient Modulus (M_R) of soils according to AASHTO T307 standards, and the test results have high precision.
- Statistical analysis results show that humidity has the greatest influence on the Resilient Modulus (M_R) of soils. When the humidity increases, the the Resilient Modulus (M_R) of soils increases.

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