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# Enhanced Performances for Marshall Properties of Hot Mix Asphalt (HMA) by Incorporated 60/70 Grade of Bitumen

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**Abstract:** During the last decade, the rehabilitation and improvements of road networks in Sri Lanka exhibited a rapid development. As a result many of roads were undergone for new asphalt surfacing with hot mix asphalt, at least a wearing course, and the black top. However, with this rapid development, few premature failures were also observed in many of these newly constructed asphalt roads covering all part of Sri Lanka. Pre-mature cracking, removal of top thin film of wearing layer, bleeding and localized failures were among them. Bitumen played a very important role in hot mix asphalt and improvement for bitumen can enhanced the improved properties of HMA significantly. In this research, instead neat 60/70 grade of bitumen, it was used modified 60/70 grade, with Nano silane, enhancing anti-stripping and bonding capabilities. Research was comprised three stages of testing, lab trials, plant trials and filed trial in Colombo- Kandy road section. Results showed significant improvement for marshal properties. The stability and flow increased by 24% and 35 %, respectively. The anti-stripping property was also increased significantly, even after 6 hr, boiling test, it showed elevated no of coated aggregates. In addition, the mix was very well after few weeks, and very sticky condition proved that the strong bonding ability. All enhanced characteristics can be caused to exhibit improved performance and can be lead to extended life period of road construction.

**Keywords:** Anti-Stripping, Hot Mix Asphalt, 60/70 grade Bitumen, Marshal Properties.

## 1. Introduction

Rehabilitation and improvement of road network is a main strategic movement of any government in order to provide a better infrastructure facilities which can be heavily affect for rapid development. The same phenomena were applied during the last two decades in Sri Lanka and as a result many of roads were gotten new shape and ultimately facilitating the commuters. The new shape basically consisted the widening and having the black top. In other words, hot mix asphalt (HMA) layer was applied all most all road networks.

Though, the government and the client of these road network, the road development authority (RDA) anticipated the significant life time of such rehabilited roads, the unsatisfactory conditions or pre-mature failures were observed in many of roads covering all over the Sri Lanka. The pre-mature failures were, surface cracking, ravelling, stripping the top layer of bitumen, corrugations and so on. Development of surface cracking was a significant problem of newly laid asphalt wearing course. On the other hand, removal of very top thin layer of bitumen was also observed in all most all cases with the traffic. All key stakeholders were alarmed and focused to investigate the possible causes, basically attention was directed in three ways, quality of aggregates, and quality of bitumen and construction process. However, having solid and comprehensive experience of construction process by main contractors, the investigate area was further narrow to quality of aggregates and bitumen. It is well known fact that the quality of aggregates in Sri Lanka is in high quality all over the country and careful selection has been well established. Therefore, finally, concentrate attention was directed for the bitumen used to produce the asphalt and its characteristics.

The bitumen plays a very vital role in hot mix asphalt and improvement of its characteristics can be greatly attribute to the enhance performance of mot mix asphalt. The quality of bitumen and its strong relationship with aggregates are essential characteristics for quality asphalt in the field to meet the desired results in long run. Basically, the bitumen act as a bonding agent in mot mix asphalt mixture. It is a durable adhesive that binds together a variety of paving materials without affecting their properties. Its durability is essential to prolong the life of pavement/roads and bitumen gives controlled flexibility to mixture of mineral aggregates and is used for paving roads. The deduction of the adhesion between bitumen and aggregates specially in the presence of water and the deterioration of the asphalt due to cohesive failure with in the binder itself has been known as two primary mechanism that may results in pre-mature distress in asphalt (Terrel and Al Swailnri, 1994).

Further, moisture damage is one of the primary modes of distress in HMA, commonly known as stripping, this damage accelerates the structural degradation of the mixture in conjunction with cracking and plastic deformation. Physio-chemical surface properties of mineral aggregates are more important for moisture induced stripping of the HMA compared to the properties of binder. Recently, with the advent of new liquid adhesive promoters in the market, and the ease of application, liquid adhesive promoters are gaining rapid popularity. The function of these promoters is to alter the relative surface properties and polarity, thus facilitating a strong bond between the bitumen and aggregates which also resists to water displacing effect for the service life of the pavement.

## 2. Problem statement

Non formation of stable bond (weak bonding) in hot mix asphalt which was used in road construction was observed. In addition, the pre-mature surface cracking and stripping were developed in many pavements in Sri Lanka.

## 3. Research Objectives

(i). To enhance the Marshall properties of HMA
(ii). To improve the bonding capabilities in HMA
(iii).To increase the resistance to moisture damage

## 4. Scope of the study

To achieve the above objectives, the only parameter alter was the type of bitumen. Same mix design and same type of aggregates were used. Neat 60/70 bitumen and silane based incorporated bitumen 60/70 were used to compare the performance. Lab evaluation and filed laying were performed in a section of Colombo – Kandy (A1) road. Hydrated Lime ($Ca[OH]_2$) was also added as 1 % from the total volume.

