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THE IMPACT OF WATER SUBMERGENCE AND HIGH PRESSURE PISTON LOADING REPETITION ON SOAKED-CBR VALUE OF SUBGRADE AND SUB-BASE LAYERS

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ABSTRACT: Road pavement deterioration is a common problem that occurs in many countries. Many researchers found that the cause of deterioration is water submergence, heavy vehicle tire pressure, and cyclic load. From those results, it is known that there is no research on road pavement deterioration caused by combination of water submergence and heavy vehicle repetition that measured based on the soaked-CBR value. Therefore, this research was conducted to find the answers. Material used in this study was selected fill material (material-1) and aggregate B (material-2). The study was conducted in 2 steps. In Step-1, six samples for each of materials were compacted at their OMC values. Afterwards, 3 of 6 samples for each of materials were soaked; the remaining were made in un-submerged condition. In Step 2, cyclic load with pressures of P=50psi, 100psi, and 150psi were applied; repetition number of cyclic load for each pressure applied was n=0, 300, 600, 900, 1200, 1500. Soaked-CBR value was determined every time finish applying at each the cyclic load. The results show that soaked-CBR value of material-1 is always lower than of material-2, in all condition. Decrement of soaked-CBR value of material-2 in submerged condition caused by cycle loading pressure is more significant compared to the one of material-1. Soaked-CBR value of material-2 is affected by water submergence regardless the loading pressure and number of cyclic repetitions applied. Grain size distribution of materials has significantly affected to change of their soaked-CBR values when cycle loading applied especially for material in submerged condition.

Keywords: Cyclic load, Heavy vehicle, Pavement deterioration, Repetition number, Soaked-CBR, Water submergence.

1. INTRODUCTION

Road pavement deterioration is a common problem that often occurs in many countries, and it is still very difficult to solve.The problems still persist in Indonesia are Premature deterioration of highway pavements in Indonesia is still occurring, even when those highways are already properly designed with international standard, and the pavements are never inundated under water; The pavement deteriorations almost always firstly detected during the wet/rainy season, even the design is already based on soaked CBR values. Premature pavement damages are hardly observed during the dry season; At many pavement locations that had to be frequently repaired due to premature damages, it was learned that the base and sub-base layers were almost always puddle by water, even when there was no rain and the pavement surface looked dry; The premature pavement damages mostly occurred in highways with heavily overloaded truck traffic, and rarely occurred on pavement with lighter traffic.[1], [2] and [3] mentioned that period of water submergence was able to reduce the strength of sub-grade and sub-base layers of pavement significantly; it means that the longer the submergence periods, the higher reduction of the sub-base strength. This study was supported by [4]and [5] where they mentioned that water caused by rainfall or flood was one of main causes of the flexible pavement deterioration. According to [6], flexible pavement deterioration could be caused by heavy vehicle tire pressure. These studies were then confirmed by [7] where flexible pavement deterioration in Malaysia was caused by water submergence and heavy vehicle**.**

In 2016, [8] mentioned that cyclic load also had effect to the road pavement deterioration. This study was then confirmed [9]and [10] where the damage of flexible pavement was getting worse when it was submerged by flood and still passed repeatedly by heavy vehicles. Relationship between vehicle tire pressure and level of pavement damage had been developed by [11]; the result showed that vehicle tire pressure type 6B (113 psi) caused the highest level of pavement damage. In study performed by [12] showed that vehicle tire pressure 76psi–140psi was able to increase the level of pavement damage until 20%.

From the research results explain above, it is known that there is no research on road pavement deterioration caused by combination of water submergence and heavy vehicle repetition that measured based on the soaked-CBR value.Indonesia still use CBR values for determining the approved strength for sub-grade, sub-base and base layers of pavement. The CBR values used for design are the soaked CBR values, representing the worst and the least values of CBR of the soil layer. Therefore, this paper will present the results of research conducted in laboratory about impact of water submergence with high pressure piston loading repetition on soaked-CBR valueof sub-grade and sub-base layers.

