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RESEARCH REGRESSION EQUATION OF STRENGTH OF ROLLER COMPACTED CONCRETE FOR ROAD CONSTRUCTION

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ABSTRACT

This paper presents the results of the research on the mechanical characteristics of roller compacted concrete (RCC) for road construction. The process of experimental studies that is used to determine the compressive strength, flexural strength is performed in accordance with ASTM standards. The results are analyzed and evaluated according to statistical methods, and then regression equations are built. The evaluation of the mechanical properties of RCC is needed for the research and application of this material in the construction.

Key words: RCC, strength, regression.

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1. INTRODUCTION

Due to the working conditions of the road, the concrete material must bear the direct load of the vehicle and the environmental conditions. This effect occurs on a wide area and sets a very different requirement for road concrete compared to other building applications. Concrete slabs also bear direct contact with the adverse conditions of hydrothermal regime, especially when the temperature changes. So, concrete materials when applied to road surfaces or road foundations must meet certain requirements for mechanical and physical properties.

In order to perform the calculation of the load capacity of the pavement, it is necessary to determine the main parameters of the concrete material when used, which is to mention the bending strength of the pavement, the compressive strength. Therefore, building regression function of strength of RCC will help to select the appropriate material to meet the design requirements of the pavement structure later.

In dissertation [1], by the preliminary calculation of mineral composition, the amount of fly ash (FA) should be over 20% by volume of binder. In this paper, the authors experimented with a change in the ratio water to binder (W/B) from 0.34 to 0.48 and the FA content compared to binder from 20% to 40% by weight. With fine aggregate and aggregates ratio was 0.42, hardness index of RCC was in about 30-40 seconds and bubble content was (1-2) %.

2. MATERIALS & EXPERIMENTAL PROCEDURES

2.1. Materials

2.1.1. Coarse Aggregate

Coarse aggregate concrete used for the experiment is quarry rubble of diameter D_{max} = 25mm. It is sieved into size group by particle size sieves and mixed to satisfy particle sizes in compliance with ASTM C136-01 [2] as seen in Figure 1 and Figure 2 below.

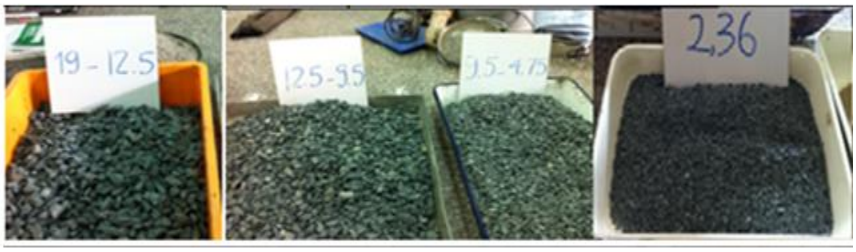

Figure 1 Particle size of aggregate after sieved according to ASTM C136-01 [2]

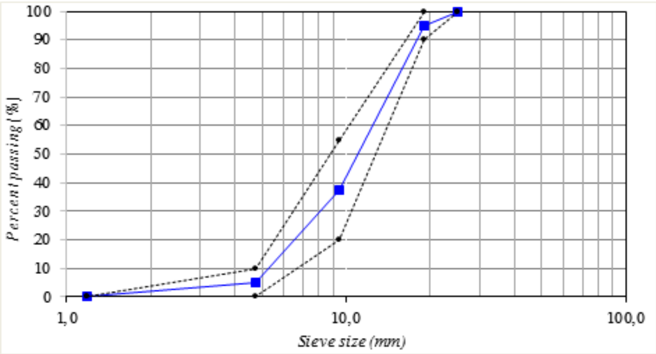

Figure 2 Grading of coarse aggregate according to ASTM C136-01 [2]

2.1.2. Fine Aggregate

Fine aggregate used for experiments is river sand. The particle size larger than 5 mm is removed by sieving in the lab. Sand has particle modules M_k = 2.55 which meets the requirements of ASTM C136-01 [2]. Figure 3 and Figure 4 below are described the grading of sand.

