Properties of Roller Compacted Concrete with Pozzolan as Cement Replacement Material

Zar Phyu Tun [1], Nyan Myint Kyaw [2] , Khin Su Su Htwe [3]

[1] Ph.D Student, Department of Civil Engineering, Yangon Technological University, East Gyogone Township, Yangon City

[2] Professor and Head, Department of Civil Engineering, Yangon Technological University, East Gyogone Township, Yangon City

[3] Associate Professor, Department of Civil Engineering, Yangon Technological University, East Gyogone Township, Yangon City

Email - [1]zptmmn@gmail.com, [2]nmkyaw@gmail.com, [3]kssh11@ytu.edu.mm

Abstract: In this paper, an attempt is made to prepare target strength 35 MPa (G35) and 45 MPa (G45) roller compacted concrete mixes and tested their Vebe time, setting time and compressive strength for various cement replacement percentage by pozzolan (i.e., 30%, 40%, 50%, 60%, 70% and 80%) for 7 days, 28 days, 90 days and 180 days respectively. It can be seen that the pozzolan replacement percent had no significant effect on Vebe time of G35. However, the more replacement contents led to increase of Vebe time for G45. The results indicated that the pozzolan retarded the the final setting times of the mixtures for both G35 and G45. However, the initial setting time has fluctuated trend compared to the reference one for both concrete mixtures. It is clear that the compressive strength of G35 observed at concrete containing 30% pozzolan. The results confirmed that the best performance was obtained at 40% replacement for G45.

Key Words: roller compacted concrete, pozzolan, compressive strength, setting time, Vebe time;

1. INTRODUCTION:

Roller compacted concrete (RCC) gets its name from the heavy vibratory steel drum and rubber-tired rollers used to compact it into its final form. RCC has similar strength properties and consists of the same basic ingredients as conventional concrete_ well graded aggregates, cementitious materials, and water_ but different mixture proportions. The largest difference between RCC mixtures and conventional concrete mixtures is that RCC has a higher percentage of fine aggregates, which allows for tight packing and consolidation [1].

RCC may be considered for applications where no-slump concrete can be transported, placed, and compacted using earth and rock-fill construction equipment or, in the case of pavements, asphalt laydown equipment. Ideal RCC projects will involve large placement areas with few interferences or discontinuities or restrictions on placement rate. The two major applications for RCC are for mass concrete such as dams and heavy-duty pavement applications including intermodal yards, port facilities, warehouse and other industrial parking and storage areas. Other applications include overtopping protection for earth fill dams, buttressing of existing concrete dams, grade control structures in riverbeds, low permeable liners, and a variety of pavement applications [2].

This paper presents the properties of roller compacted concrete obtained from laboratory tests. The Vebe time and setting time are observed. Finally, the compressive strengths of concrete with various percentages of pozzolan are also examined.

2. MATERIALS:

RCC contains the same basic materials as conventional concrete—coarse and fine aggregates, cementitious materials (cement, fly ash, silica fume, etc.), water, and when appropriate, chemical admixtures—but they are used in different proportions.

Cement**:** Cement that used in the test was Elephant cement. The cement was tested for various properties as per ASTM designation and results are shown in Table 1. Chemical composition of cement is shown in Table 2.

Name of Test		Results
Specific gravity		3.15
Setting time	Initial	1 hr 40 minutes
	Final	3 hr 46 minutes
Compressive strength	3 days	11.6 MPa
	7 days	17.7 MPa

Table 1: Properties of ordinary Portland cement (OPC)

Chemical constituent	OPC
SiO_2 (%)	23.58
Al_2O_3 (%)	4.35
Fe_2O_3 (%)	4.35
CaO (%)	63.21
MgO (%)	1.51
SO_3 (%)	1.28
Loss on ignition (%)	0.97
Fineness- Blaine(cm^2/g)	3487

Table 2: Chemical composition of OPC

Aggregates: River sand and river shingle aggregates from Shwe Pyi Thar Yard were used. Physical properties of coarse and fine aggregate are shown in Table 3.

