IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Impact Of Road Submergence On Sub Grade Strength Of Pavement

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Abstract: Deterioration of road structural integrity due to flooding may cause huge expenditure for rehabilitation and maintenance of roadways. The design of pavement structure is based on the strength of compacted soil known as the sub grade or road foundation; hence sub grade is the significant part of the road structural system. When roads are inundated for a long time or repeatedly, the materials in each layer of road structure become saturated, and the original condition of sub grade soils will be compromised. After flood, many roads were reported to be in its worst condition. In this scenario, an investigation was undertaken for determining the effect of road submergence on the sub-grade strength of road. Soaked and un soaked CBR tests were conducted on the soil samples and the results were analysed to study the effect of submergence on the performance of road pavements.

Index Terms **-** Sub grade strength, Road submergence, CBR. Flood.

I. INTRODUCTION

A good pavement is needed for the safe, comfortable and economical movement of traffic. A pavement is a durable surface having materials laid down on an area subjected to sustain mainly the vehicular traffic, such as a road or highway. A pavement is typically a structure of various layers resting over soil either in embankment or in cutting. A pavement is classified in general into two categories, i.e. namely a flexible pavement and a rigid pavement. Traditionally the design of either kind of pavement is based on the strength of the compacted soil in the pavement, called sub grade. Sub-grade is a foundation for the pavement structure to support the load from upper layer to the beneath soil. Sub-grade must be stable in performance to carry load in any weather conditions. Generally, in road engineering, CBR test is performed to determine the strength of sub-grade soil, as soil is a highly variable engineering material due to its composition and the dependence of its properties on environmental conditions. The sub grade is always subjected to variations in its water content and it is important to understand the change of sub grade strength due to change in its moisture content. When the roads are inundated for a long time, the materials in each layer for road pavement become saturated, and as flood waters drains, the sub-grade soils began to shrink and subside. The excessive water can drain into the foundation reducing its load bearing efficiency. Thus, this situation can cause the strength of road pavement systems to be compromised. This project emphasizes on understanding the performance characteristics of bituminous roads, during flooding, when the roads are inundated for the time being.

Studies were conducted by various researchers to find the effect of flooding on the subgrade strength of pavement. Hankare et al. (2018) conducted several experiments to study the effect of flooding on subgrade soil. They reported that CBR value of subgrade reduced by 41% after flooding. The subgrade of pavement is reported to be in poor condition immediately after flooding. Sulthana et al. (2015) reported the structural and functional performance of flood affected flexible pavements in Australia. The results indicate that the flood affected pavements lose their structural strength faster than their normal deterioration rate. Nivas and

Goyal (2016) investigated a comparison between the basic properties of sandy and clayey soil. An attempt has been made by varying the degree of soaking and hence the saturation level in various types of soils and thereby studying the variation in the engineering properties of soils including CBR value at different saturation levels. It is observed that for coarse grained soil, worst engineering properties are observed after three days of soaking and for fine grained soils, the same is found at the end of four days. Lebbe and Sabri (2015) examined the relationship between subgrade strength and moisture content. Study shows a strong curvilinear correlation between subgrade strength and moisture content. They pointed out that on increasing number of days of soaking, subgrade strength decreases due to increases of moisture content. The rate of change in sub grades strength with varying water percentage for unsoaked samples is 1 to 7 times that of soaked samples.

This project attempted to understand the nature of variation of subgrade strength during flooding. And for this study, tests such as soaked and un soaked CBR tests were conducted on soil samples. The results were then analysed to study the effect of flooding on the subgrade strength characteristics of pavement.

II. EXPERIMENTAL INVESTIGATION

Soil samples were collected from two locations of an existing pavement in Palakkad district, in Kerala. A series of experiments were done on those soil samples. Experiments were done as per Indian standards. The basic properties were found out initially and detailed investigation including modified proctor compaction tests and CBR tests were conducted on soil samples collected from each location of the pavement.

