# A STUDY ON THE MARSHALL STABILITY AND FLOW PARAMETERS OF SDBC MIXED WITH WASTE PLASTIC

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## Abstract

Semi Dense Bituminous Concrete (SDBC) is a composite material for the most part utilized as a part of development activities like street surfacing, airplane terminals, parking areas and so on. It comprises of bitumen (use as a binder) and mineral total which are combined and set down in layers and after that compacted.

Presently days, the enduring addition in high movement power regarding business vehicles, and the critical variety in day by day and regular temperature place us in a requesting circumstance to think about a few choices for the asphalt attributes and quality by applying some essential adjustments which might fulfill both the quality and in addition efficient angles.

Likewise considering the ecological approach, because of inordinate utilization of plastic in everyday business, the contamination to the earth is colossal. Since the plastic is non-biodegradable, the need of the present hour is to utilize the waste plastic in some valuable purposes.

This theory displays an examination directed to concentrate the conduct of SDBC mix changed with waste plastic.

Different percentage of waste plastic are utilized for preparing the mix by following the procedure given in the IRC Code. The part of waste plastic in the mix is to concentrate the different building properties by planning Marshall Test of SDBC mix with and without polymer. Marshall Properties, for example, stability, flow value, unit weight, air voids, voids filled with bitumen are utilized to decide optimum bitumen.

## Introduction

During 1900's bitumen pavements was first introduced to rural roads in order to prevent WBM roads from disintegration due to fast growth of motor cars. **Sulyman et al. 2014 [1]** Heavy oils were used to settle the dust. An eye estimation process which is called pat test was used to estimate the required quantities of the heavy oil in the mix. Sand-Bitumen mixture was used to make the first mix design for flexible pavements and known as Habbard field method. There was one limitation in this method that it cannot deal with the mixtures having large sized aggregates. Hveem, 1942; developed the Hveem stabilometer in 1927. He did not have any idea about the quantity of bitumen required to be used in a mix so, he used the surface area calculation concept (which was used to design PCC mix), to calculate the optimum bitumen required for a mix. Marshall developed the Marshal Testing Machine before the World War II. In 1930 US Army Corps of Engineer adopted it and in 1940 modified it further.

Bituminous Concrete mixes are used all over the world in the construction of roads. A Bituminous road has different layers of different thickness consists of aggregates of different sizes in all layers and the top layer is laid with bituminous concrete. Rigid and Flexible are the two types of pavements we used:

- **Rigid Pavement**

A concrete slab of good strength is used as a road top to resist heavy loads from traffic. Flexural strength of concrete plays an important role in the design of rigid pavement. The rigid pavement has rigidity and high modulus of elasticity to distribute the load over a relatively wide area of soil. A rigid pavement is constructed from PCC or RCC slabs so, when the sub grade disperse down the slab of rigid pavement, the PCC or RCC slab is able to resist the flexural strength failure and the stresses due to slab action.

- **Flexible Pavement**

Flexible pavement layers reflect the deformation of the lower layers onto the surface layers in the form of cracks, rutting and pot holes. These pavements have low or insufficient flexural strength and are flexural in nature under loads. The load transfers in this type of pavements in to the lower layers by grain to grain through the point of contact. Flexible pavements are most commonly used in India and bituminous mix design is used to lay the pavements which aims to determine the proportion of coarse aggregates, fine aggregates, fillers & bitumen. Highway constructions are turnkey projects needs a massive investment. A good highway design can save lots of investment and help to make the project economically strong and a better performance from the highway can be achieved and to make bituminous mix design Marshall Test is performed.

## Need of Modification in Bituminous Mixes

The day by day increase in the traffic increases the load on the pavement & changing climatic conditions around leads to its wear and tear and ultimately affects the life and performance of the bituminous mix pavements. Therefore, modification in the bituminous mixes is the demand of today's traffic so; we can improve the strength and increase the life of a bituminous pavement. There are many waste material available which can be use to modify bituminous mix like crumb rubber, waste plastic, fly ash, marble dust etc in order to increase the efficiency and life of the flexible pavements.

## Waste plastic is a concern

Plastics are durable & non-biodegradable; the chemical bonds make plastic very durable & resistant to normal natural processes of degradation. A study says around 1 billion tons of plastic have been disposed of, and this may continue for many years or even, a great many decades. The plastic gets mixed with water, doesn't break down, and appears as little pallets which cause the death of fishes and numerous other sea-going creatures that eat them as nourishment materials.