2. MATERIAL AND METHODS

2.1 Materials

Two types of materials were used in this study, those were selected fill material (material-1) and aggregate B (material-2). The selected fill material (material-1) is generally used as sub-grade layer of road. It is commonly mixture of gravel, sand, silt, and clay; which also has to meet the requirements of [13], where the soaked-CBR value ≥ 10% when compacted with 100% maximum compaction energy and IP ≤ 6%. For this study, material-1 was taken from the *Antirogo* area, *Jember* Regency, East Java.

Aggregate B (*Bina Marga*) called as material-2 in this study is often used as the sub-base layer of pavement. According to [13], aggregate B must have soaked-CBR value ≥ 60%. Thismaterial-2 was taken from the *Gempol* area, *Pasuruan* Regency, East Java.

2.2Equipment

Equipment for applying cyclic loads to specimens is the result of research findings that aim to imitate field conditions in the laboratory. This cyclic loading tool has never been found in previous research. This cyclic load device can be used to simulate tire vehicle repetition with pressure that can be adjusted as needed. This device is also equipped with a counter which functions to count the repetitions number of the cyclic load. The sketch of the device can be seen in Fig. 1, picture of the device is given in Fig. 2.

2.3 Test Method

This research was conducted in 2 steps; Step-1 was for preparing samples and Step-2 was for samples testing. Before preparing the samples to be tested, the maximum dry density (MDD) and optimum moisture content (OMC) of material-1 and material-2 were determined using the modified Proctor compaction test [14]. The OMC values obtained were then used to prepare samples for which the soaked-CBR values will be determined in submerged and un-submerged conditions. Besides, a cyclic loading was applied to the samples in order to see the effect of the load repetition to the soaked-CBR value of the samples in submerged and un-submerged conditions.

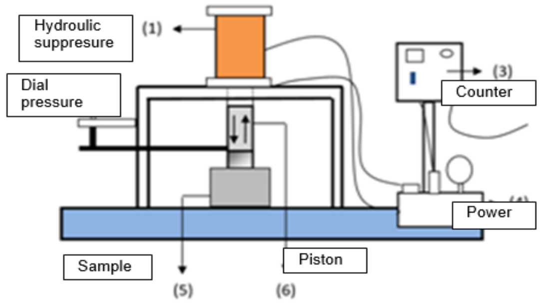


Fig.1 Schematic design of the cyclic loading device

Fig. 2 Picture of the cyclic loading device

In Step-1, six samples for each of material-1 and material-2 were prepared by compacting them at their OMC values as determined in the previous test. All of the samples prepared were then submerged in water for 4 days, as a requirement, in order to determine their soaked-CBR values; the water was then drained out for 2 hours. Afterwards, 3 of 6 samples of material-1 were submerged; the remaining 3 samples were made in un-submerged condition. The same treatment was done to other 6 samples of material-2.

In Step 2, the CBR test was carried out for all samples in order to determine their soaked-CBR value when repetition number of cycle load n1 = 0. The CBR test was performed at the center of sample tested, as shown in Fig. 3. Then, cyclic loading was carried out for all samples (material-1 and material-2), both in un-submerged and submerged conditions.

Cyclic load with number of repetitions n2 = n1 + 300 = 300 was applied at the center of sample; afterwards, the CBR test was performed at the edge of sample which had not been subjected to CBR test before (as shown in Fig. 4).Furthermore, at the same sample, another 300 times repetitions of cyclic load was applied at the center of the sample, so that the total repetition was n3 = n2 + 300 = 600; CBR test was carried out again at the another edge of the sample which has not been exposed to pressure during the previous CBR test.

Fig. 3 CBR test performed at the center of sample before cyclic loading application (n1 = 0).

In the same way, the repetitions of cyclic loads were continuously increased until n4 = n3 + 300 = 900; n5 = n4 + 300 = 1200; and n6 = n5 + 300 = 1500. With the test sequence as described above, the total CBR test performed on each sample is 6 times with details of 1x CBR test carried out at the middle of the sample without cyclic load and 5x CBR tests carried out at the edge of the sample after every number of cyclic load with different total repetitions applied. Location of the CBR test carried out for each sample can be seen in Fig. 5.

