The Effect of Existing Soil on the Unconfined Compressive Strength (UCS) Value on Cement Treated Recycling Base (CTRB) Type Flexible Pavement

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Abstract

Recycling technology or Cement Treated Recycling Base (CTRB) is one method for repairing damage to ancient road pavements, however, when the process is in place (Mixed in place), difficulties can arise, such as mixing with existing soil material that shouldn't be mixed in its implementation. because this will affect the results of Unconfined Compressive Strength (UCS). As a binder in the form of local cement from South Kalimantan, the brand is cheaper because production costs are cheaper. This study aims to obtain UCS Results at minimal cement levels that still meet the requirements with the use of brand local cement, obtain the typical influence of existing soil on UCS and what percentage of existing soil material can still be tolerated either curing or non-curing and correlation and get recommendations for the maximum percentage of influence of percent of existing land on UCS in curing or non-curing conditions. RAM samples were obtained for the purpose of investigation, which was done in a lab, existing soil and additional materials in the field. Inspection of old aggregates, making test specimens with variations in cement content of 1-10%, after obtaining minimum UCS according to technical requirements then making test specimens with variations in soil examinations and soil content of 0%, 5%, 10%, 15%, 20%, and 25% again then conducting data analysis to find correlations / relationships. The results of the research showed variances in cement content of 1% (one) - 10% that still meet the technical specifications of UCS (at least 30 kg/cm²) obtained a minimum cement content of 5% (five percent) with a UCS of 33.77 kg/cm². Then the test results of the influence of existing soil on UCS that is still tolerated are mixed, namely in curing conditions is 17% with the equation Y = -0.10075 x + 46.894 (R^2 = 0.964). and non-curing 8.9% with the equation Y = -0.1113 x + 39.814 (R^2=0.956). The R^2 conclusions for both indicate a very There is a substantial correlation between the two factors

***Keywords**: CTRB, Local Cement, RAM, Regression and Correlation Analysis, UCS.*

A. INTRODUCTION

CTRB is recycling technology is one alternative to repairing damage to old road pavements. This will save resources, reduce construction costs, and avoid the use of new materials. Job recycled pavement construction can reduce the use of new materials, thus saving the cost of road construction, energy-efficient, the elevation can be maintained roads increase the economic value scratching asphalt materials and rapid in its execution [1]. The type of material, the amount of cement added, and the material mixed partially determine the UCS that the cement stabilized material makes [2]. CTRB is one of the recycling technologies for road foundation layer reconstruction by utilizing old road material that has been damaged to be reused as material in pavement mixtures using cement as a binding material. The development of technology with this method of recycling road pavements not only repairs the damage that occurs but can also strengthen the road structure itself [3]. Recycling technology can save 45% to 60% aggregate use in new asphalt. It also increases the economic value of abrasives, saves energy when transporting materials, maintains road shape and highway elevation, and conserves natural resources [4]. At the time of CTRB, the process of raking old road material in the field experienced various obstacles, including being mixed with local / existing soil material CTRB should not be mixed with existing soil, because this would affect the results of UCS. As an added material / binder for the CTRB mixture in the form of cement which previously used a lot of cement from outside South Kalimantan such as Tonasa, Gresik and others. While in the Kalimantan area, now many local cement from Tabalong Regency, South Kalimantan, which is located closer to the project location so that transportation costs are cheaper, So it is necessary to further examine how the effect of the results of UCS if this local cement is used as a binder or add material with the condition of the test specimen curing or without curing.

The experiment was carried out by adding variations in cement content so that a minimum cement content could be used for the CTRB mixture to meet technical requirements. In connection with the explanation above, it is necessary to see to what extent the existing soil material can still be tolerated mixed with the CTRB mixture and also the extent to which the influence of existing soil on UCS in this case using local cement binders. Based on the results of laboratory testing of the Design Mix Formula (DMF) on the CTRB mixture in the Puruk Cahu-Muara Teweh Road Preservation project, variations in cement content of 1%, 2%, 3%, 4%, 5%, 6%, 7%, 8%, 9% and 10% so that more data was produced.