Today the garbage of the waste plastic is gigantic, as the plastic materials have turned into the vital part, of our everyday life. It is possible that they get blended with the Municipal Solid Waste or tossed over a land territory. On the off chance that they are not reused, their present transfer might be via land filling or it might be by incineration. Both the procedures colossal affect on nature. On the off chance that they are burned, they pollute the air and on the off chance that they are dumped into some place, they cause soil and water contamination. Under these conditions, a substitute use for this plastic waste is required. So, I decide to modify SDBC with waste plastic for my thesis work.

## Waste Plastic in SDBC Mix

BC mix modification, with the different polymers can be good a solution to overcome the problems that we are facing now days like rapid increase in wheel loads and change in climatic conditions. It can also help us to improve the fatigue life, reduce the rutting & thermal cracking in the flexible pavement.

Bitumen, when mixed with the polymer, forms a complex structure which partly isolates it from bitumen and not absorbed by the polymer. This builds the consistency of the SDBC mix by forming a more internal complex structure. Plastic has good sound absorbing properties so it helps in reducing noise from the roads and plastic also not allow seepage of water which increase the life and save the pavement from disintegration due to rains.

## Materials used

The materials used are as follows.

Aggregates

Mineral Fillers

Bitumen

Waste Plastic

**GRADATION OF AGGREGATES**

| **GRADING** | **1** | **2** | **GRADATION Used** |
|---|---|---|---|
| Nominal aggregate size | **13mm** | **10mm** | **10mm** |
| Layer thickness | **35-40mm** | **25-30mm** | **25-30mm** |
| Is sieve (mm) | **Cumulative % by weight of total aggregate passing** | | |
| 19 | 100 | - | - |
| 13.2 | 90-100 | 100 | 100 |
| 9.5 | 70-90 | 90-100 | 95 |
| 4.75 | 35-51 | 35-51 | 45 |

| GRADING | 1 | 2 | GRADATION Used |
|---|---|---|---|
| 2.36 | 24-39 | 24-39 | 30 |
| 1.18 | 15-30 | 15-30 | 15 |
| 0.6 | - | - | - |
| 0.3 | 9-19 | 9-19 | 10 |
| 0.15 | - | - | - |
| 0.075 | 3-8 | 3-8 | 5 |

Specific Gravity of Coarse aggregate = 2.60

Specific Gravity of Fine aggregate = 2.02

Specific gravity of filler = 1.78

## Results & Discussion

This chapter contains all the results of experimental work done on aggregates, bitumen and Marshall Test carry out with different proportion of waste plastic in SDBC mix prepared with these aggregates & bitumen and the plotted graphs of Marshall parameters

## Test Results

Bitumen

- Aggregates

## Bitumen

**TEST RESULT ON BITUMEN**

| PROPERTIES | TEST METHOD | SPECIFICATIONS AS PER IS: 73 (2007) | RESULTS |
|---|---|---|---|
| PENETRATION | IS:1203-1978 | 6.5-7.5 MM | 6.74 MM |
| SPECIFIC GRAVITY | IS:1202-1978 | 0.99-1.02 | 0.99 |
| DUCTILITY | IS:1208-1978 | Min 75 CM | 77 CM |
| SOFTENING POINT | IS:1205-1978 | Min 40°C | 58°C |

## Aggregates

**TEST RESULT ON AGGREGATES**

| TEST | TEST METHOD | SPECIFICATION | RESULTS |
|---|---|---|---|
| Grain size analysis | IS:2386(Part I) [ISI 62] | Max 5% passing 0.075mm sieve | 4.17 % |
| Flakiness and Elongation indices (total) | IS:2386(Part I) [ISI 62] | 30 % (max) | 28.451 % |
| Water Absorption | IS:2386(PartIII) [ISI 62] | 2.0 % (max) | 1.46 % |
| Crushing value | IS:2386(PartIII) [ISI 62] | -- | 21.07 % |
| Los Angeles Abrasion value | IS:2386(PartIV) [ISI 62] | 35 % (max) | 19.40 % |
| Impact Value | IS:2386(PartIV) [ISI 62] | 27 % (max) | 16.03 % |
| Soundness Test | IS:2386(Part V) [ISI 62] | 12 % (max) | 9.89 % |

