International Journal of Scientific & Engineering Research, Volume 4, Issue 4, April-2013
ISSN 2229-5518

Impact Evaluation of Locally Available Modifiers for Stabilization of Sub-grade soil through Triaxial and Impact Hammer Testing Techniques

Imtiaz Ahmed [1], Imran Hafeez [2], Syed Zishan Ashiq [3], Kashif Riaz [4], Bilal Ahmed Zaidi [5], M. Hassan [6]
[1] Corresponding Author: (Research Assistant, Department of Civil Engineering, University of Engineering and Technology Taxila, Pakistan. Email: imtiaz674@gmail.com)

Abstract—Pavements are founded upon the different layers of engineered soils. Being the ultimate load bearing layer of the pavement, sub-grade strength should be adequate to ensure the integrity of different layers. In Pakistan, majority of pavement failures may be attributed to improper functioning of sub-grade due to the use of inappropriate materials like Clayey soils. According to AASHTO Classification, clay is not suitable material for the sub-grade as it makes a pavement vulnerable to failure. In this research, it has been attempted to improve the stiffness properties of Clayey soil through commonly available and cheap modifiers like Lime, Marble Waste (pulverized) and Sand. The stiffness of the soil was determined by calculation of its Resilient Modulus (M_R) and Impact Value (IV). M_R and IV were measured in the laboratory through triaxial testing and Clegg Impact Hammer respectively. The modifiers were mixed with sub-grade soil in six different proportions to obtain optimum value for each. A correlation was developed between the M_R, IV and other variables involved in the study using MINITAB software. The test results revealed that the Lime improved the stiffness of the Clayey soil more than the other two modifiers. Further, the statistical parameters calculated using the software showed that the formulated correlations are efficient.

Index Terms— Sub-grade soil, Modifiers, Resilient Modulus, Impact Value, Triaxial Test, statistical Parameters

1 INTRODUCTION

Transportation is the backbone of economy of any country especially a developing country like Pakistan. The economic development of any region/country is conditioned with the development and efficient working of transportation system which in-turn depends on the proper pavements. A flexible pavement is founded on one or more layers of engineered materials. The stiffness and performance of entire pavement depends upon the stiffness of each layer. The layers are composed of binders and aggregates on the upper layers transferring the loads to underneath compacted soil layer known as sub-grade. "All pavements derive their ultimate support from the underlying sub-grade; therefore, knowledge of basic Soil Mechanics is essential" [1]. Sub-grade being the load carrying layer of the pavement should be stiff and strong enough to withstand all loads. "The soil sub-grade, which supports the above pavement layers and traffic, should be stiff enough to maintain the integrity of pavement structures and the smoothness of the pavement surface"[2].

Depending upon the soil type according to AASHTO Classification System, the soils are classified as excellent to good (A-1, A-2 and A-3) and fair to poor (A-4 to A-7) for their use as sub-grade. The material used in this research was A-6 soil, commonly called Clayey soil and is abundantly available in Pakistan. The Clayey soil is identified as poor for sub-grade use by AASHTO. "Provision of poor Clayey sub-grade results in corrugation at the surface and increase in unevenness" [3]. In this research, improvement of Clayey soil (A-6) was made using commonly available modifiers materials like lime (hydrated), marble waste (pulverized) and sand.

The improvement in the material was evaluated calculation of Resilient Modulus (M_R) and Impact Value (IV) by Triaxial test and Clegg Impact Hammer respectively. Resilient Modulus testing was used in the study as it simulates the actual dynamic loading on pavement surface instead of static loading procedure like CBR Testing. Conventionally CBR Test results have been used to estimate stiffness of pavement sub-grade since long [4]. But with research in this field, the focus has been transferred to characterize the stiffness by Resilient Modulus as it simulates the in-situ conditions. Sub-grade soil characterization expressed in terms of Resilient Modulus (M_R) has become vital for pavement design and evaluation [5] [6]. The Impact Value test has been used to augment the Resilient Modulus results in the research. Extensive research has been carried out to correlate CBR with M_R, however, there has been a little work to establish relationship between the IV and M_R. Impact Value Test being easier to perform has been used to develop the IV vs M_R relationship.

2 PROBLEM STATEMENT

During last few years, premature failures of pavements have been a great threat for engineers/designers in Pakistan. These failures including rutting, fatigue cracking and raveling may be attributed to inadequate strength of sub-grade. Commonly ob-

- Imtiaz Ahmed is currently pursuing master degree inCivil Engineering in UET Taxila, Pakistan. E-mail: imtiaz674@gmail.com (Corresponding author)
- 2(Assistant Professor, Department of Civil Engineering, University of Engineering and Technology, Taxila, Pakistan, Email2: imranhafeez783@yahoo.com)
- 3(Assistant Professor, Department of Civil Engineering, Mirpur University of Science and Technology, AJK, Pakistan, Email: zishanashiq@gmail.com)
- 5(Lecturer, Department of Civil Engineering, University of Engineering and Technology, Taxila, Pakistan, Email: bilal.zaidi@uettaxila.edu.pk, sbilalz@yahoo.com)
- 4, 6 (Reseacrh Assistant, Department of Civil Engineering, UET Taxila, Pakistan)

International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

served sub-grade failures are due to the use of unsuitable material. Pakistan soil maps show the occurrence of Clayey soils in the country and conventionally the material excavated at the site is utilized for the sub-grade preparation. This result in the use of poor soil material like Clayey soil in sub-grade without any improvement and thus makes it vulnerable to failure. Also, instead of sub-grade stabilization, granular material is imported from far places for the construction which in-turn makes the project un-economical. Therefore, the improvement of the existing material with some modifiers will make the projects economical. Moreover, the presence of the Clayey soils in major areas of the country will be efficiently utilized in sub-grade preparation with proper improvement.