Water: Water used in the test was clean and free from any visible impurities. The same water was used for mixing and curing of concrete cubes.

Name of Test	Results	
	Coarse Aggregate	Fine Aggregate
Specific gravity	2.56	2.63
Absorption (%)	0.51	0.71
Fineness Modulus	1.6	6.9

Table 3: Physical properties of aggregates

Pozzolan: The cement replacement material that used in the test was local natural pozzolan from Mont Popa. The chemical composition of pozzolan is given in Table 4. It is evident that the local natural pozzolan conforms to the requirements of ASM C 618 and hence, can be used as a partial replacement of the production of roller compacted concrete.

Description	Composition (%)	
	Local Natural Pozzolan	Requirements as per ASTM for class N
Silicon dioxide (SiO_2), aluminum oxide (Al_2O_3) and iron oxide (Fe_2O_3)	77.3	Min 70.00
Sulfur trioxide (SO_3)	0.34	Max 4.00
Loss on ignition (%)	2.26	Max 10.00

Table 4: Comparison of local natural pozzolan with Class N of ASTM C 618

4. METHOD:

The soil compaction method is the most widely used mixture proportioning method for RCC pavements. This proportioning method involves establishing a relationship between the density and moisture content of an RCC mixture to obtain the maximum density by compacting samples over a range of moisture contents.

Choosing well-graded aggregates : In the first stage, the optimization of coarse aggregate ratio was obtained by determining the minimum voids content for each combination of aggregates. Firstly, 10-20 mm and 5-10 mm of aggregates were mixed in various proportions to find the combination with minimum voids content by Loose Bulk Density Test. According to the result shown in Fig 1, 64:36 ratios of 10-20 mm and 5-10mm were selected. And then, these two aggregate and 0-5mm aggregate were mixed with various ratio. Finally, minimum void were found in a combination of 38.4:21.6:40 ratios of 10-20 mm, 5-10 mm and 0-5 mm as shown in Figure 2.

In the second stage, the optimized coarse aggregate ratio was mixed with fine aggregate of various proportions to find the minimum voids content by Compacted Bulk Density test. The results are shown in Figure 3. Minimum voids were found in a combination which contained fine aggregates content of approximately 27% in total of coarse and fine aggregate.