## 5. Materials and Methods

### 5.1. Laboratory analysis

All lab works were carried out at the laboratory located at Kotadeniyawa asphalt plant which is managed by Access Engineering PLC. The approved mix design for wearing course for the project of Kadawatha _ Nittabuwa road (KNRP) was used. The hot bin samples were collected at Kotadeniyawa plant premises. Bitumen 60/70 and Nano grip 60/70 3 E were supplied by Bitumix Pvt. Ltd for this research.

Table 1: Mix proportion used in this study

| Mix Proportions | Bitumen (%) | Hot Bin 4 (0-5 mm) | Hot Bin 3 (5-11 mm) | Hot Bin 2 (11-16 mm) | Hot Bin 1 (16-22 mm) | Filler | Total |
|---|---|---|---|---|---|---|---|
| Wearing Course | 0 | 12% | 14% | 28% | 45% | 1% | 100 |
| Wearing Course | 4.7 | 11.4 | 13.3 | 26.7 | 42.9 | 0.95 | 100.0 |

HMA design complying with type 3 grading band was carried out according to the Marshall method to evaluate the adhesion promoter. Marshall samples were prepared at the optimum bitumen content (4.7 %) using neat bitumen 60/70 and Nano grip 3 E.

Nano grip 60/70 3 E is the trade name of incorporated bitumen which was supplied by Bitumix Pvt Ltd. It is modified 60/70 bitumen with nano silane the product of UK. The 3 E denotes the Extra strong bonding, Excellent coating and Easy compaction. Through it is modified, the incorporated bitumen matches with conventional properties of 60/70 grade.

Table 2: Test Results of Nano grip 60/70 3 E

| Property | Test Method | Specification Limit | | Test Results |
|---|---|---|---|---|
| | | Min | Max | |
| Penetration $77^0F$ ($25^0C$) 100g, 5s | ASTM D 5 - 86 | 60 | 70 | 63 |
| Flash Point $^0C$ | ASTM D 92 - 78 | 232 | | 315 |
| Softning Point $^0C$ | ASTM D 36 - 86 | 48 | 56 | 49 |
| Loss on Heating for 5 hrs at $163^0C$ (i) Loss by weight percent | ASTM D6 - 80 | | 1.0 | |
| (ii) Penetration after loss on heating test percent of its original value | ASTM D5 - 86 | 75 | | 95 |
| Solubility in trichloroethyne % | ASTM D 2042 - 81 | 99 | | 99.6 |
| Specific gravity at $25/25^0C$ | ASTM D 70 - 82 | 1.01 | 1.06 | 1.021 |
| Ductility ($25^0C$) 5 cm/min., cm | ASTM D 113 - 86 | 100 | | 121 |
| Effect on water on bituminuos coated aggegates using boiling water | ASTM D 3625 - 96 | 95 | | above 95 |

Boiling water test (ASTM D 3625) and coating and stripping test (ASTM D 1664) were carried out for samples. The boiling water test was extended up to 30 min, 1 and 6 hrs in addition to the standard values of 10 min to evaluate the enhanced performances.

### 5.2. Field trial laying

Once convinced the results, all stakeholders agreed to lay the wearing course which has incorporated bitumen 60/70 3 E at site. A 300 m length and 3.7 m width stretch was selected at Colombo – Kandy road, the improvement was done by Access Engineering PLC. The all required tests were performed and extraction test was also jointly carried out at site laboratory. All personnel representing client/consultant and main contractor participated to witness the activity.

## 6. Results and Discussion

### 6.1. Marshall properties

Table 3: Comparison of Marshall Properties

| Strength & Flow Improvement | Marshall Stability (kN) | Flow (0.25 mm) |
|---|---|---|
| Control Sample | 15.6 | 10.4 |
| Nano grip 60/70 3 E | 19.5 | 13.9 |

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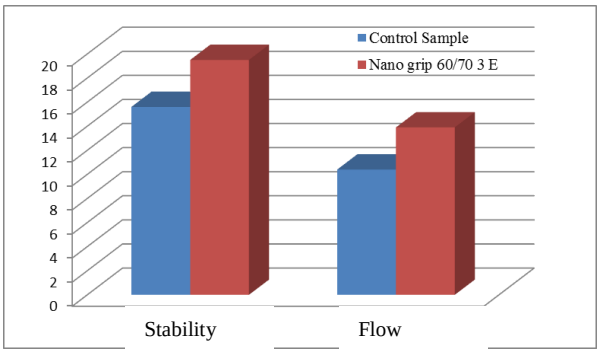


Figure 1: Comparison of Marshall Properties

The above table 2 depicts the comparison of Marshall properties of neat bitumen and Nano grip samples. The shown values are average values of duplicate samples. The Marshall stability values have been increased to 19.5 from 15.6 kN whereas the flow values has been elevated to 13.9 from 10.4. The figure 2 also illustrates the graphical view of above mentioned parameters. These two properties are very important in practical sense in the field for HMA. Generally, when stability increases the flow will reduces, but the given range of bitumen content both parameters tend to increase. Increment of stability is important to bear the traffic load without breaking, but too much stability can create the solid surface and less comfort to drive, but in this case the flow was also increased. It makes the better flexibility with hot temperature and will not allow breaking the surface. When both elevated properties arise together it can cause to keep good HMA surface in long run.