During the process of mixing material in the field (Milling) based on the results of visual observations in the field for existing soils mixed with CTRB mixtures generally do not exceed 25% of the total mixture, so for this study, existing soil variations were used in the CTRB mixture compared to the strong value of UCS pressure at the ideal cement content. These variations are 0%, 5%,10%,15%,20% dan 25 % with a minimum cement content that still meets the minimum requirements Specifications on CTRB material with the use of local cement, get a typical influence of existing soil on UCS and what percentage of existing soil material can still be tolerated in the CTRB mixture curing or no curing and correlation is not carried out and get the maximum percentage recommendation of the influence of the percent of existing land on UCS in the CTRB mixture in curing or non-curing conditions.

B. LITERATUR REVIEW

1. Pavement Construction

Road pavement is a mixture of aggregate and bonding materials used to serve traffic loads. The strength and durability of road pavement construction largely depend on the properties and carrying capacity of the base soil [5]. Road pavement construction is divided into three groups according to the binding material used to form the upper layer, namely flexible pavement, rigid pavement and composite pavement, which is rigid pavement combined with bending pavement [5]. The foundation layer is a part of the road surface where this layer is located between the road surface and One of the main functions of bending pavement is to prevent vehicle loads from affecting the road surface. Over voltages that can cause excessive deformation [6].

2. CTRB as an Alternative to Road Damage Repair

Recycling technology is a method of processing and reusing old pavement construction either with or without the addition of new materials for the purposes of maintenance, repair, or improvement of road pavement construction. Using recycling technology can save aggregate use by 45% and new asphalt by 60%. It also increases the economic value of scratching materials, saves energy for material transportation, maintains road geometry and elevation and conserves natural resources [7]. Strength criteria at the age of 7 (seven) days, must meet the minimum strength requirements set by special specifications of Highways [8]. Table 1.

Table 1. Table of CTRB and CTRSB Strength Criteria

Provisions	UCS at 7 days of age (kg/cm2)	
	UCS (dia. 70 mm x140 mm)	(dia.150 mm x 300 mm)
CTRB	Min. 30	Min.35
CTRSB	Min. 20	Min.25

In the 2018 Special Specifications [9], the Department of Public Works of the Republic of Indonesia classifies the foundation materials into the materials CTRB and CTRSB show in Table 2.

Table 2. The Gradation Requirements for Granular Aggregates as Foundation Materials

Sieve Size (ASTM)	**Percentage by Weight Passing Square**	
	(*CTRB*)	**(*CTRSB*)**
2″ (50,00 mm)		100
1 ½″ (37,5 mm)	100	88 – 95
1″ (25,0 mm)	79 – 85	70 – 85
3/8″ (9,50 mm)	44 – 58	30 – 65
No. 4 (4,75 mm)	29 – 44	25 – 55
No. 10 (2,0 mm)	17 – 30	15 – 40
No. 40 (0,425 mm)	7 – 17	15 – 40
No. 200 (0,075 mm)	2 – 8	8 – 20

3. Regression Analysis

Multiple regression analysis is a method for forecasting the value of the influence of two or more independent variables on one dependent variable. It is easier to prove the existence or absence of a relationship between two variables or more than two independent variables [10]. For a regression model to produce the best unbiased linear estimator (regression can reflect viable results from research), it must meet some classical assumptions. The classical assumption tests used are: Multicollinearity Test, Normality Test, Heteroscedasticity Test and Autocorrelation Test.

4. Correlation Analysis

Correlation is an analytical technique included in one of the measurement techniques of association or relationships (measures of association) [11]. Association measurement is an umbrella term that refers to a group of techniques in bivariate statistics used to measure the strength of a relationship between two variables. Correlation analysis is a statistical evaluation method used to study the strength of the relationship between two continuously measured variables numerically. For example, height and weight, salary and distance of the house, and so on. To see the degree of correlation between independent variables and non-free variables, guidelines are used to provide interpretation of the correlation coefficients contained in **Table 3.**

Table 3. Guidelines for providing Interpretation of correlation coefficients [12]

Coefficient Intervals	Relationship Level
0.00 – 0.199	Very low
0.20 – 0.399	low
0.40 – 0.699	Keep
0.70 – 0.899	Strong
0.90 – 1.000	Very Strong