3 OBJECTIVES

Major objectives of the research include;

1. Determining Resilient Modulus of Clayey Sub-grade Soils;
2. To study the effect of easily available modifiers on M_R (under Triaxial Test system) and IV (Clegg Impact Hammer);
3. To establish a correlation between M_R and Impact Value;
4. To evaluate stiffness (M_R) of sub-grade soil under different stress levels;
5. To determine optimum percentage of lime, marble and sand for improvement of soil to be used as sub-grade.

4 Literature Review

Characterization of sub-grade using CBR values has been a common practice by the engineers and researchers since long. However, being a static property, CBR cannot account for the actual response of the sub-grade under dynamic loads of moving vehicles, CBR is a measure of shear strength of a material and does not necessarily be correlated with stiffness or modulus such as the M_R. The western world has shifted towards the Resilient Modulus testing to determine the stiffness of the soil layers. With the advancement in research, *Janoo et al* (1999) studied five different types of sub-grade soils present in New Hampshire. They presented the resilient moduli results of all different type of soils available in the state to be used for Mechanistic-Empirical (ME) design input level 1 [7]. *Jones et al (1977)* investigated the resilient moduli of 35 different types of sub-grade soils in San Diego and explored the correlation between the laboratory and field measured values. They related the resilient moduli with soil index properties like moisture content and degree of saturation etc. Their findings were further utilized in San Diego to characterize sub-grade materials on the basis on soil index properties [8]. *Khazanvoich et al (2006)* reviewed the characterization of sub-grade material in ME Design Guide 2002 and applied it to Minnesota fine-grained soils [9]. *W. Virgil Ping et al (1997)* addressed calibration of laboratory Resilient Modulus measurements using field data of modulus of elasticity for sub-grade layer determined through plate load test [10]. *A.M. Rahim et al (2005)* focused on the characterization of sub-grade soil based on Resilient Modulus as a vital element of flexible and rigid pavement design [11]. *M. Shabbir Hossain (2008)*, characterized the Resilient Modulus of Virginia Soils followed by development of its co-relation with the other soil tests. In his research, Resilient Moduli values and regression co-efficient (k-values) were successfully computed by testing 100 different samples from Virginia [12].

4.1 Reseacrh regarding Models

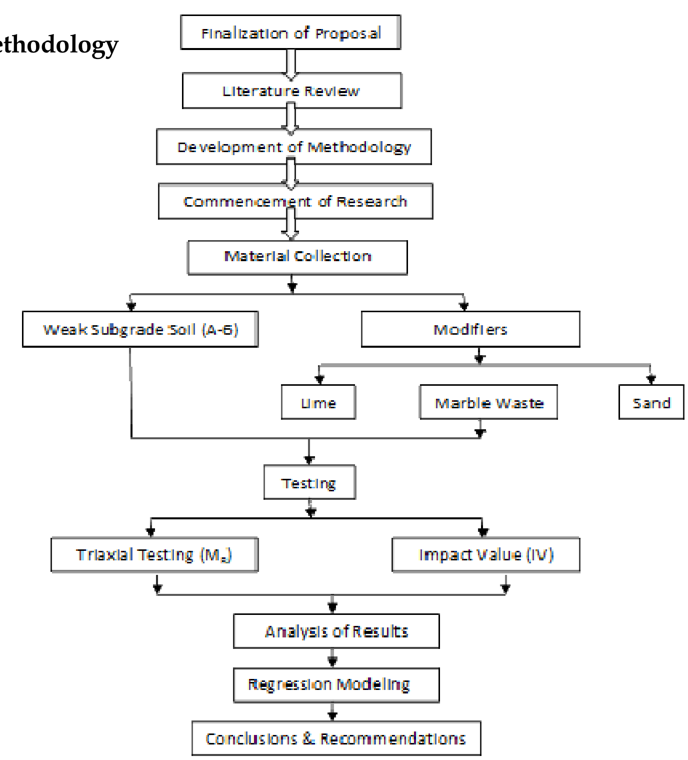
As the Resilient Modulus testing is very complex and time consuming procedure therefore, it was emphasized to correlate it with simple laboratory procedures. Following researchers developed relationship of M_R with soil index properties and CBR procedures. M_R had been correlated to CBR numerous times depending upon the test conditions. Some of these correlations have been summarized in Table 1.