Fig.4 CBR test performed at the edge of sample after cyclic loading application

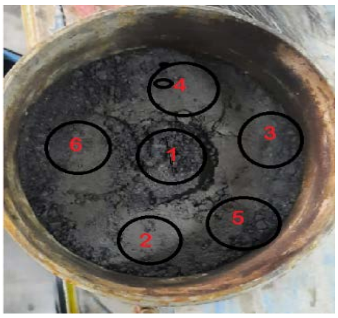
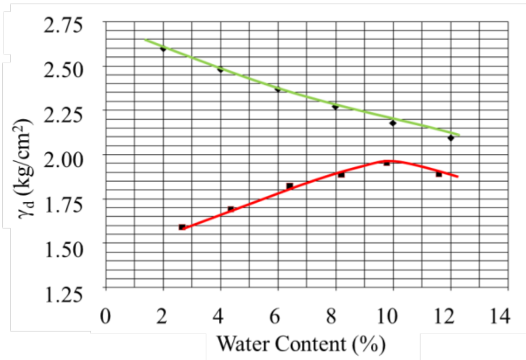


Fig.5 Location of CBR tests performed at point 1, 2, 3, 4, 5, and 6 after number of cyclic load repetition n1=0, n2=300, n3=600, n4=900, n5=1200, and n6=1500, respectively.

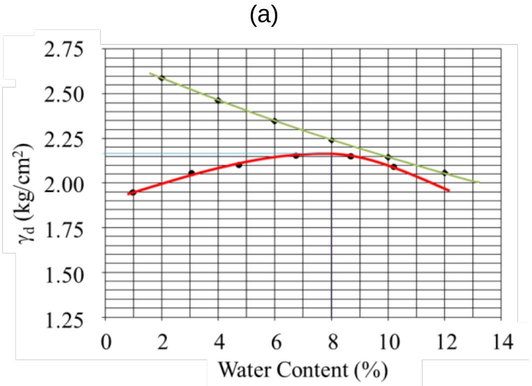
3. RESULTS AND DISCUSSIONS

3.1. Maximum Dry Density (MDD) and Optimum Moisture Content (OMC)

The compaction curves determined using in the modified Proctor test are given in Fig. 6. From those curves in Fig. 6, the optimum moisture content (OMC) of material-1 obtained is 9.8% and the OMC of material-2 is 8.0%. While the MDD of material-1 is around 1.95 gram/cm^3 and material-2 reaches 2.15 gram/cm^3. It is clear that the better quality materials require the less water to achieve higher density. The OMC values of material-1 and material-2 obtained here will be used as a reference in making the samples used in this research.



(a)



(b)

Fig 6. Compaction curves determined using the modified Proctor test; (a) material-1 and (b) material-2

3.2 Soaked-CBR Value Of Material-1 And Material-2 In Un-submergedAnd SubmergedConditions.

As previously mentioned that soaked-CBR of each sample was determined before cyclic loading was applied (n=0); afterwards, cyclic loading was applied with varying number of repetitions n = 300, 600, 900, 1200, and 1500 for each pressure applied to each sample P = 50psi, 100psi, and 150psi. From the results given in Table 1, it can be seen that before cyclic loading is applied (n = 0)