2.1 **Basic properties of soil**

To understand more about the nature and the type of soil sample, basic properties were determined. It mainly includes consistency limits (Atterberg limits), specific gravity value and free swell index. Obtained results are listed in the Table 1. Here the specific gravity of soil samples is evaluated by Pycnometer method as per IS:2720 (part lll/Sec 1)-1980. Generally, the value of specific gravity ranges from 2.65 to 2.85 [Sulthana et al. (2015)], here obtained values for soil samples are within the limits. Swelling test were conducted on all the soil samples. Free swell index values obtained for soil samples 1 and 2 shows that the soils are less expansive. For soil having free swell index less than 20% indicates degree of expansiveness low [Naser et al. (2016)]. For these soil samples, liquid limit values and plastic limit values are determined using Casagrandes's apparatus and rolling thread method respectively as per IS:2720,1970. Plasticity index values are also evaluated. The liquid limit and plasticity index values implies that the soil samples are silt. and highly compressible .

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Table 1 Basic Properties of Soil

Properties	Sample 1	Sample 2
Specific Gravity	2.62	2.71
Free Swell Index	5.55%	7.93%
Plastic Limit	35.66%	38.44%
Liquid Limit	58.19%	62.37%
Plasticity Index	22.53%	23.93%

As per ISCS (Indian Standard Soil Classification System) the soil samples are represented in the plasticity chart and from the chart it is clear that the soil samples are MH (silts of high compressibility).

2.2 Compaction Characteristics and CBR values of the soils.

The soil samples collected were subjected to compaction test corresponding to modified proctor compactive effort [IS 2720 (part 8) -1983 ; compactive efforts = 2703.88 KJ/m^3]. The obtained value for maximum dry density and optimum moisture content of soil samples are shown in Table 2. Then un saoked and soaked CBR test [IS 2720 (part 16) - 1987] were conducted on soil samples for modified proctor compactive efforts mentioned above.

Table 2 Compaction Characteristics of soil samples

Sample	Maximum dry density (KN/m^3)	Optimum moisture content (%)
1	19.72	10
2	18.25	11

Soaked CBR tests were conducted by inundated the samples for 1hr, 1 day, 4 days and for 7 days and the results are discussed below.

III. Results and Discussion

From the soaked and un soaked CBR test results the following conclusions were drawn. Figure 1 shows load versus penetration value under different soaking conditions. On increasing the number of days of soaking, the load value decreases. The load value is more for un soaked condition and it is less for 7 days-soaked condition for various penetration values.

