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STABILIZATION OF MARGINAL CRUSHED ROCK USING CEMENT AND FLY ASH AS A GREEN BASE COURSE MATERIAL

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ABSTRACT: The use of marginal materials stabilized by cement for base course applications has grown rapidly. Marginal materials consist of marginal crushed rock (MCR), marginal lateritic soil (MLS), and reclaimed asphalt pavement (RAP). However, the use of cement will release high CO_2 causing the greenhouse effect. This research investigates the stabilization of marginal crushed rock using cement (C) and fly ash (FA) as a green base course material. FA used as pozzolanic binders was obtained from the Mae Moh power plant in Thailand. The physical and engineering properties of MCR stabilized by OPC-FA were evaluated according to the specification of the Department of Highways in Thailand. The influencing factors studied included binder content of 1%, 3%, and 5% by weight of the crushed rock material, C/FA ratios of 100/0, 90/10, 80/20, 70/30, 60/40, and 50/50, and curing time of 7. The optimum ingredient of MCR stabilized by B was found at a binder content of 3% and C/FA ratios of 60/40. The strength development in MCR mixed with C and FA at all B content and C/FA ratio can be normalized by 28-day compressive strength. The proposed equation is useful for predicting the compressive strength of MCR mixed with C and FA. This research enables FA, which is a residue material, to be used as a green base course material.

Keywords: Marginal crushed rock, Binder, Cement, Fly ash

1. INTRODUCTION

Transportation is significant for the development of a country. Roadways and Highways are one major mode of transportation. According to the Ministry of Transportation (2013), it was found that the total of roads in Thailand were 115,707 km, divided into Department of Highways, 68,253 km, and 47,454 km of the Department of Rural Roads. Figure 1 shows the characteristic of road structure. Generally, roadways are constructed in four layers, which are composed of subgrade, subbase, base, and surface layer. An available material at the road construction site is used for road construction. However, some of the available material does not typically meet the standard requirement as base materials. Marginal available materials can be effectively improved by chemical stabilizing agents with an additive, such as Portland Cement (OPC) [1-4], lime, and bitumen. However, the production of 1 ton of OPC releases about 1 ton of carbon dioxide, resulting in a significant amount of greenhouse gas into the atmosphere [5-15].

Fly ash (FA) is an aluminosilicate-rich material, which is a by-product of an electrical manufacturing factory, Mae Moh, Thailand. FA is used as a pozzolanic material in Thailand (approximately 1.8 million tonnes) [15]. However, the use of cement and fly ash to stabilize marginal crushed rock (MCR) has not been investigated.

The objective of this research is to investigate the possibility of using fly ash (FA) to improve the compressive strength of (MCR) as a green pavement material. The influential factors studied include MCR:binder ratios and cement:FA ratio. Unconfined compressive strength (UCS) of MCR mixed with cement and fly ash was investigated and compared the results with the standard of the Department of Highways, Thailand. This research enables FA, which is a residue material, to be used as a green base course material. This research enables FA, which is a residue material, to be used as a green base course material. This stabilized material would also enhance the novel eco-friendly contract, which was proposed by Metham and Benjaoran (2018) [17].

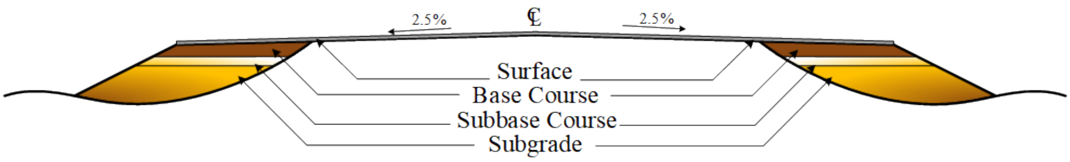

Fig.1 Characteristic of the road structure

2. MATERIALS AND METHODS OF TESTING

2.1 Material

The marginal crushed rock (MCR) was collected from Nakhon Ratchasima province, Thailand. Figure 2 shows the grain size distribution of the MCR. The MCR is classified as GC in accordance with the Unified Soil Classification System. The maximum dry unit weight and optimum water content under modified Proctor energies of MCR were 2.308 gm/m^3 and 5.2%, respectively (Figure 3).

