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EFFECT OF CURING CONDITIONS ON THE COMPRESSIVE STRENGTH OF CRUMB RUBBER CONCRETE PAVING BLOCKS

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ABSTRACT

Crumb rubber represents a potentially valuable resource as a replacement of fine aggregate in concrete paving blocks (CPBs). The objective of this study was to investigate the effect of three curing conditions on compressive strength of crumb rubber CPBs. Four batches of crumb rubber CPBs were produced in a commercial plant with replacement of sand at 0%, 10%, 20% and 30% with crumb rubber by volume. Only 0% and 10% replacement of crumb rubber CPBs satisfied the 28 days compressive strength (30MPa) for 60mm thickness rectangular paving block to carry traffic load in accordance to Concrete Masonry Association of Australia (MA20). In general, the natural weather cured gives better compressive strength than air cured and water cured at 182 days of age. In addition, high volume of daily production of CPBs makes natural weather curing to be more applicable and economic.

Keywords: *crumb rubber, concrete paving blocks, curing, compressive strength.*

INTRODUCTION

In Malaysia, a huge quantity of waste tyres are abandoned within sites annually. There is a record in year the 2006 which indicated a stockpile of one million tyres, sitting in a site along the Kuching-Serian Road in Kuching, where indirectly creates several problems because they can become fire hazard or insect and animal habitation. In addition, environmental concerns also make it more important to reuse or find suitable methods for disposal of the waste tyres.

In recent years, utilization of waste materials in construction industry has been investigated to reduce the disposal of waste materials, which results in reduction cost of waste treatment prior to disposal. Furthermore, this has a good potential to reserve natural materials such as aggregate for concrete production.

Several previous studies [1, 2] indicated that the presence of waste tyre as aggregate in concrete seems to lower the strength, but there are several other properties of concrete that are beneficial as compared to that of conventional concrete. As reported [3, 4], recycled tyre (crumb rubber) represents a potentially valuable resource as a replacement of fine aggregate in CPBs.

The main objective of this study is to investigate the effect of curing conditions on compressive strength of crumb rubber CPBs produced in a commercial plant. Three types of curing were adopted in this test, mainly air curing, water curing and natural weather curing. Four batches of CPBs were prepared with replacement of sand at 0%, 10%, 20% and 30% with crumb rubber by volume.

MATERIALS

The raw materials used in production of CPBs comprised of cement, aggregate, coarse sand, fine sand, recycled tyre, water and additive. The physical and mechanical properties of both sand and aggregate are given in Table 1. The recycled tyre used in this study to replace partial sand at facing layer and body layer were 1-3 mm and 1-5 mm crumb rubber, respectively.

Table 1: Physical and mechanical properties of sand and aggregate

Property	T1 & T2			T3 & T4		
	Fine sand	Coarse sand	3/8" aggregate	Fine sand	Coarse sand	3/8" aggregate
Silt content (%)	5.61	5.71	-	5.61	7.62	-
Moisture content (%)	5.22	8.5	-	5.22	8.95	-
Fineness modulus	1.77	3.02	-	1.77	2.86	-
Passing 10mm (%)	-	-	86.15	-	-	98.18
Passing 5mm (%)	-	-	16.18	-	-	12.41
Flakiness index	-	-	17.08	-	-	22.07

SAMPLES PREPARATION

In this study, all samples were prepared in a commercial plant production setting. Two independent mixers were used with different capacity and worked in parallel to ensure facing layer being added for appearance. Table 2 shows the mixing ratio for the components of these CPBs. Initially, aggregate, coarse sand, cement and crumb rubber were mixed in body mix mixer, water was then added to the materials and mixed again until the desired moisture content for these mixtures was obtained.

The mixtures were transferred from the pan mixer to a feed hopper and closely controlled by an automatic weighting system. The hopper discharged the correct amount of mixture into the mould with internal dimensions of 210 mm length, 105 mm width and 60 mm depth. The mould was filled by the body mix and first vibration and pressing were applied. The face mix was poured into the mould for second layer, and then final compaction and vibration were applied. The hydraulic ram was released and the head lifted to allow early stripping of CPBs from the steel moulds. The detail process of CPBs making can be found in [5].

