STUDY ON THE VARIATION OF SUBGRADE STRENGTH WITH THE NUMBER OF DAYS SOAKED

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ABSTRACT: This study presents how the subgrade strength losing with increasing of number of days soaked. The objective of this study to understand the nature of variation of subgrade strength with moisture content and propose a behaviour model for subgrade moisture content. Major function of subgrade is to provide support to pavement. Subgrade soil type, compacted density and moisture significantly affect pavement design. Surface and subsurface drainage of pavement and from adjoining land also affect subgrade strength significantly. Subgrade strength is mostly expressed in terms of California Bearing Ratio. The subgrade strength owing to its inconsistency or variable nature poses a challenge for the engineer to come up with a perfect design pavement. For example, the subgrade is always subjected to change in its moisture content due to precipitation, capillary action, and flood or subside of water table. Variation in moisture content roots variation in subgrade strength. It becomes quite crucial for an engineer to realize the exact nature of dependence of subgrade strength on moisture content. In this study variation of subgrade strength with the number of days soaked was studied by considering, the variation of subgrade strength with days soaking and to analyse the relationship between subgrade strength and days soaking by used regression analysis and statistical Mnitab16 software. Thus the different soil samples were tested for their proctor density, optimum moisture content, California Bearing Ratio after being soaked in water for 1 day, 2 days, 3 days and 4 days and Un-soaked for each sample. Study shows that there is a significant correlation between moisture content of subgrade soil and number of days soaked. On increasing the number of days of soaking, the subgrade strength decreases due to rises of moisture content, further increasing the number of days of soaking, gradual but not dramatic loss of strength is observed. The rate of increase of moisture content decreases with days of soaking due to subgrade about to saturation. More amount of water absorption on the first day of soaked was the reason for the highest drop in subgrade strength (CBR) of the subgrade soil sample. The conclusions of this study based on the laboratory results and analysis which are applicable to the materials used and the test conditions adopted. So it will help design a good road pavement because subgrade is the foundation of road pavement.

Keywords: Subgrade Strength, Moisture Content, California Bearing Ratio

1. INTRODUCTION

Subgrade soil is an integral part of the road pavement. It provides the support to pavement from beneath. Major function of subgrade is to provide support to pavement. Subgrade soil type, compacted density and moisture significantly affect pavement design. Surface and subsurface drainage of pavement and from adjoining land also affect subgrade strength significantly. The strength of road subgrades is commonly assessed in terms of the California Bearing Ratio (CBR) and this is dependent on the type of soil, its .density, and its moisture content. [Overseas road note 31, 1993]. The subgrade soils, in particular the weak soft subgrades, contribute a significant portion (above 40 %) of the total pavement rutting [Majidzadeh, et al. 1978]. The subgrade moisture conditions under impermeable road Pavements classified into three main categories. 1. Subgrades where the water table is sufficiently close to the ground surface to control the subgrade moisture content. 2. Subgrades with deep water tables and where rainfall is sufficient to produce significant changes in moisture conditions under the road. 3. Subgrades in areas with no permanent water table near the ground surface and where the climate is dry throughout most of the year with an annual rainfall of 250 mm or less. [Overseas road note 31, 1993].

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The subgrade soils which are to known undergo substantial strength loss on soaking. [Ampadu, 2006]. A sharp drop in CBR with soaking period, especially within the first week. Thereafter, the loss in CBR took place at a smaller rate. [Razouki and Janabi, 1999]. The subgrade strength owing to its inconsistency or variable nature poses a challenge for the engineer to come up with a perfect design pavement. It becomes quite essential for an engineer to understand the exact nature of dependence of subgrade strength on moisture content. An understanding of the dependence of the CBR strength of subgrade soil on moisture content will contribute towards better design and maintenance practices. So that this study conducted with the objective of to understand the nature of variation of subgrade strength with moisture content and to propose a behaviour model for subgrade moisture content.

2. METHODOLOGY

2.1 Experiment

The subgrade soil samples viz. SGS1, SGS 2, SGS 3, SGS 4, SGS 5, SGS 6, SGS 7, SGS 8, SGS 9 and SGS 10 moulded at its optimum moisture content to its proctor density was tested for its California Bearing Ratio (CBR) strength. Thus the process comprises as estimation of proctor density and optimum moisture content for each soil samples also determination of CBR strength of the respective soil samples in moulds using the CBR instrument. Each soil sample is tested for its CBR strength after being soaked in water for 1 day, 2 days, 3 days and 4 days. Un-soaked CBR is also determined for each sample.