C. METHOD

Research is carried out by experimental methods by conducting experiments in the laboratory to obtain the desired data. The research location is in the Laboratory of Transportation and Highways, Faculty of Engineering and Laboratory of structures and materials, Lambung Mangkurat University in Banjarbaru. The exsiting sampling location in the form of Reclaimed Aggregat Material (RAM) and Reclaimed Asphalt Pavement (RAP) materials as well as existing land is located between the road section puruk cahu – papar punjung - muara teweh city limits at sta. 30 + 000 - 40 + 000, then for coarse aggregate and fine aggregate taken from the stockpile location at KM.7 (seven). This road section is a nacional road section that connects the city of Muara Teweh to Puruk Cahu with a length of 91,260 km. In this study, existing materials were used as RAM. The cement used type Portland PC type I. Added Material in the form of Class A aggregate, soil material exsiting and water. The equipment used in this study is an aggregate gradation inspection tool, a test specimen maker with a mold B methode [13] and test UCS using a Universal Testing Machine Tool (UTM) then data analysis is carried out with the help of the SPSS program.

D. RESULT AND DISCUSSION

The results of sieve analysis are useful for looking at the gradation composition of old materials as described in Table 4.

Table 4. RAM Material Sieve Analysis

No. Sieve	Weight of Resisted (gr)	Cumulative Restrained (gr)	Percentage		Specification
			Resisted	Escape	
1½″	0	0	0	100	100
1″	1528.0	1528.0	25.47	74.53	79 - 85
3/8"	1764.4	3292.4	54.87	45.13	44 - 58
4	690.1	3982.5	66.38	33.63	29 - 44
10	761.0	4743.5	79.06	20.94	17 - 30
40	810.0	5553.5	92.56	7.44	7 - 17
200	157.3	5710.8	95.18	4.82	2 - 8

Table 4 showing the gradation of the sieve analysis for RAM, it is known that the results of the aggregate gradation of sieve sizes 1 1/2", 3/8", 4, 10 .40, and number 200 qualify within the specification range in the Technical Guide [6], while the sieve size of 1" does not fall within the specified specification range. In Table 5, is the result of gradation with the addition of new material to fill the gradation envelope.

Table 5. RAM Mixed Gradation Results + Additional Aggregates

No. Sieve	Existing Graded (escape)	Add. Aggregate		Restrained			Combine Graded	Specification
		2 -3"	Stone Ash	Existing Graded (escape)	2 -3"	Stone Ash		
					10%	5%		
1 1/2"	100	100	100	100,00	0,00	0,00	100,00	100
1"	74.53	53.43	100.00	74.53	5.34	0.00	79.88	79 - 85
3/8"	45.13	10.29	100.00	45.13	1.03	0.00	46.16	44 - 58
4	33.63	2.24	95.75	33.63	0.22	4.79	38.64	29 - 44
10	20.94	1.21	45.53	20.94	0.12	2.28	23.34	17 - 30
40	7.44	0.17	12.14	7.44	0.02	0.61	8.07	7 - 17
200	6.11	0.10	0.54	6.11	0.01	0.03	6.15	2 - 8

Table 5. shows the results of sieve analysis for 85% RAM gradation with the addition of coarse aggregate (2-3 cm stone) by 10% and fine aggregate (stone ash) 5% it can be seen that the aggregate gradation of the percentage of mixture in the sieve sizes 1 1/2 ", 1", 3/8", 4, 10.40, and 200 has been included in the predetermined specification range. The results of the Analysis of Abrasion are shown in Table 6.

Table 6. Analysis of Abrasion

		Amount = 500 Rounds	
No. Sieve		I	II
Escape	Resisted	Weight (a)	Weight (a)
76,2 (3")	63,5 (2½")	-	-
63,5 (2½")	50,8 (2")	-	-
50,8 (2")	36,1 (1½")	-	-
36,1 (1½")	25,4 (1")	1250	1250
25,4 (1")	19,1 (3/4")	1250	1250
19,1 (3/4")	12,7 (½")	1250	1250
12,7 (½")	9,52 (3/8")	1250	1250
9,52 (3/8")	6,35 (1/4")	-	-
6,35 (1/4")	4,75 (No. 4)	-	-
4,75 (No.4)	2,36 (No. 8)	-	-
Weight Amount		5000	5000
Retained Weight No. 12 Tested (B)		3378	3411.5
Abrasion	%	32.44	31.77

Table 6. From the results of Abrasion testing with Los Angeles Machines has met the test standards required in Specification Pd T-08-2005-B [6], which is a maximum of 40% (SNI 2417-2008) [14]. The average wear value of existing material is 32.11%. The purpose of compressive strength testing is to obtain the CTRB compressive strength value from the load application by the pressure test equipment. This compressive strength test value will be used to find CTRB compressive strength quality values that meet the minimum requirements at the age of 7 (seven) days [8]. Test results with cement content of 1%-10% are shown in Table 7.