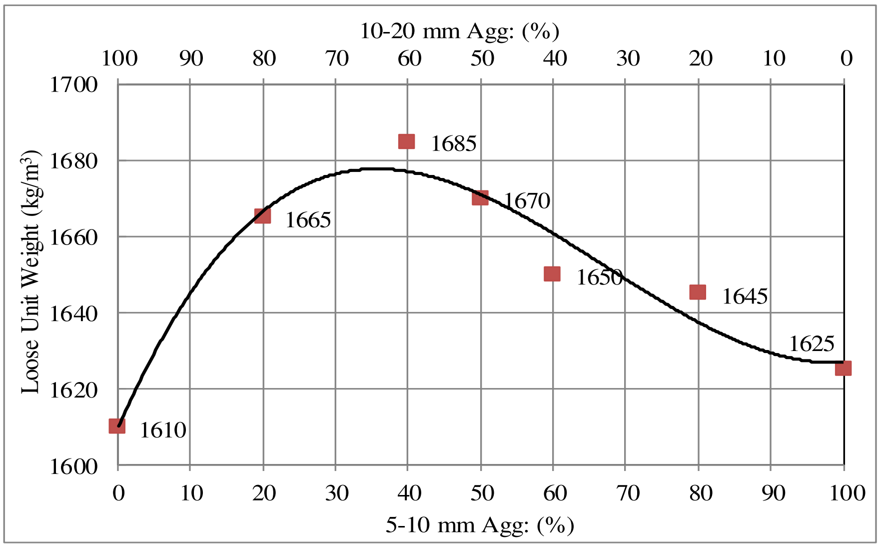

Figure 1: Optimization of coarse aggregate grading I

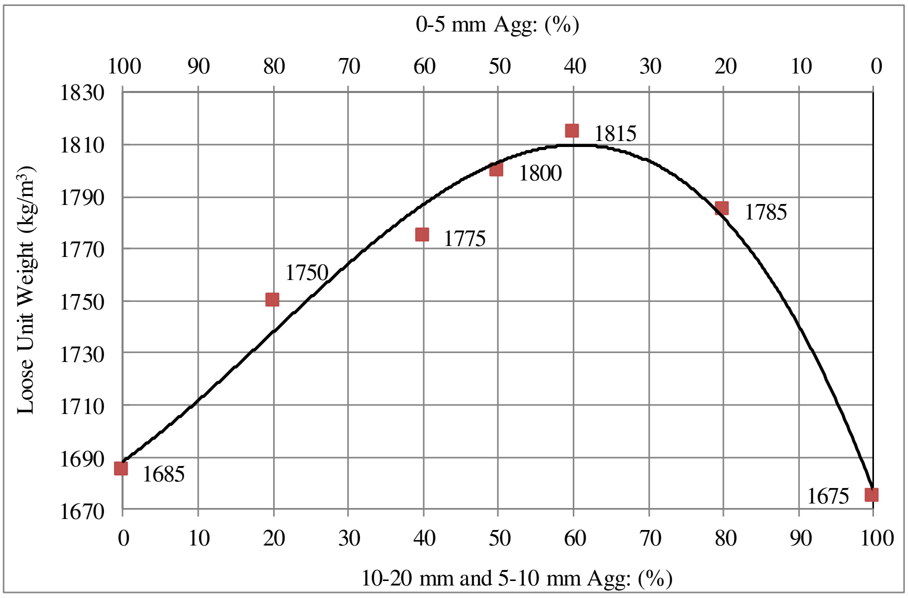

Figure 2: Optimization of coarse aggregate grading II

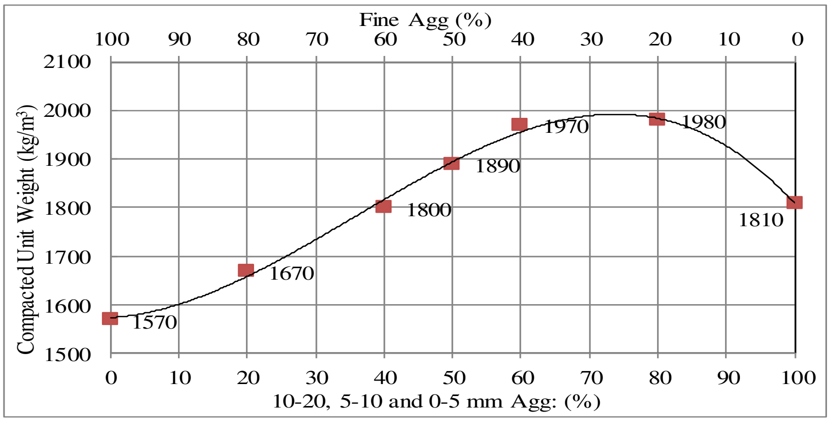

Figure 3: Optimization of all aggregate grading

Selecting a mid-range cementitious content: Choice of cementitious materials will be based on the project specifications, economic considerations, and availability of materials, and production considerations. In this study, starting points are 12, 14, 16, 18 percent for cement without the addition of supplementary cementitious materials (SCMs).

Developing moisture-density plots: For a fixed cementitious materials percentage, different moisture contents are selected to develop a moisture-density plot. ASTM C1170, Standard Test Method for Determining Consistency and Density of Roller-Compacted Concrete Using a Vibrating Table can be used to develop moisture- density relationship of RCC. Moisture-density plots are plotted in the following Figure 4, 5, 6 and 7. The maximum moisture content for 12%, 14%, 16% and 18% cement content are 6.65%, 6.7%, 6.75%, 6.7% respectively.

