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The Workability of Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) With Addition of the Reclaimed Asphalt Pavement (RAP) as Aggregate

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ABSTRACT

This paper presents the physical properties assessment of the Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC) modified mix design. Recycle Asphalt Pavement (RAP) is used to substitute the aggregate in producing the UHPFRC. Hence, the objective of this study is to determine the workability performance of the modified UHPFRC mix design which containing RAP. The RAP is used to reduce the amount of waste to be disposed at the disposal area. This practice can generate incomes by selling the RAP and help in reducing the disposal fee thus promote a sustainability. The Flow Table test that adopted from standard BS EN 1015-3 is conducted to determine the workability of the modified UHPFRC which containing RAP. Three samples of UHPFRC were prepared and labelled as UHPFRC-1, UHPFRC-2 and UHPFRC-3. UHPFRC-1 contains 0%, UHPFRC-2 contains 15% and UHPFRC-3 contains 30% of RAP. The results show that the additional of RAP in the UHPFRC had increased the workability of concrete, however it decrease the strength of concrete.
KEYWORDS: Ultra-High-Performance Fiber Reinforced Concrete (UHPFRC), Recycle Asphalt Pavement (RAP), Workability.

INTRODUCTION

In general terms, workability represents the amount of work which is to be done to compact the concrete in a given mould. The desired workability for a particular mix depends on the type and method of compaction adopted as well as the complicated nature of reinforcement used in the reinforced concrete. A workable mix should not segregate. In this context of study, asphalt milling waste or Recycle Asphalt Pavement (RAP) is used in the concrete mix as aggregate substitution. RAP can be considered as a waste product from the rehabilitation work of old pavement. RAP is usually used in the road construction due to its high strength. In this study, the RAP was collected from the Malaysian North-South Expressway demolition project. The replacement as aggregate in the concrete is due to the price of the sand which increasing and expensive. Indirectly, the use of RAP will reduce the cost of the concrete production because it is a recycled material and reduce the cost of RAP disposal. Besides, sand is one of non-renewable material. The resources of the sand will be decreasing and will be end up on day later. Other than that, the used RAP also will decrease the stockpile of waste materials in landfill that will leads to environmental problems and the serious concern either from government or non-government. The concrete mix is been modified by using different percentage of RAP. Thus, the workability of the designed UHPFRC is been studied.

LITERATURE REVIEW

Workability of Concrete

Workability is one of the physical parameters of concrete which affects the strength and durability and the appearance of the finished surface. The size of aggregate affects the workability of concrete. The used of small particles size of aggregate will increased the workability of concrete. Besides, the concrete workability depends on the water cement ratio and the water absorption capacity. The excess water added in the concrete will lead to bleeding or segregation of aggregates. Study conducted by [5] shows that greater value of water of cement ratio will increase the workability of concrete, but too much ratio will lead the concrete to total collapse during the slump test which means the concrete contain too much of water. Table 1 shows the height of fall concrete after the slump test was conducted.

Study conducted by [6] showed that the additional of fiber steel in the concrete will decrease the workability of the concrete. The results of flow table test shows that the flow diameter of fresh concrete will decrease around 4-7% if steel fiber was added into the concrete. The usage of higher volume and hooked type of

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steel fiber will decrease the workability of the concrete. To overcome this problem, super plasticizer is used as a part of water and can improve the workability of concrete.

Table 1: The height of falling concrete with [5]

Water Over Cement Ratio	Height of Cone (cm)
0.5	30
0.55	28
0.60	26
0.7	23
0.8	Total collapse

Workability of UHPFRC

UHPFRC is a combination Portland cement, sand, plasticizer, steel fiber and potable water that exhibit to high strength of concrete. In short, UHPFRC belongs to the group of High Performance Fiber Reinforced cement compositions (HPFRCC) where HPRFCC defined as the kind of Fiber Reinforced Concrete (FRC) that exhibit strain-hardening under uniaxial tension force. In addition, UHPFRC is characterized by a dense matrix and consequently a very low permeability when compared to HPFRCC and normal strength concretes [8].

