IJMTER JOURNAL ANALYSIS OF ASPHALT MIX DESIGN
(AN EXPERIMENTAL STUDY)

Umesh Prasad Chaudhari¹, Dr. Bharat Nagar² and Parvez Choudhary³
¹M.Tech Scholar, Jagannath University, Jaipur (Rajasthan)
²Head of Department, Civil Engineering, Jagannath University, Jaipur (Rajasthan)
³M.Tech Scholar Jagannath University Jaipur, Rajasthan

Abstract—Asphalt mix design requires proper selection of materials and analysis of structure so that critical levels of strain do not exceed in the design life. With proper selection of materials, the problem of pavement design narrows to ensure proper elastic stiffness of asphalt layer, thickness of asphalt layer and elastic stiffness of sub grade. This clears the importance of stiffness of asphalt layer. In Nepal, mix design in general is done by Marshall Mix Design Method in confirmation to Standard Specification for Road and Bridge Works published by Department of Road. However, mix design is done for general requirement. No site specific mix designs are done in practice. Asphalt Concrete pavement is going to be constructed in large volume in recent future as per the increasing trend of traffic volume. This research is intended to provide average compositions of typical mixes applicable to Nepalese condition. The research will be beneficial to the departments, organizations, practicing Engineers and designers, as they will be able to select mix design within a range for specific site conditions.

Keywords—Pavement design, Failure modes, Asphalt Mix Design, Average Compositions, Nepalese Condition.

I. INTRODUCTION

1.1 GENERAL

Asphaltic concrete (AC) is a dense, continuously graded mix which relies for its strength on both the interlock between aggregate particles and, to a lesser extent, on the properties of the bitumen and filler. The mix is designed to have low air voids and low permeability to provide good durability and good fatigue behavior but this makes the material particularly sensitive to errors in proportioning, and mix tolerances are therefore very narrow (Jackson and Brien (1962), Asphalt Institute (1983), (1989) and (1991)) [1].

An asphalt concrete surface will generally be constructed for high-volume primary highways having an average annual daily traffic load greater than 1200 vehicles per day [2]. Highways, Ring Road, Runways and Parking spaces in Nepal need Asphalt Concrete for better performance in terms of economy, safety, comfort and durability.

Design Methods
1. Hubbard Field Method
2. Hveem Method
3. Marshall Mix Design Method
4. Superpave Method of Mix Design

1.2 PROBLEM STATEMENT

In Nepal, Marshall Mix Design Method is generally used for mix design of Asphalt Concrete, SSRBW specifies the materials, method of construction and requirements for the construction of Asphalt Concrete and also specifies its meaning as a thoroughly controlled, hot-mixed, hot-laid, plant
mixture of well graded dried aggregate and penetration grade bitumen, which when compacted, forms a dense material.

SSRBW specifies requirements in general and instructs the Engineer to follow the special specification or BOQ if required. It is necessary to design the mix for specific site conditions in different sections even in a single project. However, in practice, mix design conforming to general requirements is only used.

1.3 OBJECTIVES OF THE STUDY

The purpose of this research is to provide recommendations on average compositions of typical mixes applicable to Nepalese condition. The departments, organizations, practicing Engineers and designers will be benefited, as they will be able to select mix design within a range for specific site conditions.

1.4 SCOPE AND LIMITATION OF STUDY

Department of Roads has constructed Asphalt Concrete in low volumes in comparison to other bituminous pavements. AC for Department of Roads is a recent technology along with absence of data about performance of constructed AC pavements due to lack of monitoring. The traffic however is ever increasing and it is time that Department of Roads considers AC pavements more often which also has been the case recently. But construction of AC pavements needs proper design of pavement thickness and proper mix design. This research focuses on providing recommendations on average compositions of mixes through proper analysis of available data on design work and bitumen and aggregates tests.

As discussed earlier, AC pavements have not been constructed in large volumes and similarly not much design have been done which makes available data on design parameters scarce. So, data on design parameters has been taken from Central Road Laboratory, Lalitpur, Nepal and some design documents available at Division Road Offices. Also, test data on bitumen has been taken from Bitumen Barrel Udhyog, Amlekhgunj, Bara, Nepal. The analysis has been done using this minimum available data. The time frame of a semester did not allow the extensive lab tests that could have been done to obtain more specific results. Moreover, the data on actual loading conditions were also not available so categorization of loading time has been done as a representative of loading conditions. The outcome of the thesis may require revision in the light of future development in the field in terms of availability of data and development of knowledge base.