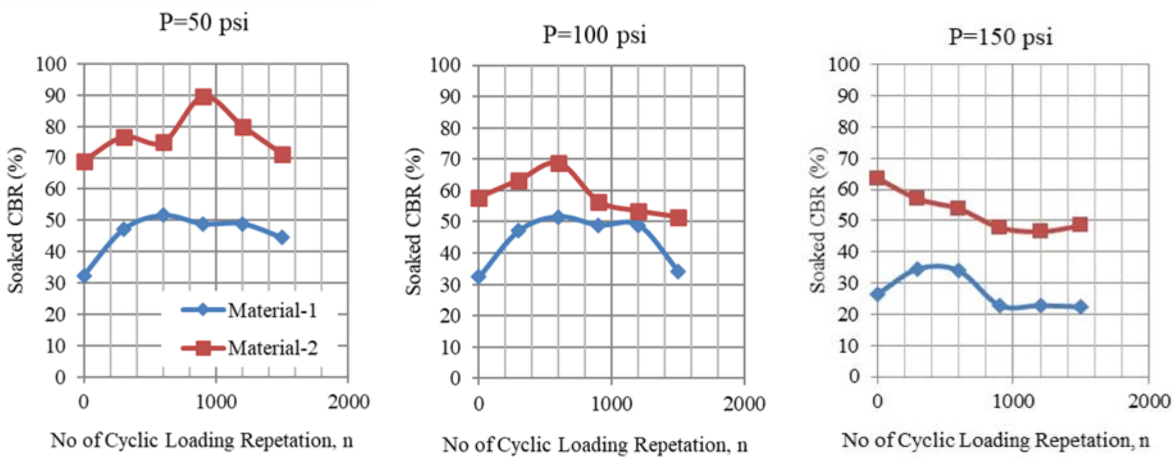
Table 1. Soaked-CBR Value Before and After Cyclic Loading Application on at Vehicle Tire Pressure P=50 psi, 100 psi, 150 psi

Condition	**UNSUBMERGED**			**SUBMERGE**		
Pressure	P = 50 psi	P = 100 psi	P = 150 psi	P = 50 psi	P = 100 psi	P = 150 psi
No of Cicles	n = 0			n = 0		
Material-1	32.44	32.44	26.22	24.22	31.72	33.56
Material-2	68.97	57.78	63.56	66.62	56.00	51.33
No of Cicles	n = 1500			n =1500		
Material-1	44.44	34.26	22.22	28.88	19.03	18.40
Material-2	71.06	51.56	48.40	46.13	40.11	25.53

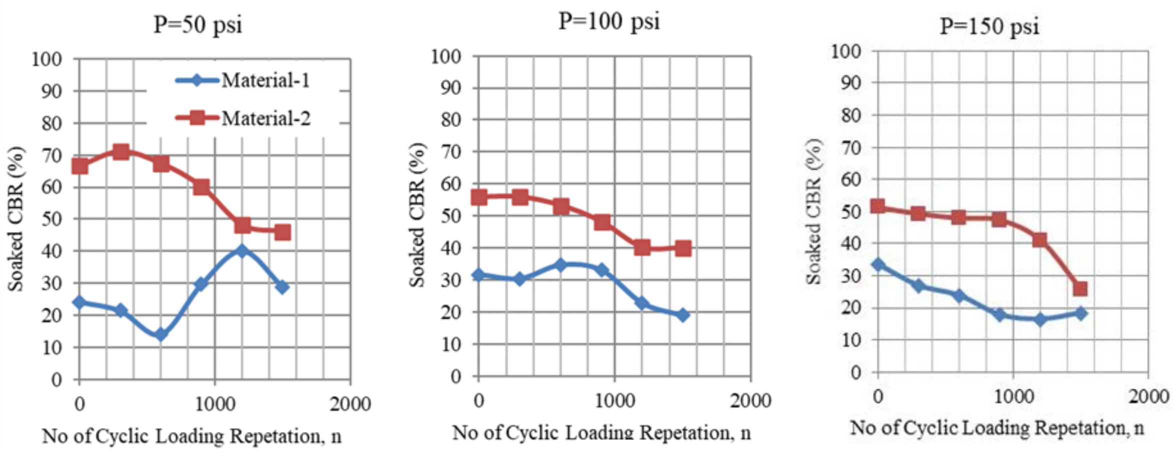
soaked-CBR value of material-2 is always higher than that of material-1. At the same pressure (P) and repetitions number (n=1500) of cyclic loading application, the soaked-CBR value of material-2 is also always higher than that of material-1. It shows that soaked-CBR value corresponds to the MDD value of each material where the MDD value of material-2 is also higher than material-1.

