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Compressive Strength of the Cement Treated Base of Runway

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ABSTRACT

Material base course on highway or runway pavement that stabilized using cement is well known as Cement Treated Base (CTB). For this kind of material it should be tested when the specimen is tested at seventh day for unconfined compressive strength (UCS). Here, it carries out testing at 7th, 14th, 21th, and 28th day respectively. Furthermore it will be got a curve with mean of normalization to compressive strength at 28th day.

1. Introduction

Indonesia is a big country and consists of lot of islands which it has scattered thousand islands. More or less 270 million in habitant live on the some big islands, even on remote islands [1]. Lot of infrastructure that built in recent years included airports contribute to economically growth national domestic. Runway is an important part of an airport in a transportation system also considered to be developed. For a new runway, type of flexible pavement generally chosen to kind of pavement because of a settlement problem if the runway over a soft soil. Regarding with rule, a runway subjected to aircraft has a take-off weight more than 100 pounds, so that a stabilized layer should be applied. Beneath hot mix layer is a base course so this layer should be stabilized using cement mixed in the base course so called Cement Treated base (CTB). Sometimes, a certain consider for pavement with surrounding high water table, using stabilized layer will reduce a deterioration effect of water on material pavement.

Material aggregate added with cement or stabilized cement is worldwide known or applied. Mixture of the aggregate, cement, and water is known as Portland cement concrete. It can be applied for a structural construction like column, beam, and plate. Meanwhile, base course for pavement when stabilized with cement, it is so called CTB. When subbase is added by using cement so called Cement Treated Sub-Base (CTSB).

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Object of the research is to know the compressive strength of CTB at the varied day of testing. After that make a comparison between CTB and Portland cement, which both of them are material aggregate that is added with cement.

2. Theoretical Approach

2.1 Material CTB

Base course is a layer on flexible pavement type which it is located on beneath hot mix layer. At certain circumstance, because of rule or situation that the base course have to stabilized in order to provide higher bearing capacity or to increase the durability material due to deterioration effect of submersion. When cement material is added to base course material, it is so called cement treated base course. The CTB is a mixed in place or central plant produced material consist of soil/aggregate, cement, and little bit of water that creates a strong and durable stabilized roadway/runway base. Basically, base course comprises coarse aggregate, fine aggregate, and little bit of water on surface of grain aggregate. Meanwhile, CTB is material of base course that added the cement powder during mixing in batching plant and then it is transported to the working place, and furthermore it is compacted until achieving a certain level of compaction degree.

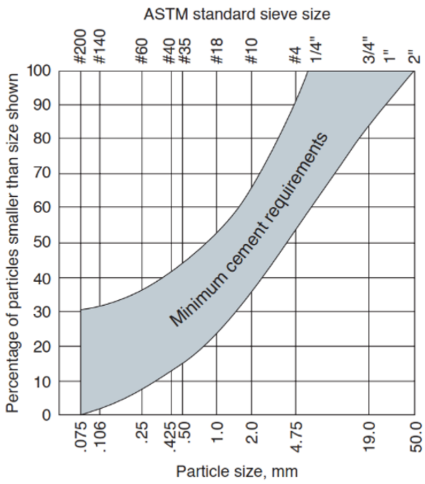

Fig. 1. Aggregate gradation band for minimum cement requirements

Figure 1 shows aggregate gradation for CTB and cement requirement. It means that bigger size of aggregate will need more cement for mixture [2].

The some advantages of CTB are many:

- CTB provides a stiffer and stronger base than unbound granular base. A stiffer base reduces deflection due to traffic loads, which result in lower strain in the asphalts surface. This delays the onset of surface distress, such as fatigue cracking, and extends pavement life.
- Thickness of layer CTB is less than those required for granular base carrying the same traffic, because the load is distributed over a larger area. Other, the strong uniform support provided by CTB will reduce stress applied to the subgrade.
- The wide variety of in-situ soil/aggregate and manufactured aggregates can be used for CTB.
- The construction operation progress is will be quickly on going with little disruption to the traveling public.
- Rutting is reduced in a CTB pavement.