Table 1: Research history regarding correlations

Sr. No.	Researcher	Year	Relationship
1	Heuklelom and Klomp	1962	M_R = 1500 (CBR)
2	Heuklelom and Klomp	1962	M_R = 2596 (CBR) $^{0.874}$ (Psi)
3	Heukelom and Foster	1960	M_R = 1565 (CBR) (Psi)
4	Heukelom and Foster	1960	M_R = 2596 (CBR) $^{0.874}$ (Psi)
5	Green and Hall (U.S. Army Corps of Engineers)	1975	M_R (psi) = 5,409 $CBR^{0.71}$
6	South African Council on Scientific and Industrial Research (CSIR)	-	M_R (psi) = 3,000 $CBR^{0.65}$
7	Transportation and Road Research Laboratory (TRRL)	-	M_R (psi) = 2,555 $CBR^{0.64}$

In the opinion of some researchers, CBR is not true reflection of sub-grade characterization. Therefore, the trend of sub-grade characterization on the basis of CBR shifted to M_R. Thomson and Robnett (1976) and Rada and Witczak (1981) [13], suggested that the use of the CBR value for designing pavements is unreliable.

5 Methodology



International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

The research was initiated with the aim to improve the stiffness of sub-grade soil (A-6) using locally available and inexpensive materials. The sub-grade soil was collected from Kashmir Highway Islamabad and mixed with three different modifiers viz. Lime; Marble and Sand. These modifiers were mixed with sub-grade soil in the following proportions shown in Table 2.

Table 2: Percentages of Modifiers mixed with Sub-grade soil

Modifiers	Proportions (%)					
Lime	2	4	6	8	10	12
Marble Waste (Pulverized)	3	5	7	9	11	13
Sand	3	6	9	12	15	18

This was followed by laboratory testing in accordance with AASHTO T 307-99 and ASTM D 5874-02 standard procedures for Resilient Modulus and Impact Value respectively. Further, MINITAB software was used to develop a correlation among index properties, M_R and IV. The computed and measured M_R values were then compared. The comparison of computed and measured values of M_R and IV showed that they are in a close relation.

6 Lab Testing

During the research, following tests were performed in the laboratory.

Table 3: Standard procedures followed

Sr. No.	Test Description	Relevant Standard
1	Sieve Analysis	ASTM D 422-65 (98)
2	Hydrometer and Specific Gravity	
3	Liquid Limit and Plasticity Index	ASTM D 4318-10
4	Triaxial Test (MR)	AAASHTO T 307-99
5	Impact Value	ASTM D 5874-02

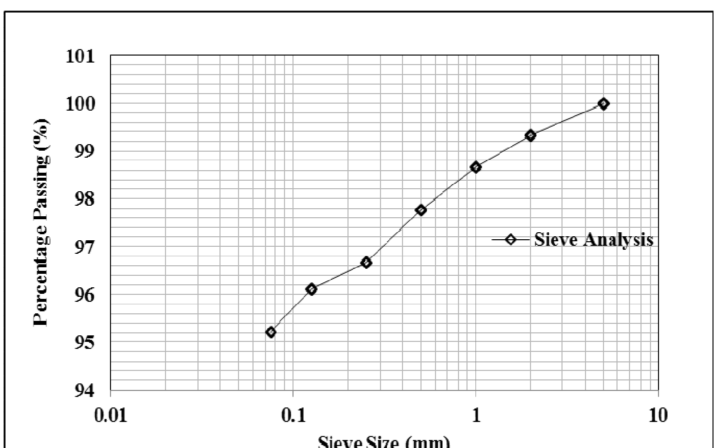


Fig 2: Sieve Analysis

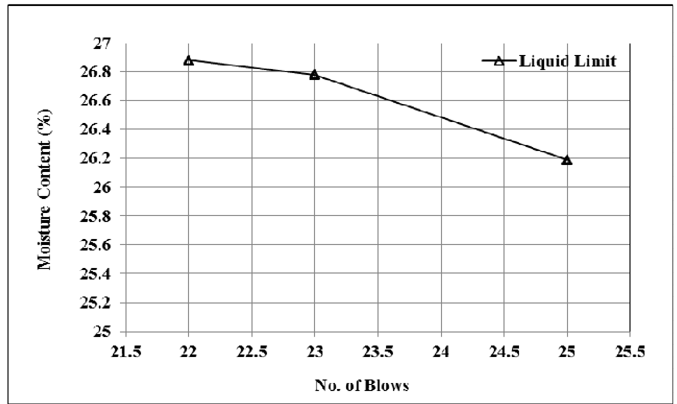


Fig 3: Liquid Limit test

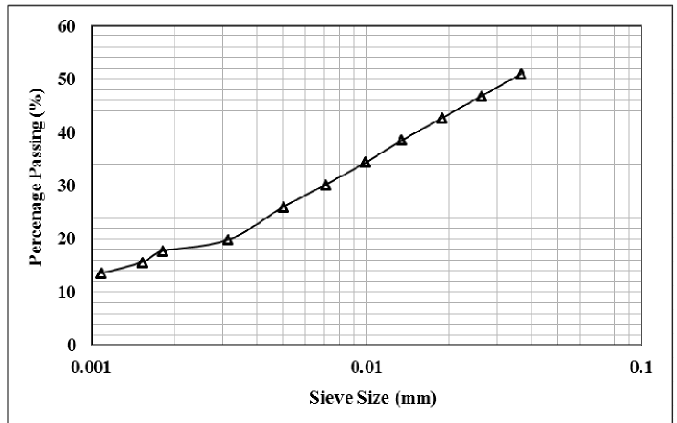


Fig 4: Hydrometer analysis

Sub-grade soil used in this research on the basis of classification and specific gravity tests were as follows:

Sieve and hydrometer analysis showed that the percentage passing in sieve # 200 was >36%. The liquid limit was 26.2% whereas Plastic limti and plasticity index were 15 and 11.2 respectively. Based on classification tests, the soil was classified as A-6 (Clayey soil) according to AASHTO Classification System. After soil was confirmed as A-6 soil, further testing was performed for the research. Specific gravity of the soil was determined to be 2.50

6.1 Specimen Preparation

Fig 5: Sample preparation in Lab

The triaxial test specimens were prepared using the hydraulic jack system as shown in Fig. 5. The diameter and length for each prepared specimen were 4" and 8" respectively. Each specimen was prepared for max dry density (lb/ft3) and optimum moisture content (%) obtained by Modified Proctor test. For Impact Value (IV) test using specified percentages of

International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

modifiers, the samples were prepared in CBR molds under un-soaked condition.