The soaked-CBR values of material-1 and material-2 due to load repetitions n = 300, 600, 900, 1200, and 1500 and vehicle tire pressures P = 50psi, 100psi, and 150psi are presented in Fig.7. From all the curves in Fig. 7, it is clear that the soaked-CBR value of material-1 is always lower than that of material-2, regardless whether it is in submerged or un-submerged conditions.

Repetitions number of cyclic loading and pressure applied, however, have more effect on the soaked-CBR value of material-2 than that of material-1.



(a)



(b)

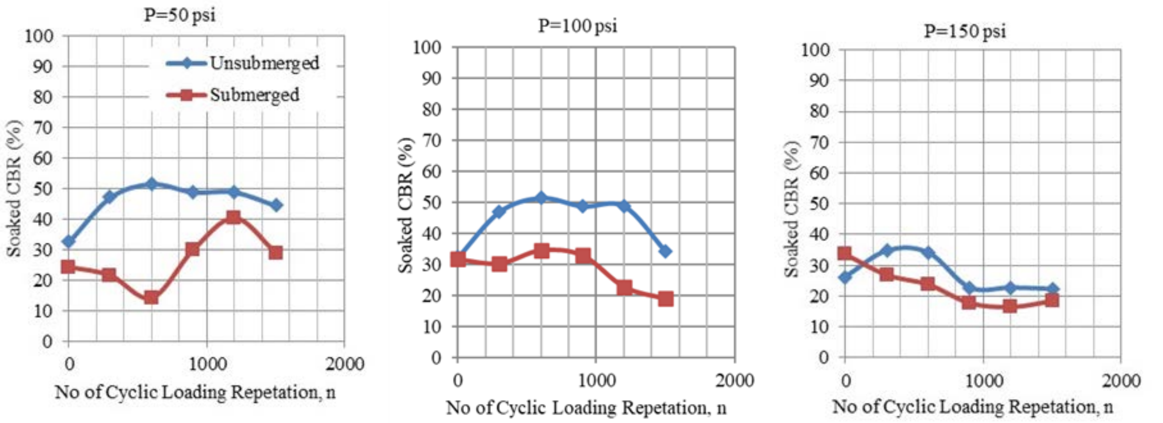
Fig. 7 The change of soaked-CBR values of material-1 and material-2 after cyclic loading application at vehicle tire pressure P=50psi, 100psi, 150psi, in (a) unsubmerged, and (b) submerged conditions

3.3.The Effect Of Water Submergence To The Saked-CBR Value Of Material Subjected To Cyclic Load

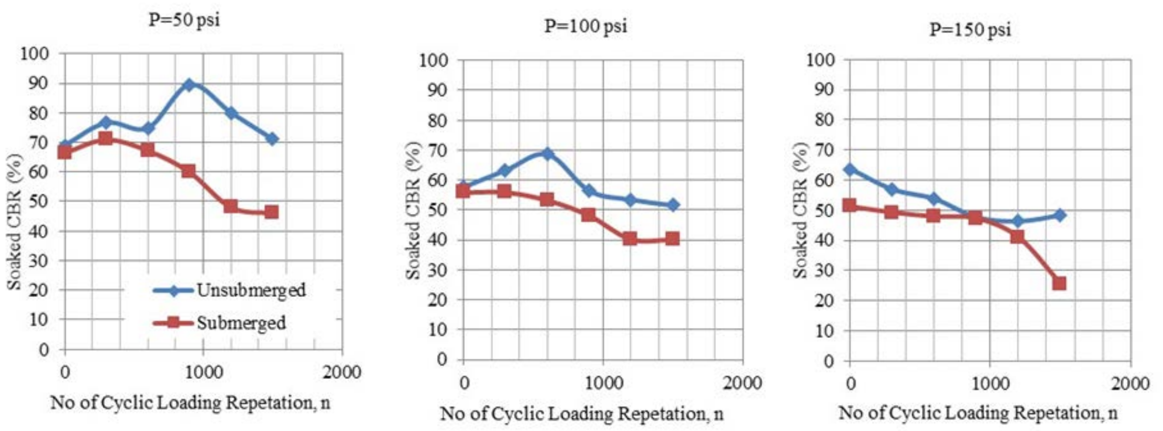
In order to study the effect of water submergence to decrement of the soaked-CBR value, material-1 and material-2 which have different MDD values are prepared in submerged and un-submerged conditions before cyclic loading is applied.Afterwards, cyclic loading with different pressures of 50psi, 100psi, and 150psi are applied; the repetition number of cyclic loading for each pressure is n = 0, 300, 600, 900, 1200, and 1500 times.The test results are then plotted as given in Fig. 8. From those curves, it can be seeninthat the soaked-CBR value of the material in submerged condition is always below or less than that of material in un-submerged condition.

