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Potential of Utilizing Asphalt Dust Waste as Filler Material in the Production of Sustainable Self Compacting Concrete (SCC)

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Abstract. Waste materials from many industries are widely used in the production of sustainable green concrete. Utilizing asphalt dust waste (ADW) as a filler material in the development of self-compacting concrete (SCC) is one of the alternative solutions for reducing environmental waste. SCC is an innovative concrete that does not require vibration for placing and compaction. However, there is limited information on the effects of utilizing ADW in the development of SCC. Therefore, this research study examines the effects of various w/b ratios (0.2, 0.3 and 0.4) and differing amounts of ADW (0% to 50%) on the rheological properties of fresh state concrete. The compressive strength of the SCC was tested only for 7 and 28 days as preliminary studies. The results revealed that mixtures $MD7_{30}$, $MD7_{40}$ and $MD7_{50}$ showed satisfactory results for the slump flow, J-Ring, L-Box and V-Funnel test during the fresh state. The compressive strength values obtained after 28 days for $MD7_{30}$, $MD7_{40}$ and $MD7_{50}$ were 35.1 MPa, 36.8 MPa and 29.4 MPa respectively. In conclusion, the distribution of materials in mixtures has significant effect in achieving rheological properties and compressive strength of SCC.

INTRODUCTION

Self-Compacting Concrete (SCC) is a concrete that have very high workability to flow during its fresh state without the need of vibration tools. It is also easy to flow in formwork and fill around reinforcement bars by the action of gravity force. It was first developed in Japan in the 80s due to a shortage of skilled workers that led to a reduction in the quality of construction work. It has excellent workability during its fresh state in terms of filling ability, passing ability and stability from segregation and was considered as a high performance concrete [1-3]. Therefore, SCC became the most important development in the construction industry due to its advantages during its fresh and hardened state. Currently, researchers from the industry and academic institutions are taking on the challenge of utilizing waste materials available to be part of constituent materials in SCC either as a replacement or as an additive to cement, aggregate, sand or filler materials. Researchers are looking forward to utilize waste materials to create new technology options and at the same time contribute towards sustainability and growth [4-6].

Nowadays, protecting the environment is one of the major challenges in our society. It is important to utilized natural raw waste materials available without creating additional consumption energy to the related industries. Waste materials may consist of unwanted materials from the industrial, quarry, mining or agricultural operations. The main reasons for reusing waste material are to reduce the required space for the landfill disposal of these waste materials and to help the industry to regenerate a sustainable economy circle based on the available resources. Therefore, utilizing waste materials as constituent materials in the construction industry is the best method to reduce negative environmental effects. According to previous research studies, different waste materials show several alternative prospective applications in the construction industry to replace conventional materials [4,6-9]. However, there is a lack of information on utilizing Asphalt Dust Waste (ADW) in the development of SCC in Malaysia.

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Therefore, the use of ADW in SCC is seen as a new potential green concrete technology. This research will also contribute towards the production of sustainable concrete products and this will help reduce negative impacts to our environment in terms of landfill hazards. This research focuses on utilizing ADW as a filler material in the development of SCC. Four different types of mixtures have been developed to evaluate fresh state SCC (Slump test, V-Funnel test, L-box test) and its compressive strength in the hardened state of SCC.

In a nutshell, this paper presents a preliminary study on the use of ADW as a filler material to improve the rheological effect in SCC in its fresh state. The results from $MD7_{30}$, $MD7_{40}$ and $MD7_{50}$ demonstrated a good performance in both the fresh state as well as the hardened state.

SCC was developed using the same constituent materials for normal concrete except for powder materials less than 0.125mm. A different concept of mix proportions was also used. Generally, SCC uses a lower proportion coarse aggregates and sand compared to normal concrete. However, the addition of fine powder is important to improve workability and stability for the fresh state properties in SCC [3,10]. In addition, a high range of water reducing admixture (HRWRA) is needed to enhance workability requirements to assist the concrete to flow under its own weight [3].

Finally, another benefit of developing SCC is to reduce noise that occurs during the concreting process due to the impact of vibration tools. Furthermore, SCC leads to homogeneity, well-compacted concrete, less air voids and eliminates honeycomb structures in concrete [11].

EXPERIMENTAL

Constituent materials

Local Ordinary Portland cement type 1 according to MS EN 197-1, CEM I 42.5 N was used in all mixes. The maximum grain size of granular materials was 12 mm for aggregates and 4 mm for sand. The aggregates, sand and ADW were air dried prior to mixing. The superplasticizer Darex Super 20 was used at 2% in order to increase the workability of SCC for all mixes. Meanwhile, the water binder ratio used was 0.2, 0.3 and 0.4. ADW was added in the percentages ranging from 0% to 50%.

