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Characterizing the Bituminous Material by Using Graphical Techniques

Anam Riaz[1], Imran Hafeez[2]
[1]*Research Scholar, M.Sc. Transportation Engineering, University of Engineering & Technology, Taxila, Pakistan*
[2]*Professor, Department of Civil Engineering, University of Engineering and Technology, Taxila, Pakistan*

Abstract: ***Material that makes bound with bitumen known as bituminous material. For determination of properties of bituminous material various field test and techniques are used which are time consuming and have expensive material cost. To avoid such problems, techniques are required which can provide basic input parameters for materials models to be used in MEPDG Level-I pavement design input. The properties of bitumen can be fully described by using both the complex modulus and phase angles. Black Space diagram determines the viscosity, Stiffness, and elasticity by using complex modulus and phase angle and the G* and δ linked to Glover-Rowe concept which defines the two damaging zones that are damage onset and significant cracking. Cole-Cole plot shows the viscous and elastic behaviour of bitumen. Two bitumen grade 40-50 and 60-70 penetration grade and PMB (modified 60-70 with 1.6% elvaloy) were studied at six temperatures of 18, 24,30,36,42 and 48°C and in a frequency range of 0.01Hz to 100Hz using a DSR (dynamic shear rheometer).***
Keywords: Bitumen rheology, Black Space Diagram, Cole-Cole Plot, Glover Rowe Parameter, Block Cracking

I. INTRODUCTION

Material that makes bound with bitumen known as bituminous material. Bitumen is a viscoelastic material which shows immediate elastic response and time dependent viscous response [1]. Bitumen depends on time of loading and temperature, and it plays an important role in defining many of the aspects of asphalt road performance, e.g., strength, stiffness, elasticity, Viscosity, and cracking. General response to load is discussed by viscoelastic behaviour of bitumen. The properties of bitumen can be fully described by using both the complex modulus and phase angles, black diagrams were created to visually correlate between these two parameters.

Black diagrams show the variation of the phase angle with the dynamic modulus. Unlike master curves, black diagrams simply plot the measured data.

There is no need to do model fitting or shifting, hence inaccuracies in modelling is minimized [2-3]. Due to this reason, black diagrams are found to be a very useful tool for analysis that is independent of temperature and frequency effects [4]. Cole-Cole shows viscous and elastic behaviour by using storage modulus and loss modulus. G* and δ linked to Glover-Rowe concept which defines the damaging zones that are damage onset and threshold cracking [5].

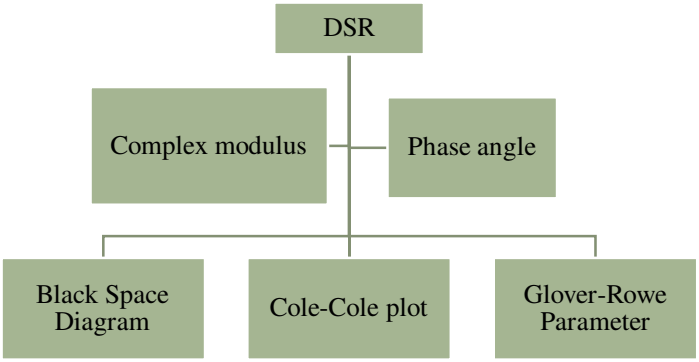
Different Binders Such as RAP, Recycled engine oil are used to study the behaviour of bitumen at different temperatures and analysed their behaviour by using point parameter [6]. For the study of effect of aging on materials Black space plot which link the Glover Rowe Parameter were calculated by using DSR and data used to draw master curves and fit the data into 2S2P1D model [7]. Different percentages of SBS (Styrene Butadiene Styrene) and PPA (Polyphosphoric Acid) are investigated by using DSR parameters (loss modulus and Storage modulus) for all samples and plot Black Space Diagram and Cole-Cole plot [8]. The rheological performance and storage stability of PMB and bitumen are investigated by using complex modulus and phase angle which help in SARA analysis as the asphaltenes show value of G* increase and Saturates Shows decreasing value of G* in their plot [9].