6.2 Summary of Test results

Table 4: Summary of Test Results

Modifiers														
Lime					Marble Wastes					Sand				
%age	OMC (%)	MDD Lb/ft³	M_R MPa	IV	%age	OMC (%)	MDD Lb/ft³	M_R MPa	IV	%age	OMC (%)	MDD Lb/ft³	M_R MPa	IV
2	9.8	130.6	275.12	13	3	9.3	139	270.09	11	3	9.2	129.8	212.06	9
4	10.2	128.4	450.09	18	5	8.9	143.25	388.09	15	6	8.78	126.4	264.25	13
6	10.8	125.9	537.27	23	7	8.75	145.24	447.57	18	9	8.23	122.9	310.67	19
8	11.4	122.3	687.43	27	9	7.9	147	546.35	21	12	7.89	120.1	342.78	21
10	12.3	120.2	642.62	22	11	7.6	138	459.15	17	15	7.36	118.6	301.86	16
12	12.9	118.7	594.35	17	13	7.2	136	384.25	12	18	6.9	116.9	254.41	12

Table 4 presents the summary of the test results i.e Modified Proctor, MR and IV for different percentages of each modifier.

In case of Lime, optimum moisture content increases with the increasing percentage of lime however maximum dry density decreases. On the other hand, M_R and IV increase up-to approximately 8.5% then decrease rapidly. While in case of Marble, moisture content decreases with the increase in percentage of marble whereas maximum dry density increases up-to optimum value of marble and then decreases on further addition. Same is the case of M_R and IV values. In case of sand, both moisture content and maximum dry density decrease on addition of modifier but the stiffness and IV increase up to optimum value and decrease on further addition of sand.

6.3 Resilient Modulus Test Results:

The M_R values can be estimated in the laboratory by measuring material's response under simulated field loading conditions [14]. For this purpose, triaxial testing was carried out in Transportation Research Laboratory of University of Engineering and Technology Taxila Pakistan.

The stiffness of the material was observed by Resilient Modulus testing and Impact Value determination. The laboratory-based Resilient Modulus determination involved the repeated load triaxial test. Only elastic (recoverable) strain was captured during the repeated load application. Earlier methods (AASHTO T274-82 and T292-91I) specify the use of either internally- or externally-mounted LVDTs.

The current method, specified by SHRP, SHRP Protocol P46, (alternatively known as TP46-94) requires two externally mounted LVDTs to determine axial recoverable deformations. AASHTO TP 46-94 procedure calls for haversine wave form instead of triangular or rectangular wave forms stipulated in the earlier testing procedures [5].

Different samples tested during the research are presented in Fig. 7. Some of these samples were failed during the testing and were replaced by the newly prepared samples.

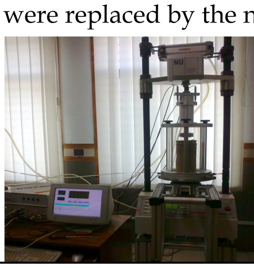


Fig 6: Resilient Modulus test in progress

Fig 7: Test samples

6.4 Effect of Modifiers on Soil Stabilization/Improvement

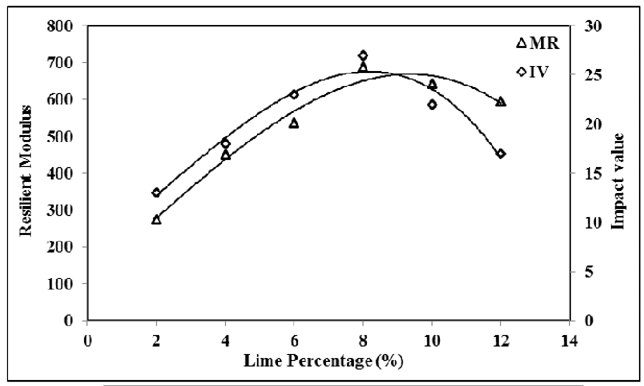


Fig 8 (a): Effect of Lime Percentage on M_R and IV

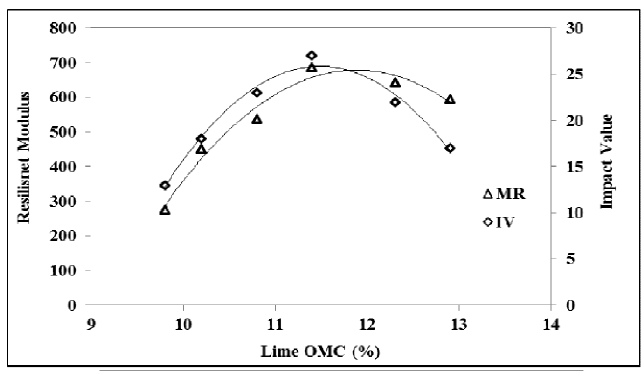


Fig 8 (b): Effect of Moisture Content on M_R and IV

It can be observed from the Fig. 8 (a) that the optimum percentage of lime for maximum value of M_R and IV is approximately 9.2% and 7.9% respectively. The small differnce for maximum value of M_R and IV (1.3%) may be attributed to the fact that different methods of compaction were used to prepare samples for each parameter (M_R and IV).

