# Correlation of Ultrasonic Pulse Velocity and the Volumetric Analysis of the Marshall Mix Design

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**Abstract: Quantifying the ability of the bitumen mixes are typically being carrying out by Marshall Stability test where the stability resembles the strength and flow value resembles the flexibility of the mix. Volumetric analysis along with the flow and stability value helps in determining the optimum binder content required for the mix. Even though the tests have given satisfactory results, adverse traffic conditions in countries like India allowing the pavements to deform in a very short period after construction. Ultrasonic Pulse Velocity (UPV) is a non-destructive test that is being used to evaluate the quality of concrete. Correlating such a parameter with volumetric analysis of Marshall Mix design throw a better light in choosing the optimum binder content and the strength of the bitumen mixes. In this paper, Marshall Stability test has been conducted on bitumen mixes with different binder contents and the results has been correlated with corresponding UPV values. UPV vs. Binder content graph has followed the same trend as the graph of stability vs. Binder content.**

***Keywords — Bitumen Mixes , Marshall Stability Test , Optimum Binder content, Pavement Deformation ,UPV, Volumetric Analysis,***

## I. INTRODUCTION

In a constant quest of improving the performance of pavement, surface characteristics has been taken into consideration and with the frequent of exposure of pavement surface to the heavy traffic, pavements are deteriorating in a short period of time after the construction. Studies over the years has proved that this deformation is mostly due to the insufficient stability and improper compaction [8].

Pavement performance is mostly relied on the quality of bitumen mixes and the test that are being conducted to assess the quality of bitumen mix are destructive tests and the widely used is Marshall Stability test. In addition to the destructive tests, non-destructive test (NDT) methods like Ultrasonic Pulse Velocity (UPV) is proved efficient and economical. [10].

Research is smoothly inclining towards innovative design mixes like superpave mix design where modified binders like crumb rubber, reclaimed asphalt pavement (RAP), plastic waste as a partial replacement of bitumen are proved to resist thermal cracking and rutting under extreme temperatures [6]. However this paper majorly concentrates on usage of better binder content for the virgin mixes. To prepare a mix which is economical and functionally stable, choosing an optimum binder content is necessary which can be obtained by considering the mix which gives the maximum stability value after conducting the Marshall Stability test [2].

Even though UPV test values determines the quality of the material, when the values are compared with the compressive strength of the concrete it has shown a linear correlation [9] which gives a conclusion that UPV values has some effect on the strength of the material or stability of the material when we consider bitumen mixes. UPV test in hot mix asphalts (HMA) are being used to determine its dynamic modulus which is proved to be an important property in asphalt concrete to indicate the rutting and fatigue cracking performance [11].

There are various parameters in volumetric analysis of Marshall Stability test that helps in determining the optimum binder content but inclusion of additional parameter like UPV test results allows an accurate prediction of the binder content and also throws a light on how UPV values are correlated with the stability of the mix[1,3,4,5,7].

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## II. METHODOLOGY

*A. Preparation of Marshall Specimens*

Marshall Specimens of 6 different binder contents, 4%, 4.5%, 5%, 5.5%, 6% and 6.5 % has been prepared for the test. Bitumen of VC-30 grade was used as a binder. Dense gradation of aggregate was chosen for an aggregate of nominal size 13.2 mm [13]. Stone dust from a construction site was used as a filler material.

**Fig 2.1: prepared Marshall Specimens and UPV test**

*B. Volumetric Analysis*

Densities of loose mix and compacted mix were taken to calculate the apparent density and bulk density respectively. Once the densities were calculated remaining volumetric details like air voids, voids in the mineral aggregate, and voids filled with the bitumen etc.

*C. Destructive and Nondestructive testing*

Before doing Marshall Stability test (which is destructive test), UPV test has been carried out for all the Marshall specimens. The same sample was kept in the Marshall Stability testing apparatus and both the stability and flow values were determined[12]

## III. RESULTS & DISCUSSION

A. *Volumetric Analysis*

Air void content was carried out by considering the densities of loose mix and compacted mix. Based on the binder content considered voids in the mineral aggregate was obtained and out of the total voids, percentage of the voids filled by the bitumen was determined. Results of the volumetric analysis has been shown in table 2.2. All the results obtained are well within the specified values. According to IRC the optimum air voids content must be between 4 and 6% and hence the optimum binder content is taken according to that.  Voids in the mineral aggregate is another important volumetric that should be consider while taking optimum binder content and the range should be between 65-75%.

Stability values were corrected based on the volume of the sample and along with corresponding flow values has been tabulated in table 2.1.