II. OBJECTIVES

The objective of this study is to characterize the bituminous material by using graphical techniques that are Black Space, Cole-Cole, and Glover Rowe Parameter. Elasticity, viscosity, and stiffness of material are evaluated by using black space diagram. Cole-Cole diagram shows the relationship between elastic and viscous behaviour of bitumen. Cracking and durability of bitumen address by using Glover Rowe diagram.

III. EXPERIMENTAL PROGRAM

Two neat bitumen with penetration grade 40-50 and 60-70 asphalt binders were studied in addition to PMB, which was PG64-22 in Superpave testing. These binders are mostly used in Pakistan on most of the highways. Samples were collected from ARL Pakistan. Ductility results of neat asphalt binders were over 100cm. PMB was prepared by using 60-70 penetration grade bitumen and 1.6% Elvaloy terpolymer. The penetration, softening point and ductility of PMB (PG 64-22) recorded in the laboratory were 47, 58oC and 65mm respectively. Based on penetration test, PG 64-22 lies in 40-50 pen grade.Testing on 25 mm diameter test specimen of bitumen was carried out on DSR as per AASHTO T-315 test protocol. Six temperatures of 18, 24,30,36,42 and 48oC in frequency range of 0.01Hz to 100Hz were selected that best simulate with the local field conditions. Frequency sweep test was run on neat and modified asphalt binder at 12% strain. Specimens in replicates were tested under each condition and results were computed to obtain complex shear modulus and phase angle. The result data sheets contained storage and loss modulus, and viscosity values. Phase angle and shear modulus were computed from deflection angle and storage modulus respectively.