SGS- Subgrade Sample

2.2 Sampling and Testing

The subgrade soil samples for this study were collected from the road sites in Sammanthurai area which is located about 18 km away from Ampara town on Ampara – Kalmunai main road and the laboratory tests carried out on the subgrade soil collected samples in accordance with British Standard Institute (1975) and ASTM (1962) standards.

2.3 Analysis

Statistical package Minitab-16 was used to analysis the tested results and to fit the statistical models for moisture content of subgrade. To select the best model for moisture content of subgrade by assessing Coefficient of determination (R^2 value), Stranded deviation (S), Sum of Square Error (SSE) an approximately best model was selected.

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3. RESULTS AND DISCUSSION

3.1 Estimation of maximum dry density and Optimum moisture content

The figure 1 show that the Compaction Characteristics Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of subgrade soil samples determined by modified proctor test.

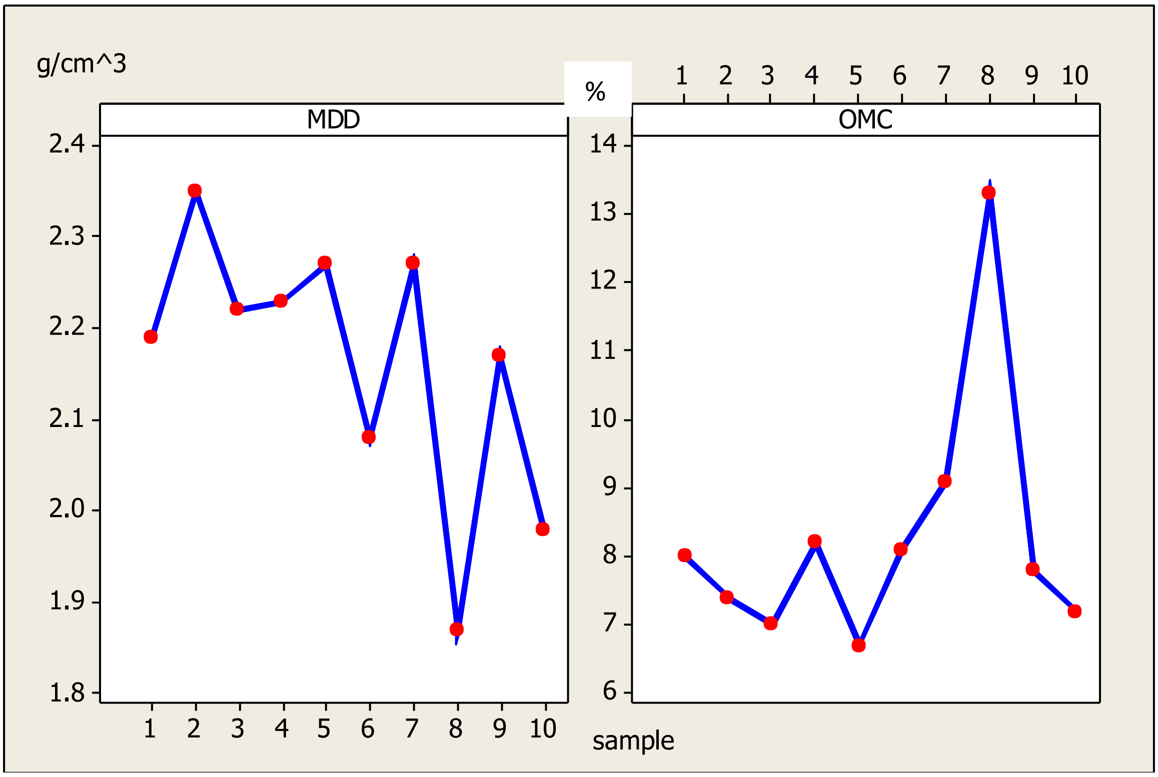

Figure: 1 Plot of MDD and OMC of subgrade soil samples

It is observed that there is a slightly increase in the Maximum Dry Density (MDD) with decreasing Optimum Moisture Content (OMC) of subgrade soil, it represents compaction characteristics of subgrade soil. The peak value of MDD recorded 2.35 g/cm^3 for sample number 2 and minimum value recorded 1.87 g/cm^3 for sample number 8. The maximum of OMC recorded 13.3% for sample number 8 and minimum value recorded 6.7% for sample number 5 respectively

3.2 Estimation of moisture content and subgrade strength

The California Bearing Ratio values of un-soaked subgrade soil higher than soaked subgrade soil and subgrade dramatic losses its strength when un-soaked soil was soaked for one day, on further increasing the number of days of soaking up to four days, gradual but not dramatic loss of subgrade strength was observed. Hence the Figure 2 for California bearing ratio of various subgrade soil samples with different days of soaked and un-soaked commences with a steep fall and then goes on with feeble falls.