Portland Cement Type 1 (OPC) has a specific gravity (Gs) = 3.10. The chemical composition of OPC is shown in Table 1. It is found that the main chemical composition of OPC was calcium oxide (CaO) content, which was 75.96%

Fly ash (FA) was collected from Mae Moh Power Plant, Lampang, Thailand. It is found that FA has a brown color, and FA has a specific gravity (Gs) = 2.31. The chemical composition of FA by using X-Ray Fluorescence Spectrometer (XRF) technique. According to ASTM C618 is shown in Table 1. It can be soon that the amount of SiO_2 + Al_2O_3 + Fe_2O_3 is 67.31% by weight. The calcium oxide (CaO) content was 30.24%, and the loss of ignition (LOI) was 0.42 by weight. This fly ash is classified as a Class C fly ash.

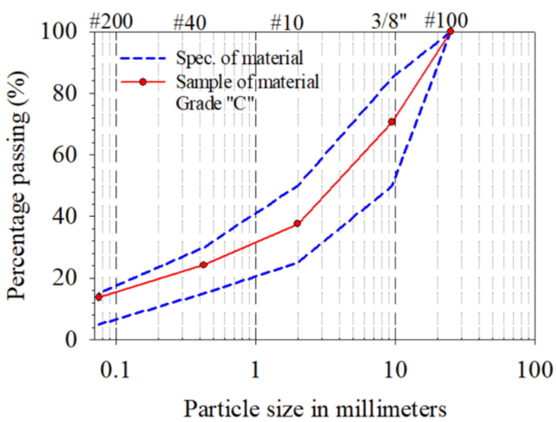

Fig.2 Grain size distribution of the MCR

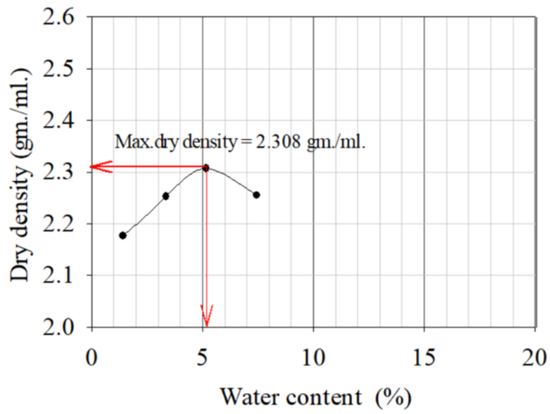

Fig.3 Compaction curves of MCR

Table 1 Chemical Properties of OPC and FA

Chemical composition	OPC (%)	FA (%)
SiO_2	9.81	47.51
Al_2O_3	4.64	13.14
Fe_2O_3	2.03	6.66
CaO	75.96	30.24
SO_3	2.58	ND
K_2O	1.62	1.63
NO_2	0.24	0.40
LOI	3.12	0.42

2.2 Methods of Testing

The composition of marginal crushed rock (MCR) stabilized with cement (C) and fly ash (FA) sample was MCR, C, FA, and water. Binder (B) is a mix of C and FA. The B content was added by 0, 1, 3, and 5% by weight of MCR. The C/FA ratios were 100/0, 90/10, 70/30, 60/40, and 50/50. The mixing ratio used in the study is shown in Table 2. The MCR and B were mixed until an observable consistency was observed for 2 minutes. The optimum water content was added, and 5 minutes mixed. Under modified Proctor energies in preventing liquid evaporation, compaction was continued immediately thereafter. The mixture was then compacted in a standard mold of 101.6 mm in diameter and 116.4 mm in height. The Unconfined Compressive strength (UCS) specimens were wrapped in clear vinyl and cured at room temperature for 7 days.