**Table 2.1: Stability and flow values of various binder contents**

| Binder content (%) | Sample thickness (mm) | Stability (kg) | Corre-ction | Actual Stability (kg) | Flow Value (mm) |
|---|---|---|---|---|---|
| 4 | 66 | 570 | 0.93 | 530 | 12 |
| 4.5 | 65 | 680.45 | 0.96 | 653.18 | 14.62 |
| 5 | 66 | 856.05 | 0.93 | 796.12 | 14.91 |
| 5.5 | 68 | 702.4 | 0.89 | 625.136 | 15.85 |
| 6 | 67 | 680.45 | 0.91 | 619.20 | 16.5 |
| 6.5 | 69 | 557.53 | 0.86 | 479.44 | 17.7 |

**Table 2.2: Volumetric analysis of Marshall Specimens**

| Binder Conten t (%) | Apparent Sp.gravity ($G_a$) | Bulk Sp.gravity ($G_b$) | %Air voids ($V_v$) | VMA ($V_b+V_V$) % | VFB (Vb/VMA) x100 | UPV (m/sec) |
|---|---|---|---|---|---|---|
| 4 | 2.51 | 2.36 | 5.96 | 9.56 | 41.84 | 3423 |
| 4.5 | 2.52 | 2.38 | 5.24 | 9.57 | 46.39 | 3631 |
| 5 | 2.54 | 2.41 | 4.8 | 9.8 | 51.02 | 3839 |
| 5.5 | 2.52 | 2.40 | 4.3 | 10.3 | 53.3 | 4048 |
| 6 | 2.50 | 2.40 | 3.9 | 9.9 | 60.6 | 3941 |
| 6.5 | 2.49 | 2.39 | 3.44 | 9.94 | 65.39 | 3366 |

B. *Selection of optimum binder content*

Conventional graphs were drawn between binder content and stability, flow and various other volumetric. This paper concentrates on choosing the optimum binder content by introducing additional parameters, which in this case is a UPV. Along with the five conventional graphs drawn, an additional graph was drawn between binder content and UPV and it was seen that the trend is same as that of the graph between binder content and stability.

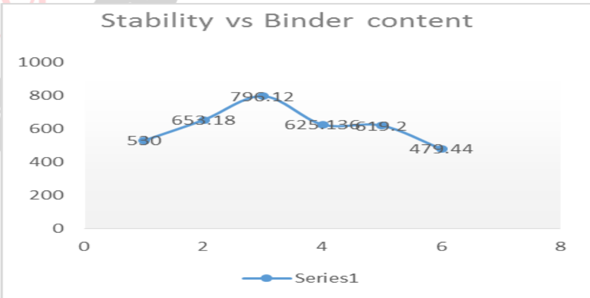


**Fig 3.1: Relation between binder content and stability**

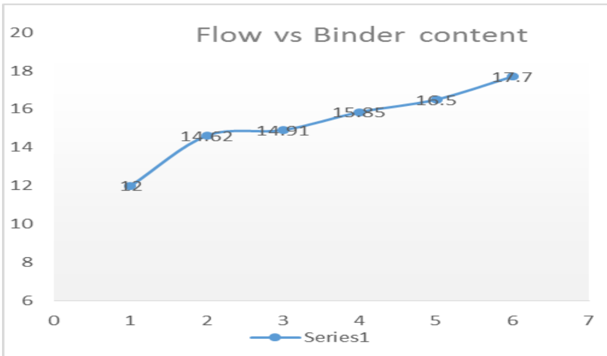


**Fig 3.2: Relation between binder content and flow value**


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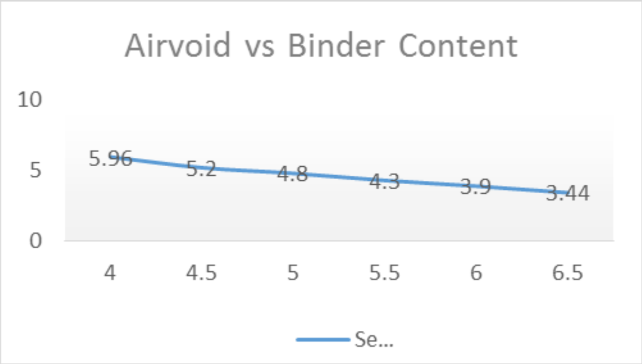


