EFFECT OF CONCRETE WASTE AS STABILIZATION MATERIAL ON CBR VALUE AND SWELLING POTENTIAL OF EXPANSIVE SOIL

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ABSTRACT: The objective of this research is to improve expansive soil as a construction material using concrete waste, which is recognized as an environmental pollutant. The relationships between the amount of concrete waste with the compaction blows, curing days, CBR values, and swelling potential values was studied in this research. The test results show that replacing expansive soil by concrete waste formed a strong bond between the soil particles and the cementitious compound, resulting in the improvement of CBR values and the inhibition of soil swelling and shrinkage.

Keywords: Concrete waste, CBR value, swelling potential, compaction blows, curing days

INTRODUCTION

There are many locations in Indonesia contain expansive soil that shows shrinking and swelling movements which cause damage to road bases, embankments, and foundations of dwelling houses.

Demolition of old bridges, old buildings and buildings damaged by earthquakes or fires produce concrete waste. In addition, sometimes some productions do not meet the standards and become waste material in the numbers of ready mix concrete plants, and precast concrete plants. The concrete waste is recognized as an environmental pollutant, its increase could harm the ecosystem surrounding dumping area. In order to reduce the increase of concrete waste, this material could be used as the construction material. The utilization of waste concrete as material construction has benefits in environmental protection and sustainable development. The waste concrete still contains calcium hydroxide, $Ca(OH)_2$; therefore, it can be used as stabilization material of expansive soil.

This research tried to use the waste concrete to stabilize the expansive soil by replacing the expansive soil with concrete waste up to 40% by weight. The relationships between the amount of waste concrete with the compaction blows, curing days, CBR values and swelling potential values were studied in this research.

MATERIALS AND EXPERIMENTAL METHODS

Testing Method for Soil Properties

Some series of testing were conducted to find out the physical properties and chemical compound of soil. Table 1 shows some testing to determine the physical properties of soil used in this research.

Table 1. Testing Method for Physical Properties

Physical Properties	Test Method
1. Specific Gravity	
2. Atterberg Limits	
a. Liquid Limit (LL)	SNI 1966:2008
b. Plastic limit (PL)	SNI 1966:2008
c. Plasticity index	SNI 1966:2008
d. Shrinkage Limit (SL)	SNI 3422-2008
3. Grain size distribution	SNI 3423:2008
4. Level of activity (A_c)	
5. Soil Classification	a. USCS
	b. ASSHTO
6. Standard Proctor (compaction) W_{opt} and γ_d	SNI 03-1742:1989

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Waste Concrete Grain

Waste concrete was crushed to divide it into the coarse aggregates and grains of mortar or cement paste. Heretofore, the grains of mortar or paste cement are called waste concrete grain in this research. This grain was further pulverized so that it can pass through number 4 sieve. Chemical test was conducted to find out the chemical compound of the waste concrete grain.

Composition of Waste Concrete Grain and Soil

The composition of soil and waste concrete grain is shown in Table 2. Waste concrete grain was added up to 40% in this research. The addition of waste concrete grain was followed by the reduction of soil in order to keep the constant weight of mix.

Table 2 Composition of Waste Concrete Crain and Soil

Composition of Waste concrete grain and Soil	
Soil	Waste Concrete
90%	10 %
80%	20%
70%	30%
60%	40 %

Compaction, CBR Test, and Swelling Potential Test

Compaction of the expansive soil specimens was carried out in accordance to Indonesian standard, SNI 03-1742:1989. The number of blows were made varies, 30, 40 and 60 blows. After compacted, the specimens were prepared for CBR test and swelling potential test. The curing days were 7, 14 and 28 days. Testing for CBR soaked soil and CBR unsoaked soil were conducted in accordance to SNI 03-1744:1989. Testing for potential swelling was conducted by using the test piece of CBR soaked soil as shown in Figure 1. The swelling height was measured and compared to the initial height of test piece.

Fig. 1 Swelling Potential Test

RESULTS AND DISCUSSION

Expansive Soil

The physical properties and some chemical compounds of soil used in this research were shown in Table 3 and Table 4, respectively. Its properties show that the soil can be categorized as expansive soil.