According to the [1], the addition of material such as Glass Powder (GP) and reject Fly Ash (r-FA) in the UHPFRC will reduce the workability of concrete as shown in Figure 1. The higher the percentage of additional materials such as GP and r-FA will lead to the lower of concrete workability. All specimens which contains additional materials such as GP and r-FA shows decrease in flow diameter compare to the control specimen.

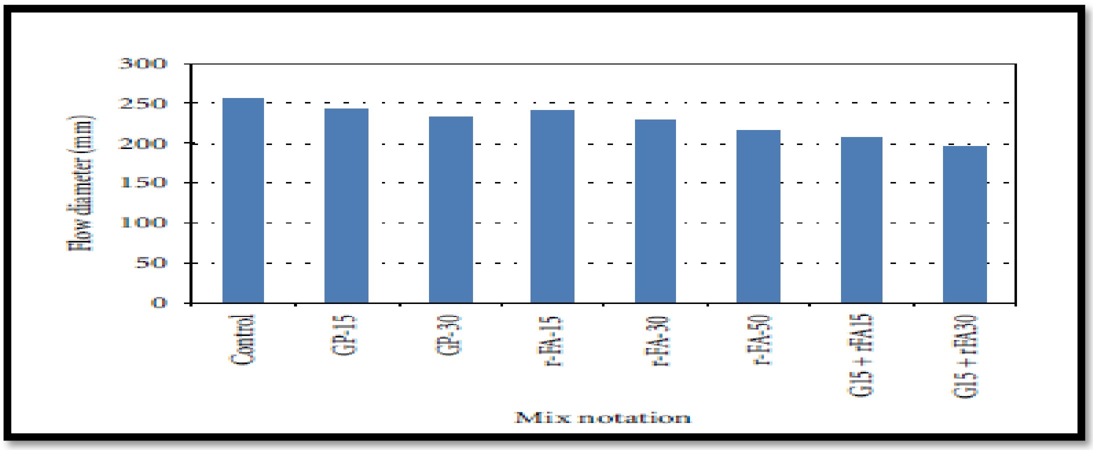

Figure 1: The flow diameter of UHPFRC with additional materials

Besides, the additional of materials such as Ground Dune Sand (GDS) and Ground Brick Waste (GBW) will reduce the workability of the concrete if the percentage is lower. This indicates in Figure 2 which shows the results of mini slump of the UHPFRC with the addition of GDS and GBW [4]. By increasing the percentage of GDS and GBW, the mini-slump also increase which means the workability of concrete also increased.

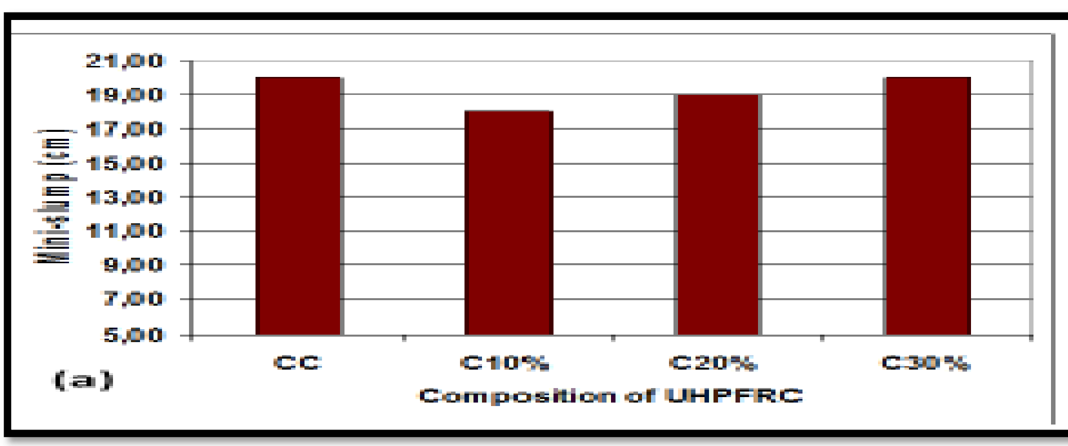

Figure 2: The mini-slump of UHPFRC with the addition of GDS and GBW

Based on the previous research conducted on the concrete workability, it can be concluded that several factors that will affect the workability of concrete. The first factor is water over cement ratio. The higher volume of water in a concrete will lead to the increasing workability of concrete. Besides that, the volume and shape of steel fiber also affect the workability of concrete.