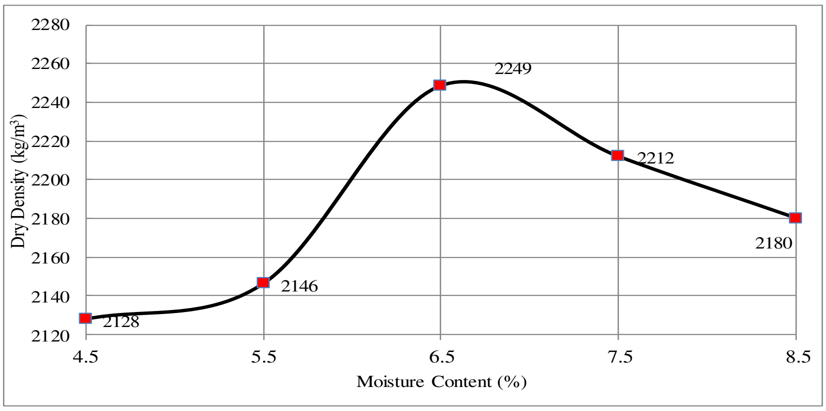

Figure 4: Moisture-Density plots for 12% cement content

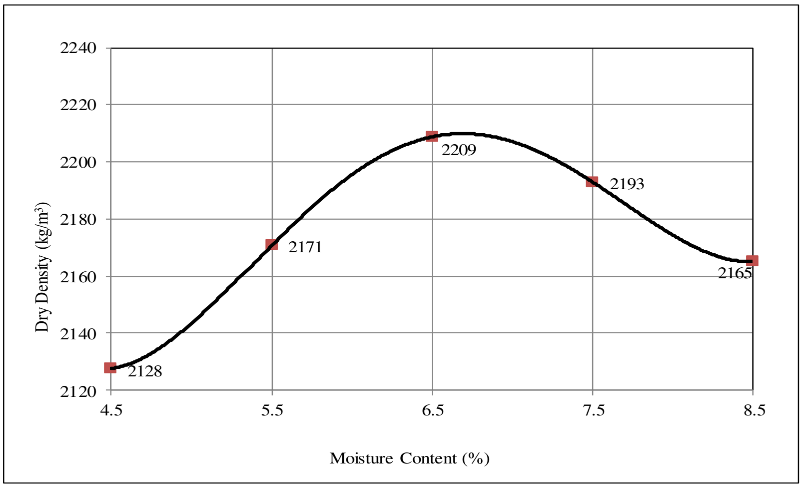

Figure 5: Moisture-Density plots for 14% cement content

Casting samples to measure compressive strength: For each cementitious content, compressive strength specimens are made using the vibrating table method (ASTM C1176). The data are plotted and a compressive strength versus cementitious content curve is developed, as shown in Figure 8. From this curve, a cementitious content can be selected to meet the required strength. The required strength, f 'cr, should be equal to the specified strength, f 'c, plus a strength safety factor.

