NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Strength Properties Evaluation of Asphalt Concrete Produced with Sandcrete Block Powder

Nwankwo E.[1*] and John A. T.[2]
[1]Department of Civil Engineering, University of Benin, Benin City, Nigeria
[2]Department of Civil Engineering, Niger Delta University, Bayelsa State, Nigeria
*Corresponding Author Email: Ebuka.nwankwo@uniben.edu

Article information

Article History
Received 10 January 2022
Revised 25 January 2023
Accepted 18 February 2023
Available online 16 March 2023

Keywords:
Stability, Flow, Sandcrete Block, Stone dust, Fillers, Asphalt concrete

https://doi.org /10.5281/zenodo.7741223

https://nipesjournals.org.ng

Abstract

This paper presents the results of the strength properties evaluation of asphalt concrete produced with sandcrete block powder. Sandcrete block powder (SBP) was used as a mineral filler, while stone dust (STD) filler was used in this research as the control material. Sixteen (16) asphalt concrete specimens were produced with 5 % bitumen, 40% fine aggregate, 60% coarse aggregate, and 2-5% filler proportions by weight of 8 kg. The samples were produced separately in 2, 3, 4, and 5% proportions by weight of each of SBP and STD. The aggregates were properly mixed and stirred while being heated to a temperature of 1000–1200 °C. A total of sixteen (16) cylindrical asphalt concrete samples were produced with 5% bitumen, 2 to 5% fillers (SBP and STD), 40% fine aggregate, and 60% coarse aggregate proportions by weight. Eight (8) samples were submerged in water for 24 hours from the sixteen (16) samples in view. The Marshall stability test examined the flow and stability of the asphalt concrete samples. The results showed that using sandcrete block powder as a filler material increases stability by up to 340%. However, it reduces when the asphalt concrete samples are soaked. The optimum stability value was reached at 2% sandcrete block powder as filler. The sandcrete block powder as filler in asphaltic concrete production should not be more than 3%. Asphaltic concrete's stability and flow results conform to the specifications stated by the Asphalt Institute. This makes the sandcrete block powder suitable for use in asphaltic concrete production.

1. Introduction

The study on construction waste materials as a possible alternative in asphalt concrete production is of global interest because it reduces construction costs, encourages global sustainability, reduces waste in the environment, and preserves natural resources [1].

Asphalt concrete, according to Garber and Hoel [2], is a composite material that comprises a binder and mineral aggregates (filler, fine and coarse aggregates) in different proportions. Filler plays a significant role in the asphalt concrete mix. In terms of engineering properties, filler contributes to the toughness and stiffness of asphalt concrete [3]. According to Recasens et al [4], filler potentially modifies the aging process as well.

With fast economic growth and incessantly increasing development, considerable construction waste is generated [5]. Waste is dumped into the environment without being properly treated. When it enters the soil, it causes the buildup of hazardous compounds and, in certain circumstances, nutritional enrichment [6]. Several investigations have demonstrated that the chemical properties of mineral filler have a considerable effect on the mechanical properties of asphalt concrete [7]. As a result, the concept of using recycled materials in asphalt pavements has attracted the interest of several highway engineers who are considering various study approaches to solve these enormous challenges [8, 9, 10] in the construction industry and explore the suitability of using construction waste as alternatives in asphalt pavements. Recently, scholars have actively researched the use of construction waste materials in place of conventional virgin construction materials owing to economic and environmental interests [11, 12, 13]. The use of waste materials not only provided an acceptable waste disposal system but also minimized both the need for virgin natural materials and the overall cost of development [14]. It has been recommended in highway construction to use the various waste materials generated from various activities instead of dumping them into the environment, causing significant amounts of environmental deterioration [15, 16]. According to Al-Mashgbeh [17], additives such as olive husk ash and rubber improved the resistance of asphalt mixes to permanent fatigue cracking and deformation at a lower cost than conventional asphalt-concrete mixtures. Dartnell [18] experimentally investigated the use of calcined shale, asbestos, and limestone dust as fillers in asphalt paving mixes. The author revealed that the order of preference is best-calcined shale, followed by limestone dust, and asbestos.

Sandcrete blocks are masonry components made of fine aggregate, cement, and water, and they are an essential part of building development. Sandcrete blocks are often employed for both non-load-bearing and load-bearing walls. Waste generated by sandcrete blocks during construction or demolition is an environmental concern that can only be reduced by reusing and recycling the waste it produces. Considering the sustainable management of waste and natural resources, the use of waste sandcrete block powder as a filler other than limestone powder in the asphalt concrete mix is worthwhile investigating. As a result, this paper aims at using sandcrete block powder generated during construction as an alternative material for the conventional mineral filler in the asphalt concrete mix.

2. Materials & Methods

2.1. Materials

The materials considered in this study were carefully chosen to meet the standard requirements for asphalt concrete production. The bitumen of 60-70 penetration grade was sourced from Ringardas Nigeria Limited in Port Harcourt, Rivers State, Nigeria, while the aggregates used were sourced from a construction site at Niger Delta University, Wilberforce Island, Nigeria. The fillers used are sandcrete block powder (SBP) and stone dust (STD). See Figure 1a for the sandcrete filler materials.

