New Laboratory Mix Methodology of Microsurfacing and Mix Design

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Abstract

Microsurfacing was introduced in Germany, Spain, and France since 1976 and in the United States in 1980 (NCHRP 411, 2010). In India, it was introduced only in 1999-2000 (Yala construction, 2011) under the brand name, Macroseal by Yala construction and Elsamex SA, Spain. Established mix methodologies (Kharagpur and TxDOT methods) were evaluated and balling appeared to be still present with this method. A different mix methodology was explored and observed to have reduce or solve balling, the common problem of mixing coarse, fine aggregates with emulsion. The mix methodology was developed for type II, and type III gradation for microsurfacing and was adopted for the study. By adopting the mixing methodology, break time, setting times and consistency test were evaluated with variable water content 5%, 7%, 8% 10%. The consistency value observed was between 2cm to 4cm and that microsurfacing of Type II and III satisfies all the criteria given in Technical Bulletin of ISSA.

Modified marshal test was also carried out to determine the optimum residual bitumen content. It was found that at 4% air voids the optimum residual bitumen content for Type III gradation is 10% and for Type II gradation is 7.7% and at these optimum contents, flow, air voids, VFB and VMA satisfy the requirement of Marshall Criteria.

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1. Introduction

Road transport is considered to be one of the most cost-effective and preferred modes of transport for both freight and passengers. India has an extensive road network of 4.24 million km, the second largest in the world. The National Highways have a total length of 70,934 km and serve as the arterial road network across the country (Kumar & Ryntathiang, 2012). It’s estimated that roads handled more than 70% and 85% of freight and passenger traffic throughout the country. Expressways and highways constitute only about 2% of the entire road length in India, but they carry about 40% of the road traffic, leading to a strain on their capacity (NHAI, 2011).

The focus of roadway activity in the early to mid-20th century was on the construction of new pavements. In the latter part of the 20th century continuing into the 21st century, this focus has been shifted to maintenance and rehabilitation of pavement infrastructures (Guignier and Madanat, 1999). Maintenance includes actions that can retard or correct the deterioration of infrastructure facilities. These actions include crack sealing, resurfacing, etc. and pavements must be selected for maintenance when they are still effective. In most cases, the proper time to apply maintenance is before the need is apparent to the casual observer. This is because once pavements start to deteriorate; they deteriorate rapidly beyond the point where maintenance is ineffective. One of the solutions for preventive maintenance of pavement is microsurfacing.

Microsurfacing has been used in Germany, Spain, and France since 1976 and was introduced to the United States in 1980 (NCHRP 411, 2010). Though microsurfacing has been in use worldwide for a very long time as a routine form of maintenance in preference to the conventional overlays of the hot mix, it was introduced to India only in 1999-2000 by Yala Construction, SA Spain (2011) under the brand name, Macroseal. Indian specifications of microsurfacing are governed by IRC SP: 81.

The methodology of mix design for microsurfacing as described by ASTM and ISSA, clearly stated that the methods for mix design should be used only as a guide. Therefore, a more exact method is needed to provide successful mix designs, based on performance-related tests included in the design method rather than relying heavily on the experience of the construction crew with these types of treatments. The two method ‘Laboratory method of mixing and curing microsurfacing mixtures (TxDOT, 2004)’ and “A Laboratory Investigation on Bitumen-Emulsion Mixes” (Tipnis and Pandey, 2001) have been tried in the laboratory but there were some limitations to these methods as balling could not stop completely unless a very careful mixing of the mix is taken care off. Therefore, a different mixing methodology of mixing coarse and fine aggregates with emulsion is explored and is explained in section 2 (“New Laboratory Modified Mix Method’) where it is found that forming of a ball during the mixing of aggregates with emulsion appeared to have been solved, and no balling was formed.