Table 7. UCS Testing Vs 1%-10% cement content

Sample Code	Cement content (%)	Weigh (Kg)	Load (Kg)	Area (cm²)	Strength (Kg/cm²)	Information (Min. 30 g/cm²)
A1	1	1152	191	38.465	5.98	NO
A2	2	1162	194	38.465	6.08	NO
A3	3	1216	243	38.465	7.61	NO
A4	4	1218	371	38.465	11.62	NO
A5	5	1246	1078	38.465	33.77	OK
A6	6	1244	1651	38.465	51.71	OK
A7	7	1222	1807	38.465	56.60	OK
A8	8	1254	1849	38.465	57.92	OK
A9	9	1156	2022	38.465	63.33	OK
A10	10	1220	2027	38.465	63.49	OK

Based on the results of compressive strength testing on variations in cement content from 1 - 10%, results are obtained that do not meet and meet the specifications with Special Specifications Skh 5.6 Bina Marga Division IV.b [8], which has a minimum compressive strength value of at least 30 kg / cm². From the test result data, it was found that the cement content of 1-4% did not meet the minimum compressive strength requirements, while from the cement content of 5-10%, the compressive strength was found to meet the minimum compressive strength requirements, which was at least 30 kg / cm². This shows that cement content correlates with CTRB compressive strength value; Where the cement content is higher, the compressive strength increases.

After compressive strength testing, a minimum compressive strength that meets the specification requirements is obtained, then the number of test specimen samples with variations in local soil content amounts to 18 UCS samples under Curing conditions, **Table 8**. shows the result.

Table 8. Compressive Strength Test Results in Curing Conditions

Sample Code	Cement content (%)	Weigh (Kg)	Load (Kg)	Area (cm²)	Strength (Kg/cm²)	Average (Kg/cm²)	Information (Min. 30 Kg/cm²)
A1	0	1198	1496	38.465	46.86		
A2	0	1178	1486	38.465	46.55	47.00	OK
A3	0	1200	1520	38.465	47.61		
B2	5	1202	1277	38.465	40.00	40.00	OK
C1	10	1196	1266	38.465	39.65		
C2	10	1216	1275	38.465	39.94	39.71	OK
C3	10	1240	1262	38.465	39.53		
D1	15	1178	936	38.465	29.32		
D2	15	1214	1080	38.465	33.83	30.40	OK
D3	15	1194	896	38.465	28.06		
E1	20	1144	913	38.465	28.60		
E2	20	1194	896	38.465	28.06	27.71	NO
E3	20	1168	845	38.465	26.47		
F1	25	1140	674	38.465	21.11		
F2	25	1162	689	38.465	21.58	20.98	NO
F3	25	1180	646	38.465	20.23		

While the relationship between the addition of soil (%) and the compressive strength value of curing conditions is seen in Figure 1.