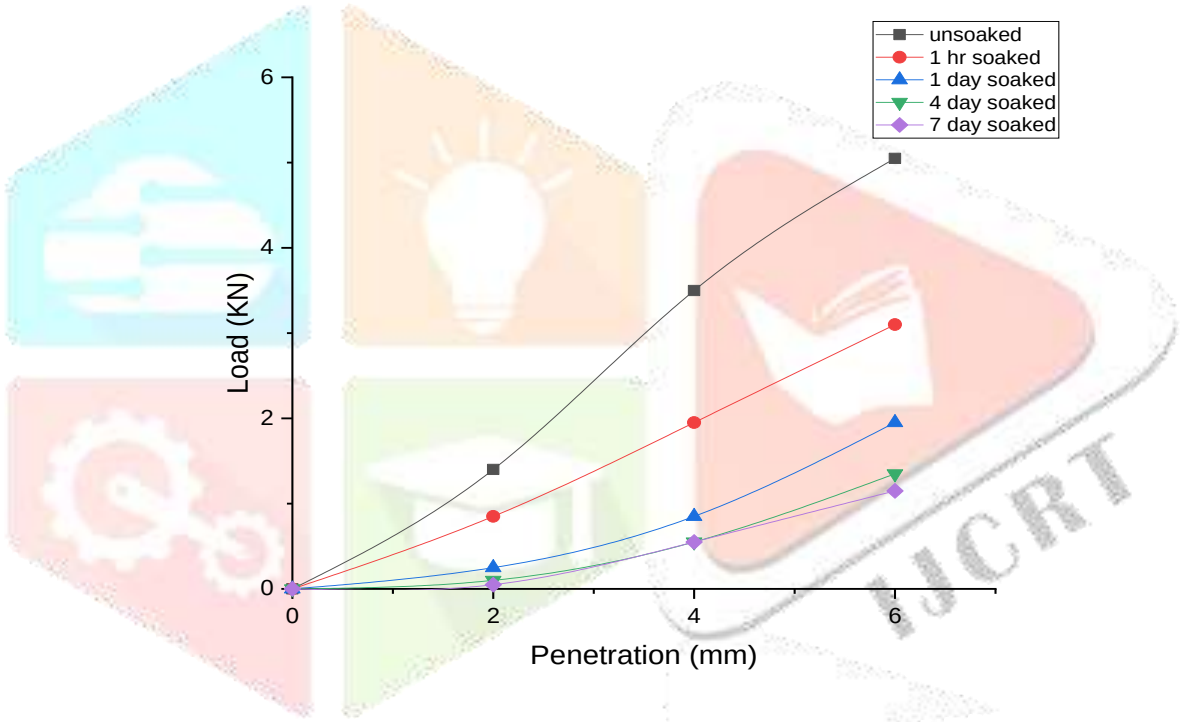

Figure 1 Load versus Penetration curve for different days of soaking (Sample 1)

The CBR values obtained for un soaked and soaked specimens are shown in Table 3. The percentage decrease of CBR value of various soaking conditions when compared with un soaked condition is also shown in Table 3.

Table 3 The CBR value and percentage decrement in the CBR value with respect to unsoaked conditions (Sample 1)

Soaking Condition	CBR Values	(%) decrease
Un-soaked	24.06	-
1hr soaked	13.89	42.27
1day soaked	10.91	54.65
4day soaked	9.92	58.77
7day soaked	7.94	66.99

The CBR value obtained for un soaked condition is 24.06% and on submerging the soil samples for 1hr 1, 4 and 7 days, the CBR values obtained are 13.89%, 10.91%, 9.92% and 7.94% respectively. The percentage decrement reported in Table 3 indicates that there is not much decrease in CBR value after 1 day of soaking. The result of CBR test presented in Figure 2 (bar chart) shows the comparison of soil strength for unsoaked and soaked condition. From the bar chart, it is clear that the CBR value for soaked conditions is relatively lower than CBR value for unsoaked condition. The presence of water when the soil had been soaked in different time interval contributes to the decrease of soil strength. The CBR value for soaked condition decreases with number of inundation days.

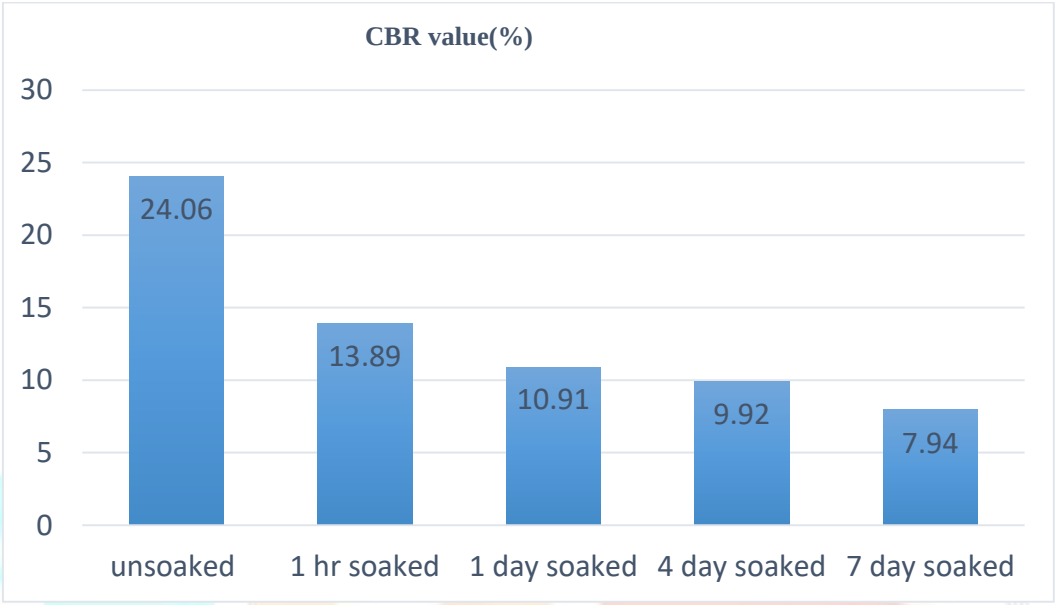

Figure 2 Comparison of CBR values unsoaked and soaked samples (Sample 1)