## Calculated Values of Marshall Parameters

Bulk Density

Marshall Stability & Flow Values

Vv & VFB

## Bulk Density

**Calculated Bulk Density**

| Sample No. | W.P (%) | Bitumen content (%) | Wt. of sample (kg) | Submerged Wt. of sample | Bulk Density | Average |
|---|---|---|---|---|---|---|
| 1 | 0 | 5.0 | 1272.5 | 626.5 | 1.969 | 1.980 |
| 2 | 0 | 5.0 | 1263.0 | 629.0 | 1.992 | |
| 3 | 0 | 5.0 | 1266.5 | 627.0 | 1.980 | |
| 4 | 0 | 5.5 | 1242.0 | 627.0 | 2.019 | 2.008 |
| 5 | 0 | 5.5 | 1241.0 | 621.5 | 2.003 | |
| 6 | 0 | 5.5 | 1257.0 | 630.0 | 2.004 | |
| 7 | 0 | 6.0 | 1227.0 | 619.5 | 2.019 | 2.000 |
| 8 | 0 | 6.0 | 1225.0 | 612.0 | 1.998 | |
| 9 | 0 | 6.0 | 1267.0 | 637.0 | 2.011 | |
| 10 | 5 | 5.0 | 1197.5 | 621.0 | 1.984 | 1.986 |
| 11 | 5 | 5.0 | 1211.0 | 624.5 | 1.991 | |
| 12 | 5 | 5.0 | 1218.5 | 630.0 | 1.985 | |
| 13 | 5 | 5.5 | 1209.0 | 626.0 | 1.984 | |

| Sample No. | W.P (%) | Bitumen content (%) | Wt. of sample (kg) | Submerged Wt. of sample | Bulk Density | Average |
|---|---|---|---|---|---|---|
| 14 | 5 | 5.5 | 1226.0 | 630.0 | 1.996 | 1.993 |
| 15 | 5 | 5.5 | 1243.0 | 621.0 | 2.001 | |
| 16 | 5 | 6.0 | 1191.0 | 619.0 | 1.980 | |
| 17 | 5 | 6.0 | 1184.5 | 612.0 | 1.994 | 1.987 |
| 18 | 5 | 6.0 | 1181.0 | 612.5 | 1.988 | |
| 19 | 10 | 5.0 | 1257.5 | 617.0 | 1.963 | |
| 20 | 10 | 5.0 | 1262.0 | 618.0 | 1.959 | 1.970 |
| 21 | 10 | 5.0 | 1263.0 | 628.0 | 1.988 | |
| 22 | 10 | 5.5 | 1269.0 | 631.0 | 1.989 | |
| 23 | 10 | 5.5 | 1254.5 | 624.0 | 1.989 | 1.995 |
| 24 | 10 | 5.5 | 1261.0 | 633.0 | 2.007 | |
| 25 | 10 | 6.0 | 1234.5 | 610.0 | 1.976 | |
| 26 | 10 | 6.0 | 1251.0 | 629.0 | 2.011 | 1.990 |
| 27 | 10 | 6.0 | 1277.5 | 640.0 | 2.003 | |
| 28 | 15 | 5.0 | 1266.5 | 633.0 | 1.992 | |
| 29 | 15 | 5.0 | 1238.0 | 610.0 | 1.971 | 1.993 |
| 30 | 15 | 5.0 | 1243.5 | 619.5 | 1.992 | |
| 31 | 15 | 5.5 | 1217.5 | 606.5 | 1.992 | |
| 32 | 15 | 5.5 | 1247.0 | 623.5 | 2.000 | 1.999 |
| 33 | 15 | 5.5 | 1261.5 | 633.0 | 2.007 | |
| 34 | 15 | 6.0 | 1241.0 | 617.0 | 1.988 | |
| 35 | 15 | 6.0 | 1245.0 | 619.5 | 1.990 | 1.990 |
| 36 | 15 | 6.0 | 1256.0 | 626.0 | 1.993 | |