2.2. Sample Preparation

Sixteen (16) asphalt concrete specimens as shown in Figure 2. (a) were produced with 5 % bitumen, 40% fine aggregate, 60% coarse aggregate, and 2-5% filler proportions by weight of 8 kg . The samples were produced separately in 2, 3, 4, and 5% proportions by weight of each of SBP and STD. The aggregates were properly mixed and stirred while being heated to a temperature of 1000–1200 °C. See Table 1 for sample types. The completed mixture was poured into an asphaltic concrete mould of 0.105 m in diameter and 0.1154 m in height with a collar. Figure 2 depicts the asphalt concrete samples and cylindrical mould. Each sample has an approximate 1.2 kg weight.

Table 1: Sample Types

Sample ID	Configuration	Filler content %	Bitumen content (%)	Fine aggregate (%)	Coarse aggregate (%)
SBPU2	unsoaked	2.0	5.0	40	60
SBPU3	unsoaked	3.0	5.0	40	60
SBPU4	unsoaked	4.0	5.0	40	60
SBPU5	unsoaked	5.0	5.0	40	60
SBPS2	soaked	2.0	5.0	40	60
SBPS3	soaked	3.0	5.0	40	60
SBPS4	soaked	4.0	5.0	40	60
SBPS5	soaked	5.0	5.0	40	60
STDU2	unsoaked	2.0	5.0	40	60
STDU3	unsoaked	3.0	5.0	40	60
STDU4	unsoaked	4.0	5.0	40	60
STDU5	unsoaked	5.0	5.0	40	60
STDS2	soaked	2.0	5.0	40	60
STDS3	soaked	3.0	5.0	40	60
STDS4	soaked	4.0	5.0	40	60
STDS5	soaked	5.0	5.0	40	60

Figure 1: (a) Sandcrete block power (b) Stone dust

A 0.004536-ton rammer was used to compact the asphalt concrete samples on the compaction pedestal, 75 blows were given to one side of the sample, thereafter, the mould was reversed, and the same 75 blows were given to the opposite side. The compacted asphalt concrete samples are extracted from the mould with a sample ejector after 24hrs. To ascertain the effect of soaking on Marshall stability, eight (8) samples (SBPU2, SBPU3, SBPU4, SBPU5, STDU2, STDU3, STDU4, and STDU5) were submerged in water for 24 hours from the sixteen samples in view.

2.3. Method

Tests were carried out according to relevant codes on the bitumen used to examine their engineering properties in this study. Fire and flash point tests were conducted on bitumen according to ASTM

D92-16 [19] to examine its properties. The flow and strength properties of the samples with SBP and STD were investigated by carrying out a stability test according to ASTM D6927-15 [20].

(a) Samples of Asphaltic Concrete (b) Cylindrical Mould

Figure 2: (a) Samples of Asphaltic Concrete and (b) cylindrical mould

3.0 Results and Discussion

The results of the strength properties evaluation of asphalt concrete produced with sandcrete block powder are discussed in detail below.

3.1. Results of Tests on Bitumen

Table 2: Penetration and Flash and fire point test

Test	Unit	60/70 Grade		Result
		Min	Max	
Penetration Grade @25^{0}C	0.1mm	60	70	65
Specific gravity @ 25^{0}C		1.01	1.06	1.038
Flash point	^{0}C	230	300	Greater than 278.5
Softening point	^{0}C	46	54	49.8
Solubility in trichloroethylene	%WT	99	-	Greater than 99
Ductility @ 25^{0}C	CM			Greater than 100

Table 2 shows the outcome of this bitumen test. The average bitumen penetration value is 65 decimillimetres (dmm), indicating that the bitumen employed was 60/70 penetration grade bitumen. Table 2 also includes the results of a flash point test. The average flash point achieved from the test is 278.5^{0}C, which is within the allowed range of 230^{0}C to 300^{0}C. Similarly, the average softening point obtained is 49.8^{0}C. This measurement falls within the required range of 46^{0}C to 54^{0}C and indicates that the bitumen can be employed to produce asphalt.

3.2. Results of the Asphaltic Concrete

3.2.1. Marshall stability results

The Marshall Stability and flow performance of soaked and unsoaked asphaltic concrete samples with sandcrete block powder as filler are depicted in Tables 2 and 3. The results showed that when 2, 3, 4, and 5% sandcrete block powder was considered as fillers, the Marshall stability is 11, 6.5, 5.0, and 4.7 kN respectively. The optimum Marshall stability of 11.0 kN was attained at 2% with SBP and the least was recorded at 5% when SBP was used as filler. Figure 3 confirms that the stability values of soaked and unsoaked samples with sandcrete block powder decrease with an increase in sandcrete content.