2. New laboratory modified mix methodology

The aggregate collected from the Gurunanak crusher plant nearby IIT-Guwahati has been used for this study. Three type of aggregate sample has collected from crusher plant. Sample 1 is coarse aggregate which is 9.5 mm passing and 4.75 retained. Sample 2 is fine aggregate which is 4.75 mm passing. Sample 3 is dust which is passing 4.75 mm passing. In this study, the gradation of aggregates was evaluated through standard sieve analysis described by the ISSA manual. Type III and Type II gradation has used for present study as shown in table 1.

2.1. New laboratory modified method of mixing and consistency test of microsurfacing:

A 400 gram dry aggregate mixture is prepared using the particle sizes retained on and passing through 4.75mm as coarse and fine aggregates, the desired quantities of fillers, water, and emulsion. The methodology adopted for mixing the mixture is as given below:

- Coarse and fine aggregates were weighed separately into separate mixing bowls.
- Calculated quantity of mixing/premix water was divided in an approximate proportion of estimated surface areas of coarse and fine aggregate and was added to coarse and fine aggregate separately.
- Coarse and fine aggregate were mixed thoroughly with the premix water to obtain two separate mixes with uniformly wetted aggregate mass.
Table 1: Gradation of Type III and Type II aggregate for 400 gm sample

| Sieve Size (mm) | Type III - % Passing | Type II - % Passing |
|-----------------|-----------------------|---------------------|
|                 | Min | Max | Avg | Sample (gm) | Min | Max | Avg | Sample (gm) |
| 9.5             | 100 | 100 | 100 | 80          | 100 | 100 | 100 | 80          |
| 4.75            | 70  | 90  | 80  | 104         | 90  | 100 | 95  | 82          |
| 2.36            | 45  | 70  | 57.5| 57          | 65  | 90  | 77.5| 70          |
| 1.18            | 28  | 50  | 39  | 43          | 45  | 70  | 57.5| 59          |
| 0.6             | 19  | 34  | 26.5| 35          | 30  | 50  | 40  | 50          |
| 0.3             | 12  | 25  | 18.5| 27          | 18  | 30  | 24  | 40          |
| 0.15            | 7   | 18  | 12.5| 23          | 10  | 21  | 15.5| 34          |
| 0.075           | 5   | 15  | 10  | 31          | 5   | 15  | 10  | 44          |

- The moistened aggregate masses were allowed to stand for 10 minutes, so as to provide time to allow water to fill up surface voids and uniformly coat the aggregate pieces.
- The quantity of emulsion (in quantity of 6%, 8%, 10% etc.) and water (in quantity of 3%, 5%, 7% etc.) were calculated by weight of dry aggregate.
- The additive manufacture by Akzonoble (E11) with water was added in required solution concentration and if there was remaining water then it was added in emulsion.
- The estimated quantity of emulsion for coarse aggregate was first poured into the mixing bowl containing the moistened course aggregate.
- The moistened coarse aggregate were mixed thoroughly with the added emulsion so that the emulsion was uniformly distributed over the surface of all aggregate pieces and uniform coating was obtained.
- Moisten fine aggregate were then transferred into the mixing bowl containing coated coarse aggregate mass uniformly with emulsion together and mixed at uniform speed. After finishing the 50% of emulsion and fine aggregate the concentrated solution of additive was added.
- Remaining quantity of bitumen emulsion and fine aggregate was again transferred uniformly such that a uniform mix was obtained.
- During mixing process, care was exercised to limit mixing time to an optimum (Optimum time is given in minutes) and not to allow loss of coating due to friction between the aggregate pieces.
- The cone test was used to determine the amount of water required to form a stable, workable mixture.

Several trial mixtures were made using 400 grams of aggregate at ambient temperature, optimum emulsion and varied water contents. The cone was centered on the flow scale and after 30 second of thorough mixing the cone was loosely filled, struck off and immediately removed with smooth vertical motion. The outflow of the slurry was measured at four point’s 90° apart, average in cm as shown in figure 1. flow at particular % added mix water. The consistency test is described in ISSA TB106. The obtained value of consistency is shown in table 3 and table 4 for Type III and Type II respectively.