### 6.2. Extended boiled water tests (% coating ability)

Table 4: Extended boiled water tests **Error! Not a valid link.**

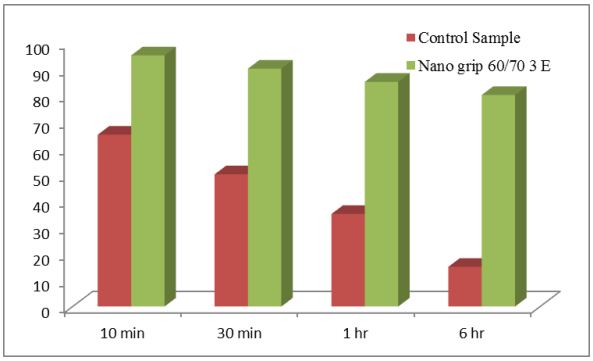


Figure 2: Graphical representation of extended boiled water test

The boiling water (ASTM D 3625) test is to quantify the coating ability (%). The standard is 10 min boiling and visually observes the coating retention. However, to further convince the ability the extended boiling water test up to 6 hr was carried out. The table 3 showed the values and figure 2 illustrates the graphical representation. It is clearly observed that even after 6 hr, the Nano grip samples showed higher coating ability, in other words, the very low stripping values. Interestingly, the neat bitumen showed very low coating ability values with the time, highlighting the elevated stripping values. Even rate of stripping is very rapid in neat bitumen samples. This result

highlights the weak bonding the ease to de-bonding with the presence of moisture in neat bitumen.

When carrying out the experiments, it was shown that very strong bonding of aggregates and Nano grip 3 E compared to the neat bitumen samples. The state of very stickiness was very high and even the coated aggregates were strongly stick to the hand and was not fall apart freely. In addition, the whole surface of aggregates was covered by incorporate bitumen with relatively thicker layer. The samples which were broken after even 2-3 weeks later, showed very fresh state compared to neat bitumen.

### 6.3. Observations at field laying

The filed trial were carried out at a section of Kadawatha – Nittabuwa road project (KNRP), the main contractor was the Access Engineering PLC. With the proper approval of client (RDA), Quality consultant (R & DA) the both binder and wearing courses were laid. The length and width of the sections were 300 m and 3.75 m, respectively. The thickness of the wearing course was 50 mm. The following special observations were made during the filed application.

- Samples which casted using Nano Grip 60/70 3 E, exhibited very fresh/live conditions compared to the samples prepared with neat 60/70 bitumen.
- Once mixed, Nano Grip showed very sticky state and all aggregates were well coated
- Even after several days later, the broken samples showed same bonding/stickiness, and neat bitumen samples were looked like little ageing.
- Nano Grip samples exhibited fresh/live condition after several weeks later while neat bitumen samples showed little ageing conditions.
- Once tested for Marshal properties both stability and flow had increased significantly in Nano Grip samples compared to neat bitumen.

In addition to the above, the self-compaction ability has also shown increment while lying.


Figure 3: Asphalt laying using paver


Figure 4: Initial compaction by steel roller


Figure 5: Final compaction by pneumatic roller

### 7.0 Conclusions

All three experimental conditions (Lab, Plant and Field) exhibited enhanced performance of asphalt specially Marshal properties. The stability and flow

has improved averagely 25 % and 35 %, respectively with compared to the neat bitumen asphalt.

Bonding abilities have been also improved, resulting higher no of coated aggregates, which shows the low stripping abilities with the present of moisture.

Asphalt mixture showed very fresh and lively conditions and higher workability.

## 8.0 Special notes and recommendations

- Even through, the lab, plant trials exhibited enhanced properties; it is a must to confirm those at site in longer run. So that some realistic mechanism must be in place to confirm the advantages of adding this modified/improved bitumen.

- It is advisable to set up a team comprising a member from main contractor, RDA, R & D and one from independent body such as university.

- The team first has to outline the mechanism and activities to be carried out at particular time intervals

- If within reasonable time frame, the enhance properties are existing, then concrete decision can be taken to move forward in large scale or can be produced to policy makers.

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