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IOP Conference Series: Earth and Environmental Science

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To cite this article: S F Badaron *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **419** 012084

IOP Conf. Series: Earth and Environmental Science **419** (2020) 012084 doi:10.1088/1755-1315/419/1/012084

# Soaking effect on bearing capacity of subgrade material

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**Abstract.** Research aims to analyze the index properties and minerals content of subgrade materials, as well as to analyze how much degradation of bearing capacity of subgrade by providing immersion cycles. Research to be performed in the laboratory sequentially starting from material index properties tests to ensure the soil sample meets the requirements as a subgrade. The test was continued by unconfined compression (UCS) and CBR test against each test specimen after being subjected to immersion cycles in 4 days, 8 days, 12 days and 16 days. The last step is to compare the degradation of subgrade bearing capacity before and after immersion cycles. Test results of index properties are in conformity with x-ray diffraction test results, based on index properties results of activity degree (A) is 0.52 including kaolinite minerals and x-ray diffraction test results of this subgrade material is largely dominated by Kaolinite clay minerals. Test results by immersion cycles shown significant decrease in the value of CBR and UCS, especially in the initial immersion for 4 days, CBR and UCS values drastically decreased by 90% and 97%, subsequent to 8 days, 12 days and 16 days CBR and UCT values, not significant decrease compared to age 4 days.

## 1. Introduction

The durability of pavement structures is strongly influenced by the capacity of the subgrade layer, so it is necessary accuracy in determining these parameters in pavement design stage. Even on pavement with thin paved layers, a small error in the evaluation of the ground can cause a reduction in service life to only a tenth of the planned service life [1]. On the other hand, road pavement should sometimes be built on areas that often experience water pools in turn according to the climate so that it is suspected that there will be degradation of the subgrade layer capacity which will be different in value when tested during the dry season. Justification capacity of the subgrade layer regardless of the conditions that will be experienced during the service time of the road will be fatal because it can cause early damage. So the main thing required is the belief in the material used as a subgrade layer concerning the criteria of physical and mechanical characteristics that meet the requirements of existing techniques.

## 2. Literature review

### *2.1. Subgrade layer characteristics*

The subgrade is the surface of the original soil, excavated surface, or surface of the embankment which is the surface for placement of other pavement layers. The subgrade function is to receive pressure due to traffic loads on it. Therefore the subgrade layer must have an optimal bearing capacity so that it can accept the force due to traffic load without damage [2]. The quality of the subgrade layer greatly determines the thickness of the pavement layer above it so the accuracy in assessing the quality of the subgrade will have an impact on the cost aspect of the road, meaning that if the subgrade quality is good then the pavement cost is cheaper but if misinterpretation of subgrade support capacity will result in premature road pavement damage boils down to financial losses.

*2.2. Mineralogy with X-Ray diffraction*

X-rays are one form of electromagnetic radiation with wavelengths ranging from 0.001Å up to 100Å. The electromagnetic wavelengths emitted by X-rays and their ori- ces are equal to the spacing of the atomic plane in crystals ranging from 0.5-2.5Å, therefore the X-rays are able to analyze the crystalline structure and identify the crystalline soil minerals. X-rays will show diffraction symptoms if they fall on objects whose distances are approximately equal to the wavelength of the light. X-rays are produced from high-speed electron collisions with target metals that provide characteristic radiation [3]. Any mineral with different crystalline structures will have different X-ray diffraction patterns, so from these different X-ray diffraction patterns can be used to identify minerals contained in a soil sample. The diffraction patterns of common minerals have been known previously so that they can easily be compared with the diffraction patterns of the tested soil samples. Based on the Bragg hypothesis, "If two parallel x-ray beam (n λ) about the crystal planes is equal to the spacing between plane (d), then the difference in the distance traveled by both rays is directly proportional to the wavelength"If two x-ray beams are parallel to the wavelength (n λ) about the crystal planes equal to the spacing between plane (d), then the difference in the distance travelled by both rays is directly proportional to the wavelength".