- Moisture intrusion on pavement layer of construction can destroy un-stabilized pavement bases, but it will be not to be occurred, when cement is used to bind the base. CTB pavements form a moisture-resistant base that keeps water out and maintains higher levels of strength, even when saturated, thus reducing the potential for pumping of subgrade soils.
- CTB provides a durable properties of material, long-lasting base in all types of climates and thawing.
- It is similar property to slab concrete, the CTB is going to continues to gain strength with age.

2.2 Performance of CTB

CTB is widely used as a pavement base for highways, roads, streets, parking areas, airports, industrial facilities, and materials handling and storage areas. The structural properties of CTB depend on the soil/aggregate material, quantity of cement, curing conditions, and age.

Table 1
Properties of CTB

Properties	**7-day values**
Compressive strength	300 – 800 psi (2,1 – 5,5 MPa)
Modulus Rupture	100 – 200 psi (0.7 – 1.4 MPa)
Modulus of elasticity	600,000 – 1,000,000 psi (4,100 – 6,900 MPa)
Poisson's ratio	0.15

Source: Portland Cement Association (2006) [1]

As a comparison from other reference that compressive strength of CTB is range of 45 to 55 kg/cm^2 [3], which it is still in the range (see Table 1). Chai et al. (2002) carried out the trial of CTB found from two sources that is from core drill, and from laboratory testing at variety day of test. The compressive strength values of both at 7th day are around 6.0 MPa, and the compressive strength value at 28th day of testing is 7.5 MPa.

Table 2
Compressive strength of CTB

Curing (day)	**Compressive Strength (MPa)** *Test from Core Drill*	*Test from Specimen*
1	-	3
3	-	5.5
4	4.5	-
7	-	6.0
8	6.0	-
28	7.5	-

Source: Chai et al. (2002) [4]

During designing a road pavement or airfield pavement structure must complies with some regulation, standard and codes. It consist of a pavement thickness, materials, and strength requirements [9], [10], [11], [12]. The CTB is a material that has a susceptible characteristic due to fatigue cracks, and it is such as other material pavement has a fatigue behavior after serving repetition load, and it will get a modulus deterioration [13], [20]. Some studies have already done to well understand the characteristic of CTB when inserted of fine material or other kind of materials with aim to improve it. Some waste materials have a potential solution to overcome environmental concerns and potentially to improve mechanical properties and durability point of view [14]. Fly ash for stabilizing base or subbase material for pavement. It can replace the cement role on mixture. By adding fly ash it is able to increase the unconfined compressive strength, resilient modulus which the coefficient of determination or correlation is to be between 0.8 and 0.9 and the finally it can enhances the service life of pavement [15]. Jarofix is a waste material which is from extraction process of zinc from ore. Cement-stabilized Jarofix material is able to reduce the thickness layer of pavement by 20% and provide sustainable and economical construction of pavement [16]. Moorum is lateritic soil that has high plasticity. Portland cement has been used to stabilize the high plasticity of moorum and it has satisfactory properties for a road base or subbase layer [19], [26].

Structural coefficient for the CTB as a mechanistic properties and durability of this layer to be elaborated using laboratory and finite element [17], [18]. Rigid pavement for apron is comprised of unreinforced slabs of concrete which is constructed on a bound granular base. Using of finite element to model the behavior of concrete slab for rigid aircraft pavement is to elaborate load transfer during thermal expansion and contraction [21]. Some studies to be done to investigate mechanical performance and durability of cement-stabilized macadam properties [22], [24]. Influence of traffic load amplitude on cracking of asphalt pavement on a semi-rigid base. Study to investigate the effect of traffic load with field and laboratory trials on cracking performance of hot-mix asphalt [23], [25].