Table 2 Mixing ratio used in the study

Mixed proportion	OPC (%)	FA (%)
M1	100	0
M2	90	10
M3	80	20
M4	70	30
M5	60	40
M6	50	50

3. TEST RESULT

3.1 Compaction of MCR Mixed with C and FA

Table 3 shows the compaction results of MCR mixed with C and FA at the B content of 1%, 3%, and 5% and C/FA ratios of 100/0, 90/10, 70/30, 60/40, and 50/50. It can be seen that the maximum dry unit weight of MCR mixed with C and FA increases as B content increases because of the higher specific gravity of C. The optimum water content of MCR mixed with C and FA was about 4.1-4.85%. The maximum dry unit weight of MCR mixed with C and FA was 2.288 gm/m^3.

Table 3 The compaction results of MCR with C and FA

Mixed proportion	MDD (gm/m^3)			Optimum water content (%)		
	1 (%)	3 (%)	5 (%)	1 (%)	3 (%)	5 (%)
M1	2.236	2.261	2.257	4.85	4.40	4.33
M2	2.245	2.260	2.288	4.80	4.30	4.29
M3	2.28	2.254	2.268	4.60	4.28	4.20
M4	2.268	2.255	2.260	4.55	4.20	4.20
M5	2.273	2.263	2.257	4.50	4.15	4.18
M6	2.259	2.246	2.256	4.40	4.10	4.10

3.2 Compressive Strength of MCR Mixed with C and FA

Figure 4 indicates the 7-day compressive strength of MCR mixed with C and FA samples at various at the B content of 1%, 3%, and 5% and C/FA ratios of 100/0, 90/10, 70/30, 60/40, and 50/50. The 7-day compressive strength of MCR mixed with C and FA increases with the increase in a binder (C and FA). For example, the 7-day compressive strength of MCR mixed with C and FA samples with C/FA ratios of 60/40 were 12.7, 26.5, and 28.5 ksc for B content of 1, 3, and 5%, respectively. The 7-day UCS of MCR mixed with C and FA samples at B content of 5% and C/FA ratios of 100/0 give the highest UCS values, which is about 40 ksc. The 7-day UCS values of MCR mixed with C and FA at B content greater than 3% and C/FA ratios of 100/0, 90/10, 70/30, and 60/40 are also met the minimum strength requirement for UCS of 24.61 ksc specified by the Department of Highways, Thailand [16]. The optimum ingredient (considering FA content) of MCR stabilized by B was found at binder content of 3% and C/FA ratios of 60/40.

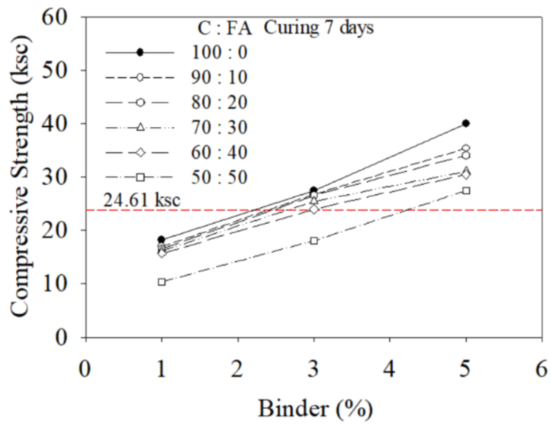

Fig.4 7-day compressive strength of MCR mixed with C and FA

3.3 Strength Development in MCR Mixed with C and FA

Figures 5-7 show the compressive strength development in MCR mixed with C and FA samples at various at the B content of 1%, 3%, and 5% and C/FA ratios of 100/0, 90/10, 70/30, 60/40, and 50/50. The compressive strength of MCR mixed with C and FA samples increased with varying curing times for all ingredients. For example, the compressive strength of MCR mixed with C and FA samples with C/FA ratios of 80/20 and B content of 5% were 32.1, 39.6, 57.6, 58.9, and 61.8 ksc for curing time of 7, 14, 28, 60, and 90 days, respectively. This is because the silica (Si) and alumina (Al) from FA can react with calcium (CaO) from C stimulate, resulting in a pozzolanic reaction (CSH) [17].