IV. RESULTS AND DISCUSSION

A. *Black Space Diagram*

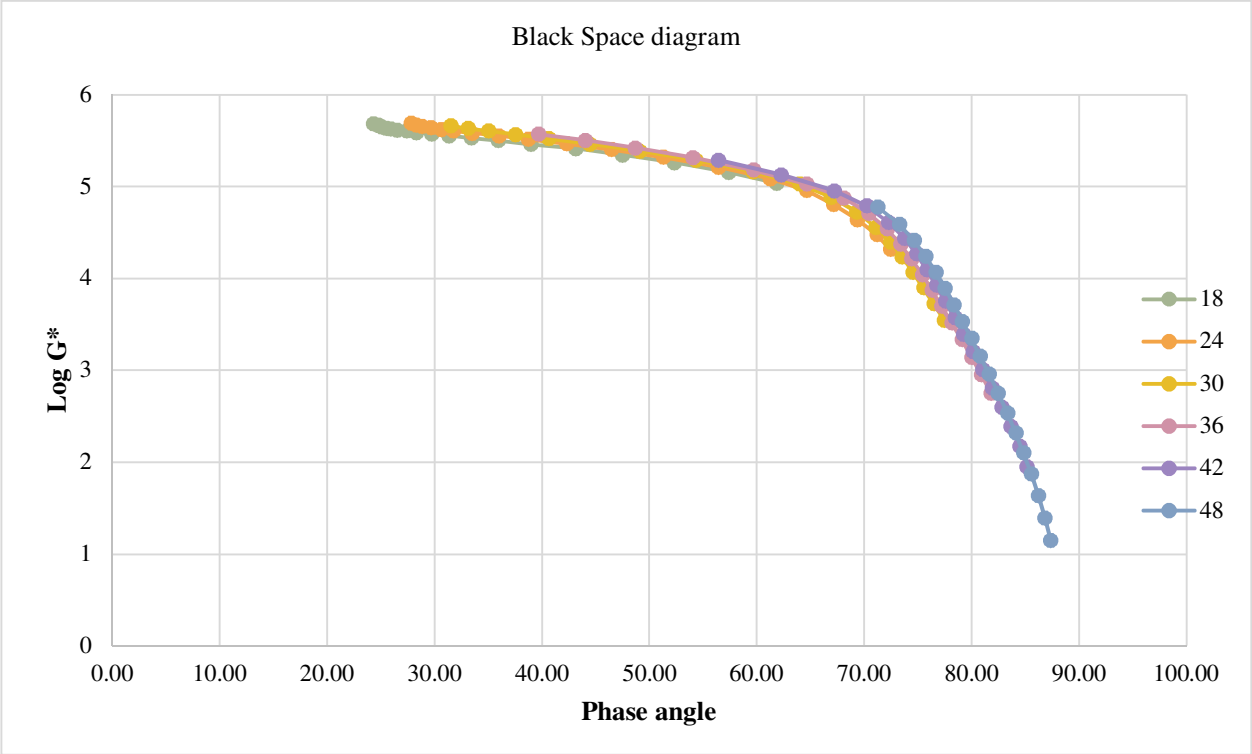


Figure 1(Black space diagram for bitumen grade 40-50 at different temperatures)

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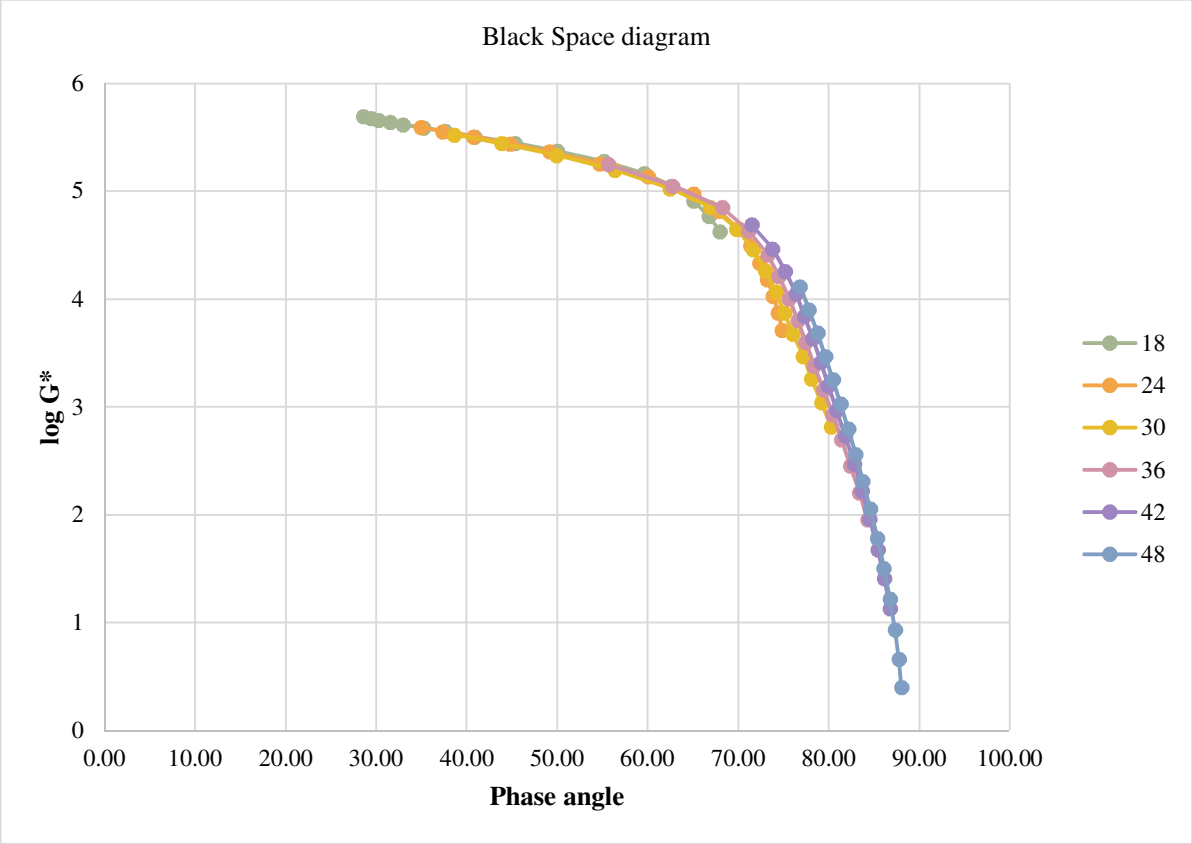