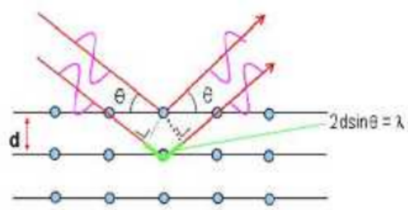


**Figure 1**. X-ray reflections on two crystal surface planes.

The Bragg Law formulation can be written as:

$$n\lambda = 2dsin\theta \tag{1}$$

where: $n$ = number of reflections (n = 1, 2, 3, ......)
$\lambda$ = wavelength
$d$ = distance between fields
$\theta$ = the diffraction angle to the parallel crystal plane

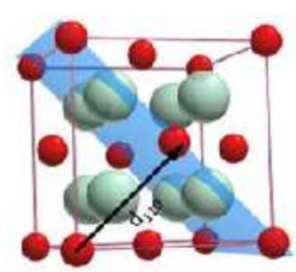

**Figure 2.** The position of the peak diffraction is determined by the distance between the parallel plane of the atom.

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This Bragg law is used as a basis for identifying crystals with X-ray diffraction, where the law is grounded in that no minerals have the same atomic spacings in 3 dimensions so that the diffraction angle that occurs (and the distance between the calculated atomic spheres) used to identify these minerals.

### *2.3. Pavement road water submerged condition*

In tropical areas many instances where road bodies are submerged in the rainy season, either because of high rainfall intensity and poor drainage conditions. This condition is very detrimental because there will be degradation of the capacity to support the subgrade layer to decrease the performance of road infrastructure and will also be a waste of resource consumption which resulted in the allocation of maintenance and rehabilitation cost is relatively large. The results of research related to waterlogged roads due to inundation have been conducted in many countries, including research conducted in Bangladesh trying to investigate the effect of waterlogging on the pavement on the soil density of the subgrade layer and the impact of water puddle on the value of CBR [4]. Where the results of the study can conclude that the period of inundation by the flood water significantly affects the pavement layer strength.

## 3. Research methodology

The location of subgrade material sampling is around the campus of Engineering Faculty, Hasanuddin University in Gowa District. Research methods are performed in the laboratory sequentially starting from physical, mechanical and mineral characteristic tests to ensure the soil sample meets the requirements as a subgrade. The test was continued with unconfined compression test (UCS) and CBR test against each test specimen after being treated by soaking with well water 4 days, 8 days, 12 days and 16 days.

## 4. Result and discussion

Laboratory tests results of physical and mechanical properties of subgrade samples material can be seen in table 1 below.

**Table 1**. Characteristics of soil physical and mechanical properties.

| Index properties | Test results |
|---|---|
| a. Grain Size Analysis | |
| - Gravel Fraction (gravel) | 13.40 % |
| - Sand Fraction (sand) | 23.20 % |
| - Silt-Clay Fraction | 63.40 % |
| b. Consistency dan Activity | |
| - Liquid Limit (LL) | 61.19 % |
| - Plastic Limit (PL) | 28.37 % |
| - Plasticity Index (PI) | 32.82 % |
| - Shrinkage Limit (SL) | 13.21 % |
| - Activity (A) | 0.52 |
| c. Gravity (Gs) | 2.62 |
| d. Dry Density max. ($\gamma_d$) | 1.47 gr/cm$^3$ |
| e. Optimum Water Content ($w_{opt}$) | 30.76 % |
| f. Soil Classification | |
| - USCS | CH |
| - AASHTO | A–7–6 |

From table 1 above, it can be seen that the soil particle size is quantitatively dominated by the silt-clay fraction from the proportion of the soil sample, this is consistent with the classification of soil according to the Unified Soil Classification System (USCS) system by classifying the soil type as CH (high plasticity clay) and with the AASTHO system including A-7-6. Testing of California Bearing Ratio and unconfined strength is also carried out in the laboratory to determine the mechanical properties of the soil (engineering properties), concerning the carrying capacity and compressive strength of the free sample material subgrade. From this test obtained CBR value of 18.66% and UCS value of 0.405 kg/cm$^2$.

### 4.1. *Mineral X-Ray diffraction pattern subgrade*

The results of X-Ray Diffraction testing of subgrade samples as the relationship between intensity and diffraction angle (2θ) can be seen in the picture below.

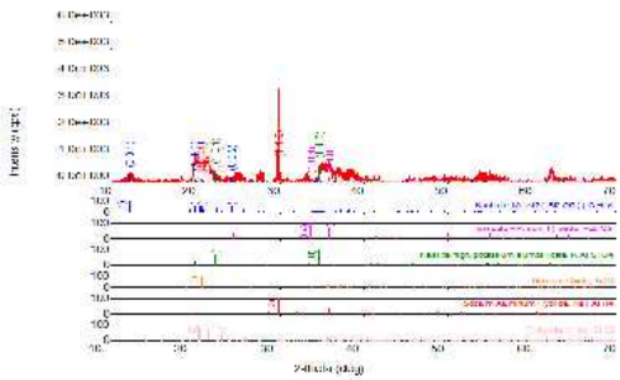

**Figure 3.** Graph of X-Ray diffraction test results.

From the graphic above, we identified the content and composition of both clay minerals and non clay minerals in the soil samples tested, as shown in table 2 below.