In terms of UHPFRC, it is that noticed this kind of concrete use fiber steel as a main reinforcement to the concrete. According to [7], it is important to notice that with the addition of steel fiber, the relative slump flow ability of all the UHPFRC linearly decreases. The test conducted following the ES 1015-5 where the test is determine the consistency of fresh mortar by using flow table. Figure 3 shows the relative slump flow of different type of UHPFRC.

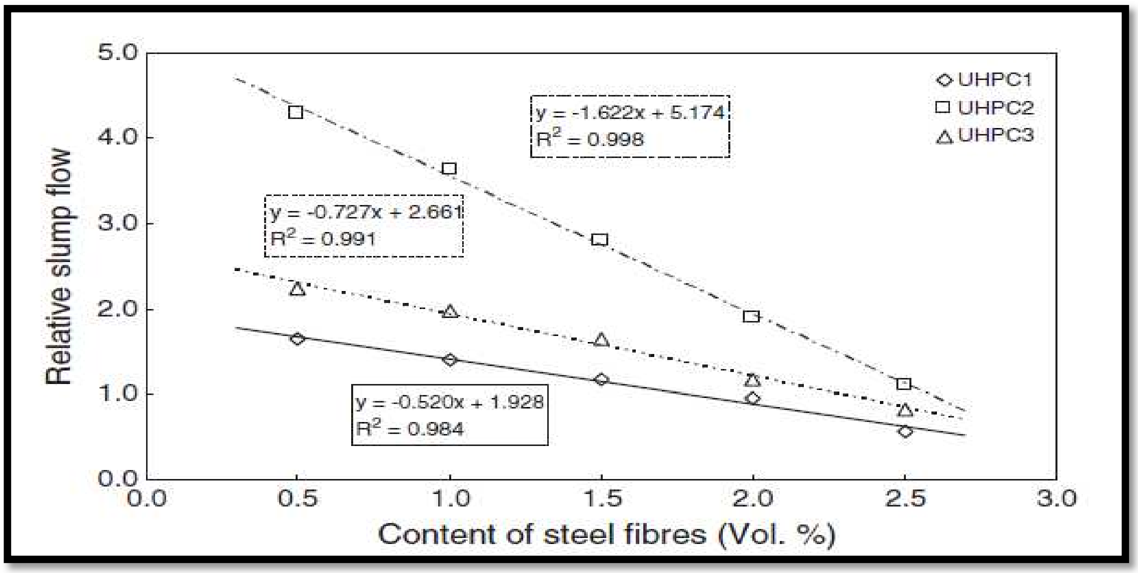

Figure 3: Variation of relative slump flow of UHPFRC

METHODOLOGY

Materials

The materials involved in preparing the UHPFRC including aggregate, fiber steel, micro silica and superplasticizer. The material preparation is important to ensure its follow the specifications and adequate. In this study, the aggregate is substituted by the recycle premix which is Recycle Asphalt Pavement (RAP). Three types of aggregate were used namely as normal size of sand with the fractions of 0-2 mm, micro-sand with the fractions of 0-1 mm and RAP which the fraction of 0-2 mm. All of these aggregates were obtained from the process of crushing and sieving. In this study, no coarse aggregate is used.

The type of fiber steel used in this study is long hooked length over diameter (l/d) equal to 80. This material addition is as a replacement for reinforcement bar. The benefit of using fiber steel because it is lightweight materials, thus can reduce the weight of the concrete. Only 2% of fiber steel was added in each specimen of UHPFRC due to the optimum volume based on the previous UHPFRC done by [2]. About 5% of microsilica is used in the design mix and the super plasticizer used is Estop Admix AP,which followed the standard compliance of ASTM C494-92 Type C & E and BS 5075: Part 1: 1982. DESIGN MIX.

Specimen of Concrete

A total of 3 batches of UHPFRC were produced in this study. The first batch acted as control specimen (UHPFRC-1), which no RAP was added into the UHPFRC-1. The second batch of UHPFRC (UHPFRC-2), 15% of RAP was added while for third batch of UHPFRC (UHPFRC-3), 30% of RAP. The mix design used in this study is adopted from previous researcher [7] as shown in Table 2.