The percentage decrease of CBR value of 1 hr soaked specimen when compared with un- soaked specimen is 42.27 % and the percentage decrease of 54.65% is observed for 1day soaked specimen when compared with un-soaked specimen. There after the percentage decrease of 58.77% and 66.99% is observed for 4 day and 7day soaked specimen respectively. It is observed that there is a tremendous decrease in the CBR value (42.27%) when soaked for 1hr and 54.65% wwhen soaked for 1 day. After that it was observed that percentage decrease of the CBR value diminishes when soaked for 4day and 7day.Therefore, it can be concluded that increasing the number of days of soaking decreases the CBR value gradually and the percentage of decrease in CBR value diminishes after a soaking period of 1 day

Soaked and un soaked CBR test results of soil samples collected from location 2 (sample 2) were also analysed and results are discussed below. On increasing the number of days of soaking, the load value decreases for every penetration value. Figure 3 shows load value for penetration under different soaking conditions. The load value is more for un soaked condition and it is less for 7 days-soaked condition under various penetration values.

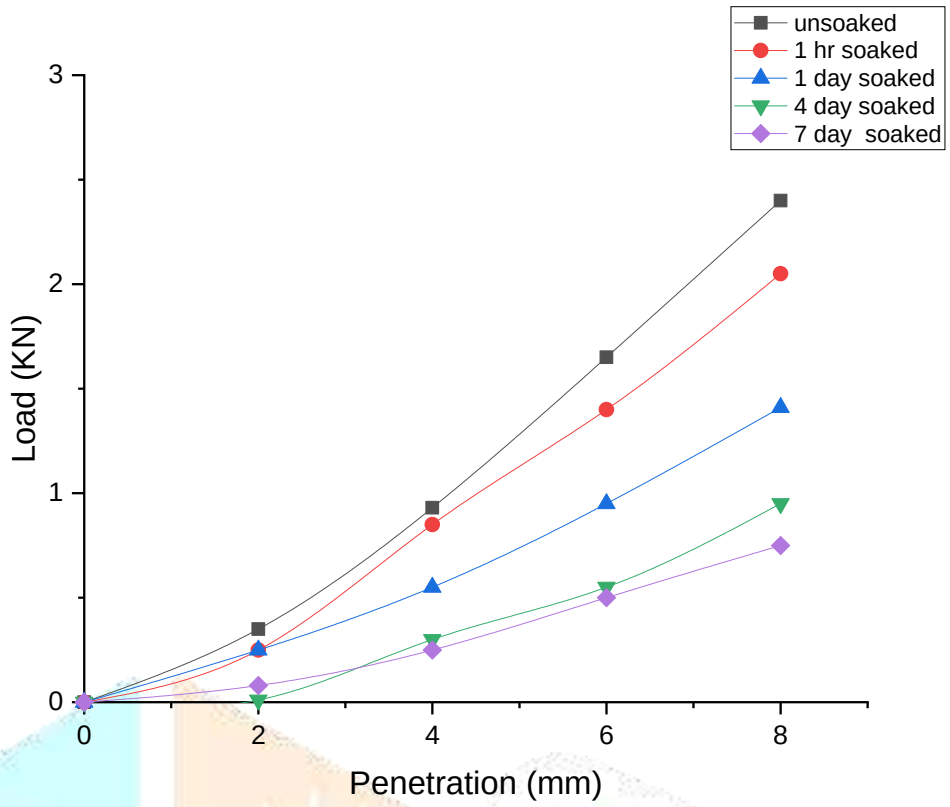

Figure 3 Load versus Penetration curve for different days of soaking (Sample 2)

The CBR values obtained for un soaked and soaked specimens (sample collected from location 2-Sample 2)are shown in Table 4. The percentage decrease of CBR value of various soaking conditions when compared with un soaked condition is also shown below.