Mixed proportion

Basically, the performance of fresh and hardened state of SCC significantly depend on the proportion of constituent materials, water binder ratio (w/b) and admixture (SP) [12]. This research developed four series of mix designs by utilizing ADW in concrete mixing ranging from 0%, 10%, 20%, 30%, 40% and 50%. The mix design designations are $MD1_{0\text{-}50}$, $MD2_{0\text{-}50}$, $MD3_{0\text{-}50}$, and $MD7_{0\text{-}50}$ as shown in Table 1 and Table 2. $MD1_{0\text{-}50}$, $MD2_{0\text{-}50}$ and $MD3_{0\text{-}50}$ were designed with different w/b ratios ranging from 0.2 to 0.4 and 2% of SP. The mix proportion of MD1, MD2 and MD3 was based on volumetric ratios of 25% cement, 60% aggregate, 15% sand and ADW ranging between 0% to 50% by volume of aggregate. Meanwhile, the modifications of mix design MD7 are based on 20% cement, 50% aggregate, 60% of sand (from aggregate volume), a w/b ratio of 0.3, 2% of SP and ADW based on the volume of aggregates ranging between 0% to 50%.

TABLE 1. Proportion mixed design for $MD1_{0\text{-}50}$, $MD2_{0\text{-}50}$ and $MD3_{0\text{-}50}$

Weight (kg)	**Percentages of Asphalt Dust Waste**					
	0%	10%	20%	30%	40%	50%
Cement	288	288	288	288	288	288
Chipping	801	801	801	801	801	801
Sand	240	240	240	240	240	240
ADW	0	63	126	190	253	316
w/b	For ($MD1_{0\text{-}50}$ - 0.2) , ($MD2_{0\text{-}50}$ - 0.3) and ($MD3_{0\text{-}50}$ - 0.4)					
Superplasticizer	2%					

TABLE 2. Proportion mixed design for $MD7_{0-50}$

Weight (kg)	Percentages Asphalt Dust Waste					
	0%	10%	20%	30%	40%	50%
Cement	230	230	230	230	230	230
Chipping	668	601	534	467	401	334
Sand	479	431	384	336	288	240
ADW	0	84	168	253	337	421
w/b	0.3					
Superplasticizer	2%					

RESULTS AND DISCUSSIONS

Fresh State Conditions

It is important to evaluate fresh states properties immediately after mixing before proceeding with the evaluation of hardened properties. The initial key performance of developed SCC is by measuring the diameter of slump flow. The slump flow value should be more than 550 mm in diameter before proceeding with the J Ring test, V-funnel test and L-box test. The slump flow for $MD1_{0-50}$, $MD2_{0-50}$, $MD3_{0-50}$ and $MD7_{0-20}$ is less than 550 mm except for $MD7_{30-50}$. However, some of the slump flow values $MD1_{0-50}$, $MD2_{0-50}$, $MD3_{0-50}$ and $MD7_{0-20}$ are very close to 500 mm flow and there is a possibility to have a higher flow by increasing the w/b ratio and the amount of SP during the fresh state evaluation. $MD7_{30-50}$ has shown the contribution of ADW in developed SCC. Therefore, there are some factors that contribute to the fresh properties of SCC such as the distribution ratio between aggregates and sand, w/b ratio, amount of SP and constituent materials used. Table 3 shows the details of the fresh state properties of $MD7_{0-50}$.

TABLE 3. Fresh state properties for $MD7_{0-50}$

	$MD7_0$	$MD7_{10}$	$MD7_{20}$	$MD7_{30}$	$MD7_{40}$	$MD7_{50}$
Slump flow	370 mm	415 mm	405 mm	590 mm	665 mm	645 mm
SF for T_{500}	-	-	-	3 s	3 s	3 s
J Ring flow	-	-	-	620 mm	630 mm	645 mm
JR T_{500}	-	-	-	5 s	5 s	4 s
VF T_{5s}	-	-	-	32 s	30 s	25 s
VF T_{5m}	-	-	-	37 s	35 s	30 s
L Box $_{(H2/H1)}$	-	-	-	0.81	0.81	0.92
L Box T_{20}	-	-	-	3 s	3 s	2 s
L Box T_{40}	-	-	-	5 s	5 s	4 s

Compressive Strength of ADWSCC

The compressive strength was measured on day 7 and day 28. The cube size measured 100mm x 100mm x100mm and there was a total of 144 cube samples as shown in Figure 1. Generally, an increasing amount of ADW in the mixture as a filler material has shown an increase in compressive strength as well. However, the utilization of ADW up to 50% may reduce the compressive strength of all mixtures. Therefore, the limitation of utilizing ADW in mixtures should be evaluated based on the purpose of application.

The use of ADW as a filler material in the mixture has shown some drastic changes in compressive strength in all mixtures compared to the control sample without ADW. This compressive strength performance is also influenced by w/b ratio and the percentage of SP in each mixture. Based on Figure 1(d), $MD7_{30}$, $MD7_{40}$ and $MD7_{50}$ are the SCC that have fulfilled the fresh properties and recorded compressive strength values of 35.1 MPa, 36.8 MPa and 29.4 MPa on the 28th day.