## Marshall Stability and Flow Values

**Calculated Marshall Stability and Flow Values**

| Sample No. | W.P (%) | Bitumen content (%) | Stability Value (kg) | Average (kg) | Flow Value (mm) | Average (mm) |
|---|---|---|---|---|---|---|
| 1 | 0 | 5.0 | 721 | | 2.76 | |
| 2 | 0 | 5.0 | 959 | 883 | 2.73 | 2.73 |
| 3 | 0 | 5.0 | 967 | | 2.70 | |
| 4 | 0 | 5.5 | 719 | | 2.78 | |
| 5 | 0 | 5.5 | 1153 | 1056 | 3.01 | 3.07 |
| 6 | 0 | 5.5 | 1296 | | 3.44 | |
| 7 | 0 | 6.0 | 735 | | 3.76 | |
| 8 | 0 | 6.0 | 727 | 721 | 3.73 | 3.65 |

| Sample No. | W.P (%) | Bitumen content (%) | Stability Value (kg) | Average (kg) | Flow Value (mm) | Average (mm) |
|---|---|---|---|---|---|---|
| 9 | 0 | 6.0 | 701 | | 3.46 | |
| 10 | 5 | 5.0 | 1066 | | 3.35 | |
| 11 | 5 | 5.0 | 983 | 1045 | 3.28 | 3.39 |
| 12 | 5 | 5.0 | 1088 | | 3.54 | |
| 13 | 5 | 5.5 | 1246 | | 3.03 | |
| 14 | 5 | 5.5 | 1335 | 1166 | 3.75 | 3.56 |
| 15 | 5 | 5.5 | 917 | | 3.88 | |
| 16 | 5 | 6.0 | 853 | | 4.31 | |
| 17 | 5 | 6.0 | 1055 | 994 | 4.54 | 4.01 |
| 18 | 5 | 6.0 | 1074 | | 4.20 | |
| 19 | 10 | 5.0 | 832 | | 3.86 | |
| 20 | 10 | 5.0 | 1068 | 1040 | 3.59 | 3.76 |
| 21 | 10 | 5.0 | 1220 | | 3.84 | |
| 22 | 10 | 5.5 | 1298 | | 3.56 | |
| 23 | 10 | 5.5 | 1993 | 1735 | 4.07 | 3.94 |
| 24 | 10 | 5.5 | 1915 | | 4.21 | |
| 25 | 10 | 6.0 | 848 | | 4.21 | |
| 26 | 10 | 6.0 | 1201 | 1176 | 4.20 | 4.73 |
| 27 | 10 | 6.0 | 1480 | | 4.80 | |
| 28 | 15 | 5.0 | 1280 | | 6.91 | |
| 29 | 15 | 5.0 | 1595 | 1551 | 6.74 | 6.68 |
| 30 | 15 | 5.0 | 1778 | | 6.40 | |
| 31 | 15 | 5.5 | 2416 | | 6.39 | |
| 32 | 15 | 5.5 | 2104 | 1988 | 7.67 | 7.29 |
| 33 | 15 | 5.5 | 1444 | | 7.83 | |
| 34 | 15 | 6.0 | 1100 | | 7.81 | |
| 35 | 15 | 6.0 | 1482 | 1326 | 7.51 | 7.77 |

## Vv, VMA, VFB

**Calculated Vv, VMA & VFB**

| Sample No. | W.P (%) | Bitumen content (%) | Vv (%) | Mean (%) | VMA (%) | Mean (%) | VFB (%) | Mean (%) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 5 | 4.08 | | 13.55 | | 69.88 | |
| 2 | 0 | 5 | 4.08 | 4.21 | 13.66 | 13.73 | 70.13 | 69.39 |
| 3 | 0 | 5 | 4.47 | | 13.99 | | 68.04 | |
| 4 | 0 | 5.5 | 3.89 | | 14.51 | | 73.19 | |