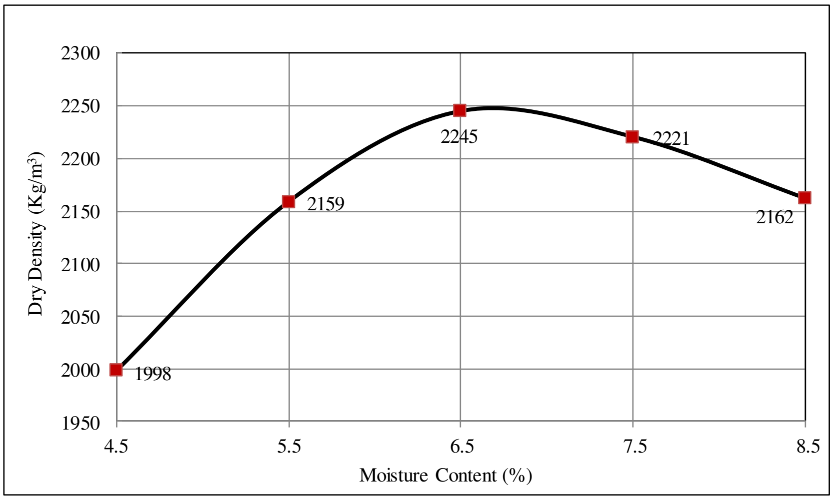

Figure 6: Moisture-Density plots for 16% cement content

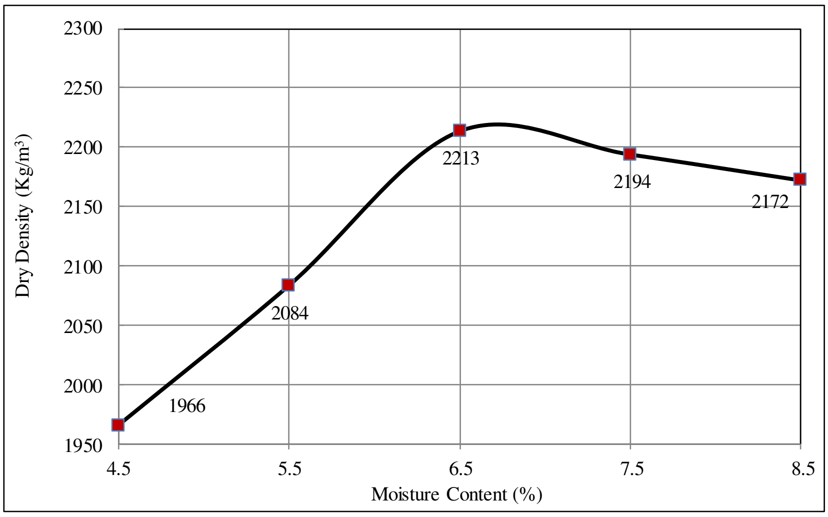

Figure 7: Moisture-Density plots for 18% cement content

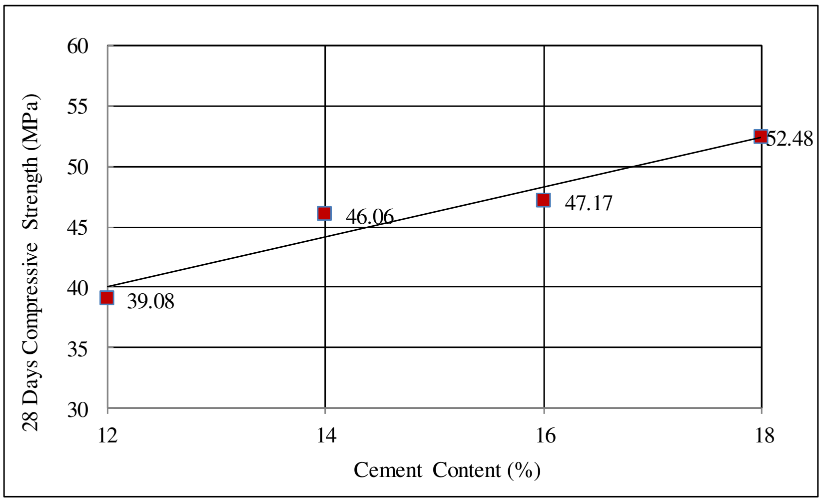

Figure 8: Strength versus cementitious content plot

Calculating mixture proportions: After final selection of the cementitious content and optimum moisture content, the final mix proportions can be calculated for the project. Saturated surface-dry (SSD) conditions of the aggregates were used when determining the weight and corresponding volume calculations.

Mix No	W/C	Quantities (kg/m^3)						
		Cement	Pozzo lan	Aggregates				Water
				10-20	5-10	0-5	Sand	
G35-0	0.49	324.3	-	523.32	299	542	504.6	157.45
G35-30	0.49	227.0	97.29	523.32	299	542	504.6	157.45
G35-40	0.49	194.6	129.7	523.32	299	542	504.6	157.45
G35-50	0.49	162.2	162.2	523.32	299	542	504.6	157.45
G35-60	0.49	129.7	194.6	523.32	299	542	504.6	157.45
G35-70	0.49	97.3	227.0	523.32	299	542	504.6	157.45
G35-80	0.49	64.9	259.4	523.32	299	542	504.6	157.45