Figure 3 Particle size of sand after sieved according to ASTM C136-01 [2]

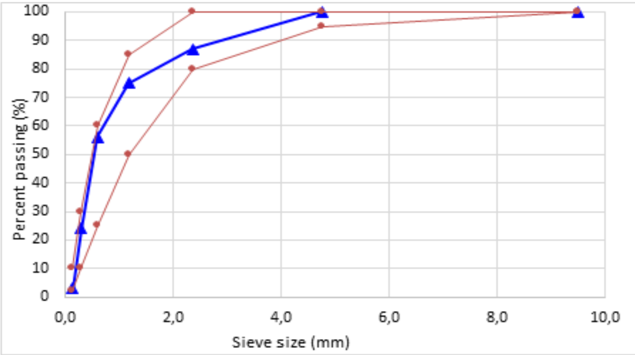

Figure 4 Grading of fine aggregate according to ASTM C136-01 [2]

2.1.3. Fly Ash (FA)

Fly ash in the experiment is supplied by the factory Vina F & C fly ash origin from Thermal Power Plant, Pha Lai. Test results of chemical composition of fly ash provided by the Institute of Building Materials are presented in Table 1 below. This is similar to fly ash type F in ASTM C618-03 [3].

Table 1 Chemical composition of fly ash used in the study (% by weight)

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	SO_3	Weight loss by heating
54.42	23.90	8.14	2.56	1.74	1.77	0.43	1.32	0.78	4.31

2.1.4. Cement

The cement used in the paper is PC40 type of But Son, with a specific weight of 3100kg/m^3 and technical specifications in accordance with ASTM C595 [4].

2.1.5. Water

Water is used to make roller compacted concrete, as well as for conventional concrete.

2.2. Component Proportion of RCC

Component proportion of RCC used in testing is presented in Table 2:

Table 2 Proportion for 1m^3 mixture of RCC

	Ratio	**Water**	**Binder**	**Fly Ash**	**Cement**	**Fine aggregate (Sand)**	**Coarse aggregate (crushed stone)**	Samples
	$\frac{W}{B}$	**W (liter)**	**B (kg)**	**FA (kg)**	**C (kg)**	**S (kg)**	**CA (kg)**	
20% FA	0.34	117	344	69	275	841	1196	6
	0.36	117	325	65	260	849	1208	6
	0.38	117	308	62	246	856	1218	6
	0.40	117	293	59	234	862	1226	6
	0.42	117	279	56	223	867	1233	6
	0.44	117	266	53	213	872	1241	6
	0.46	117	254	51	203	877	1248	6
	0.48	117	244	49	195	881	1253	6
	0.34	117	344	103	241	835	1188	6
	0.36	117	325	98	228	843	1199	6

30%FA	0.38	117	308	92	216	850	1209	6
	0.40	117	293	88	205	856	1218	6
	0.42	117	279	84	195	862	1226	6
	0.44	117	266	80	186	868	1235	6
	0.46	117	254	76	178	873	1242	6
	0.48	117	244	73	171	877	1248	6
40% FA	0.34	117	344	138	206	829	1179	6
	0.36	117	325	130	195	838	1192	6
	0.38	117	308	123	185	845	1202	6
	0.40	117	293	117	176	851	1211	6
	0.42	117	279	112	167	857	1219	6
	0.44	117	266	106	160	863	1228	6
	0.46	117	254	102	152	868	1235	6
	0.48	117	244	98	146	872	1241	6

2.3. Testing Plan

With 72 cylindrical samples of 15x30 cm were used to verify the compressive strength, 72 beam samples of 10x10x40 cm to find out flexural strength**, c**orresponding to each RCC mixture. Determining compressive strength by C39-01 [5], tensile flexural strength by ASTM C78-02 [6].