Table 1: The UHPFRC modified mix design

Materials	UHPFRC-1 (kg/m^3)	UHPFRC-2 (kg/m^3)	UHPFRC-3 (kg/m^3)
CEM I 42.5 N	874.9	874.9	874.9
Micro-sand (0-1 mm)	218.7	218.7	218.7
Sand(0-2mm)	1054.7	896.5	738.3
RAP (0-2mm)	0%	15%	30%
Micro Silica	43.7	43.7	43.7
Water	297.5	297.5	297.5
Superplasticizer	45.9	45.9	45.9
Water/cement ratio	0.34	0.34	0.34
Percentage of Fiber steel (l/d=80)	2%	2%	2%

Experiment Set up

In general, UHPFRC was classified as mortar. The workability test or also known as flow table test conducted is followed standard of BS EN 1015-3. This standard is adopted due to the small size of aggregate, which was below 2 mm. The mould with the specification of 50 mm in height and internal diameter: base of 100 mm-top 70 mm is placed on the center of flow table. Then, the fresh concrete is poured into the mould in two layers. Each layer was tamped for 10 times by using the tamper. The process need to be done in proper order to make sure the compaction takes place. Next, the excess mortar at the top of the mould is removed by using the palette knife and the area around the base of the mould was cleaned with cloth. The mould is removed and the table was jolted for 15 times at a rate of one jolted per second. The diameter of spread mortar (d_1 and d_2) is measured in two directions at right angles to each other by using callipers. The diameters were perpendicular to each other. Both the value d_1 and d_2 were included equation 1 to calculate the relative slump of fresh concrete. The value of relative slump determined the workability of fresh concrete either the high workability or low workability.

$$(\xi p) = \left[\frac{d_1+d_2}{2d_0}\right]^2 - 1 \quad (1)$$

whered_1 = flow diameter 1 (mm), d_2 = flow diameter 1 (mm) and d_0 = the bottom's diameter of the mold (100 mm).

RESULTS AND DISCUSSION

Table 3 shows the value of flow diameter of the fresh UHPFRC. The value of relative slump for control sample of UHPFRC-1 with 0% of RAP is 1.12. The value of relative slump for the UHPFRC-2 and UHPFRC-3, which contains 15% and 30% of RAP are 1.16 and 1.25 respectively. This shows that the changes of relative slumps are slightly different between the samples.

Table 3: The relative slump of fresh UHPFRC

Sample	UHPFRC-1(0% of RAP)		UHPFRC-2(15% of RAP)		UHPFRC-3(30% of RAP)	
Diameter of UHPFRC	d_1	d_2	d_1	d_2	d_1	d_2
Flow Diameter (mm)	145	146	146	148	149	151
Relative slump	1.12		1.16		1.25	

Based on the materials used in the designed UHPFRC, the factors that can affect the workability of the UHPFRC were different type of aggregates, volume of steel fiber and addition of superplasticizer. The volume of steel fiber and addition of superplasticizer were constant variables because the amount used in each concrete were same. In this study, the only factor affected the workability of UHPFRC were the volume of RAP used in each concrete. Figure 4 showed that with the increasing of volume RAP in UHPFRC lead to the increasing of workability of the UHPFRC.