3. Methodology

Trial test in the field and also laboratory testing have been carried out in Malaysia for base course of roadway which it is stabilized by cement, it is so called Cement treated base (CTB) [4], [5]. From the research it is concluded that more lower deflection of CTB shows that stiffness of CTB is increased significant. As we know well that strength of cemented material like CTB must be tested at 7th day after molding and compaction of the specimen. It is little bit different compared to the testing of concrete that it should be done when the specimen achieves at 28th day. At the Material Laboratory of Engineering Faculty of the Universitas Tanjungpura that the test will be done when the curing period of specimen at 3, 7, 14, and 28 day, respectively.

Each variant of day for testing the specimen is provided 5 specimens. So totally there are 20 specimens prepared for testing to know the strength of specimens. Type of cylinder mold for specimen is provided for testing the specimens. Correction factor of compressive strength for specimen when using type of cylinder mold with dimension 150 mm in diameter, and 300 mm length is around 0,83 [6].

By statistically approach to interpret the dispersion of data from the testing of specimen, the central tendency likely mean, deviation standard, and coefficient of variation is applied to understand the spreading of data. Various average values are used to indicate a central value of a set of data [7]. Some of these are referred to as means. The averages, the most common and familiar is the arithmetic mean, defined by:

$$x \text{ or } \mu = \sum x_i / N \qquad (1)$$

The standard deviation is extremely important. It is defined as the square root of the variance:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\mu)^2}{N}} \quad (2)$$

A dimensionless quantity, the coefficient of variation is the ratio between the standard deviation and the mean for the same set of data, expressed as a percentage.

4. Result and Discussion

Trial test in the field and also laboratory testing have been carried out in Malaysia for base course of roadway which it is stabilized by cement, it is so called Cement treated base (CTB) [4], [5]. From the research it is concluded that more lower deflection of CTB shows that stiffness of CTB is increased significant. As we know well that strength of cemented material like CTB must be tested at 7th day after molding and compaction of the specimen. It is little bit different compared to the testing of concrete that it should be done when the specimen achieves at 28th day. At the Material Laboratory of Engineering Faculty of the Universitas Tanjungpura that the test will be done when the curing period of specimen at 3, 7, 14, and 28 day, respectively.

Table 3
Compressive Strength Values

No	Curing Period (day)	Weight (kg)	Max Load (kg)	Area (cm^2)	Compressive Strength (Kg/cm^2)
1		11.17	7,200		40.74
2		10.32	6,300		35.65
3	3	11.28	6,000	176.71	33.95
4		10.96	6,500		36.78
5		11.38	6,200		35.09
1		11.45	11,400		64.51
2		11.40	12,300		69.60
3	7	11.65	11.600	176.71	65.64
4		11.00	8,500		48.10
5		10.85	7,000		39.61
1		11.23	12,600		71.30
2		10.89	8,700		49.23
3	14	11.27	15,400	176.71	87.14
4		11.28	14,200		80,36
5		11.15	10,800		61.12
1		10.97	12.600		71.30
2		11.13	14,200		80.36
3	28	11.18	14,600	176.71	82.62
4		11.02	12,400		70.17
5		10.95	12,200		69.04

Table 3 shows that the compressive strength for the curing period 3 day is various between 33.95 and 40.74 kg/cm^2. For the curing period 7 day is various between 39.61 and 69.60 kg/cm^2. For the curing period 14 day is various between 49.23 and 87.14 kg/cm^2. For the curing period 28 day is various 69.04 and 82.62 kg/cm^2.

Table 3 also shows the weight of specimen. The weight of specimen for the curing period 3 day is various between 10.32 and 11.38 kg. For the curing period 7 day is various between 10.85 and 11.65

kg. For the curing period 14 day is various between 10.89 and 11.28 kg. For the curing period 28 day is various 10.95 and 11.18 kg/cm^2.

During testing of cylinder specimen, the maximum load will be achieved on each specimen which the specimen is cracked. Generally the pattern of crack on specimen is diagonally or vertically type. Figures below show some pattern of crack during testing. Most of specimens have diagonally crack pattern.

Fig. 2. Crack pattern of testing specimen

Furthermore, covariance analysis regarding with data of compressive strength of specimen testing is needed to understand the distribution of testing values. Hence, the central tendency measure consist of mean, deviation standard, and coefficient of variation (CoV) of compressive strength values will be elaborated. Table 4 shows the central tendency measure to provide the statistical analysis of data.