In Fig. 8a, it is shown that soaked-CBR value of material-1 in submerged condition due to cyclic loading with pressure of P=50psi is varies depending on the number of cyclic repetitions applied. The lowest soaked-CBR value occurs when the number of cyclic loading repetition n=600 then increases at n=1200, and finally it is the same with soaked-CBR value for n=0.Soaked-CBR value of material-1 inun-submerged condition, however, slightly increases at the end of cyclic loading repetitions n = 1500. When cyclic loading pressure 100psi, soaked-CBR value of material-1 in submerged condition slightly decreases with the increase of cyclic repetitions number; but in un-submerged condition, soaked-CBR value at n=1500 does not change. At pressure load 150psi soaked-CBR value of material-1 slightly decreases, regardless in soaked or un-submerged condition. It means that the cyclic loading and water submergence have no effect to the soaked-CBR value of material-1 if the loading pressure is 50psi. In the contrary, soaked-CBR value of material-1 decreases if loading pressure is 150psi, regardless in submerged or un-submerged condition.These results strengthen research by [15].

Material-2 in un-submerged condition, as shown in Fig. 8b, has similar behavior as material-1 where the soaked-CBR value is about constant although repetitions number of cyclic loading n = 1500 and pressures applied are P = 50psi and 100psi; decrement of soaked-CBR value occurs when the cyclic loading pressure applied is 150psi.



(a)



(b)

Fig 8. The effect of water submergence to the soaked-CBR value (a) material-1, and (b) material-2

Different conditions occurs when material-2 is submerged in water where soaked-CBR value decreases with the increase of repetition number of cyclic loading although the pressureapplied is P = 50psi. The largest decrement of soaked-CBR value occurs when the pressure of the cyclic loading is P = 150psi and number of cyclic repetition n = 1500. It means that in un-submerged condition, the soaked-CBR value of material-2 has similar behavior with the one of material-1 if pressure applied 50psi and 100psi although number ofcyclic loading repetition n = 1500; but the effect occurs when the pressure applied 150psi. The soaked-CBR value of material-2, however, is affected by water submergence regardless the pressure and number of cyclic loading repetitions.

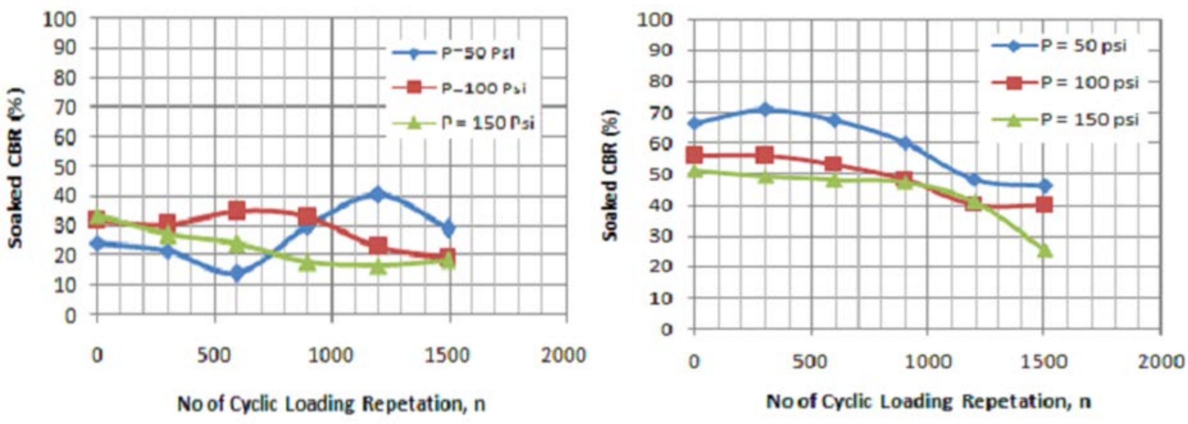
3.4. The Changes Of Soaked-CBR Value Caused By Pressure Variations Of Cyclic Load Of Sample In Submerge Condition