Table 3 Physical properties of expansive soil

Physical Properties	**Value**
1. Specific Gravity	2.67
2. Atterberg Limits	
a. Liquid Limit (LL)	61.54%
b. Plastic limit (PL)	24.36%
c. Plasticity index	37.19%
d. Shrinkage Limit (SL)	10.95%
3. Grain size distribution (Sieve analysis reported that 50% of soil passed the sieve number of 200)	
a. Clay	23%
b. Silt	77%
4. Level of activity (A_c)	2.86 (active)
5. Soil Classification	
a. USCS	CH
b. ASSHTO	A-7
6.Standard Proctor (compaction)	
a. W_{opt}	24.02%
a. γ_d	1.57 gr/cm^3

Table 4 Chemical compounds of soil

Chemical Compound	Value (%)
SiO_2	62.25
Al_2O_3	15.12
Fe_2O_3	4.5

Waste Concrete Grain

The results of chemical test showed the waste concrete grain containing 15.56% of Ca $(OH)_2$ by weight.

CBR Value

Table 5 and Table 6 show the results of CBR unsoaked test and CBR soaked test, respectively. The results are based from three measurements for each data point. In comparison by curing days, at the same number of the compaction blows, the CBR value became higher with the increase in curing days. Without the addition of concrete waste grain, the expansive soil can be compacted and achieve CBR value of 7.31% and 5.7% with 28 days curing time for unsoaked soil, and soaked soil, respectively.

In general, all of the CBR values increased with the increased of percentage of concrete waste grain that added to replace some part of the expansive soil.

The replacement of the expansive soil by the concrete waste grain up to 40% by weight, with the increase in the number of compaction blows and curing days made the expansive soil more stable and achieved CBR value of 46.04% and 42.02% with 28 days curing time for unsoaked soil, and soaked soil, respectively.

The significantly increase in CBR value that observed after the addition of the concrete waste grain can be explained due to the development of chemical process between $Ca(OH)_2$ in concrete waste grain and minerals compound of soil (SiO_2, Al_2O_3, Fe_2O_3).

The chemical process increased the volume of the cementitious compound ($CaO.2SiO_2.3H_2O$) that made the soil stronger, more stable and led to improvement in CBR value.

The relationships between the amount of waste concrete with the compaction blows, curing days, CBR value of unsoaked soil and CBR value of soaked soil are described in Equation 1 and 2, respectively. These equations show the improvement of all the CBR values were influenced by the addition of the concrete waste, the numbers of compaction blows and the curing days.

$$\hat{y} = -6.09 + 0.81\, x_1 + 0.15\, x_2 + 0.40\, x_3 \quad (1)$$

where:

$\hat{y}$ = CBR value of unsoaked soil (%)

x_1 = the content of wasted concrete grain (%) $\{x_1|0\le x_1\le 40\}$

x_2 = compaction blows $\{x_2|10\le x_2\le 65\}$

x_3 = curing days $\{x_3|7\le x_3\le 28\}$

$$\hat{y} = -6.67 + 0.70\, x_1 + 0.12\, x_2 + 0.36\, x_3 \quad (2)$$

where:

$\hat{y}$ = CBR value of unsoaked soil (%)

x_1 = the content of wasted concrete grain (%) $\{x_1|0\le x_1\le 40\}$

x_2 = compaction blows $\{x_2|10\le x_2\le 65\}$

x_3 = curing days $\{x_3|7\le x_3\le 28\}$

Table 5 Test Results of CBR unsoaked soil

Expansive soil		**Waste Concrete**		**CBR unsoaked (%)**								
				7 days			**14 days**			**28 Days**		
%	**kg**	**%**	**kg**	**10 Blows**	**35 Blows**	**65 Blows**	**10 Blows**	**35 Blows**	**65 Blows**	**10 Blows**	**35 Blows**	**65 Blows**
100	5	0	0	1.6	3.57	4.33	3.06	4.11	4.50	5.06	5.38	7.31
90	4.95	10	0.55	6.63	15.43	16.29	9.39	17.30	17.54	16.08	20.70	24.54
80	4.4	20	1.1	9.36	18.38	22.98	17.31	26.80	30.30	19.24	27.43	33.78
70	3.85	30	1.65	22.06	24.11	28.93	22.94	33.52	34.38	27.21	37.28	40.41
60	3.3	40	2.2	26.15	28.82	32.64	35.57	40.64	45.81	40.48	43.66	46.04