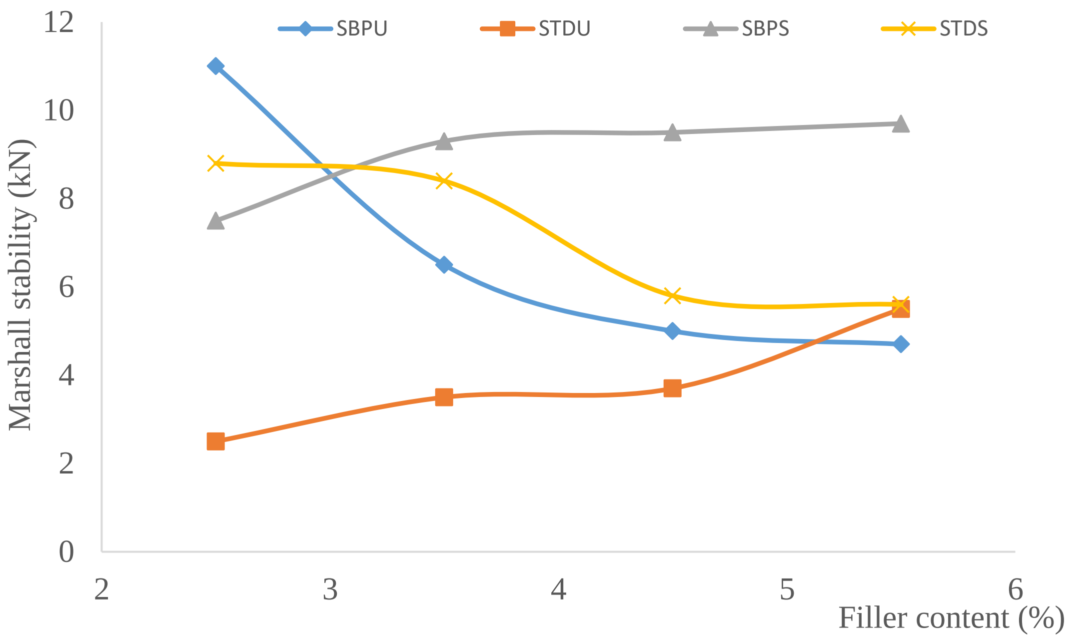

Figure 3: Marshall stability against filler content

The performance of soaked samples with sandcrete block powder as filler showed relative stability values, as evidently depicted in Figure 3 and Table 2. The results of the soaked sample showed that when 2, 3, 4, and 5% SBP were considered as fillers, the stability value was 7.5, 9.3, 9.5, and 9.7 kN, respectively. The optimum Marshall stability of 9.7 kN was reached at 5% with SBP.

Table 2: Marshall stability and flow performance for SBP

Sample ID	Marshall Stability (kN)	Flow value (mm)
SBPU2	11.0	3.8
SBPU3	6.5	2.4
SBPU4	5.0	2.7
SBPU5	4.7	2.4
SBPS2	7.5	3.0
SBPS3	9.3	3.8
SBPS4	9.5	3.6
SBPS5	9.7	2.2

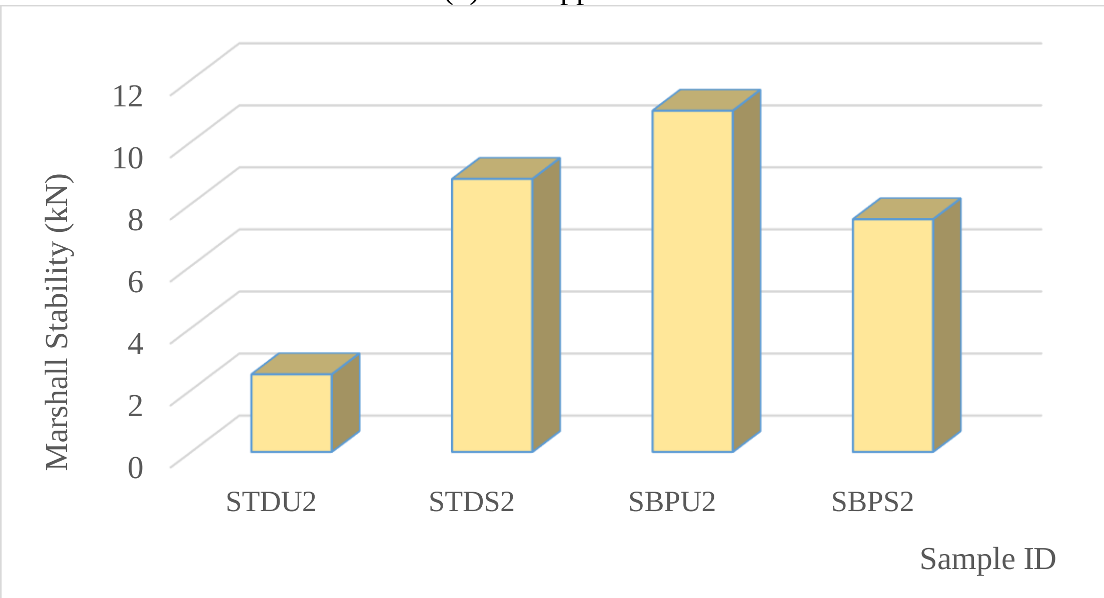

Figure 4: Marshall stability values for 2% filler

It is clear from Figures 4, 5, 6, and 7 that at 2% SBP as filler, the stability value reduces by 32% when soaked for 24 hrs. While at 3, 4, and 5% SBP as filler, the stability value increases by 43, 90, and 106% respectively when soaked for 24 hrs. The results followed the specifications as stated by the Asphalt Institute [21]. This makes the sandcrete block powder suitable for use in asphaltic concrete production.