Table 5: Mixture proportions of RCC for G35

Mix No	W/C	Quantities (kg/m^3)						
		Cement	Pozzo lan	Aggregates				Water
				10-20	5-10	0-5	Sand	
G45-0	0.39	415.2	0	510.72	291.8	529	492.5	160.8
G45-30	0.39	290.6	124.56	510.72	291.8	529	492.5	160.8
G45-40	0.39	249.1	166.1	510.72	291.8	529	492.5	160.8
G45-50	0.39	207.6	207.6	510.72	291.8	529	492.5	160.8
G45-60	0.39	166.1	249.1	510.72	291.8	529	492.5	160.8
G45-70	0.39	124.6	290.6	510.72	291.8	529	492.5	160.8
G45-80	0.39	83.0	332.2	510.72	291.8	529	492.5	160.8

Table 6: Mixture proportions of RCC for G45

5. RESULTS AND DISCUSSION:

Results for Vebe time: Vebe times for G35 and G45 are shown in Figure 9 and Figure 10, respectively. It can be seen that the pozzolan replacement percent had no significant effect on Vebe time of G35. However, the more replacement contents led to increase of Vebe time for G45.

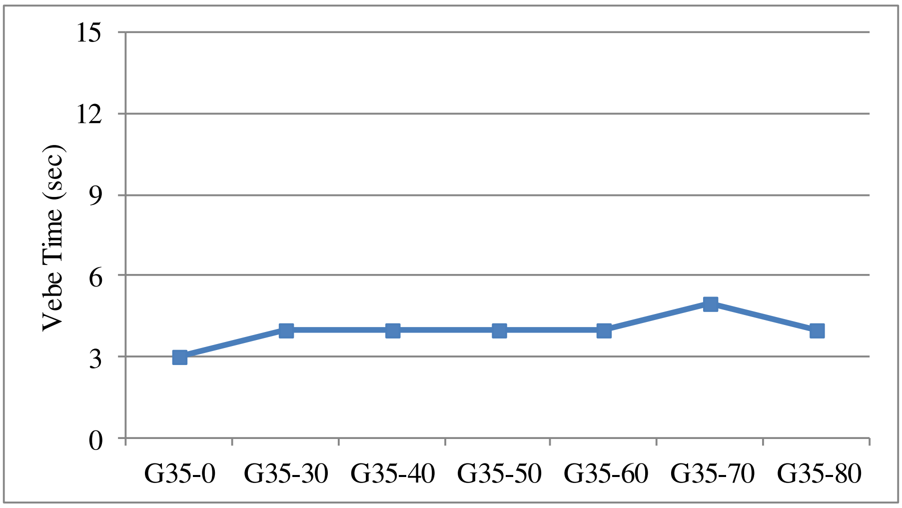

Figure 9: Vebe time for G35

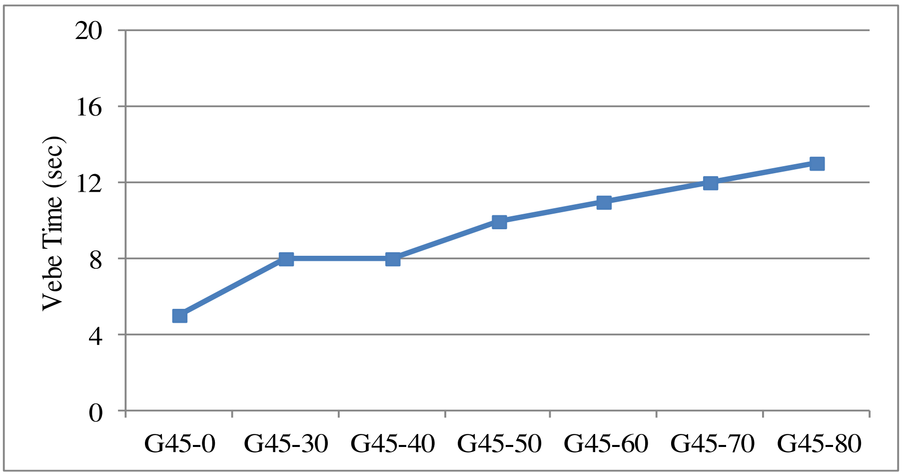

Figure 10: Vebe time for G45

Results for setting time: The initial and final setting times of concrete mixtures containing different pozzolan materials percent were determined in accordance to ASTM C 403. The setting time results are given in Figure 11 and Figure 12. The results indicated that the pozzolan retarded the final setting times of the mixtures for both G35 and G45. However, the initial setting time had fluctuated trend compared to the reference one for both concrete mixtures.