Figures 8-11 indicate the normalized strength (q_{uD}/q_{u28}) of MCR mixed with C and FA at C/FA ratios of 100/0, 90/10, 70/30, 60/40, and 50/50, and the B content of 1%, 3%, and 5%. It can be seen that the strength development in MCR mixed with C and FA at all B content and C/FA ratio can be normalized by 28-day compressive strength. The correlation of normalized strength (q_{uD}/q_{u28}) of MCR mixed with C and FA at different at C/FA ratios and B content was expressed by using a curve fitting as a logarithmic function as follow:

$$q_{uD}/q_{u28} = 0.2882+0.193\ln(D) \quad \text{for } 7<D<90 \text{ days} \quad (1)$$

With a coefficient of correlation of 0.9077. The proposed equation is useful for predicting the compressive strength of MCR mixed with C and FA when 28-day compressive strength is known.

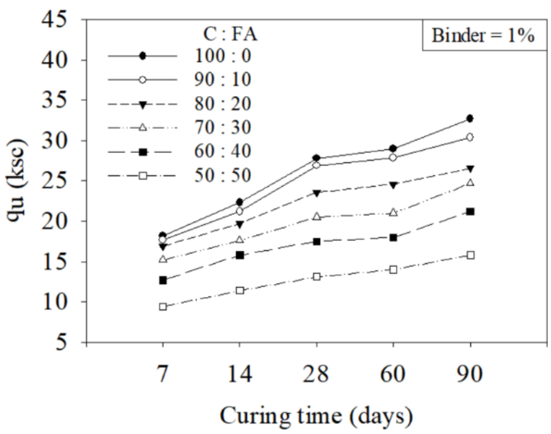

Fig.5 Strength development of MCR mixed with C and FA at B content of 1%

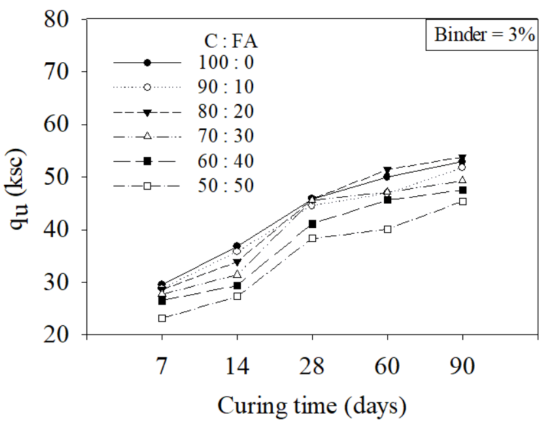

Fig.6 Strength development of MCR mixed with C and FA at B content of 3%

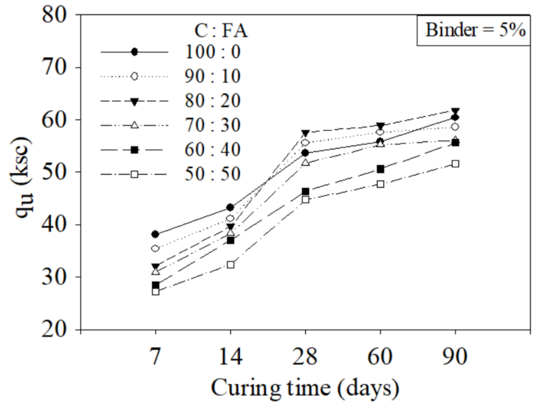

Fig.7 Strength development of MCR mixed with C and FA at B content of 5%

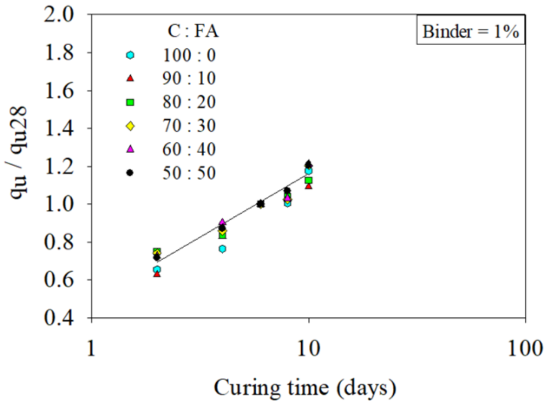

Fig.8 Normalized strength (q_{uD}/q_{u28}) of MCR mixed with C and FA at B content of 1%