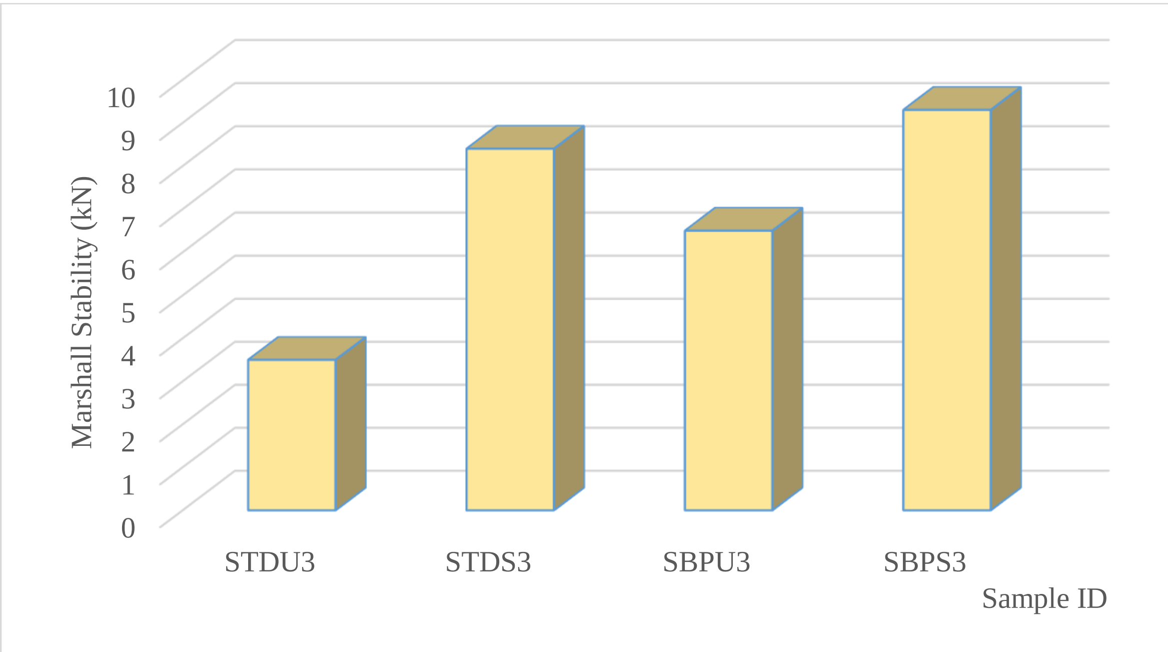

Figure 5: Marshall stability values for 3% filler

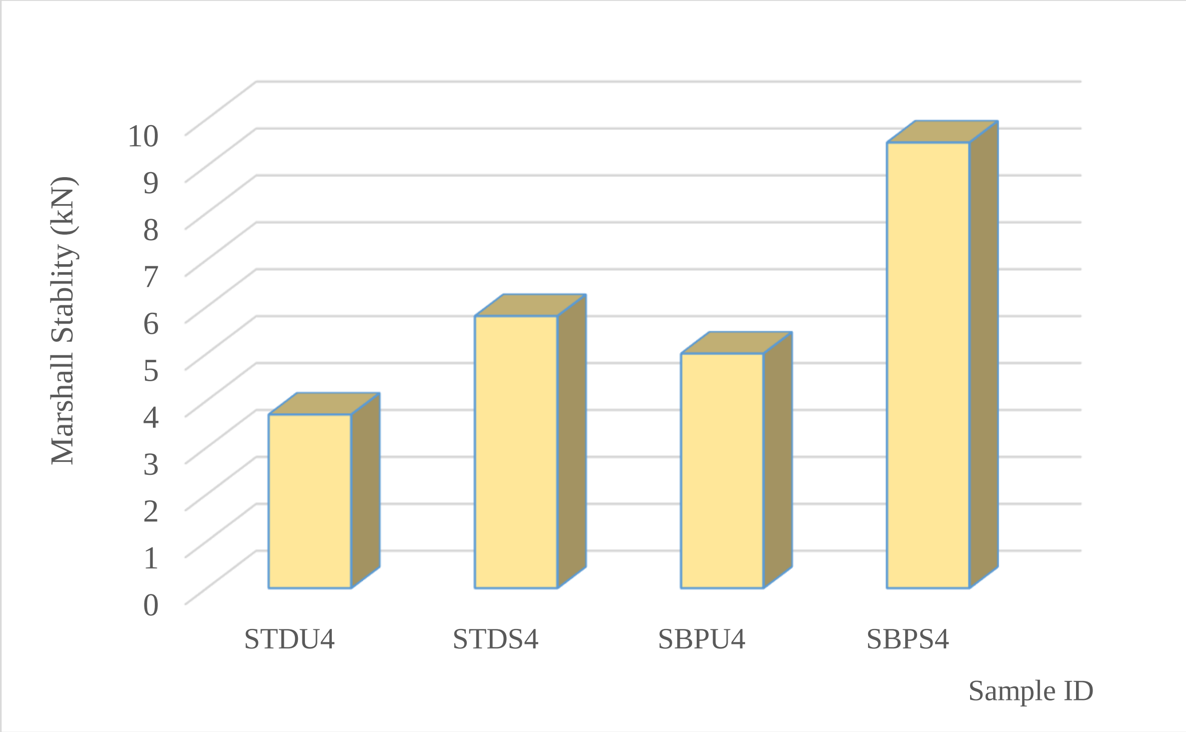

Figure 6: Marshall stability values for 4% filler

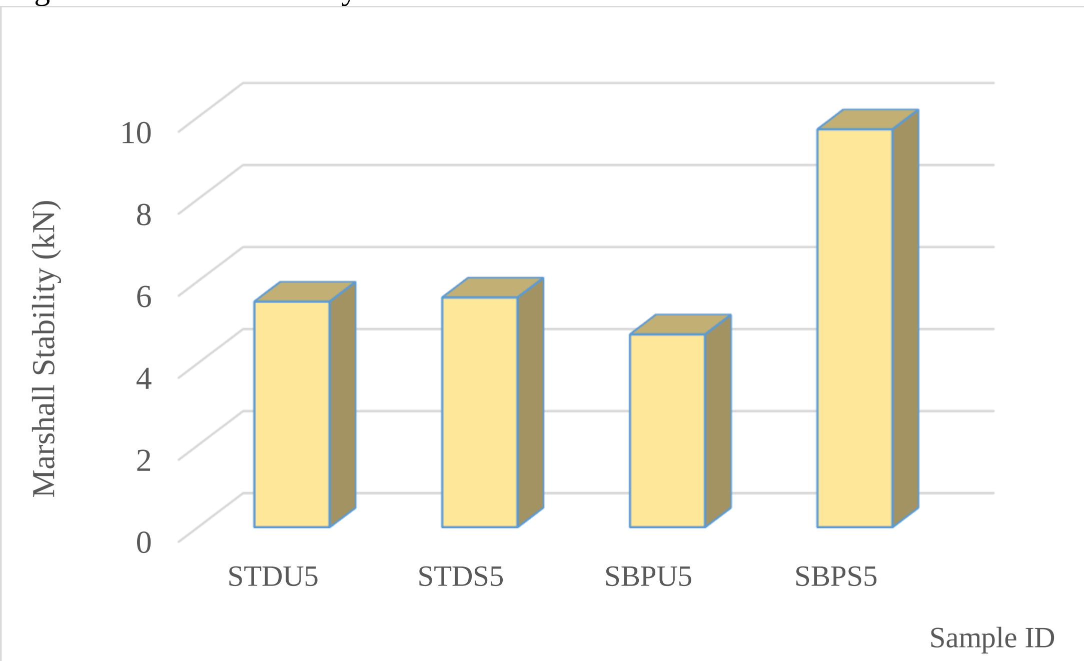

Figure 7: Marshall stability values for 5% filler

The variation of Marshall stability values with stone dust (conventional filler) content is depicted in Figure 3 and Table 3. Figure 3 shows that for an unsoaked sample, the stability value increases with an increase in stone dust content, while the stability of soaked samples decreases as the filler content increases. A comparison of asphalt concrete samples SBP and STD indicates marginal stability improvements in SBP. For unsoaked samples, an increase in stability of 340, 86, and 35% for 2, 3, and 4% SBP, respectively, was observed, while the stability increased by 10.3, 64, and 73% for 3, 4, and 5% SBP of soaked samples.

Table 3: Marshall stability and flow performance for STD

Sample ID	Marshall Stability (kN)	Flow value (mm)
STDU2	2.5	4.0
STDU3	3.5	3.3
STDU4	3.7	3.8
STDU5	5.5	2.4
STDS2	8.8	3.6
STDS3	8.4	2.0
STDS4	5.8	2.8
STDS5	5.6	2.0

3.2.2. Flow results

The flow values of soaked and unsoaked asphaltic concrete samples with SBP and STD as fillers are depicted in Tables 2 and 3. The variation of flow values with SBP and STD is presented in Figures 8, 9, 10, 11, and 12, which show that the flow of the SBP soaked samples increases initially, attains an ultimate flow value, and then decreases with an increase in SBP percent, while the SBP unsoaked samples decrease initially, reach a minimum value with an increase in SBP content. However, all of these flow values presented in Tables 2 and 3 are within the range recommended by the Asphalt Institute [21], which states that the flow values should be between 2-4 mm.