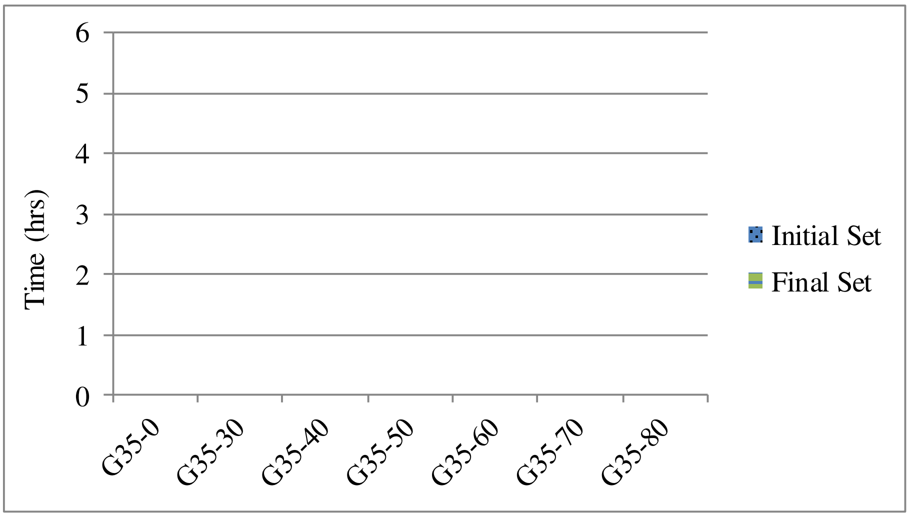

Figure 11: Setting time for G35

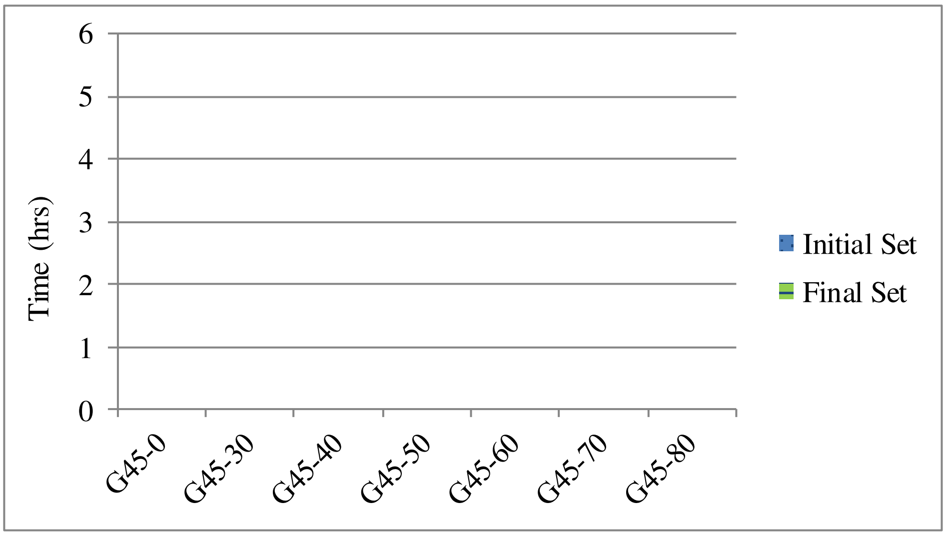

Figure 12: Setting time for G45

Results for compressive strength: Compressive strength tests were performed on the cubes at 7,28,90, and 180 days from mixing. Each strenth value published in this paper is the average value from three tests. The compressive strength results for the mixes containing pozzolan and the control mix are presented in Figure 13 and Figure14. It can be observed from the test results that the more replacement of pozzolan is used, the weaker the compressive strength is in this study. This is probably due to the more pozzolan may able to react with calcium hydroxide produced by hydration of cement. It is clear that the compressive strength of G35 observed at concrete containing 30% pozzolan. The results confirmed that the best performance was obtained at 40% replacement for G45.