**Table 2**. Mineral content and not clay minerals.

| Type of content | Chemical formulation | Content (%) |
|---|---|---|
| Kaolinite 1A | $Al_2Si_2O_5(OH)^4$ | 43(6) |
| Hematite HP,iron (III) oxide | $Fe_2O_3$ | 2.80(19) |
| Kalsilite hight,potassium | $K AiSiO_4$ | 30(5) |
| alumosilicate | $TiO_2$ | 2.91(19) |
| Titanium Oxide | $Na(AIH_4)$ | 15.4(16) |
| Sodium Aluminum hydride | $SiO_2$ | 5.5(4) |
| Tridymite M low | | |

The above data show that in natural clay soils contain more than one type of minerals, whether clay minerals, non-clay minerals, or other organic and inorganic materials. To date, no single study has been able to explain clearly how the effects and interactions of individual mineral types on soil behavior are, however, information on the composition and proportion of these minerals is essential to provide a comprehensive understanding and use as a reference in describing the qualitative and empirical soil behavior. Kaolinite clay minerals predominantly dominate the subgrade material samples seen in the data. The kaolinite minerals include silicate clay minerals that have very simple structures. The kaolinite structure is composed of one $SiO_4$ tetrahedral plate and one gypsite plate. The bond between the crystal unit is somewhat stronger than that of the smectite mineral group where cations and water molecules are more difficult to enter in the cavity between the mineral crystal units, so this mineral does not give rise to expansive properties.

### *4.2. Value of CBR with variations of soaking time*

The test results of CBR and UCS values can be seen in table 3 and figure 4.

**Table 3**. Test Results of CBR and UCS values against variations of immersion time.

| Testing | 0 day | 4 day | 8 day | 12 day | 16 day |
|---|---|---|---|---|---|
| CBR (%) | 18.66 | 1.90 | 0.76 | 0.60 | 0.50 |
| UCS, qu (kg/cm$^2$) | 0.405 | 0.014 | 0.012 | 0.010 | 0.009 |

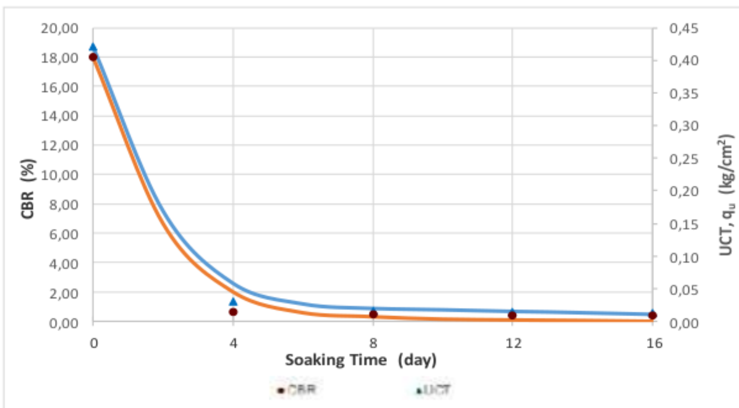


**Figure 4**. Graph of time immersion relationship with UCS and CBR.

From table 3 and figure 4 it can be seen that 4 days immersion, CBR and UCS values decreased significantly by 90% and 97% respectively. At subsequent immersion for 8 days, 12 days and 16 days the value of CBR and UCS decreased not significantly from the age of 4 days. From the graph the time-immersion relationship of CBR and UCS values dropped drastically as a result of describing the process of filling the pore of subgrade particles soil, after 4 days the value of CBR and UCS will decrease not very significant reflecting that the water began to be absorbed and reacted with clay minerals, clay has the ability to absorb water through the process of suction and bonding of mineral clay in subgrade materials .

## 5. Conclusion

1. The test results of physical and mechanical properties conform to the results of x-ray diffraction testing. Based on the results of physical and mechanical analysis test Activity (A) is kaolinite clay minerals mostly dominate 0.52 including kaolinite mineral and x-ray diffraction test results of this subgrade material.
2. As a result of immersion there is a significant decrease in the value of CBR and UCS, especially in the initial immersion for 4 days, the value of CBR and UCS decreased drastically by 90% and 97%, subsequently at 8 days, 12 days and 16 days degradation of CBR and UCS not significantly decreased compared to age 4 days.

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