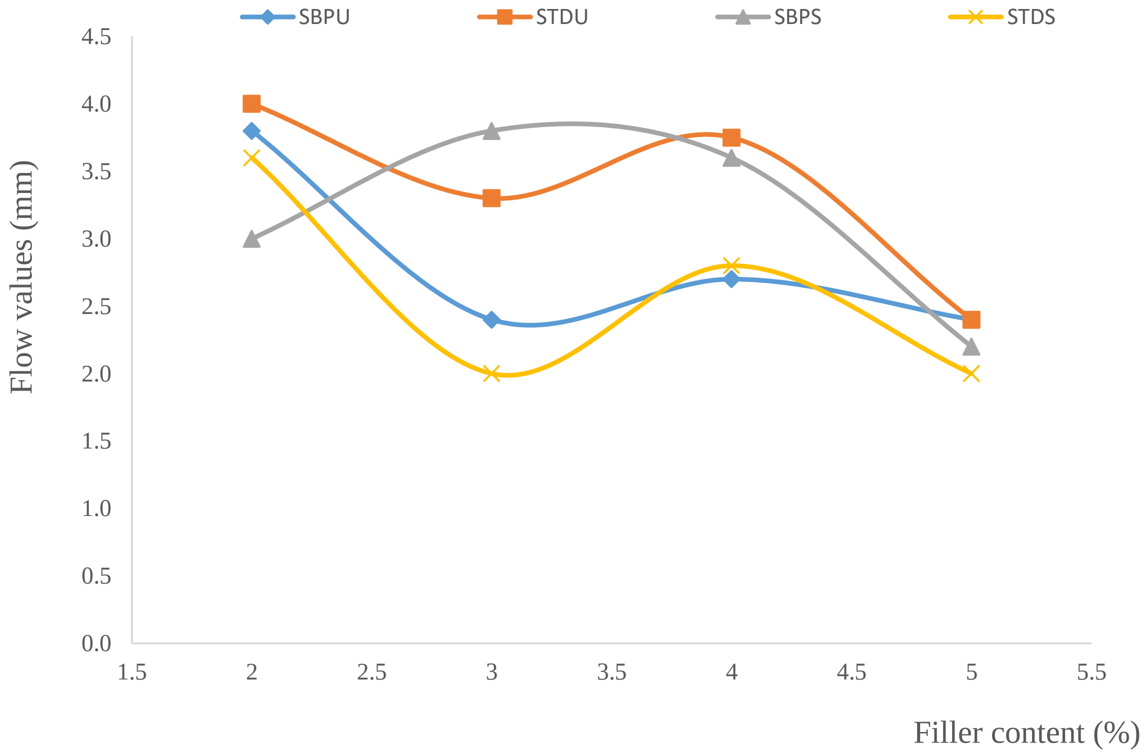

Figure 8: Flow against Filler content.