2.1.1. Sample Calculation of consistency test for Type II Aggregate:

Example of Calculations:

- Table 2 shows an example of calculations required to determine batch weights of various Microsurfacing components. The following mixture proportions are identified from mixture design.
Figure 1: consistency test of sample (no separation of water)

### Table 2: Sample Preparation

| Materials                  | Quantity and Percentage                  |
|----------------------------|------------------------------------------|
| Aggregate                  | 400 g sample of dry aggregate            |
| Emulsion                   | 14% by weight of dry aggregate           |
| Water                      | 10% by weight of dry aggregates          |
| Liquid Additive            | 0.5% by weight of dry aggregates         |
| Polymer Modified Emulsion  | 65% residual bitumen                     |

### Table 3 Result of consistency test (Type III)

| Water Cont. (%) | Emulsion (%) | Cement (gm.) | Consistency (cm) | Additive (gm.) | Mixing time (sec) | Breaking time (min) | Initial S.T (min) | Final S.T (hr) |
|-----------------|--------------|--------------|------------------|----------------|-------------------|---------------------|------------------|---------------|
| 5               | 20           | 0            | 2.25             | 2              | 180               | 6                   | 30               | 24            |
| 7               | 18           | 0            | 2.45             | 2              | 180               | 6                   | 30               | 24            |
| 8               | 18           | 0            | 2.37             | 2              | 180               | 5                   | 30               | 24            |
| 10              | 18           | 0            | 2.65             | 2              | 180               | 7                   | 30               | 24            |

Examples: The surface area of aggregate calculated as given in NCAT Report 98-01.

- Total surface area of Type III gradation = 8.56 m²/kg
- Surface area of coarse aggregate (C.A) = 0.74 m²/kg
- Surface area of fine aggregate (F.A) = 7.82 m²/kg
- Absorption of water (C.A) = 0.66%
- Absorption of water (F.A) = 0.70%
- Water mix in C.A = weight of C.A × absorption of water + surface area of C.A = 80 × 0.0066 + 0.74 = 1.28 g – 2 g
- Water mix in F.A = weight of F.A × absorption of water + surface area of F.A = 80 × 0.007 + 7.82 = 8.38 g – 8 g

- Emulsion content = (0.14 × 400) = 56 g
- Water = 0.1 × 400 = 40 g
- Liquid Additive = (0.5 × 400)/100 = 2 g
- Water content for additive = 40 – (2 + 8) = 30 g
3. **Modified Marshall method of mix design:**

This method is employed in the laboratory mix design of micro-surface mixtures. It is used to provide characterization of optimum mix formulation. The ISSA prescribe the use of Marshall Method for micro-surface specimens for evaluation by hot mix asphalt design methods as Modified Marshall Test ISSA T148 (2010). The procedure for Marshall Test has been standardized by the American Society for Testing and Materials same as HMA mix design only have to find the mixing and compaction temperature by viscosity methods but most of them using ISSA TB-140 method. In present study ISSA TB-140 procedure has adopted as Marshall for low volume roads.

The procedure is summarized below:

- Firstly, dry sieved aggregates have taken into individual sieve fraction then it has washed in each fraction so as to remove all sieve material less than the size of the retaining sieve. The aggregates have dried at 105°C to 110°C.
- Added necessary mineral admixtures to the aggregate then it has mixed for 60 seconds and added the emulsified asphalt Mix thoroughly with a mechanical mover for 90 to 120 seconds.
- A large metal pan has taken with a piece of waxed paper of adequate size to extend above the sides of the container then it has poured the mixture into metal pan.
- During preparation of sample the mix and all components has maintained at 25 ± 5°C.
- Immediately after casting, the specimen placed in a 60 ± 5°C. It has allowed setting and curing undisturbed for 24 ± 0.5 hours.
- Compaction temperatures are decided depending on the viscosity of residual of emulsion. As per ISSA Manual Series No. 148, the compaction temperatures are measured with the kinematic viscosities at 280 ± 30 centistokes (compaction temperature is tested by ASTM D217 for viscosity).
- The sample was remaining in the oven for a period of 2 ± 0.5 hours to stabilize at the compaction temperature.
- The Marshall samples are then prepared at different residual bitumen contents using the standard size of the mould. The compaction is achieved using an impact compactor by applying 30 blows on either side of the specimen for low traffic condition.
- After 24 hours of curing, the samples are extracted from the mould and then tested for Stability, Bulk Density, Flow, Air Voids (VA), and Voids in Mineral Aggregates (VMA) and Voids Filled with Bitumen (VFB).
- Graphs for residual bitumen content versus i) Stability, ii) Flow, iii) Bulk Density, iv) Air void, v) VMA & vi) VFB are plotted.
- The binder content corresponding to 4% air voids is selected and remaining mixture properties are cross checked at the same residual bitumen content. If all the criteria are satisfied, the binder content is selected as the optimum residual bitumen content else the mixture is redesigned.
3.1 Properties of the Mix:

3.1.1 Theoretical Specific Gravity of the Mix (Gt):
Theoretical specific gravity Gt is the specific gravity without considering air voids, and is given by:

\[ G_t = \frac{W_1 + W_2 + W_3}{G_1 + G_2 + G_3} \]

where, \( W_1 \) is the weight of coarse aggregate in the total mix, \( W_2 \) is the weight of fine aggregate in the total mix, \( W_3 \) is the weight of filler in the total mix, \( W_b \) is the weight of bitumen in the total mix, \( G_1 \) is the apparent specific gravity of coarse aggregate, \( G_2 \) is the apparent specific gravity of fine aggregate, \( G_3 \) is the apparent specific gravity of filler and \( G_b \) is the apparent specific gravity of bitumen.

3.1.2 Bulk Specific Gravity of Mix (Gm):
The bulk specific gravity or the actual specific gravity of the mix \( G_m \) is the specific gravity considering air voids and is found out by:

\[ G_m = \frac{W_m}{(W_m - W_w)} \]

Where, \( W_m \) is the weight of mix in air, \( W_w \) is the weight of mix in water, Note that \( W_m - W_w \) gives the volume of the mix. Sometimes to get accurate bulk specific gravity, the specimen is coated with thin film of paraffin wax, when weight is taken in the water. This however requires considering the weight and volume of wax in the calculations. The aggregate bulk specific gravity is given in table 5.

3.1.3 Air Voids Percent (Vv):
Air voids \( V_v \) is the percent of air voids by volume in the specimen and is given by:

\[ V_v = \left( \frac{G_t - G_m}{100} \right) \]

Where \( G_t \) is the theoretical specific gravity of the mix and \( G_m \) is the bulk or actual specific gravity of the mix.

3.1.4 Percent Volume of Bitumen (Vb):
The volume of bitumen \( V_b \) is the percent of volume of bitumen to the total volume and given by:

\[ V_b = \frac{W_b}{G_m} \]

Where, \( W_1 \) is the weight of coarse aggregate in the total mix, \( W_2 \) is the weight of fine aggregate in the total mix; \( W_3 \) is the weight of filler in the total mix, \( W_b \) is the weight of bitumen in the total mix, \( G_b \) is the apparent specific gravity of bitumen, and \( G_m \) is the bulk specific gravity of mix.

3.1.5 Voids In Mineral Aggregate (VMA):
Voids in mineral aggregate VMA is the volume of voids in the aggregates, and is calculated as the sum of air voids and volume of bitumen,

\[ V_{MA} = V_v + V_b \]

Where, \( V_v \) is the percent air voids in the mix, given by above equation and \( V_b \) is percent bitumen content in the mix.

3.1.6 Voids Filled With Bitumen (VFB)
Voids filled with bitumen VFB is the voids in the mineral aggregate frame work filled with the bitumen, and is calculated as:

\[ V_{FB} = \frac{V_b \times 100}{V_{MA}} \]
Where, \( V_b \) is percent bitumen content in the mix and VMA is the percent voids in the mineral aggregate.