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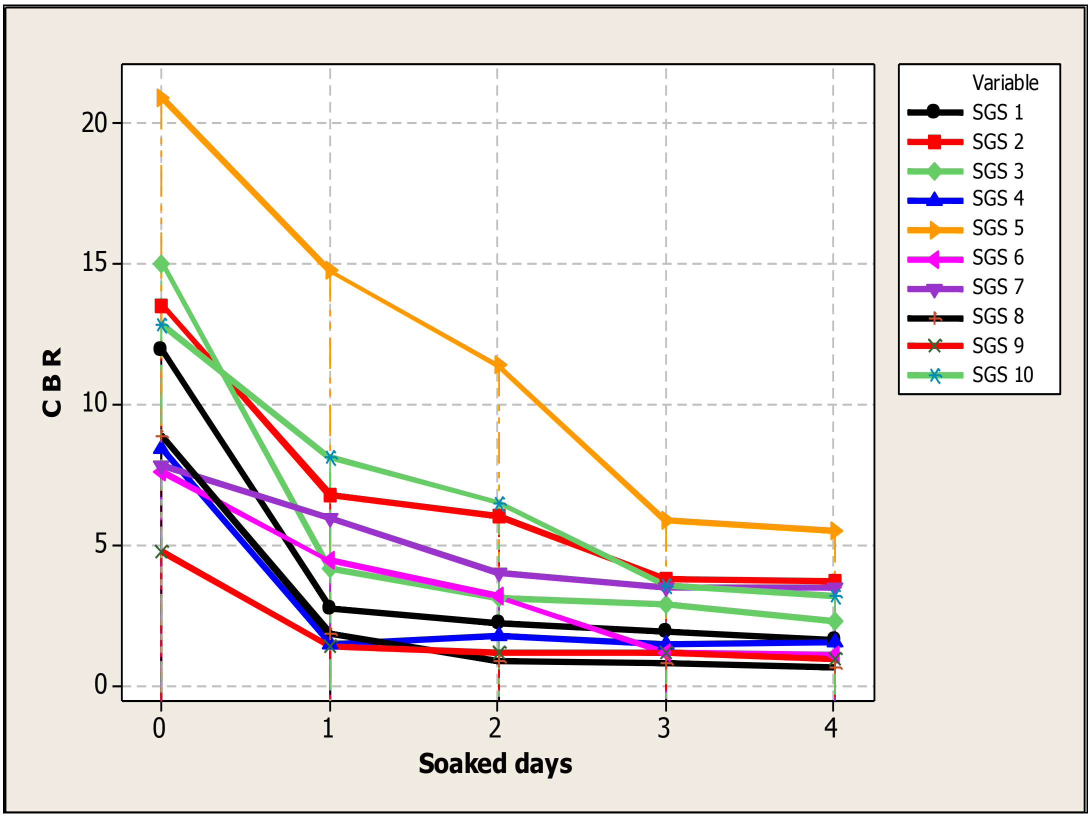

Figure: 2 Plot for California bearing ratio of various subgrade soil samples with different days of soaked and un-soaked

According to "A Guide to the structural design of Roads under Sri Lankan condition" of Road Development Authority (RDA) only one subgrade sample which was tested is S3 subgrade strength class, four samples were S2 class and remaining five tested samples were S1 subgrade strength class.

The increase in moisture content is observed when un-soaked soil is soaked for one day. On further increasing the number of days of soaking up to four days the moisture content also increased. Figure 3 clearly shows that how the moisture contents of subgrade soil samples increased with the days of soaked under water and also the gradient of increased subgrade moisture contents.