2.4. Testing Procedure

- Determining the order of mixing RCC;

- The order of testing to determine the stiffness index according to ASTM C1170 [7].

- Casting test specimens to determine compressive strength, bending tensile strength according to ASTM C1176-92 [8].

- Sample maintenance in laboratory according to ASTM-C192 standard [9]. The samples are stored in the laboratory for 28 days of age and laboratory tests were performed to determine mechanical properties (Figure 5).

Figure 5 Samples in laboratory and laboratory equipments

3. RESULT AND DİCUSSİON

3.1. Compressive Strength

After got the testing results of each test sample, statistical analysis and evaluation of the results with a 99% assurance probability are conducted in accordance with ACI 214.R-02 [10]. The results of experiments to find the compressive strength of the samples were presented in Table 2 and Figure 6 as follows:

Table 2 Compressive strength of RCC

W/B	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48
R_n^{28}, 20% FA (MPa)	51.4	48.2	45.9	43.2	40.5	37.2	33.2	29.5
C_v (%)	6.2	5.6	2.7	2.2	1.7	2.8	2.1	1.3
R_n^{28}, 30% FA (MPa)	43.2	40.1	36.7	34.2	33.2	29.8	26.1	23.6
C_v (%)	6.3	5.2	2.5	1.5	2.8	1.3	2.1	2.7
R_n^{28}, 40% FA (MPa)	37.8	35.4	33.2	30.4	27.6	24.8	22.5	20.6
C_v (%)	6.7	5.3	3.4	2.6	2.3	4.3	2.8	2.5

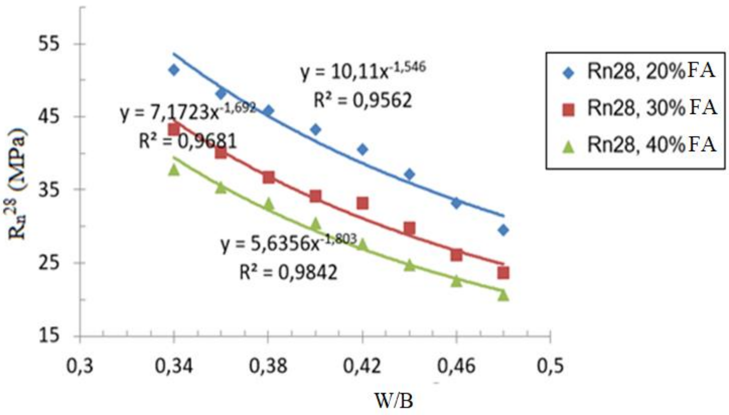

Figure 6 Relationship between R_n^{28} and W/B

From Table 2, the regression analysis was constructed the correlation between Rn and variables including FA and W/B. Using the software Minitab 17 analysis and data processing, the results were represented in Table 3 as follows.

Table 3 Analysis of regression for compressive strength

Analysis of variables

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	1576,49	394,123	1122,22	0,000
FA	1	40,20	40,198	114,46	0,000
W/B	1	110,30	110,296	314,06	0,000
FA*FA	1	15,87	15,870	45,19	0,000
FA*W/B	1	5,81	5,814	16,56	0,001
Error	19	6,67	0,351		
Total	23	1583,17			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,592620	99,58%	99,49%	99,32%

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	140,07	4,67	30,02	0,000	
FA	-2,179	0,204	-10,70	0,000	189,05
W/B	-178,1	10,1	-17,72	0,000	14,50
FA*FA	0,01725	0,00257	6,72	0,000	109,00
FA*W/B	1,315	0,323	4,07	0,001	94,55

Regression Equation of compressive strength:

$$\mathbf{R_n = 140,07 - 2,179\ FA - 178,1\ W/B + 0,01725\ FA*FA + 1,315\ FA*W/B} \quad (1)$$

From equation (1) can be seen:

- It is possible to determine the compressive strength of RCC when knowing the W/B ratio and the FA content.
- The lower the W/B ratio, the greater the intensity of RCC;
- In addition, the content of FA used different also significantly affect the compressive strength of the team.