Table 6 Test Results of CBR soaked soil

Expansive soil		**Waste Concrete**		**CBR soaked (%)**								
				7 days			**14 days**			**28 Days**		
%	**kg**	**%**	**kg**	**10 Blows**	**35 Blows**	**65 Blows**	**10 Blows**	**35 Blows**	**65 Blows**	**10 Blows**	**35 Blows**	**65 Blows**
100	5	0	0	1.38	2.33	3.35	2.42	3.17	3.36	3.60	4.78	5.70
90	4.95	10	0.55	5.53	8.29	11.02	7.21	9.32	11.06	12.90	16.87	19.52
80	4.4	20	1.1	9.35	12.82	15.51	10.52	13.68	19.30	17.32	24.91	31.50
70	3.85	30	1.65	19.70	21.65	25.97	20.95	23.90	28.21	23.19	27.15	32.50
60	3.3	40	2.2	23.77	25.52	30.15	28.26	32.82	35.75	28.70	38.02	42.02

Table 7 Result of Swelling Potential Test

Expansive soil		**Waste Concrete**		**Swelling Potential (%)**								
				7 days			**14 days**			**28 days**		
%	**kg**	**%**	**kg**	**10 Blows**	**35 Blows**	**65 Blows**	**10 Blows**	**35 Blows**	**65 Blows**	**10 Blows**	**35 Blows**	**65 Blow**
100	5	0	0	5.95	5.12	4.56	5.26	4.90	4.33	4.38	4.13	3.23
90	4,95	10	0,55	4.36	4.16	4.04	3.08	3.04	2.94	1.64	1.54	1.44
80	4,4	20	1,1	2.31	2.19	2.04	0.71	0.64	0.60	0.44	0.34	0.34
70	3,85	30	1,65	0.618	0.59	0.54	0.42	0.34	0.26	0.21	0.19	0.18
60	3,3	40	2,2	0.250	0.18	0.14	0.11	0.06	0.05	0.04	0.01	0.04

Potential Swelling

Table 7 shows the results of Potential Swelling test. The results are based from three measurements for each data point. At the soil without addition of concrete waste grain, after compacted the soil with 65 blows and cured up to 28 days, the soil had the potential value of 3.23%.This results revealed the soil can generate swelling and shrinkage movements, therefore it can be categorized as expansive soil.

The potential swelling value decreased with the increase in compaction blow and the period of curing for all percentages of concrete waste grain added as described in Table 7. The decline trend of swelling potential result was attributed to the development of the cementitious compound that also decreased the porosity of expansive soil that led to the decrease of the capacity of the water to enter into the pore spaces of the soil, and resulting in the reduction of the swelling potential value.

At the expansive soil that replaced with 20% of concrete waste grain, the compaction with 10 blows, and curing days of 14 days made the potential swelling value became less than 1%. At the expansive soil that replaced with 30% of concrete waste grain, all of the swelling potential value became less than 1%. At the expansive soil that replaced with 40% of concrete waste grain, the swelling potential value became less than 0.1% by compaction with 35 blows, and curing days of 14 days. For 28 days of curing, the compaction with 10 blows can reduce the potential swelling value to less than 0.1%.

Equation 3 shows the improvements of all the swelling potential value that were influenced by the addition of the concrete waste, the numbers of compaction blows and the curing days.

$$\hat{y} = 5.32 - 0.12x_1 - 0.01\,x_2 - 0.06\,x_3 \qquad (3)$$

where :

$\hat{y}$ = the swelling potential value (%)

x_1 = the content of waste concrete grain (%) $\{x_1|0 \le x_1 \le 40\}$

x_2 = compaction blows $\{x_2|10 \le x_2 \le 65\}$

x_3 = curing days $\{x_3|7 \le x_3 \le 28\}$

CONCLUSIONS

1. Replacing of the expansive soil by the concrete waste formed the strong bond between the soil particle and the cementitious compound, resulting in the improvement of CBR value.
2. The strong bond between the soil particle and the cementitious compound improved the compactness of soil, which then led to soil impermeability and inhibit swelling and shrinkage.

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