Figure 2 (Black space diagram for bitumen grade 60-70 at different temperatures)

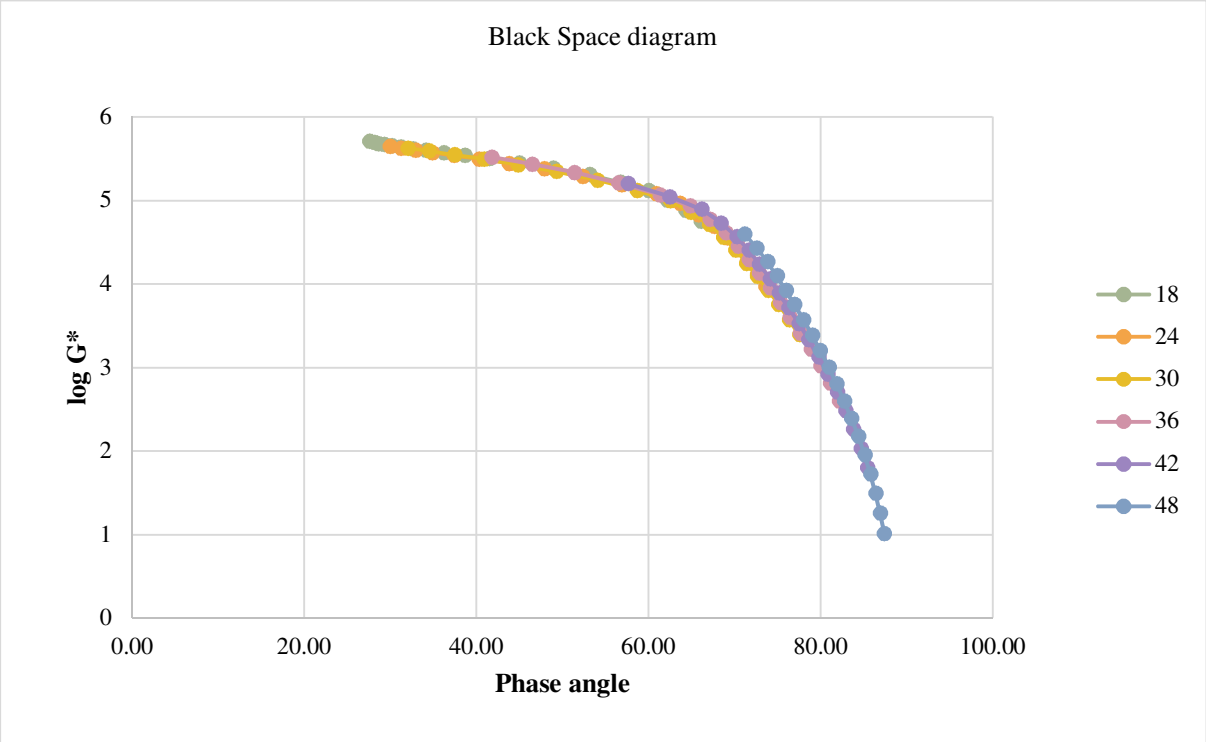

Figure 3(Black space diagram for PMB (60-70) at different temperatures)