Fig. 8 (b) shows the effect of moisture content on M_R and IV values. The optimum moisture content for maximum value of M_R and IV are 11.85% and 11.45% respectively.

International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

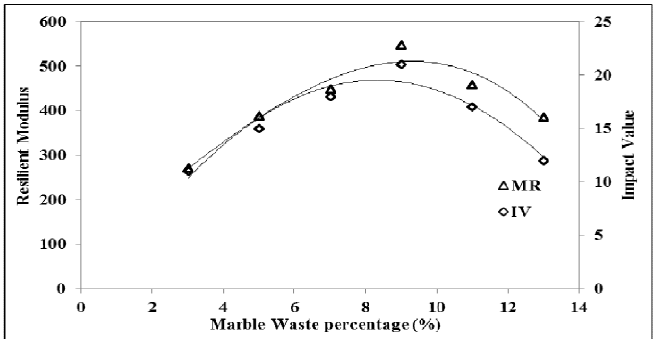


Fig 9 (a): Effect of Marble Percentage on M_R and IV

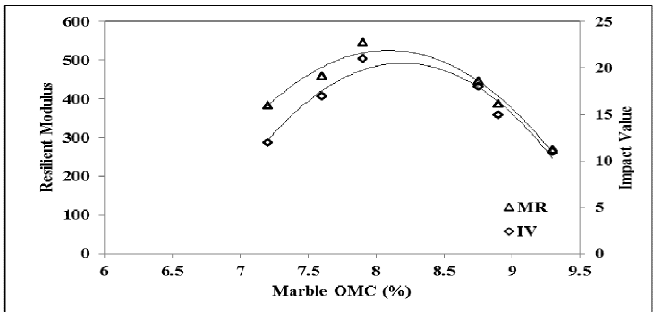


Fig 9 (b): Effect of Moisture Content on M_R and IV

Fig. 9 (a) presents the effect of percentages of Marble wastes on M_R and IV. The optimum percentage of marble for maximum improvement of sub-grade soil is 8.5% whereas optimum moisture content at which marble should be added to the soil is 8.2% [Fig. 9 (b)].

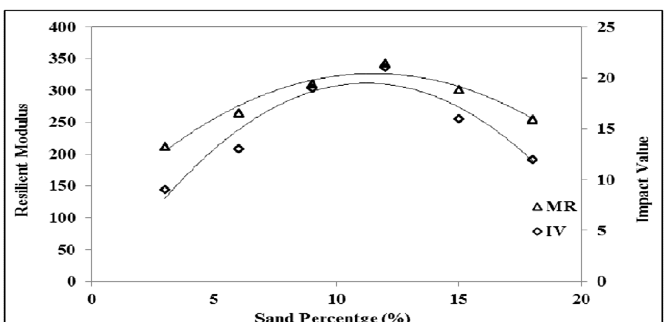


Fig 10 (a): Effect of Sand Percentage on M_R and IV

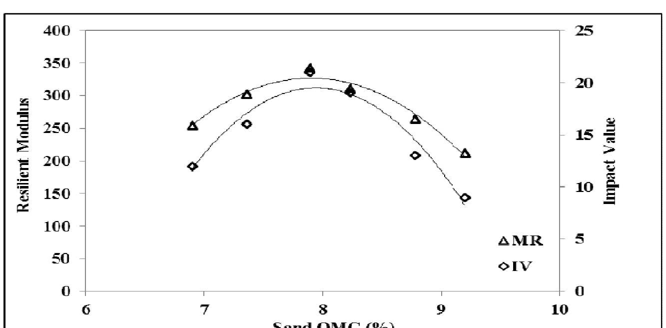


Fig 10 (b): Effect of Moisture Cotent on M_R and IV

Fig. 10 (a) and (b) represent the influence of sand proportions and moisture content on the improvement of sub-grade soil. The optimum values for sand proportion and moisture content are 11.5% and 7.9% respectively.

6.5 Effect of stresses on M_R

The effect of variation of stress level on the magnitude of Resilient Modulus is very critical because the stresses in a sub-grade soil depend on pavement thickness [15]. The effect of deviator stresses for each modifier is shown in figures 11 (a) to (c) for Confining Pressures of 41.4, 27.6 and 13.8 kPa. For each proportion of modifiers, two samples were tested. The general trend of variation for MR with deviatoric stresses at optimum percentages of modifiers determined during the research is shown in figure 11.