3.2. Tensile Flexure Strength

After got the testing results of each test sample, statistical analysis and evaluation of the results with a 99% assurance probability are conducted in accordance with ACI 214.R-02 [10]. The results of experiments to find the tensile strength of the samples were presented in Table 4 and Figure 7 as follows:

Table 4 Tensile flexure strength of RCC

W/B	0.34	0.36	0.38	0.40	0.42	0.44	0.46	0.48
R_{ku}^{28}, 20% FA (MPa)	5.4	5.2	5.1	5.0	4.8	4.5	4.2	4.0
R_{ku}^{28}, 30% FA (MPa)	5.0	4.7	4.5	4.4	4.3	4.1	3.9	3.6
R_{ku}^{28}, 40% FA (MPa)	4.6	4.5	4.3	4.1	3.9	3.8	3.6	3.3

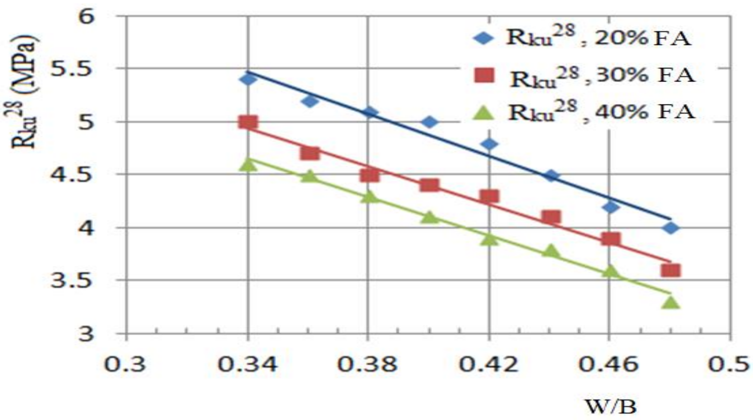

Figure 7 Relationship between R_{ku}^{28} and W/B

Similar to compressive strength, tensile flexure strength is also a function of the variables FA and W/B. Based on the experimental results in Table 4, data processing using Minitab17 software is shown in Table 5 as follows.

Table 5 Analysis of regression for tensile flexual strength

Analysis of variables					
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	4	6,81290	1,70322	402,32	0,000
FA	1	0,11079	0,11079	26,17	0,000
W/B	1	0,00570	0,00570	1,35	0,260
FA*FA	1	0,03521	0,03521	8,32	0,010
W/B*W/B	1	0,03175	0,03175	7,50	0,013
Error	19	0,08044	0,00423		
Total	23	6,89333			
Model Summary					

S	R-sq	R-sq(adj)	R-sq(pred)		
0,0650654	98,83%	98,59%	98,17%		
Coefficients					
Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	6,73	1,23	5,46	0,000	
FA	-0,0869	0,0170	-5,12	0,000	109,00
W/B	6,90	5,95	1,16	0,260	421,25
FA*FA	0,000812	0,000282	2,88	0,010	109,00
W/B*W/B	-19,84	7,25	-2,74	0,013	421,25

Regression Equation of tensile flexure strength:

$$\mathbf{R_{ku} = 6{,}73 - 0{,}0869\ FA + 6{,}90\ W/B + 0{,}000812\ FA*FA - 19{,}84\ W/B*W/B} \quad (2)$$

From equation (2) can be seen:

- It is possible to calculate the tensile flexure strength of RCC when knowing the W/B ratio and FA content.

- The degree of impact is significant when increasing the W/B ratio, tensile flexure strength is reduced.

4. CONCLUSIONS

From the testing results in this study, the conclusions and recommendations can be drawn:

- The intensity of the roller concrete is inversely proportional to the W/B ratio, which is similar to conventional cement concrete.

- When knowing the FA content, W/B can determine the compressive strength and flexural strength of the concrete.

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