### Table 5: Coarse and Fine Aggregate

| Properties                  | Coarse Aggregate | Fine Aggregate |
|-----------------------------|------------------|----------------|
| Apparent relative density  | 2.59             | 2.59           |
| Bulk relative density      | 2.55             | 2.55           |
| Saturated surface density  | 2.57             | 2.53           |
| Absorption                  | 0.63%            | 0.70%          |

3.2 Properties of microsurfacing mix and Determination of OBC:

From the modified Marshall Test different properties have been found out which are given in table 6 for TYPE III and TYPE II gradation. The required Marshall criteria is given in table 7.

Residual Bitumen Content corresponding to 4% Air Voids = OBC

Thus, from the above graph (figure 2) ORBC obtained for TYPE III = 10% and for TYPE II = 7.7%

### Table 6: Properties of microsurfacing TYPE III and TYPE II

| PROPERTY                  | % Binder Content (Type III) | % Binder Content (Type II) |
|---------------------------|----------------------------|---------------------------|
| Stability (kg)            | 6.5 7.8 9.1 10.4 11.7      | 6.5 7.8 9.1 10.4 11.7     |
| Bulk Density (gm./ce)     | 2.09 2.10 2.15 2.21        | 2.09 2.10 2.15 2.21       |
| Flow (mm)                 | 5.2 2.49 3.16 3.74         | 5.2 2.49 3.16 3.74        |
| Air Voids (%)             | 10.5 8.38 5.09 3.6 2.60    | 10.5 8.38 5.09 3.6 2.60   |
| VFB (%)                   | 43.3 53.41 68.98 78.06     | 43.3 53.41 68.98 78.06    |
| VMA (%)                   | 18.5 17.99 16.40 16.40     | 18.5 17.99 16.40 16.40    |

Graphical Plots

The average value of the above properties is determined for each mix with different residual bitumen content and the following graphical plots are prepared for Type III & Type II gradation which is given in figure 3 & figure 4.

- Residual bitumen content versus corrected Marshal Stability
Residual bitumen content versus Marshal Flow
Residual bitumen content versus percentage of void (Vv) in the total mix
Residual bitumen content versus voids filled with bitumen (VFB)
Residual bitumen content versus unit weight or bulk specific gravity (Gm)
Residual bitumen content versus voids filled with mineral aggregate (VMA)

3.3 Marshal Properties at Optimum Bitumen Content

Table 7: Marshall Criteria

| PROPERTIES          | RESULT (TYPE III) | RESULT (TYPE II) | Requirement for bituminous layers |
|---------------------|-------------------|------------------|----------------------------------|
| Stability (kg)      | 6.08              | 6.07             | 2-9                              |
| Bulk Density (gm/cc)| 2.15              | 2.21             | --                               |
| Flow (mm)           | 3.56              | 5.99             | 4                                |
| Air Voids (%)       | 4.06              | 3.8              | 3-5                              |
| VFB (%)             | 75.26             | 80.45            | 65-75                            |
| VMA (%)             | 16.4              | 19.33            | > 15                             |

Marshal Test Results

- At 4% air voids the OBC for Type III gradation is 10% and for Type II gradation is 7.7% of % residual bitumen.
- At the optimum residual bitumen the flow, air voids, VFB and VMA value is in requirement range.

Figure 3: graph plot for Type III gradation
4. CONCLUSION:
Based on the choice of microsurfacing type, the following conclusion can be brought out with the mix design carried out with consistency test and Modified Marshall Mix design from the present study:

- From literature, microsurfacing is emerging as the first choice chosen as preventive maintenance.
- The new approached for mixing of coarse and fine aggregates with emulsion appear to have eliminated balling.
- The required consistency value for Type III gradation was found with water content in the range of 5% to 10% and with emulsion content of 18% and 20%.
- The required consistency value for Type II gradation without filler was found with water content in the range of 3% to 8% and emulsion content of 14% to 16%.
- The required consistency value for Type II gradation mix with cement was found with water content of 3% and 5% with emulsion content of 18% and 20% respectively.
- At 4% air Voids the OBC for Type III gradation is 10% and for Type II gradation is 7.7% of % residue emulsion.

At the optimum residual bitumen content, the mix satisfies the criteria of flow, air voids, VFB and VMA.

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