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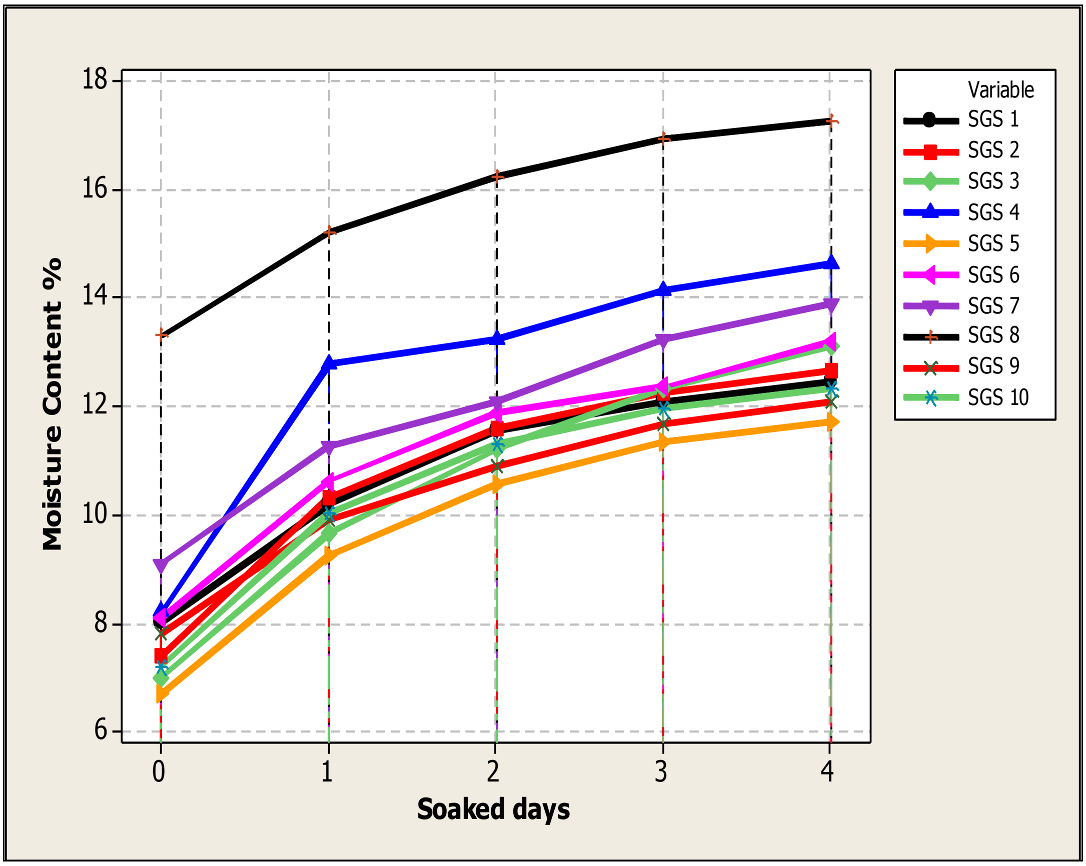

Figure: 3 Plot for Moisture content of various subgrade soil samples with different days of soaked and un-soaked

3.3 The variation of subgrade strength with the number of days soaked

The Figure 4 shows that how subgrade losses its strength from un-soaked subgrade to soaked. It is observed that when un-soaked subgrade soil sample was soaked the strength loss in subgrade was very high which is from 24% to 82% of loss in strength with the average of 56% strength loss. After two days soaked from 46% to 90% of loss in strength with the average of 66% strength loss. After three days soaked from 56% to 91% of loss in strength is observed with the average of 77% strength loss. Also After four days soaked from 55% to 93% of loss in strength is observed with the average of 79% strength loss respectively. Here it is observed that the trend of losing subgrade strength was increased with increment of soaking days from one to four but the increment is slightly fall down.