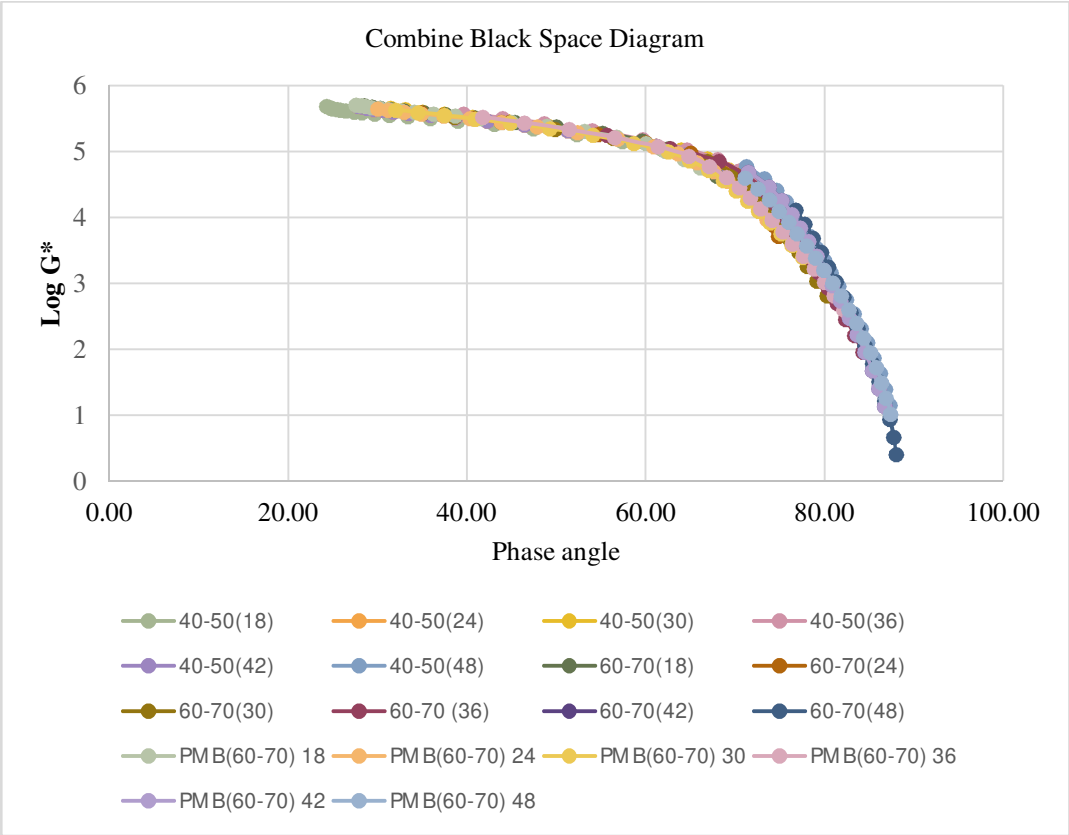

Figure 4 (Combine black space diagram)

All bitumen grade shows smooth curve with no discontinuities means that material is rheological simple, and data is consistent. Bitumen grade 40-50 has less phase angle as compared to 60-70 and PMB. Slope of line becomes steeper after 70 and hence loss of binder stiffness