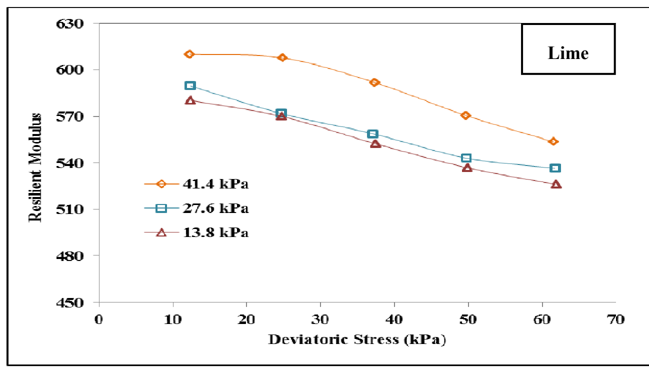


Fig. 11 (a)

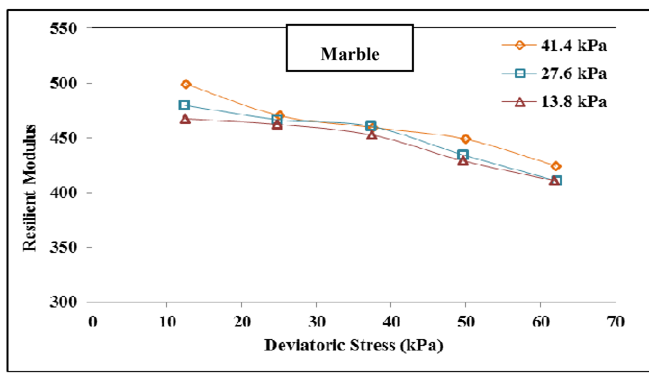


Fig. 11 (b)

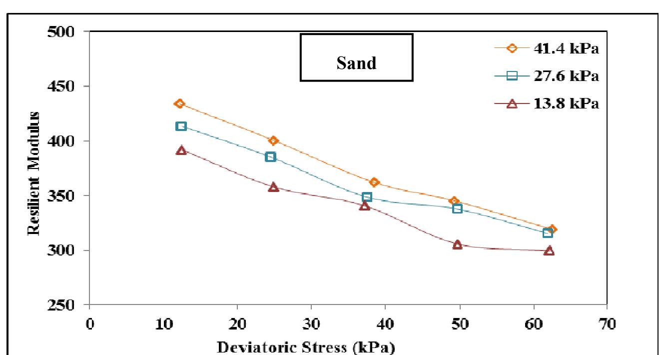


Fig 11 (c): Effect of deviator stress on Resilient Modulus

International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

6.6 Comparison of Modifiers

Figures 12 (a) and (b) presents comparative improvement of sub-grade soil by mixing it with optimum proportion of each modifier. It may be observed that improvement in MR and IV is maximum for Lime.

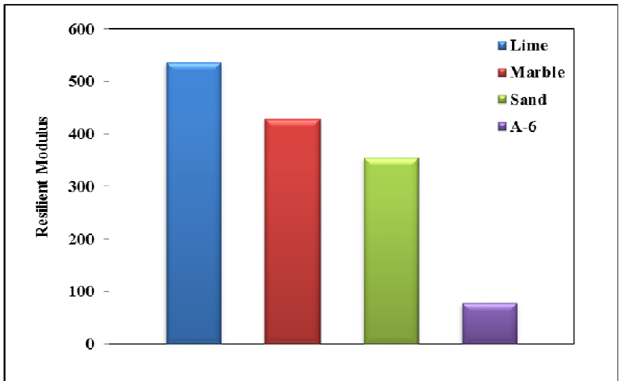


Fig 12 (a): Comparative improvement of sub-grade soil for different modifiers

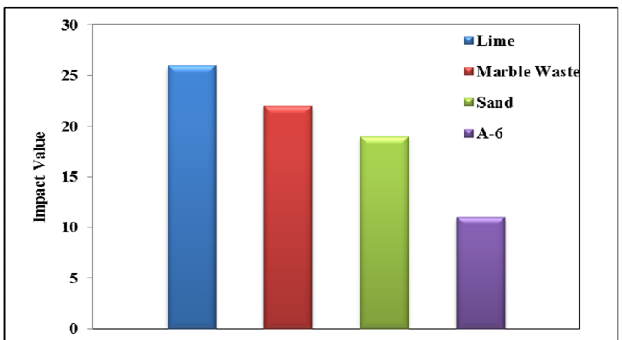


Fig 12 (a): Comparative improvement of sub-grade soil for different modifiers

6.7 Regression Analysis

Regression analysis was carried out using MINITAB software to compute M_R for all the modifiers. All the variables were considered for correlation. A correlation for each modifier is shown as below;

1) *Correlation for Lime:*

$$M_R = 7319 + 44.0 \% M - 207 OMC - 40.0 MDD + 10.3 IV$$

Where; % M = Percentage of Modifier
OMC = Optimum Moisture Content
MDD = Maximum Dry Density
IV =Clegg Impact Value

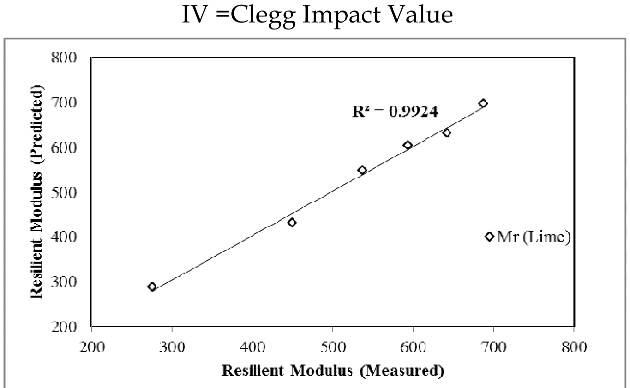


Fig 13 (a): M_R Comparison (Lime)