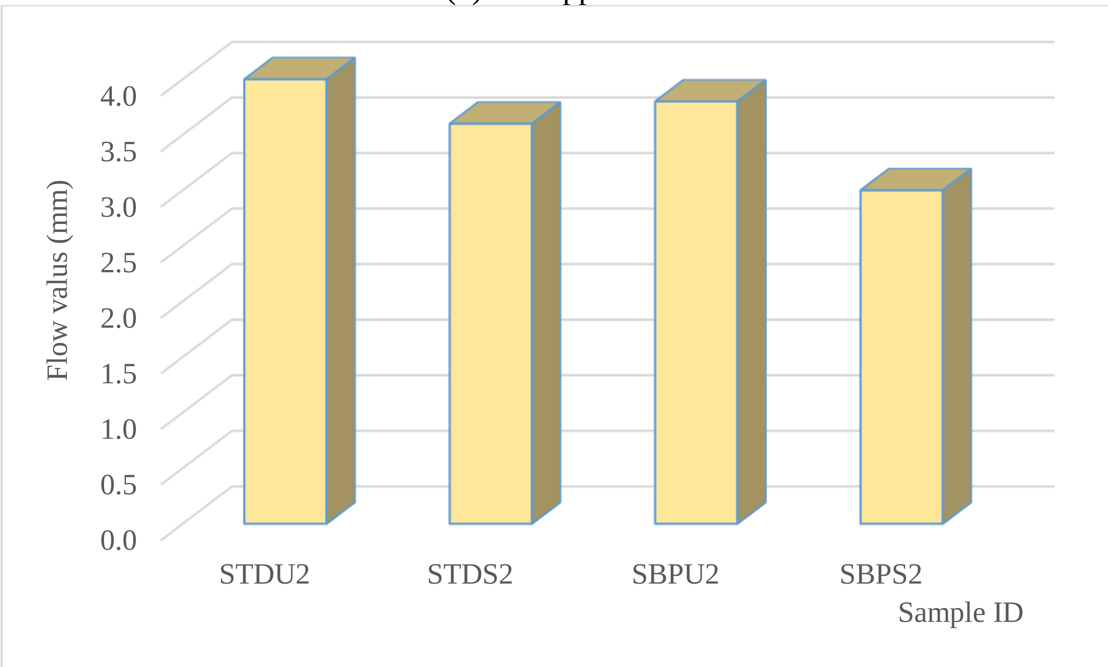

Figure 9: Flow values for 2% filler

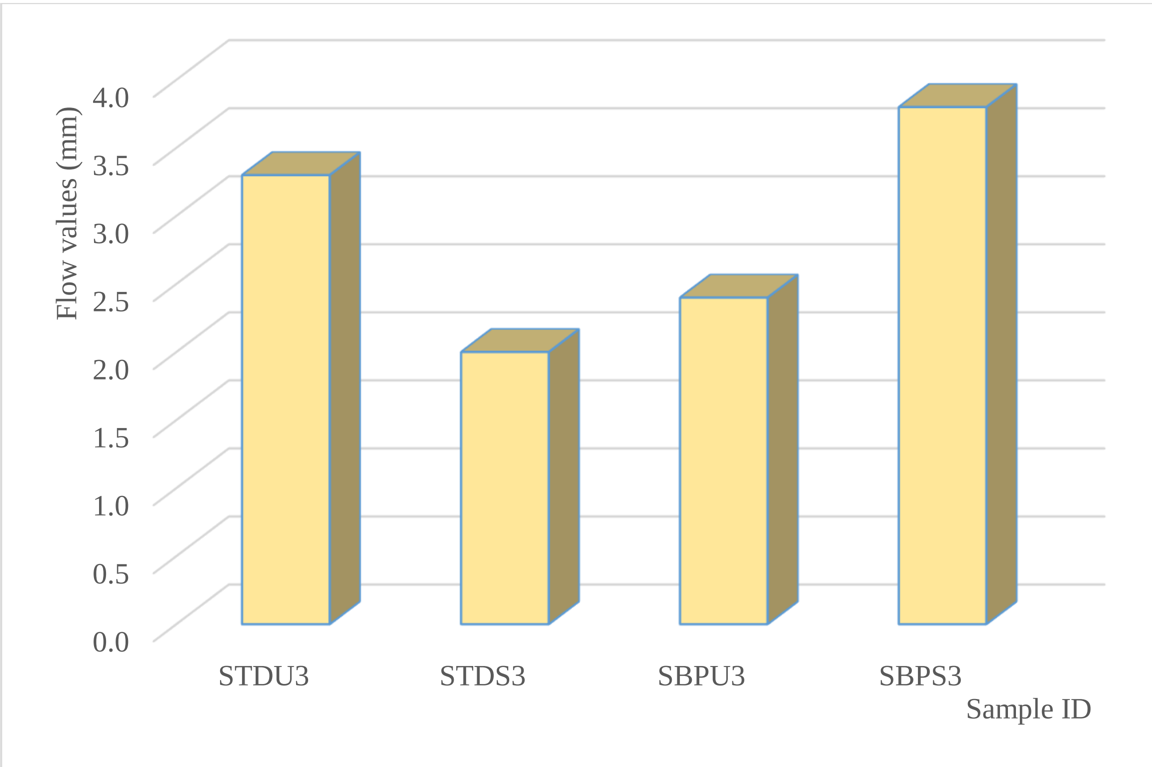

Figure 10: Flow values for 3% filler

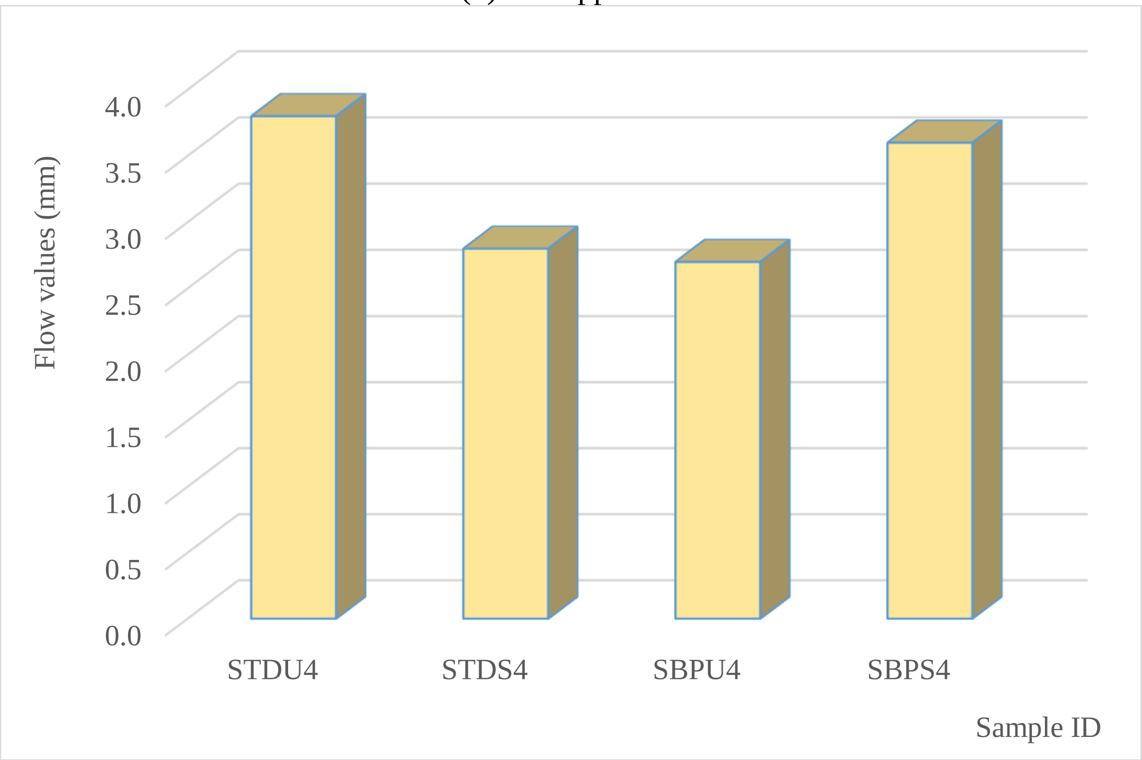

Figure 11: Flow values for 4% filler

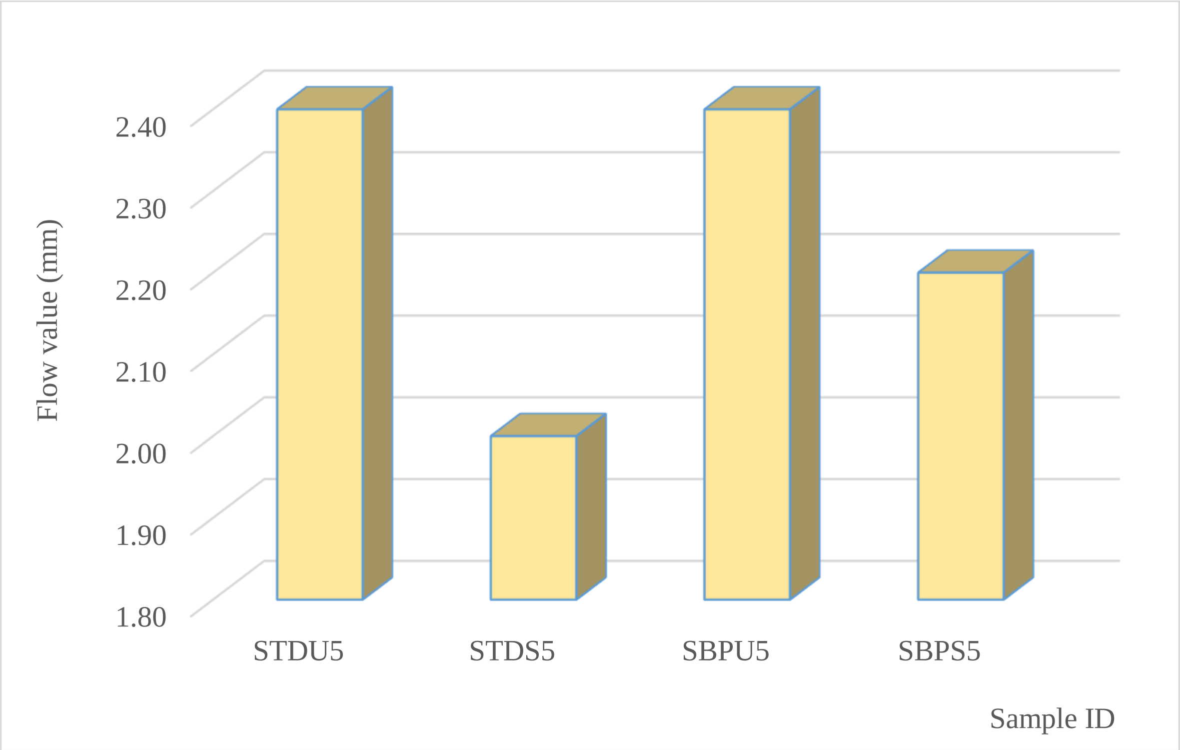

Figure 12: Flow values of 5% filler

4.0 Conclusion

The strength properties of asphaltic concrete with sandcrete block powder have been investigated and the following conclusions are drawn:

i. The stability and flow results of the asphaltic concrete conform to the specifications as stated by the Asphalt Institute (1997). This makes the sandcrete block powder suitable for use in asphaltic concrete production.

ii. Sandcrete block powder as a filler material increases stability by up to 340%. However, it reduces when the asphalt concrete samples are soaked.

iii. The optimum stability value was reached at 2% sandcrete block powder as filler.

iv. The sandcrete block powder as filler in asphaltic concrete production should not be more than 3%.

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