Table 2: Mixing ratio

Mix symbol	Mix proportion		Cement content (kg/m ³)		w/c ratio		% rubber by sand volume		Demolded fresh density (kg/m ³)
	Facing (C:S)	Body (C:A:S)	Facing	Body	Facing	Body	Facing	Body	
T1	2.3	1:1.9:3.8	660	323	0.25	0.45	0	0	2170
T2	2.3	1:2.0:3.7	620	312	0.23	0.43	8.8	9.7	2140
T3	2.1	1:2.4:4.3	640	260	0.29	0.48	21.6	19.4	2100
T4	2.0	1:2.1:3.7	610	274	0.26	0.39	30.4	29.0	2030

CURING CONDITIONS

For a normal concrete, curing plays an important role for strength development. The properties and performance of concrete are affected under situations where environmental temperatures during concreting and subsequent curing periods are markedly different from those in normal conditions. All the samples prepared in this study were cured under elevated curing temperature for the first day. The samples on pallets were then removed from the roller-conveyors mounted on the outlet side of the press, and on to a lowerator. Samples were then collected and cured at three different curing regimes for 3, 7, 28, 91 and 182 days before being tested. Five samples were used for each set of test in accordance to Concrete Masonry Association of Australia, MA20 [6].

RESULTS AND DISCUSSIONS OF COMPRESSIVE STRENGTH

Figure 1, 2, 3 and 4 show the change in compressive strength of three curing regimes over time and varying rubber content. Evaluation of the results led to the following conclusions. Figure 1 shows the rate of gain in strength is rapid up to 28 days of three curing regime. It then slows down with additional curing time. For the 182 days strength, there was an improvement of about 35%, 37% and 47% over the 28 days strength of natural

weather, air and water cured, respectively. This behaviour is largely attributed to the mixture's low water-cement ratio.

Figure 2 shows the three curing regime obtained a similar strength at each curing days of age. As the curing age increased, the compressive strength of the CPBs kept on increasing. However, result for 91 days of age indicated an opposite trend, which the strength decreased somewhat there and then increased again. This point of inflexion is not known.

Overall, at 3 days of age, all the samples in T1 and T2 met the 28 days compressive strength requirement of MA 20 (30 MPa) for 60mm thickness rectangle block to carry traffic load. The main reason for this could be no or small amount of rubber contains in CPBs and high compaction casting method in the commercial plant. Therefore, it can be considered there is no effect upon strength for crumb rubber content less than 10% by sand volume in CPBs.

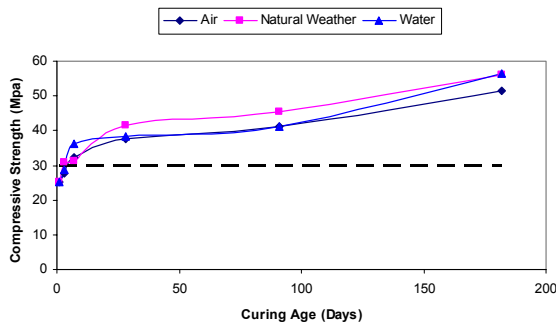


Figure 1: T1 compressive strength

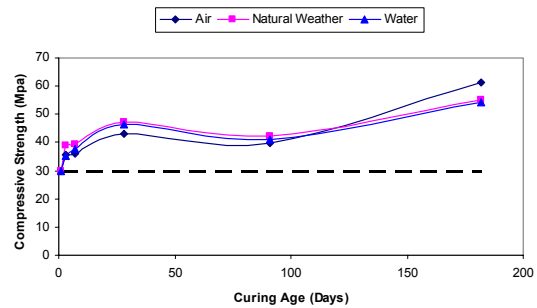


Figure 2: T2 compressive strength

As expected, the compressive strength of CPBs greatly depends on the crumb rubber content. Figure 3 and 4 indicated that as partial replacement of sand with crumb rubber exceeded 20% by sand volume it resulted in compressive strength decreased significantly and did not meet the minimum requirement strength even until 182 days of age. This could be attributed to the large amount of rubber contain in CPBs. At the higher volume content of crumb rubber, stress concentrations in the crumb rubber CPBs were much bigger and the strength were affected significantly due to the loss of adhesion between the crumb rubber and the surrounding cement paste. This is because while plant machine applied a high compaction, crumb rubbers would be dense and after the compaction when the hydraulic ram is released, the crumb rubbers would return to the actual size resulting in micro cracks and voids between the interfaces in concrete matrix.