Table 4
Compressive Strength Values, CoV, and Conversion Factor

No	Curing Period (day)	Mean (Kg/cm2)	Deviation Standard (Kg/cm2))	CoV (%)	Factor of conversion to 28th day (%)
1	3	36.44	2,51	7.17	49
2	7	57.49	12.94	22.51	77
3	14	69.83	15.11	21.63	93
4	28	74.70	6.30	8.44	100

Based on Table 4 that the CoV values are between 7 to 22.5%. The appropriate CoV is less than 30%, it is mean that the data of trial has a good of dispersion value.

Generally, compressive strength for Concrete is considered at 28th day. Meanwhile, compressive strength for CTB is tested at 7th day. When we want to know the value of compressive strength with different day, we must have a factor to convert them. This paper elaborates the factor in order to make it easy when the testing is carried out not the certain day should test the specimen. From Table 3 we find the conversion factor based on compressive strength at 28th day,

Conversion factor is important to be known when we need to early prediction a value of compressive strength at 28th day based on a value of compressive strength at 3rd day or 7th day. Some conversion factor from code, reference, and result of this paper can be listed on Table 4.

Wibowo has carried out the research to determine the compressive strength for normal concrete and high volume fly ash - self compacting concrete (HVFA-SCC) varied the day of testing [8]. His research is really interesting related to topic of the research conducting and it will be compared.

There are three kinds of cement that can be used to add on material aggregate. They comprise Portland Cement (PC), Portland Composite Cement (PCC), and Portland Pozzolan Cement (PCC). Now a day, in Indonesia, PCC is worldwide applied to build some infrastructures. This kind of cement is made by adding PC with filler like fly ash which this kind of cement is cheaper or economic price. PCC in concrete mixture on some research indicates behaviour of early strength.

The range of conversion factor of compressive strength based on the day of testing for material stabilized cement according to Table 4 which for CTB, normal concrete, and early strength concrete are 0.40 to 0.55, 0.58 to 0.77, 0.78 to 0.93, 0.80 to 0.95, 1.15 to 1.20, 1.20 to 1.35 for 3, 7, 14, 21, 90, and 365 day of testing, respectively.

To easier find the conversion factor of compressive strength material aggregate stabilized cement, the illustration can be provided from Table 4 into Figure 3.