| Sample No. | W.P (%) | Bitumen content (%) | Vv (%) | Mean (%) | VMA (%) | Mean (%) | VFB (%) | Mean (%) |
|---|---|---|---|---|---|---|---|---|
| 5 | 0 | 5.5 | 3.15 | 3.75 | 14.28 | 14.52 | 76.97 | 73.84 |
| 6 | 0 | 5.5 | 4.23 | | 14.77 | | 71.36 | |
| 7 | 0 | 6 | 3 | | 14.22 | | 78.9 | |
| 8 | 0 | 6 | 3.7 | 3.56 | 14.89 | 14.82 | 75.15 | 75.66 |
| 9 | 0 | 6 | 3.99 | | 15.35 | | 74 | |
| 10 | 5 | 5 | 4.47 | | 14.01 | | 68.09 | |
| 11 | 5 | 5 | 4.03 | 4.06 | 13.6 | 13.61 | 70.36 | 70.2 |
| 12 | 5 | 5 | 3.68 | | 13.22 | | 72.16 | |
| 13 | 5 | 5.5 | 4.08 | | 14.51 | | 71.88 | |
| 14 | 5 | 5.5 | 3.12 | 3.54 | 13.62 | 14.02 | 77.09 | 74.79 |
| 15 | 5 | 5.5 | 3.43 | | 13.95 | | 75.41 | |
| 16 | 5 | 6 | 3.6 | | 14.91 | | 75.85 | |
| 17 | 5 | 6 | 3.2 | 3.5 | 14.59 | 14.85 | 78.06 | 76.44 |
| 18 | 5 | 6 | 3.7 | | 15.06 | | 75.43 | |
| 19 | 10 | 5 | 5 | | 14.34 | | 65.13 | |
| 20 | 10 | 5 | 4.9 | 4.53 | 14.22 | 13.9 | 65.54 | 67.51 |
| 21 | 10 | 5 | 3.7 | | 13.16 | | 71.88 | |
| 22 | 10 | 5.5 | 5 | | 15.46 | | 67.65 | |
| 23 | 10 | 5.5 | 4.6 | 4.16 | 15.06 | 14.81 | 69.45 | 71.84 |
| 24 | 10 | 5.5 | 3 | | 13.92 | | 78.44 | |
| 25 | 10 | 6 | 4.4 | | 15.69 | | 71.95 | |
| 26 | 10 | 6 | 4.5 | 4.03 | 15.99 | 15.44 | 71.85 | 73.96 |
| 27 | 10 | 6 | 3.2 | | 14.66 | | 78.1 | |
| 28 | 15 | 5 | 4.8 | | 14.38 | | 66.62 | |
| 29 | 15 | 5 | 4.4 | 4.26 | 13.87 | 13.81 | 68.27 | 69.19 |
| 30 | 15 | 5 | 3.6 | | 13.18 | | 72.68 | |
| 31 | 15 | 5.5 | 3.2 | | 13.67 | | 76.59 | |
| 32 | 15 | 5.5 | 4 | 3.76 | 14.52 | 14.28 | 72.45 | 73.68 |
| 33 | 15 | 5.5 | 4.1 | | 14.65 | | 72.01 | |
| 34 | 15 | 6 | 3.7 | | 15.08 | | 75.46 | |
| 35 | 15 | 6 | 3.1 | 3.43 | 14.47 | 15.81 | 78.57 | 76.84 |
| 36 | 15 | 6 | 3.5 | | 14.89 | | 76.49 | |

## Conclusion

This research studies the use of waste plastic to create modified Semi-Dense Bituminous Concrete for paving high strength roads for heavy traffic. For this waste plastic in different proportions was added in bitumen & samples were prepared and from the calculated results following conclusions were drawn:

- It was observed that modified SDBC mix gives improved results of Marshall Characteristics than conventional SDBC mix.
- It is observed that the Marshall Stability values increases with the increase in waste plastic for the aggregates and bitumen used.
- The optimum bitumen content of the bitumen used was found to be 5.5% at which samples get the high stability values.
- At 5.5% of bitumen content and 0%, 5%, 10% & 15% of waste plastic stability values were 1056 kg, 1166 kg, 1735 kg & 1988 kg respectively, but the flow values were found to be within permissible limits as specified by MORTH up to 10% addition of waste plastic
- The other parameters ofkMarshall Test like Vv, VFB & Unit weight were under specified limits of MORTH for SDBC.
- The stability value was kept on increasing even after the addition of 15% of waste plastic and the flow value too which shows waste plastic increase the melting point of bitumen and will results in rutting, potholes & disintegration of roads.
- The optimum waste plastic content to be used in modified SDBC mixes should be 5% to 10%.
- This study has an affirmative impact on the environment as it not only helps in reducing plastic waste but also gives us high strength roads with long life.

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