B. Cole-Cole Plot

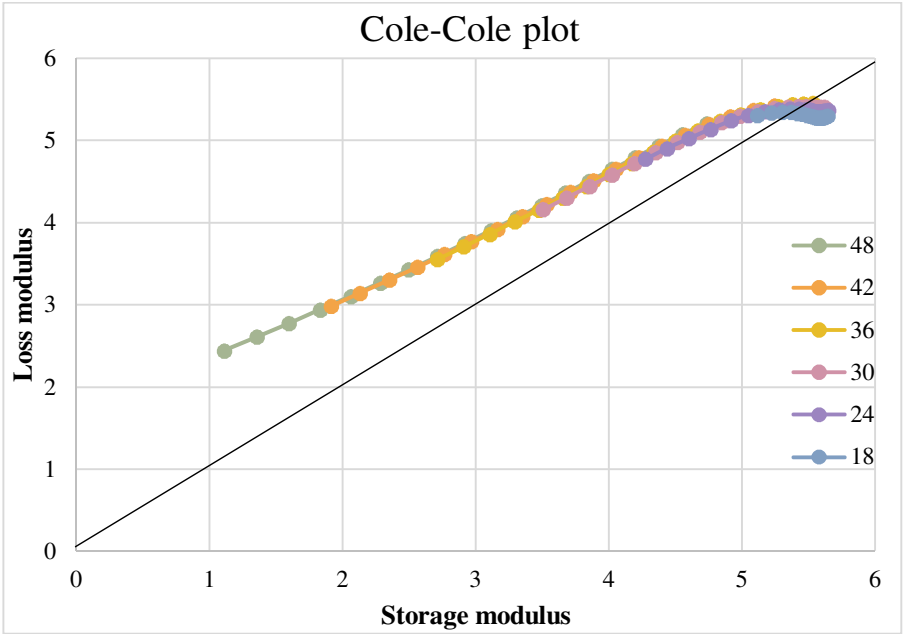

Figure 5(Cole-Cole plot for bitumen grade 40-50 at different temperatures)

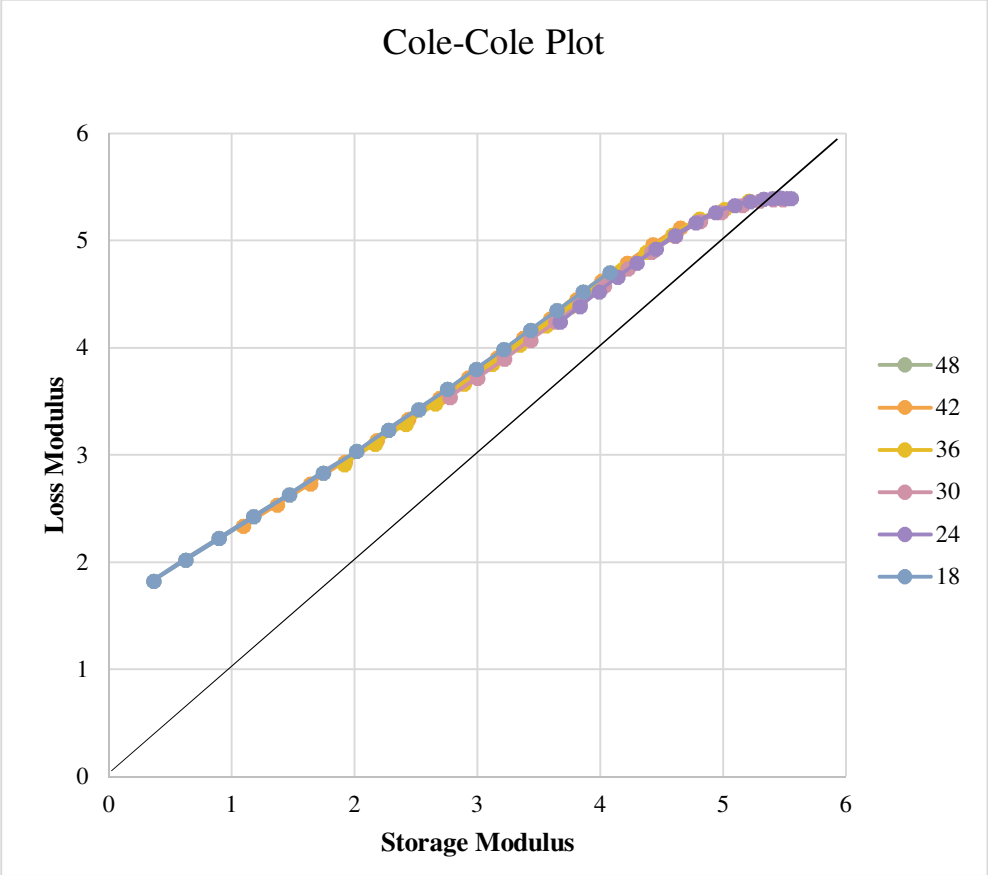

Figure 6 (Cole-Cole plot for bitumen grade 60-70 at different temperatures)