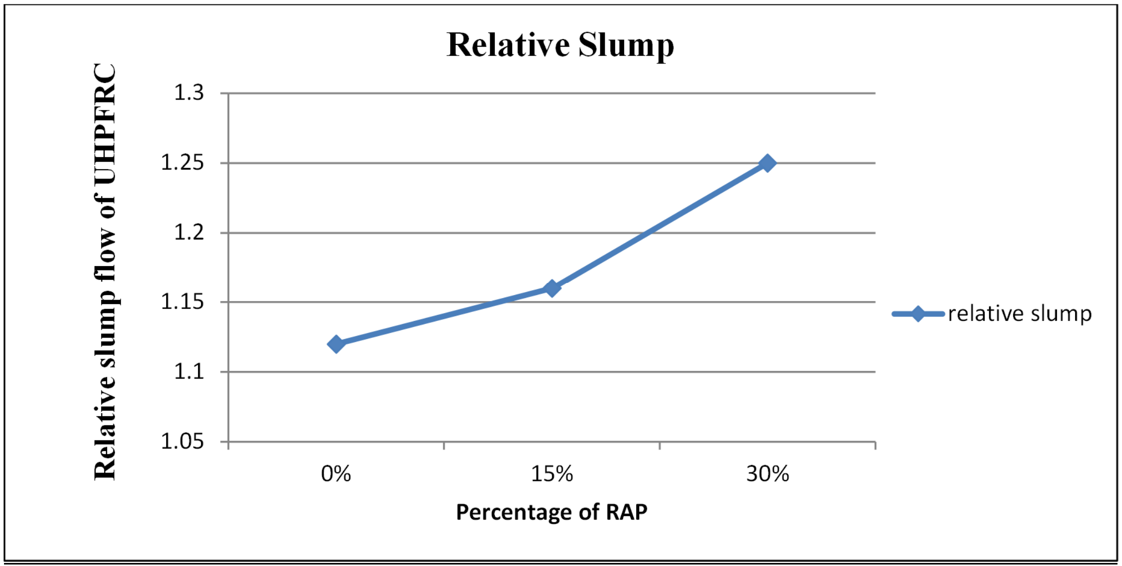

Figure 4: The graph of relative slump of different type of UHPFRC

Figure 5 shows the relatives slump from research conducted by [7]. The result shows that the relative slump of their specimen was around 1.05-1.15 when 2% of steel fiber was added. The material used for their sample and our sample (UHPFRC-1) were same except the type of cement and the dimension of steel fiber. In comparison with the previous research, it indicates that the relative slump value for the sample in this study is within the range.

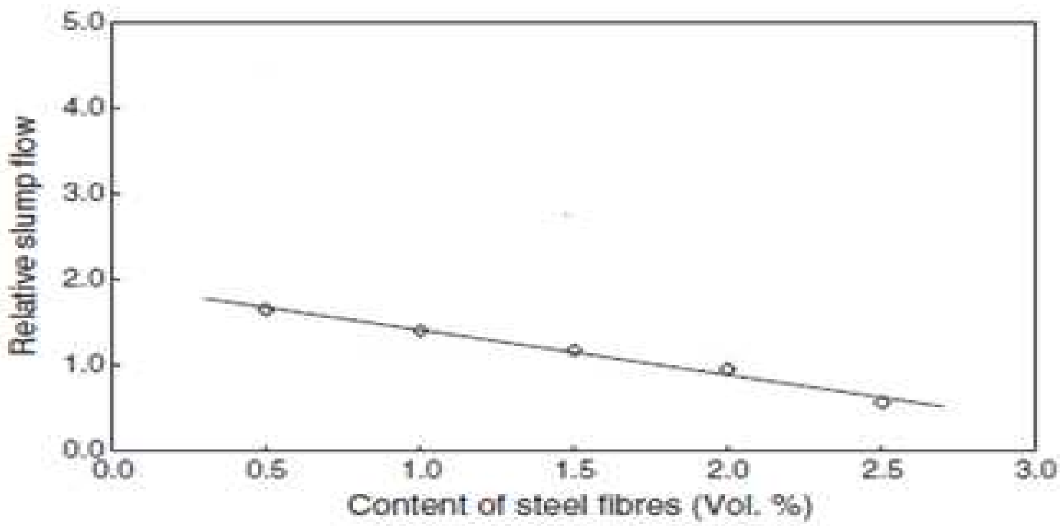

Figure 5: The relative slump flow of previous UHPFRC

CONCLUSION AND RECOMMENDATIONS

In general, RAP is an aggregate that coated with asphalt which is oily compare to the normal sand. This made the surface area of RAP smoother compare to the surface area of normal sand. The smooth surface may reduce the cohesive force between the materials thus increase the workability of the UHPFRC. This is in line with [3], which mentioned that the texture and chemical of the aggregate is a factor that could affect the workability of concrete. The smooth surface of aggregate will lead to the improvement of concrete workability. In conclusion, it shows that the substitution of sand with RAP can improve the workability of UHPFRC. This can be considered as the volume of other materials such as cement, sand, micro silica, water, superplasticizer, water/cement ratio and percentage of fiber steel between the UHPFRC specimens are same and constant.

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