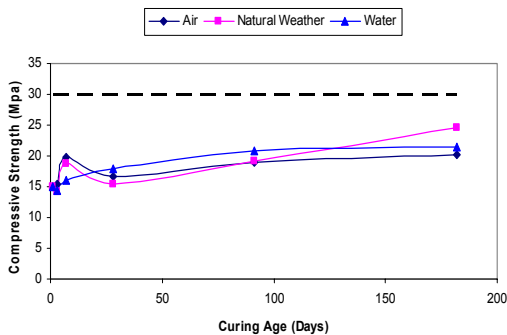


Figure 3: T3 compressive strength

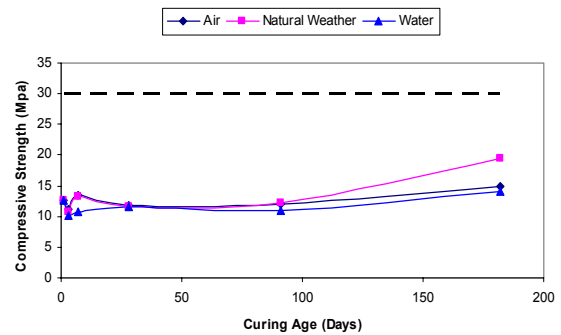


Figure 4: T4 compressive strength

Figure 3 and 4 show the rate gain in strength is fairly rapid up to 7 days of air and natural weather curing. However, the strength dropped at the 28 days and then increased again. It is noted that with the increase curing age from 91 days to 182 days, the strength under air and water curing conditions improved at the same rate. On the other hand, natural weather shows a rapid strength gain from 91 days to 182 days of age by about 1.28 and 1.61 in ratio, for T3 and T4 respectively.

In general, the negligible strength difference resulting from the three curing conditions indicated that air, water and natural weather curing give similar effect on the strength development of all CPBs sample. However, at 182 days of age, natural weather cured gains the higher strength over air and water cured for T1, T3 and T4, while air cured gains higher strength over natural weather cured and water cured for T2.

Further study is needed to make firm conclusions because the relative fluctuations in strength with time may be attributed to inherent variations of these plant CPBs product in the degree of compaction and in the initial accelerated curing and the storage conditions. Nevertheless, natural weather cured seems to provide better strength than air cured and water cured. In addition, high volume of daily production of CPBs makes natural weather curing to be more applicable and economic.

It is recommended if CPBs are subjected to trafficking environment, use of higher percentages of crumb rubber (above 20 % by sand volume) may be avoided. However, it is believe only acceptable for pedestrian area or non trafficking application. Beside the strength, the authors also carried out a small scale test on structural performance of crumb rubber concrete block pavement and observed under Highway Accelerated Loading Instrument (HALI).

CONCLUSIONS

This study was undertaken to investigate the effect of curing condition on compressive strength of crumb rubber CPBs produced at commercial paving block plant. Based on the data obtained, the following conclusions can be drawn.

1. Partial replacement of sand with crumb rubber resulted in considerable decrease in compressive strength only when replacement was above 10 % by sand volume. Clearly, CPBs with replacement less than 10% do not contribute any effect to the strength.
2. T1 and T2 CPBs are found to gain in strength over days of age. In general, all samples under three curing regime satisfy MA 20 requirement (30 MPa).
3. T3 and T4 CPBs are found to provide low strength due to high content of crumb rubber in CPBs. In general, all samples under three curing regime do not satisfy MA 20 requirement (30 MPa) even when they reached 182 days of curing age.
4. In general, the negligible strength difference resulting from the three curing conditions indicated that air, water and natural weather curing give a similar effect on the strength development of all CPBs sample.
5. However, comparing the three curing regimes at 182 days of age, natural weather cured gain the higher strength over air and water cured for T1, T3 and T4, while air cured over water and natural weather cured for T2. In addition, high volume of daily production of CPBs also makes natural weather curing to be more applicable and economic.
6. Relative fluctuations in strength with time may be attributed to inherent variations of these plant CPBs product in the degree of compaction and in the initial accelerated curing and the storage conditions.
7. For CPBs expected to be subjected to trafficking environment, use of higher percentages of crumb rubber (above 20 % by sand volume) should be avoided.

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