2) *Correlation for Marble:*

$$M_R = 2071 - 7.7 \% M - 28.8 OMC - 12.8 MDD + 21.9 IV$$

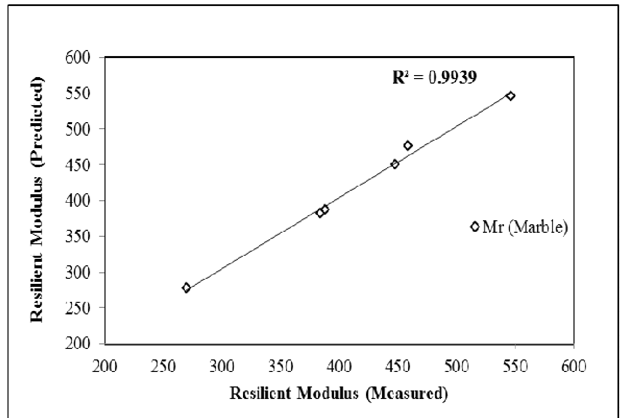


Fig 13 (b): M_R Comparison (Marble)

3) *Correlation for Sand:*

$$M_R = - 2370 + 20.7 \% M + 154 OMC + 7.8 MDD + 9.97 IV$$

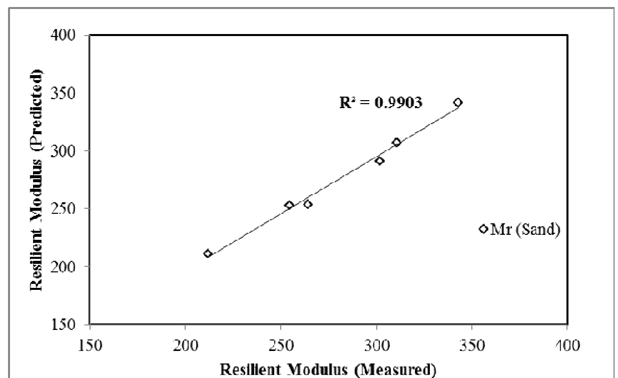


Fig 13 (c): M_R Comparison (Sand)

In the next step, all the variables were then correlated with M_R without considering the difference of modifiers.

The relationship developed is stated below;

$$Mr = -3.34x10^7 - 157 M.T + 3.95x10^5 \%M + 1.24 x 10^6 OMC + 1.6x10^5 MDD + 3.64x10^5 IV$$

Where; M.T= Modifier type

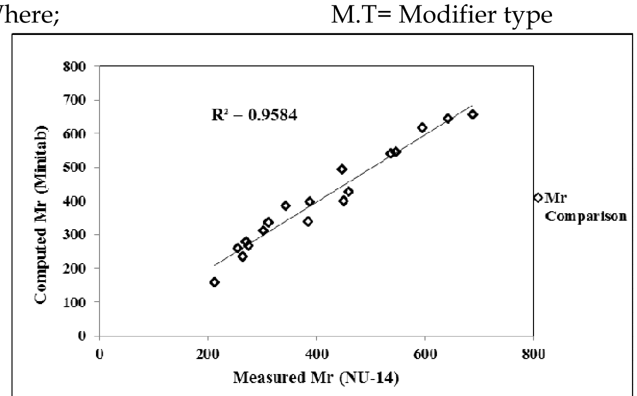


Fig 13 (d): M_R Comparison (General)

The p (probability) value is a calculation used in studies to determine if the results are caused by chance or not. The lower

International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

the p-value, the more likely it is that the difference between groups was caused by treatment. Based on p values, IV is the parameter which affected the relationship more than other variables.

Table 5: Statistical parameter (p value)

Variable	p Value
Filler Type	0.694
%age Filler	0.000018
OMC	0.00011
MDD	0.000089
IV	**0.000003**

Statistical parameters supporting the regression analysis results are shown in Fig.13 (e).