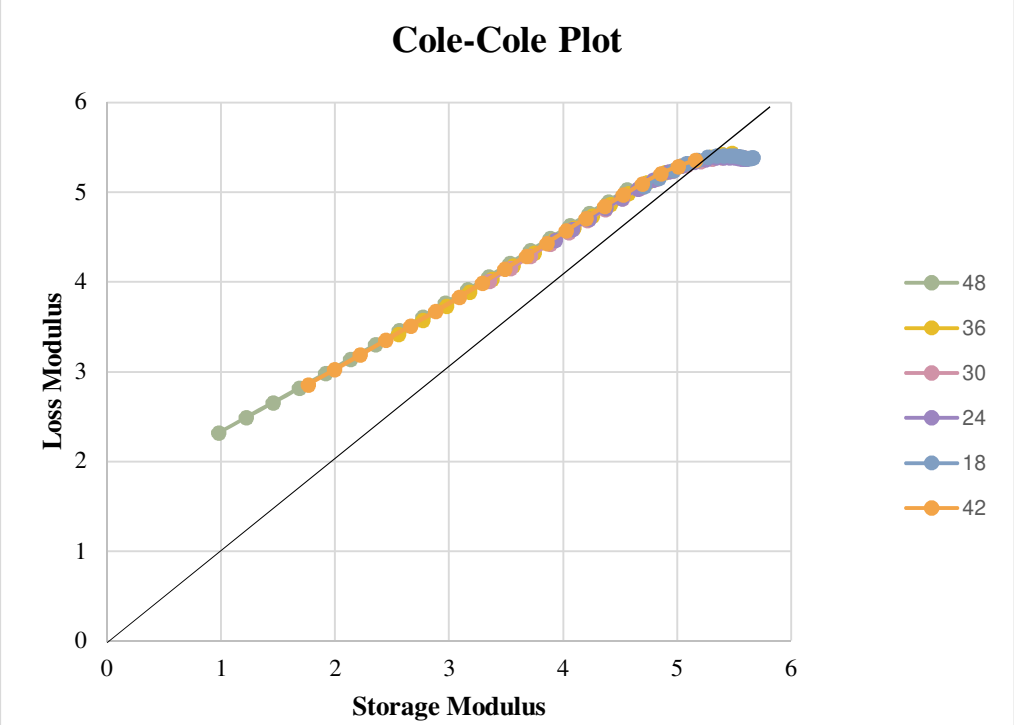

Figure 7(Cole-Cole plot for PMB (60-70) at different temperatures)

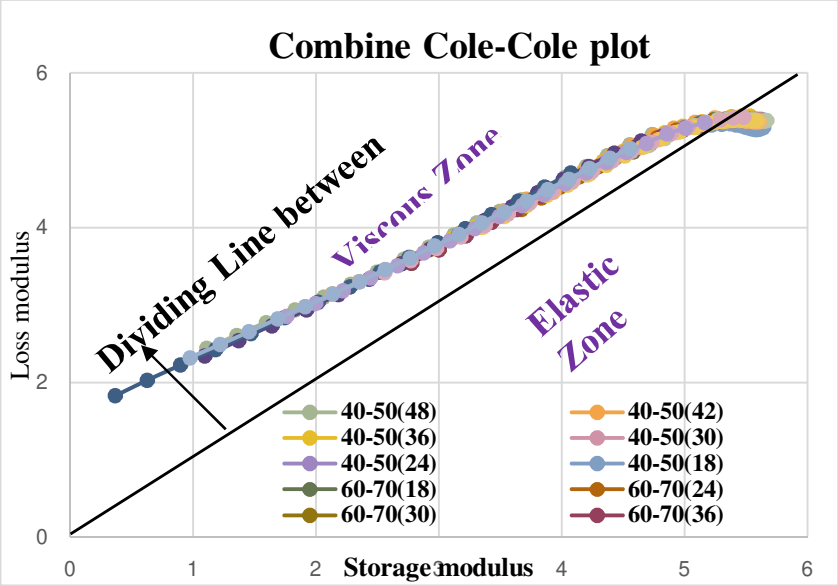

Figure 8 (combine Cole-Cole plot)