Finally, only $MD1_0$, $MD1_{10}$ and $MD7_0$ achieved below target compressive strength, which is 30 MPa. Therefore, the utilization of ADW in concrete mixture partly contributed to the advancement of materials in engineering especially for the concept of sustainable material. The ADW has performed as a filler to fill the pores or voids between the sand and aggregates. Beside that, it also facilitates flow ability, passing ability and segregation resistance with suitable proportions [11].

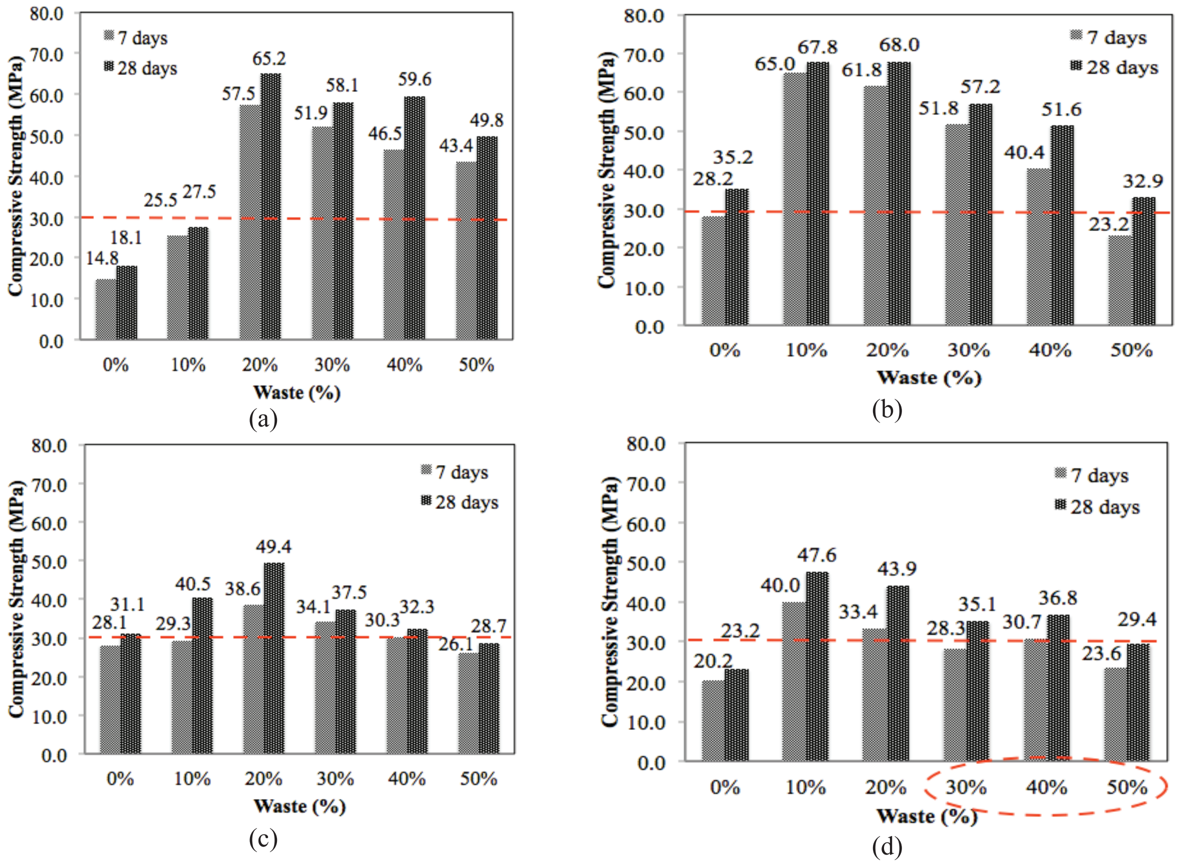

FIGURE 1. Compressive test for 7 and 28 days (a) MD1, (b) MD2, (c) MD3 and (d) MD7

CONCLUSIONS

In this research, the use of ADW from asphalt premix industry as a filler material in production of high workability concrete and SCC was successful. This is part of solution to reduce the environmental effect by utilizing waste in sustainable concrete. $MD7_{30}$, $MD7_{40}$ and $MD7_{50}$ provide satisfactory fluidity and stability in segregation resistance in fresh state concrete condition. However, only $MD7_{30}$ and $MD7_{40}$ exceeded 30MPa in terms of compressive strength. Therefore, adjustment in proportion of constituent materials with w/b ratio and percentage of superplasticiser should be conducted to obtain an economical mix design ratio in future research. Furthermore, the compressive strength also should be evaluated more than 28 days to evaluate the effect of ADW in hardened concrete in longer duration.

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