II. STUDY DATA AND METHODOLOGY

The purpose of this research is to provide recommendations on average compositions of typical mixes applicable to Nepalese condition. Literature Review has been done which has helped to develop a methodology for undertaken research.

The present outcome of literature review has been presented as:

1. Stiffness of Bitumen, $S_b$ depends on loading time, softening point, penetration index and temperature, i.e. $S_b = f (LT, SP, PI, T)$

2. Voids in Mix/Mineral Aggregate, $VMA = V_V + V_B$

3. Volume of air voids depends on theoretical maximum density and mix density

4. Stiffness of mix when greater than 5 MPa depends on stiffness of bitumen and voids in mixed aggregate. $S_{me} = f (S_b, VMA)$ as shown in Figure 3.1.

Stiffness of mix when less than 5 MPa shows visco-elastic to viscous behavior as shown in Figure 3.1.
Data collection and Methodology

For Bitumen Stiffness

- Loading time has been categorized as:
  - Fast road traffic: 0.01 – 0.10 seconds
  - Braking and accelerating traffic: 0.10 – 1.00 seconds
  - Parked Vehicles: 1.0 minutes – 10 hours

- Temperature:
  - Average annual air temperature has been found out from Department of Meteorology and for average pavement temperature readings has been taken at different locations.
  - Softening point of different samples (60/70 and 80/100) of bitumen has been assesses from available secondary data and accordingly penetration index has been determined from empirical relation/Nomo graph.

Bitumen Stiffness in a range has been obtained after calculation from above collected data. Calculation has been done on the basis of empirical relation/Nomo graph.

For VMA

- Mix density of samples designed in laboratory, theoretical maximum density and specific gravity for different aggregates used in Nepal has been obtained from available secondary data.
- VMA in range has been obtained from calculations of $V_V$ and $V_B$.

With range of bitumen stiffness and VMA so obtained a range of mix stiffness has been obtained.

III. RESULTS AND DISCUSSIONS

For Bitumen Stiffness

As Stiffness of Bitumen, $S_b$ depends on loading time, softening point, penetration index and temperature, i.e. $S_b = f (LT, SP, PI, T)$ so,

Loading time has been categorized as:

- Fast road traffic: 0.01 – 0.10 s (such as NH)
- Braking and accelerating traffic: 0.10 – 1.00 s (at grades and urban area)
- Parked Vehicles: 1.0 minutes – 10 hours (Airports and others)

Air temperature has been taken from reports of Department of Hydrology and Meteorology as $-15^\circ C$ to $47^\circ C$[15][16] and corresponding pavement temperature has been established by readings at different locations taking note of temperature difference between air and pavement and plotting a best fit line using the obtained data as follows:
The pavement temperature corresponding to highest temperature has been taken as $65^\circ C$ and for lowest is taken as $-7^\circ C$ as there is no significant fall in pavement temperature beyond that as can be seen from Figure 2.

Softening point of different samples (60/70 and 80/100) of bitumen from test data (2005 – 2016, random sampling) at Bitumen Barrel Udhyog, Amlekhgunj, Bara, Nepal comes out to be in a range between $44^\circ C$-$48.5^\circ C$ with an average value of $46.74$ for bitumen of penetration grade 80/100. The specification SSRBW specifies the range for 80/100 as $41^\circ C$-$51^\circ C$ and for 60/70 as $44^\circ C$-$54^\circ C$ so the range here has been taken as $41^\circ C$-$54^\circ C$. For in service behavior then softening point comes out to be $50.54^\circ C$-$56.4^\circ C$ for penetration range of 60-$100$ from following relations.

1. $P_r = 0.65 P_i$, For 60-100, $P_r = 39-65$
2. Softening Point
3. $SP_r = 98.4 - 26.4 \log P_r$, For $41^\circ C$-$54^\circ C$, $SP_r = 50.54^\circ C$-$56.4^\circ C$
4. Penetration Index

$$P_{Ir} = (1951 - 500 \log P_r - 20 SP_r)/(50 \log P_r - SP_r - 120)$$

The penetration index (PI) has been determined from above empirical relation and comes out to be $-0.28$ to $-0.42$, so an average of $-0.3$ has been taken for use. Also, nomograph has been shown in Figure 4.4 below.