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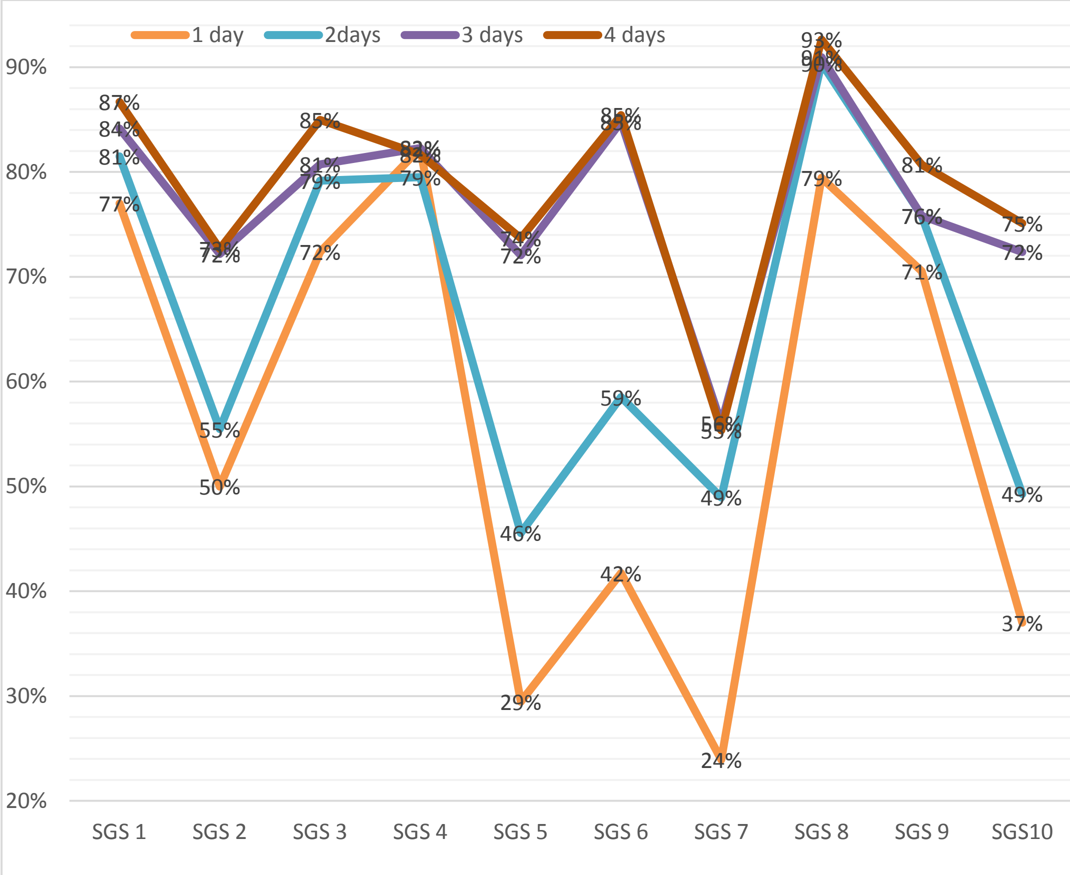

Figure: 4 Plot for subgrade strength losing percentage from un-soaked to soak

The Figure: 5 clearly shows that the variation of average subgrade strength loss with the number of day soaking. The average subgrade strength losing from after one day soaking to after three days soaking rapidly increasing with the upward trend and from after three days soaking to after four days soaking the increment is low.

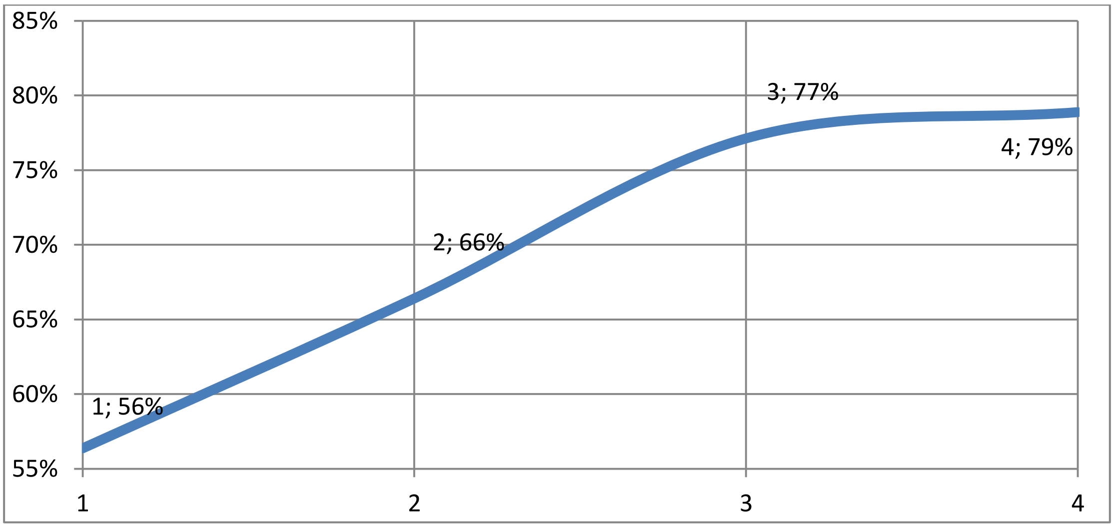

Figure: 5 Plot for average subgrade strength losing percentage from un-soaked to soak

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3.4 Statistical model for subgrade Moisture content

The linear regression relationship of the model for subgrade Moisture content verses number of days soaked is shows that in the table 1 is

Moisture content = 9.08 + 1.20 (number of days soaked) - equation 1

The slope of the linear regression equation is 1.20 and the intercept is 9.08. The R square value of this equation is 48.9%, the adjusted R square value 47.8%.and the standard error of this simulation is 1.77321 . Also its shows that there no evidence of lack of fit so the relationship between Moisture content and number of days soaked is not linear. Adjusted R square value improve a little but it show a very Weak linear correlation.