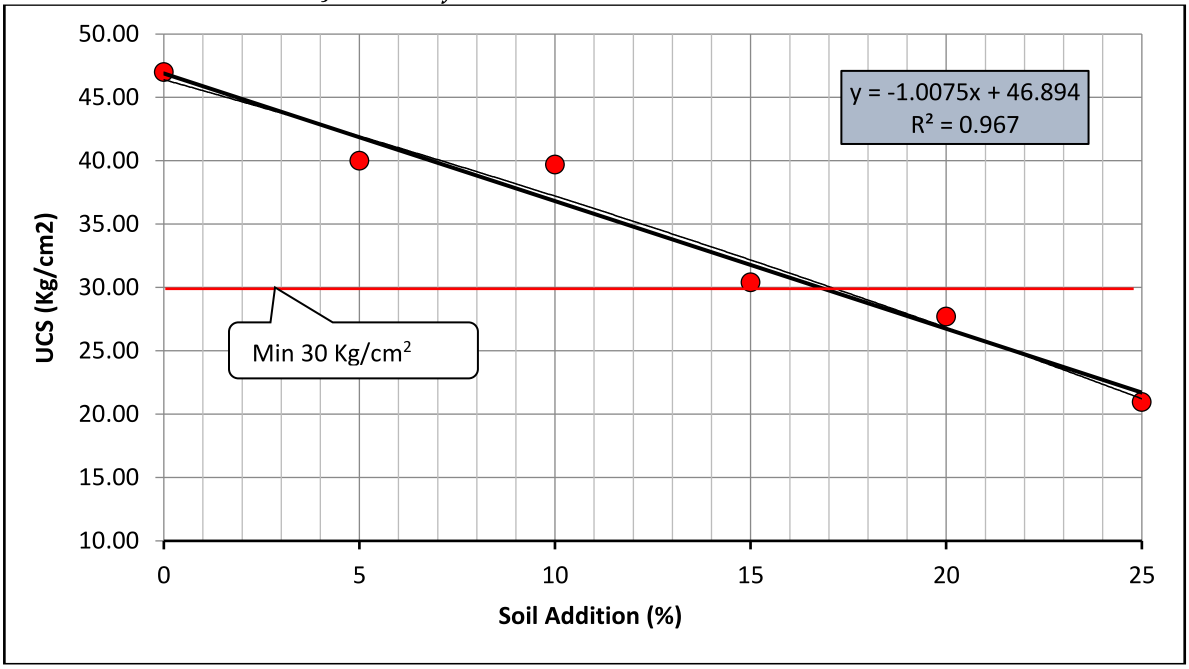

Figure 1. the relationship between the addition of soil (%) and the compressive strength value *of curing*

Of the 18 CTRB samples where samples in the planned curing condition were treated, samples with a cement content of 5% after being added with soil variations for those that still meet the minimum compressive strength of at least 30 kg / cm², namely under the condition of adding soil by 15%. While the results of the recapitulation of CTRB compressive strength testing in Non-Curing conditions **Table 9.** Show CTRB Non curing test results:

Table 9. UCS Test Results in Non-Curing Conditions

Sample Code	Cement content (%)	Weigh (Kg)	Load (Kg)	Area (cm²)	Strength (Kg/cm²)	Average (Kg/cm²)	Information (Min. 30 Kg/cm²)
A1	0	1266	1241	38.465	38.87	38.71	OK
A3	0	1232	1231	38.465	38.56		
B1	5	1198	1166	38.465	36.52		
B2	5	1222	1153	38.465	36.11	36.91	OK
B3	5	1194	1216	38.465	38.09		
C1	10	1256	1140	38.465	24.74		
C2	10	1176	790	38.465	28.19	29.55	NO
C3	10	1182	900	38.465	18.26		
D1	15	1148	583	38.465	18.86		
D2	15	1112	602	38.465	20.95	19.36	NO
D3	15	1142	669	38.465	17.51		
E1	20	1102	559	38.465	17.20	17.35	NO
E3	20	1126	549	38.465	10.43		
F1	25	1094	333	38.465	15.32		
F2	25	1128	489	38.465	14.85	13.53	NO
F3	25	1132	474	38.465	17.20		

The relationship between the addition of soil (%) and the UCS value of non-curing conditions in **Figure 2.**