As previously explained that pressure of cyclic loads was applied in 3 different variations, 50psi, 100psi, and 150psi. From the curves in Fig 9, it can be seen that soaked-CBR values of material-1 and material-2 decrease due to cyclic loading regardless the loading pressure applied, except for material-1 under loading pressure P = 50psi. Decrement of soaked-CBR value of material-2, however, is much greater than to the ones of material-1.

The change of soaked-CBR value of material-1 (Fig. 9a) due to cyclic loading is not significantly compared to the soaked-CBR value before the cyclic loading applied (n=0).For cyclic loading pressure 50psi, the soaked-CBR value at n = 1500 slightly increases. When cyclic loading pressure P=100psi applied, the soaked-CBR value increases slightly at cyclic load repetitions n = 600x and then its value continues to decrease until the number of cyclic loading repetitions n = 1500x. If pressure of the cyclic loading is 150psi, the soaked-CBR value of material-1 continues to decrease although decrement is relatively small compared to the initial soaked-CBR value, as shown in Fig 9a.

Material-2 whose MDD value is higher than Material-1, it also has high initial soaked-CBR value about twice of the soaked-CBR value of material-1, as shown in Table 1. The cyclic loading, however, causes decrement of the soaked-CBR value. The soaked-CBR value of material-2 always decreases with the increase the number of cyclic loading repetition, as shown in Fig. 9b. The largest decrement of soaked-CBR value of Material-2 occurred when the cyclic loading pressure 150psi is applied.

From Fig. 9 and Fig. 7b, it can be easily compared that decrement of soaked-CBR value of material-2 in submerged condition is more significant when it is compared to material-1. This may caused by their different grain size distribution. Material-1 has well graded grain size distribution so that when it is compacted, the grains fill almost all of the existing voids which means the grain positions interlocked to each other. This condition causes the position of the grains not easily changed when it is submerged in water and cyclic loading is applied. Material-2 is dominated by coarse grains so that not all of the voids can be filled by smaller materials. As a result, when material-2 in submerged condition exposed to cyclic loading, the grains will be released gradually according to the pressure and the numbers of cyclic loading repetitions applied. At load P = 150psi, the decreased of soaked-CBR value is the largest, especially at number of cyclic loading repetitions n = 1500.



(a) (b)

Fig. 9 Changes of soaked-CBR value caused by water submergence and pressure variation of cyclic loading: (a) material-1, and (b) material-2

4. CONCLUSION

From the data and the analysis provided above, it can be concluded that:

- Maximum Dry Density (MDD) value of material-1 (selected fill material) = 1.95 gr/cm3;and material-2 (Aggregate *Bina Marga*) = 2.15 gr/cm3; the OMC value of material-1 = 9.8% and material-2 = 8.0%.
- Soaked-CBR value of material-1 is always lower than that of the material-2, regardless it is in submerged or unsubmerged conditions;
- Soaked-CBR value of material-1 is not affected by the cyclic loading repetition and water submergence when the pressure of cyclic loading is 50psi; it slightly decreases when pressure of cyclic loading 100psi is applied on material-1 in submerged condition; besides, it decreases if cyclic loading pressure applied is 150psi regardless in submerged or un-submerged condition.
- Soaked-CBR value of material-2 in un-submerged condition has similar behavior with the one of material-1 when pressure of cyclic loading applied is = 50psi and 100psi; but the effect of cyclic loading occurs when the pressure of its cyclic loading pressure applied is 150psi.
- Soaked-CBR value of material-2 is really affected by water submergence regardless the pressure (P) and number (n) of cyclic loading repetitions applied.
- Decrement of soaked-CBR value caused by cyclic loading pressure of material-2 in submerged condition is more significant compared to the one of material-1.
- Grain size distribution of materials studied, material-1 and material-2, has significantly effect to the change of their soaked-CBR values when they are subjected to cyclic loading especially in submerged condition.