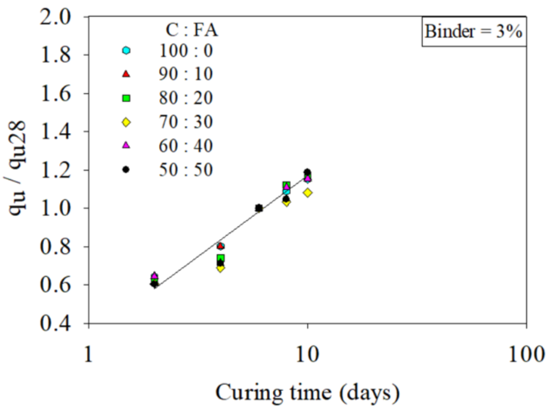

Fig.9 Normalized strength (q_{uD}/q_{u28}) of MCR mixed with C and FA at B content of 3%

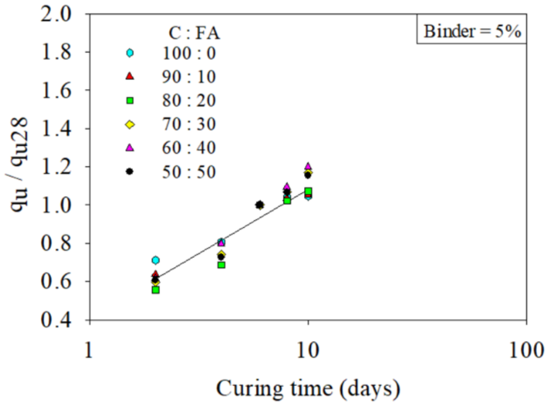

Fig.10 Normalized strength (q_{uD}/q_{u28}) of MCR mixed with C and FA at B content of 5%

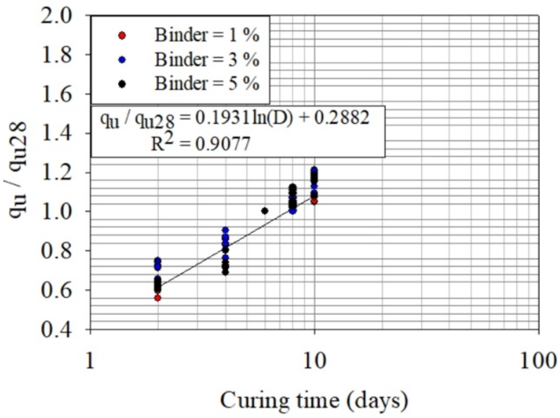

Fig.11 Normalized strength (q_{uD}/q_{u28}) of MCR mixed with C and FA at all B content and C/FA ratio

4. CONCLUSION

The marginal crushed rock mixed with cement (OPC) and fly ash (FA) as a green base course material is presented in this study.

1. The maximum dry unit weight of MCR mixed with C and FA increases as B content increases because of the higher specific gravity of C.

2. The optimum water content of MCR mixed with C and FA was about 4.1-4.85%. The maximum dry unit weight of MCR mixed with C and FA was 2.288 gm/m^3.

3. The 7-day UCS of MCR mixed with C and FA samples at B content of 5% and C/FA ratios of 100/0 give the highest UCS values, Which is about 40 ksc.

4. The strength development in MCR mixed with C and FA at all B content and C/FA ratio can be normalized by 28-day compressive strength. The proposed equation is useful for predicting the compressive strength of MCR mixed with C and FA when 28-day compressive strength is known.

5. ACKNOWLEDGMENTS

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