The curvilinear regression relationship of the model for subgrade Moisture content verses (Number of days soaked) ^{2} are shows that in the table is

Moisture content = 9.99 + 0.25 (number of soaked days) ^{2} - equation 2

The coefficient (β1) of the regression equation is 0.25 and the intercept is 9.99. The R square value of this equation is 36.7% the adjusted R square value 35.4%and the standard error of this simulation is 1.97309 respectively.

The curvilinear regression relationship of the model subgrade Moisture content verses, number of days soaked, (number of day soaked) ^{2} are shows that in the table 1 is

Moisture content = 8.42 + 2.52 (number of day soaked)

- 0.330 (number of soaked day) ^{2} - equation 3

The coefficients of the regression equation are β1=2.52 and β2= - 0.330 and the intercept is 9.99. The R square value of this equation is 36.7% the adjusted R square value 35.4%and the standard error of this simulation is 1.97309 respectively

Also for each model as shown in the table 1, Importance of Slope (β 0) and coefficients (β 1 and β 2) were tested. Since the probability value (P value=0) for all three model's slope (β 0) was zero, we can say that the slope β 0 is important to the model at 5% of significant level for all three models. Since the probability value (P value=0) for all three model's coefficients (β 1) was zero, we can say that coefficients (β 1) is important to the model at 5% of significant level for all three models. For model number 3 the coefficient's (β 2) probability value was 0.026 (P value=0.026), since it was grater then two tailed significant level 0.025, we can say that coefficients (β 2) is not important to the model at 5% of significant level for model number 3.

If we analysed both linear and curvilinear regression models for subgrade Moisture content verses number of days soaked as summarized in the Table 1 and analysed three statistical models statistically significant at 5% of significant level but higher R square value which was 54.1% and low standard error which was 1.69880 for the

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statistical model $Y=a + b X + c X^2$ at 5% of significant level. So that significant model was selected as in the equation -3.

Table: 1 Summery of Statistical analyses for Statistical model for subgrade Moisture content verses no of day soaked

Model no		**1**	**2**	**3**
Model		$Y= \beta_0 + \beta_1 X$	$Y= \beta_0 + \beta_1 X^2$	$Y= \beta_0 + \beta_1 X + \beta_2 X^2$
R^2 value		48.9%	36.7%	54.1%
Adjusted R^2 value		47.8%	35.4%	52.1%
S		1.77321	1.97309	1.69880
SSE		295.31	295.31	295.31
Model significance		P value=0 Model is statistically significant at 5% of significant	P value=0 Model is statistically significant at 5% of significant	P value=0 Model is statistically significant at 5% of significant
Importance of Slope (β 0) and coefficients (β 1 and β 2	*β_0*	P value=0 β_0 is Important to the model at 5% of significant level	P value=0 β_0 is Important to the model at 5% of significant level	P value=0 β_0 is Important to the model at 5% of significant level
	β_1	P value=0 β_1 is Important to the model at 5% of significant level	P value=0 β_1 is Important to the model at 5% of significant level	P value=0 β_1 is Important to the model at 5% of significant level
	β_2			P value=0.026 *Here p=.026 > 0.025 β_2 is Not important to the model* at 5% of significant level
Significant model		Moisture = 9.08 + 1.20 (number of days oaked)	Moisture = 9.99 + 0.25 (number of soaked days) ^{2}	Moisture = 8.42 + 2.52(number of day soaked) - 0.330 (number of soaked day) ^{2}

4. CONCLUSIONS

The study shows that there is a significant correlation between moisture content of subgrade soil and number of days soaked. On increasing the number of days of soaking, the subgrade strength (CBR) decreases due to increases of moisture content (water), further increasing the number of days of soaking, gradual and not dramatic loss of strength is observed. The rate of increase of moisture content decreases with days of soaking due to subgrade about to saturation. More amount

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of water is absorbed on the first day of soaked and thus accounts for the highest drop in subgrade strength (CBR) of the subgrade soil sample. Also equation - 3 can be used to predict moisture content of subgrade by just substituting the numbers of days soaked in the equation. The conclusions of this study based on the laboratory results and analysis which are applicable to the materials used and the test conditions adopted.

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