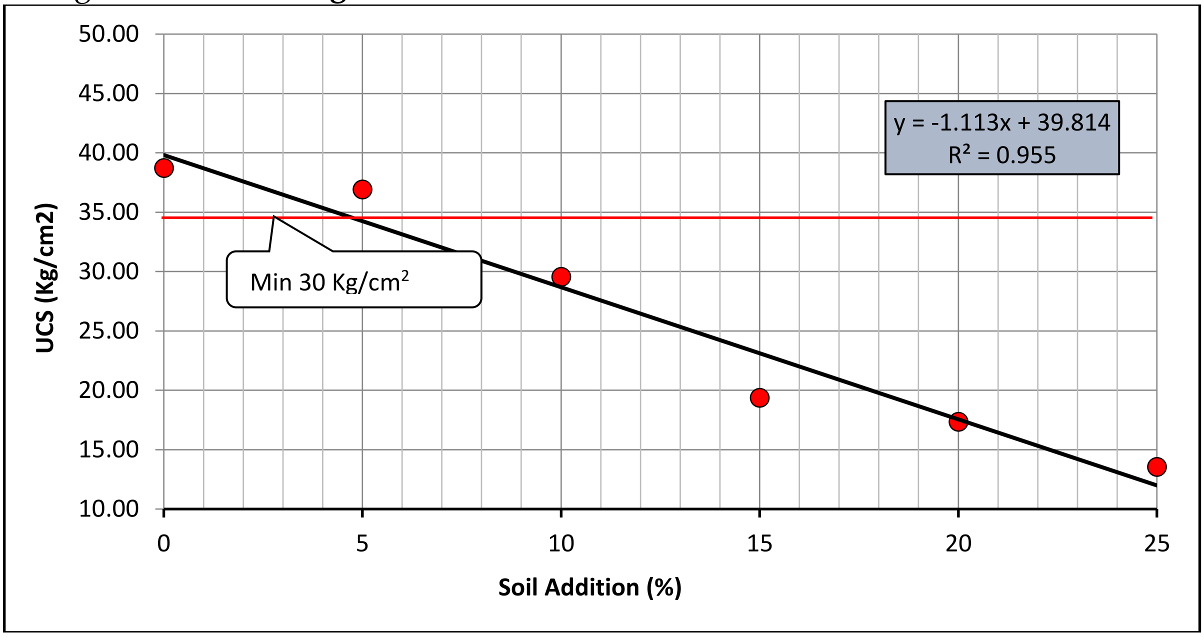

Figure 2. the relationship between the addition of soil (%) and the UCS value of non-curing

Results of Recapitulation UCS both with Curing and Non-Curing conditions are shown in **Table 10.**

Table 10. Recapitulation UCS either with Curing or Non-Curing conditions

No.	Soil percentage (Y)	Strength (kg/cm²)	
		Curing (X1)	*Non-Curing* (X2)
1	0	47.00	38.71
2	5	40.00	36.91
3	10	39.71	29.55
4	15	30.40	19.36
5	20	27.71	17.35
6	25	20.98	13.53

Table 10. is a recapitulation of UCS either with curing or non-curing conditions, The number of samples used is 6 test average samples where the research variable Compressive Strength curing as an independent variable (X1), the free variable (X2) and the fixed variable is the percent of soil (Y). The table of test results is created from the results of calculations performed with the SPSS program. The correlation between Soil Percent (Y) and Compressive Strength (Curing) can be seen in Table 11.

Table 11. Correlation between Ground Percent (Y) and UCS (Curing)

Model	R	R Square	Adjusted R Square	Std. Error of Estimate	Durbin-Watson
1	**0.983**[a]	0.967	0.959	1.902	3.367

a. Predictors/(Constant), *Curing (X1)*
b. Dependent Variable: % Tanah (Y)

Table 11. showing an R value of 0.983 indicates a very strong correlation level (0.76-0.99). The table above shows that the R^2 (adjusted R Square) figure is 0.959 or (95.5%). This shows that the percentage of the influence of the independent variable (X_1) on the dependent variable (Yi) is 95.9 percent, and the remaining 4.1 percent (100%-95.9%) is influenced by other variables. While Table 12. shows the results of the correlation test between Percent of Land (Y) and UCS (Non-Curing) table of test results made calculations carried out using the SPSS program.

The correlation between Soil Percent (Y) and Strength *(Non-Curing)* can be seen in Table 12.

Table 12. Correlation between Land Percent (Y) and UCS (*Non-Curing)*

Model	R	R Square	Adjusted R-Square	Std. Error of Estimate	Durbin-Watson
1	**0.977**[a]	0.955	0.944	2.221	2.097

a. Predictors (Constant), *Non-Curing*
b. Dependent Variable: % (Tanah)

In Table 12. showing an R value of 0.977 indicates a very strong correlation level (0.76-0.99) [12]. From the table above also obtained the value of R^2 (Adjusted R Square) of 0.944 or (94.4%), this shows that the percentage of influence of the independent variable (X_2) on the dependent variable (Yi) is 94.4% and the rest (100%-94.4% = 5.6%) is influenced by other variables. UCS testing with a cement content of 5% (five percent) with the effect of adding existing soil can be illustrated in Figure 3.