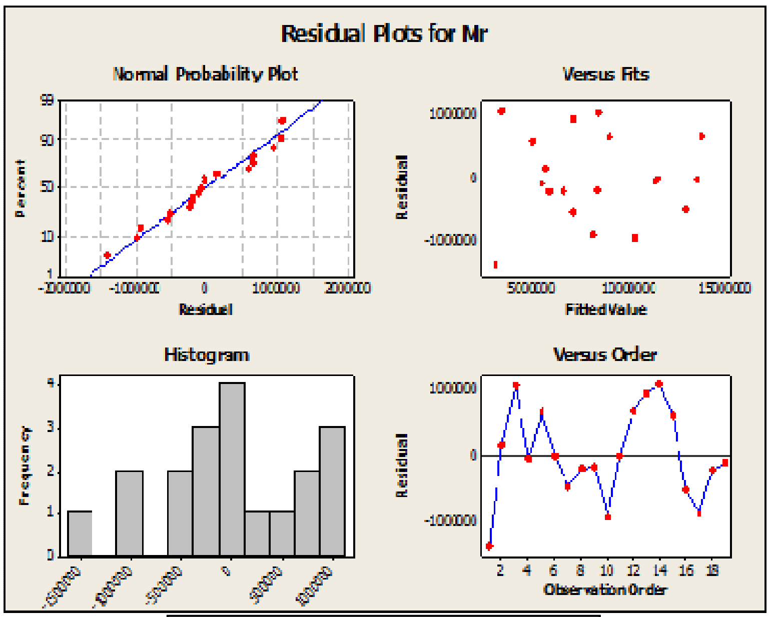


Fig 13 (e): Residual plots by MINITAB

7 Conclusions

- The sub-grade soil was significantly improved through the use of different modifiers.
- On the basis of triaxial testing and IV values, it was concluded that the Lime was the most suitable modifier.
- The statistical analysis revealed the value of $R^2>0.9$ for M_R obtained from other variables used in the research. Thus it is concluded that the results of statistical analysis are reliable.
- Optimum % ages of modifiers used to improve sub-grade soil (A-6) are as below;

Modifier Type	Optimum Values	
	Percentage of Modifier	Optimum Moisture Content
Lime	8.9	8.12
Marble	9.2	11.85
Sand	11.25	7.9

These results were further verified by preparing and testing the specimens on the basis of optimum percentages found by the research.

References

[1] Yoder, E. J. and M. W. Witczak, *Principles of Pavement Design*, 2nd ed., John Wiley&Sons, New York, 1975

[2] (Zhou et al, 2013). Changjun Zhou, Baoshan Huang, Eric Drumm, Xiang Shu, Qiao Dong and Sampson Udeh, "Seasonal Resilient Modulus Inputs for Tennessee Soils and Their Effects on Asphalt Pavement Performance" in TRB 2013 Annual Meeting.

[3] Praveen Kumar and Ankit Gupta, "Case Studies on Failure of Bituminous Pavements" Compendium of Papers from the First International Conference on Pavement Preservation, *Indian Institute of Technology Roorkee, India*

[4] (Hopkins, T.C., Beckham, T.L., and Sun C. Resilient Modulus of Kentucky Soils. University of Kentucky, (2004.)

[5] K. P. George and Waheed Uddin, "Sub-grade Characterization for Highway Pavement Design" Final report submitted to Mississippi Department of Transportation, Dec 2000.

[6] Pranshoo Solanki, Musharraf Zaman, Kanthasamy K. Muraleetharan and David Timm "Evaluation of Resilient Moduli of Pavement Layers at an Instrumented Section on I-35 in Oklahoma" in Road Materials and Pavement Design. ICAM 2009, pp. 167-188

[7] Janoo, V.C., Bayer, J.J., Durell, G.D., and Smith, C.E. "Resilient Modulus for New Hampshire Sub-grade Soils for use in Mechanistic AASHTO Design" Special Report 99-14. U.S. Army Corps of Engineers, Cold Regions Research & Engineering Laboratory, Hanover N.H., 1999

[8] Jones, M.P., and Witczak, MW. "Sub-grade Modulus on the San Diego Test Road" In Transportation Research Record No. 641. Transportation Research Board, Washington, D.C., 1977, pp.1-6.

[9] Khazanvoich, L., Celauro, C., Chadbourn, B., Zollars, J., and Dai, S. "Evaluation of Sub-grade Resilient Modulus Predictive Model for Use in Mechanistic-Empirical Pavement Design Guide" In Transportation Research Record No. 1947. Transportation Research Board, Washington, D.C., 2006, pp. 155-166

[10] W. Virgil Ping and Ling Ge, "Field Verification of Laboratory Resilient Modulus Measurements on Sub-grade Soils" in Journal of the Transportation Research Board, Volume 1577, 1997, pp. 53-61

[11] A.M. Rahim. "Sub-grade soil index properties to estimate Resilient Modulus for pavement design" in The International Journal of Pavement Engineering, Vol. 6, No. 3, September 2005, pp. 163–169

[12] M. Shabbir Hossain, "Characterization of Sub-grade Resilient Modulus for Virginia Soils and Its Correlation with the Results of Other Soil Tests" in Virginia Transportation Research Council, Report No. VTRC 09-R4.
http://www.virginiadot.org/vtrc/main/online_reports/pdf/09-r4.pdf

[13] Rada, G., and Witczak, M.W. "Comprehensive Evaluation of Laboratory Resilient Moduli Results for Granular Material" In Transportation Research Record. No. 810. Transportation research Board, Washington, D.C., 1981,pp. 22-33.

[14] Pranshoo Solanki, Musharraf Zaman, Kanthasamy K. Muraleetharan and David Timm "Evaluation of Resilient

International Journal of Scientific & Engineering Research Volume 4, Issue 4, April -2013
ISSN 2229-5518

Moduli of Pavement Layers at an Instrumented Section on I-35 in Oklahoma" in Road Materials and Pavement Design. ICAM 2009, pages 167 to 188

[15] Drumm, E. C., Boateng-Poku, Y., and Pierce, T. J. "Estimation of Subgrade Resilient Modulus from Standard Tests." Journal of Geotechnical Engineering, Vol. 116, No. 5, ASCE, 1991, pp. 774-789

[16] Heukelom, W., and Klomp, A.J.G. (1962), "Dynamic testing as a means of controlling pavement during and after construction," Proceedings of the 1st international conference on the structural design of asphalt pavement, University of Michigan, Ann Arbor, MI.

[17] Standards involved in the study.