The assumption thatthe existence of water that puddle under the pavement and the repetitive loading of high pressure of truck tires may cause the soaked CBR values of sub-gradeand sub-base to deteriorate further, lower than the original values. These results are the findings of this study.

5. REFERENCES

[1] Alam M.J.B. and M Zakaria (2002). Design and Construction of Roads in Flood Affected Areas. corpus id. Bangladesh University of Engineering and Technology, Dhaka, Bangladesh. 213196438.

[2] Jaleel Z. Tariq (2011). Effect of Soaking on the CBR-Value of Subbase Soil. Engineering & Technology Journal, Vol.29, No.6.

[3] SultanaMasuda, Gary Chai, Sanaul Chowdhury, and Tim Martin (2016). Deterioration of flood affected Queensland roads – Aninvestigative study. International Journal of Pavement Research and Technology. 424–435.

[4] Roslan Nursabihah, A.N. Abdul Ghani, and A.H. Abdul Hamid (2015). Road Subgrade Strength Under Various Flooding Event, Jurnal Teknologi 75:5. 39-43.

[5] Abdul Ghani A.N., A.H. Abdul Hamid, and N. Roslan (2016). Road Submergence During Flooding And its Effect On Subgrade Strength. International Journal of Geomate, vol 10, issue 21, pp. 1848-1853.

[6] BonaquistRamon F, Charles J. Churilla, And Deborah M. Freund (1987). Effect of Load, Tire Pressure, and Tire Type on Flexible Pavement Response. Transportation Research Record 1207. TRB, National Research Council,Washington, D.C., pp. 207-216.

[7] Shehu Zayyana, Nurul Elma, Endut and Gary D. Holt (2014). Factors influencing road infrastructure damage in Malaysia. https://www.researchgate.net/publication/270425887. 1-11.

[8] RysDawid, Jozef Judycki, and Piotr Jaskula (2016). Determination of vehicles load equivalency factors for polish catalogue of typical flexible and semi-rigid pavement structures. 6th Transport Research Arena. 2382-2391.

[9] Nurtjahjaningtyas I., I.B. Mochtar, N.E. Mochtar (2017) The Change of Value of soaked-CBR in Embankment of Subgrade Due to Water Logging and Repeated Vehicles Load. IOP Conference Series Materials Science and Engineering 403(1):01202.

[10] J. M. Sadeghi and M. Fathali (2007). Deterioration Analysis of Flexible Pavements under Overweight Vehicles. Journal Of Transportation Engineering© ASCE. 625 – 633.

[11] Dani Sahri, and Zulkarnain A. Muis (2018). Potensi Pengaruh Beban Overloading Terhadap Perkerasan (Studi Kasus: Jalan Raya Lubuk Pakam, Sumatera Utara), Jurnal USU.ac.id vol 7 no 1.

[12] A.K. Arshad, M.S.Harun, N.Jasmi, S.Yaacob and H.A. Haron (2018). Effect of Heavy Vehicles' Tire Pressure on Flexible Pavements, International Journal of Civil Engineering and Technology, 9(9), pp. 1161–1170.

[13] SNI 03-1744-1989Standart Nasional Indonesia of California Bearing Ratio Laboratory Testing Methods

[14] SNI 03-2832-1992 Standart Nasional Indonesia of Testing Methods To Get Maximum Dry Density(MDD) With Optimum Moisture Content (OMC)