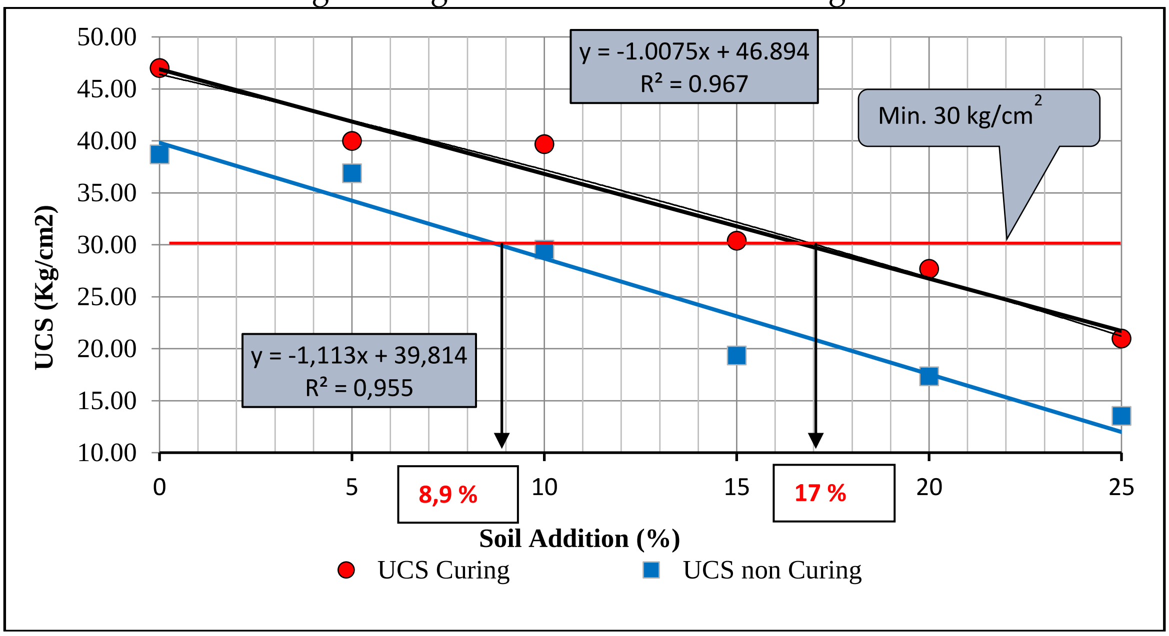

Figure 3. the relationship between the addition of soil (%) and the compressive strength value of-curing and non-curing

From the results of Figure 3. It can be concluded that, the compressive strength results that still meet the technical specifications of CTRB (minimum 30 kg / cm2) with the condition of the Test Specimen in the treatment / curing that the percent of soil that is still allowed to be mixed is 17% while if the test specimen is not treated / non curing it is concluded that the percent of soil that is still allowed to be mixed with the CTRB mixture is 8.9% (eight-point nine percent).

E. CONCLUSION

Based on the test results on CTRB samples thus, the following conclusions can be made (1) UCS examination on CTRB material with the use of local cement after a trial of variations in cement content ranging from 1%, 2%, 3%, 4%, 5%, 6%, 7% 8%, 9%, 10% obtained results that meet the requirements of Special Specifications Skh 5.6 Highways Division IV.b, which has a minimum UCS value of at least 30 kg / cm² is at a cement content of 5% (five percent) of 33.77 kg / cm² with the relationship equation between UCS with cement content is Y = 20.046x - 60.865 (R^2 = 0.9964); (2)The results of the recapitulation of the UCS test with curing conditions after which still meet the minimum UCS of at least 30 kg / cm², namely under the condition of adding soil by 17% and a model of the relationship between the results of free compressive strength and the addition of soil Y = -0.10075x + 46.894 (R^2 = 0.964). The results of the recapitulation of the UCS test with Non curing conditions that still meet the minimum UCS of at least 30 kg/cm², namely in the condition of adding soil by 8.9% and an equation model is produced between the results of free compressive strength with the addition of soil Y = -0.1113 x + 39.814 (R^2 = 0.956) and (3) The maximum percentage of the effect of mixing existing soil in the CTRB mixture that can still be tolerated in curing and non-curing with an increase in soil mixing by 17% - 8.9% or 8.1% (eight point one percent).

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