**Fig 3.3: Relation between binder content and air voids**

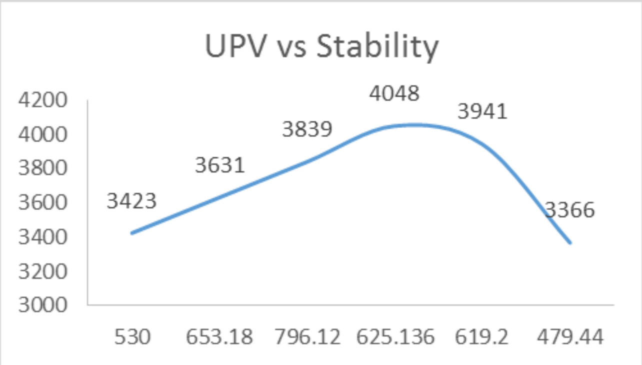


**Fig 3.4: Relation between UPV and stability**

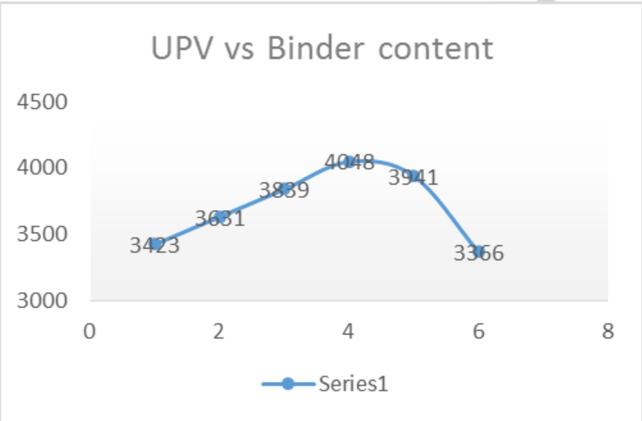


**Fig 3.5: Relation between binder content and UPV**

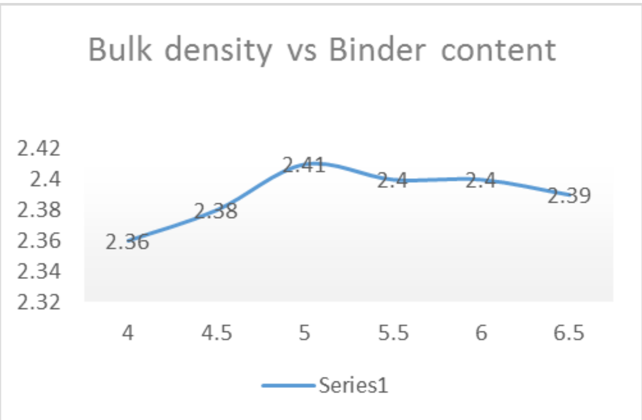


**Fig 3.6: Relation between binder content and bulk density**

## IV. CONCLUSION

Since the UPV determines the quality of the mix, considering an optimum binder content based on the UPV vales does provide a better optimum binder content. The graph between stability and UPV tells that it follows the similar trend that we see between binder content and stability which tells that UPV changes exactly the way stability changes with the change in binder content.

## REFERENCES

[1] Putman, Bradley J., and Laura C. Kline. "Comparison of mix design methods for porous asphalt mixtures." *Journal of Materials in Civil Engineering* 24.11 (2012): 1359-1367.

[2] Joshi, Darshna B., and A. K. Patel. "Optimum bitumen content by marshall mix design for DBM." Journal of information Knowledge and Research in civil Engineering 2.2 (2013): 104-108.

[3] Abu Abdo, Ahmad M., and S. J. Jung. "Effects of asphalt mix design properties on pavement performance: a mechanistic approach." Advances in Civil Engineering 2016 (2016).

[4] Asi, Ibrahim M. "Performance evaluation of SUPERPAVE and Marshall asphalt mix designs to suite Jordan climatic and traffic conditions." Construction and Building Materials 21.8 (2007): 1732-1740.

[5] Harun-Or-Rashid, G. M., et al. "Marshall Characteristics of Bituminous Mixes Using Reclaimed Asphalt Pavement." American Journal of Traffic and Transportation Engineering 3.4 (2018): 57.

[6] Modarres, Amir, and Hamidreza Hamedi. "Effect of waste plastic bottles on the stiffness and fatigue properties of modified asphalt mixes." Materials & Design 61 (2014): 8-15.

[7] Panda, Mahabir, and Mayajit Mazumdar. "Engineering properties of EVA-modified bitumen binder for paving mixes." Journal of materials in civil engineering 11.2 (1999): 131-137.

[8] Shiva Prasad, K., K. R. Manjunath, and Prasad K VR. "Study on Marshall Stability Properties of BC Mix Used In Road Construction by Adding Waste Plastic Bottles." *Journal of Mechanical and Civil Engineering* 2 (2012): 12-23.

[9] Dahiru, D. "Relationship between ultrasonic pulse velocity test result and concrete cube strength." ATBU Journal of Environmental Technology 9.2 (2016): 13-25.

[10] Jiang, Zhi-Yong, Joseph Ponniah, and Giovanni Cascante. "Improved ultrasonic pulse velocity technique for bituminous material characterization." Transportation Association of Canada (2006).

[11] Medina, Jose Roberto, B. Shane Underwood, and Michael Mamlouk. "Estimation of Asphalt Concrete Modulus Using the Ultrasonic Pulse Velocity Test." Journal of Transportation Engineering, Part B: Pavements 144.2 (2018): 04018008.

[12] Tavassoti-Kheiry, Pezhouhan, et al. "Application of Ultrasonic Pulse Velocity Testing of Asphalt Concrete Mixtures to Improve the Prediction Accuracy of Dynamic Modulus Master Curve." International Conference on Highway Pavements and Airfield Technology 2017: Testing and Characterization of Bound and Unbound Pavement Materials. American Society of Civil Engineers (ASCE), 2017.

[13] Minstry of Roads Transport and Highways (MoRTH) 2013, Specifications for Road and Bridges works, Fifth Revision, Indian Road Congress, New Delhi.

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