Table 4 The CBR value and percentage decrement in the CBR value with respect to unsoaked conditions (Sample 2)

Soaking Condition	CBR Values	(%) decrease
Un-soaked	9.92	-
1hr soaked	6.94	30.04
1day soaked	4.97	54.66
4day soaked	4.48	54.83
7day soaked	3.98	59.87

The CBR value obtained for unsoaked condition is 9.92% and on submerging the soil samples for 1hr 1 day, 4day and 7 day, the CBR values obtained are 6.94%,4.97%,4.48% and 3.98% respectively. The percentage decrement reported in Table 4 indicates that there is not much decrease in CBR value after 1 day of soaking. The result of CBR test presented in Figure 4 (bar chart) illustrates the comparison of soil strength for unsoaked and soaked condition. From the bar chart, it is clear that the CBR value for soaked conditions is relatively lower than CBR value for unsoaked condition. Obviously, the presence of water when the soil has been soaked in different time interval contributes to the decrease of soil strength. The CBR value for soaked condition decreases with number of inundation days.

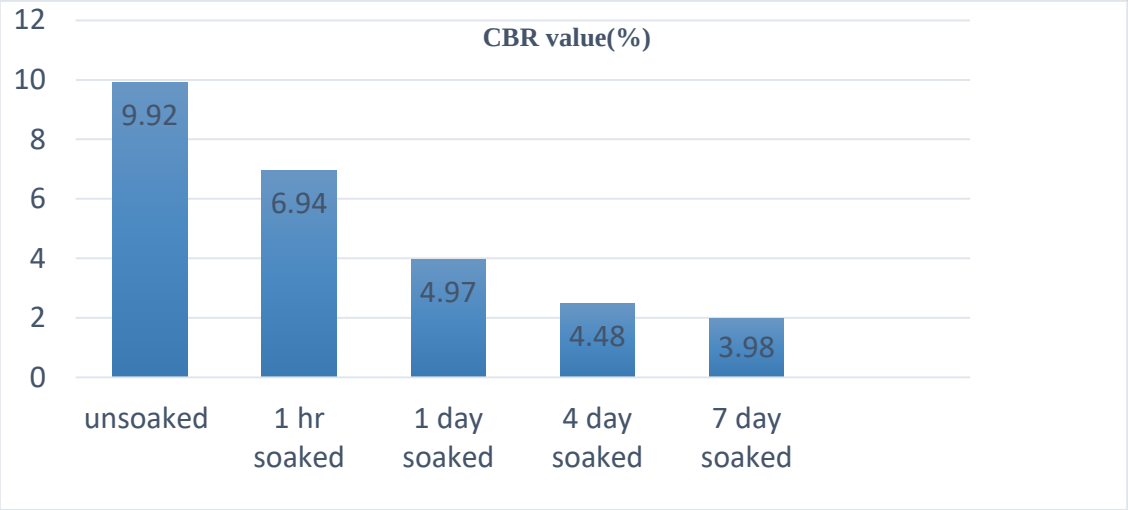

Figure 4 Comparison of CBR values unsoaked and soaked samples (Sample 2)

The percentage decrease of CBR value of 1 hr soaked specimen when compared with un- soaked specimen is 30.04 % and the percentage decrease of 54.66% is observed for 1day soaked specimen when compared with un-soaked specimen. There after the percentage decrease of 54.83% and 59.87% is observed for 4 day and 7 day soaked specimen respectively. It is observed that there is a tremendous decrease in the CBR value (30.04%) when soaked for 1hr and then for 1 day of soaking, the CBR value decreases to 54.66%. It was also observed that percentage decrease of the CBR value diminishes when soaked for 4 days and 7days.Therefore, it can be concluded that increasing the number of days of soaking decreases the CBR value gradually and the percentage of decrease in CBR value diminishes after a soaking period of 1 day.

IV. Conclusions

Experimental study has been carried out in this project work to determine the performance characteristics of sub grade, in different inundation conditions. From the results obtained it is evident that, the CBR value of soil samples decreases due to higher inundation days. A sudden slump in CBR values were observed when samples are subjected to 1day soaking condition. It can be concluded that the strength of soil further decreases when inundated for a longer period. Remedial measures are to be provided to negate the impact flooding and saturation conditions on subgrade. Strength of subgrade can be improvised by incorporating geocell and geo synthetics as reinforcement which helps in improving the performance of the pavements. Inclusion of polyurethane in soil samples also helps in increasing and maintaining the strength of subgrade. But much detailed studies are to be conducted on this field which is beyond the extent of this project

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