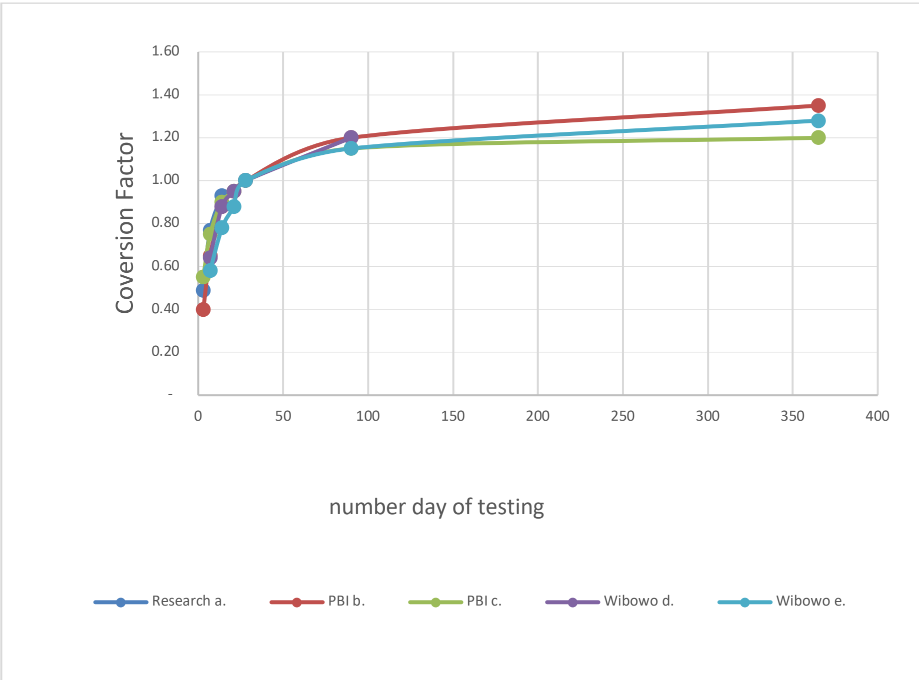

Fig. 3. Conversion factor based on day of testing until 365 day

Figure 3 shows the trend-line of curve compressive strength using conversion factor until a year according to number day of testing specimen. Hence, the pattern of curve shows non-linear. The type of curve is approximately logarithmic trend.

It also comes from Table 4. Furthermore, Figure 4 is a trend of the conversion factor from 3, 7, 14, 21, and 28 day of testing. It is clear that the strength of cement stabilized material particularly base course, it will be gradually increased along the time.

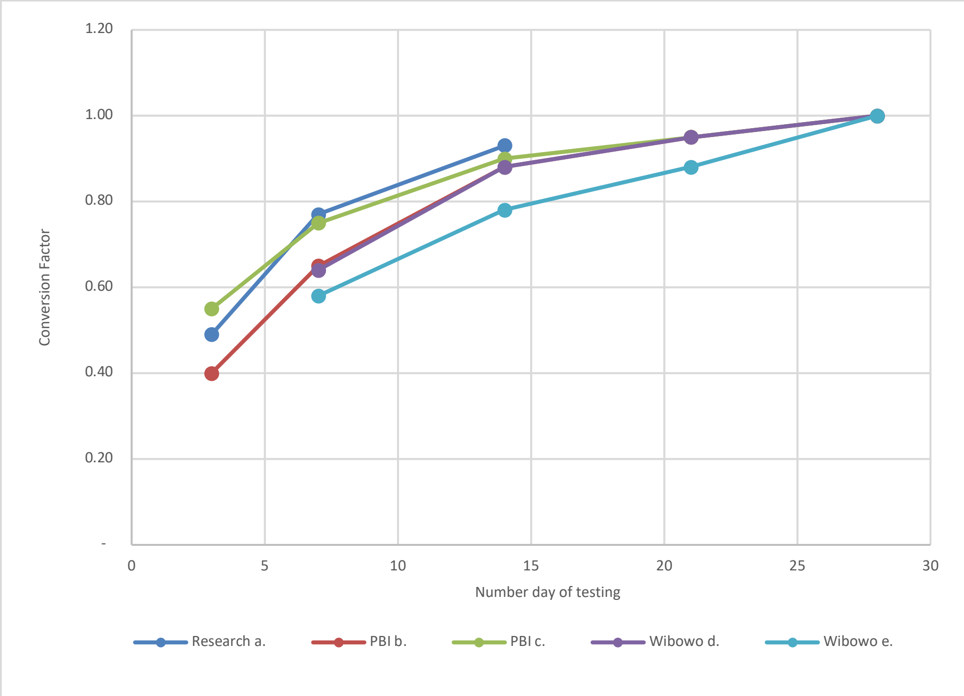

Fig. 4. Conversion factor based on day of testing until 28 day

From Figure 4 it indicates that compressive strength increases according to time or day of testing with curve pattern. Granular material of pavement that is stabilized with cement must be tested to determine UCS value at seventh day. The conversion factor for seventh day is between 0.6 and 0.8 compared to 28th day.

4. Conclusions

From Table 2 and then it is resumed on Table 4 and illustrated on Fig.3 that compressive strengths of material aggregate stabilized using cement will increase until 365 day. From 5 sources of data from laboratory test and reference above as shown on Table 4 that the trend-line of increased compressive strength by the time is elaborated with conversion factor. Furthermore, we are able to predict a value of the compressive strength for a certain time of specimen. The UCS value for cemented material of pavement layer that is tested at seventh day, it has various conversion factor between 0.6 and 0.8, but in this research the value is 0.77.

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