The stiffness of Bitumen has been determined from use of above data using the nomograph for determining the stiffness modulus for bitumen and comes out to be in range of $2*10^2$ to $800$ Mpa for loading time of $0.01$s to $0.1$s, $2*10^3$ to $500$ Mpa for loading time of $0.1$s to $1$s, and $2*10^7$ to $75$ Mpa for loading time of $1$ min to $10$ hrs as shown in Figure 4.2, Figure 4.3 and Figure 4.4 respectively.

5. For VMA

For VMA Marshall Mix Design data was collected from Central Road Lab, DOR, Lalitpur and various mix designs available at Division Level of DOR, from these data after analysis of extremes the
range for VMA was assessed as 12-24 for Nepalese Condition to make it compatible/adjustable to diverse conditions such as terrain, traffic, temperature and loading.

6. After determination of range of bitumen stiffness \((2 \times 10^{-7} \text{ to } 800 \text{ Mpa})\) and VMA, Mix (12-24) the mix stiffness in elastic region, \(S_{me}\) (Bitumen Stiffness > 5 Mpa) has been determined from empirical relation to be 370 Mpa to greater than 50000 Mpa.

Mix Stiffness in viscous region, \(S_{mv}\) when bitumen stiffness is less than 5 Mpa depends upon bitumen stiffness, VMA, aggregate type, grading, shape, texture, interlock, confining conditions, compaction, voids and method as shown in Figure 2.13.

![Penetration Index](image)

**Figure 3 Penetration Index**
Figure 4 Stiffness of Bitumen for Loading Time 0.01s to 0.1s
Figure 5 Stiffness of Bitumen for Loading Time of 0.1s to 1s
Figure 6 Stiffness of Bitumen for Loading Time of 1min to 10hr
Figure 7 The relationship between mix stiffness, binder stiffness and VMA in the elastic region

IV. CONCLUSIONS

4.1 CONCLUSIONS

- The pavement temperature was recorded in Terai/Plains to Hills and extrapolated for cold regions with pavement temperatures approximately 10°C above average air temperatures for average annual air temperature of 11.4°C and 22.4°C (16) in Nepal in comparison to pavement temperatures approximately 3°C above average air temperatures for average annual air temperature between 8.5°C and 10°C in the UK, indicating temperatures to be considered for site specific conditions for mix design.

- The softening point was assessed from available secondary data from mentioned supplier. With softening point, temperature, loading time (categorized) and penetration index (empirical relation) the stiffness of bitumen was assessed. The penetration index was found to be -0.3 which shows that relatively soft bitumen is being used.

- Range for VMA was chosen as per Marshall Specification validating it from lab data on aggregates and bitumen used in Nepalese context.

- Finally, with Bitumen Stiffness and VMA the Mix Stiffness was determined which was found to be 0.37GPa at high temperature and creep speeds to about 50 GPa at low temperatures and high speeds in comparison to 1 GPa to 15GPa respectively under those conditions in general practice (20)

- In summary, the process for mix design was identified in context of Nepal.
V. SCOPE OF FUTURE STUDY

The mix design should incorporate the local pavement temperature and overall loading conditions (gradient and loading time) to make it site specific and practical while the bitumen should be chosen depending upon the requirement criteria (penetration, softening point and viscosity) at the site. For example in Terai/Plains 60/70 and lower penetration, grade bitumen is recommended with reasonable softening point.

In addition, the aggregate gradation should be chosen for maximum compaction using Fuller’s curve. However, mix design should be optimized regarding economy and performance.

Also, the design stiffness of pavement layer should be assessed according to loading conditions and mix should be designed conforming to requirements.

Finally, the mix design should also be analyzed for strain criterion assessing the fatigue life of pavement with due consideration of construction period and construction traffic load.

REFERENCES

[1] TRL: Overseas Road Note 31, “A guide to the structural design of bitumen-surfaced roads in tropical and sub-tropical countries”.
[5] Pavement Design Guidelines (Flexible Pavement), Department of Road, Nepal