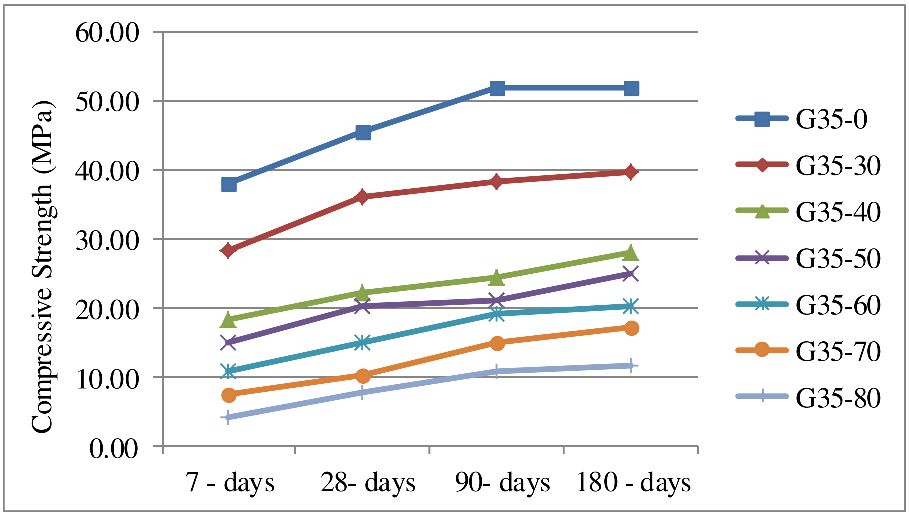

Figure 13: Compressive strength for G35

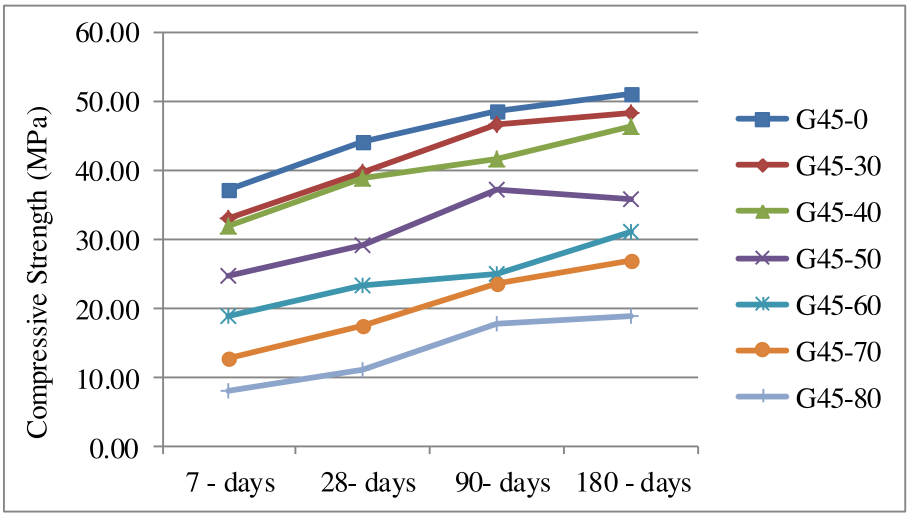

Figure 14: Compressive strength for G45

6. CONCLUSION:

From the results presented in this paper, the following conclusions can be drawn:

1. The pozzolan replacement percent had no significant effect on Vebe time of G35. However, the more replacement contents led to increase of Vebe time for G45.
2. The results indicated that the pozzolan retarded the final setting times of the mixtures for both G35 and G45. However, the initial setting time had fluctuated trend compared to the reference one for both concrete mixtures.
3. The more replacement of pozzolan is used, the weaker the compressive strength is in this study.
4. It is clear that the compressive strength of G35 observed at concrete containing 30% Mont Popa pozzolan. The results confirmed that the best performance was obtained at 40% Mont Popa pozzolan replacement for G45.

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