In Cole-Cole plot straight line separates the viscous and elastic behaviour. All the binders show linear association of complex modulus and phase angle. There was no structural change in the binders, which proved the materials stability. The C-C diagram is an important source of presenting viscoelastic balance of asphalt binders (Airey, 2003).40-50 Grade bitumen shows elastic behaviour as it is towards the right of dividing line 60-70 and PMB shows more viscous behaviour as it is towards the left of dividing line. Due to addition of PMB in 60-70 line of Cole-Cole move to upper right corner by 6 to 7 degree.

C. Glover Rowe Parameter

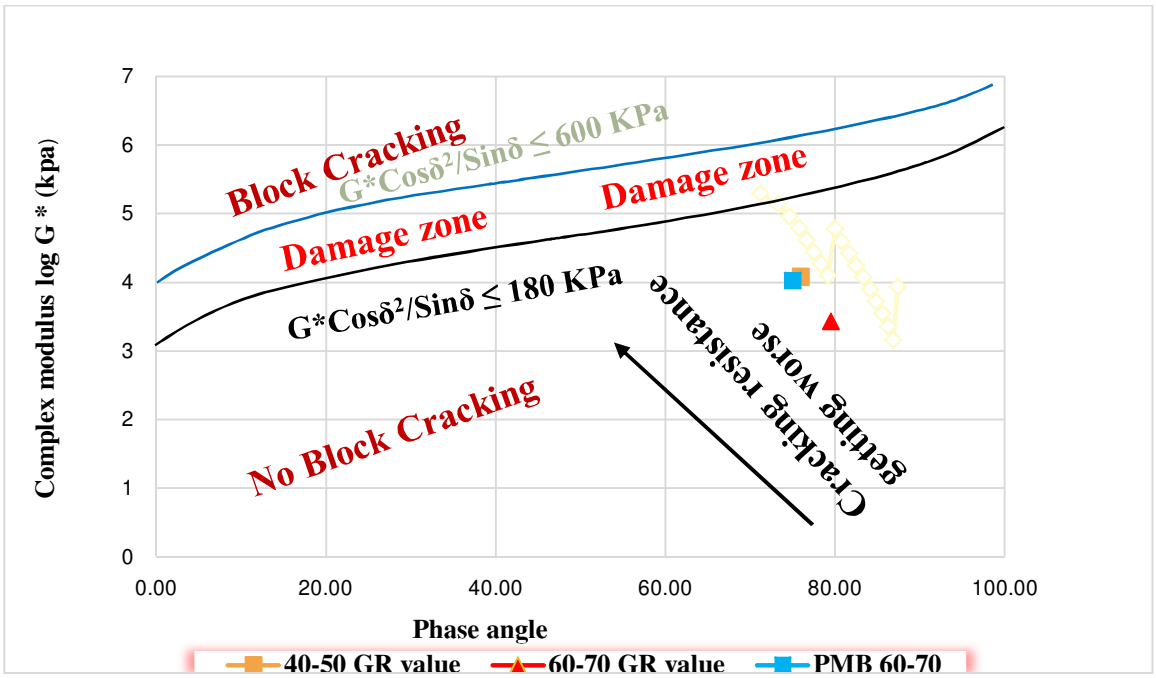

Figure 9 (Glover Rowe parameter For 40-50,60-70 and PMB)

GR value for all three samples lies below the damage zone of cracking. High GR value indicates an increase in brittleness of asphalt binder. PMB 60-70 has less GR value as compared to 40-50 and 60-70 grade bitumen

V. CONCLUSIONS

This study includes the two-bitumen grade 40-50 and 60-70 and one PMB.DSR test conducts on different temperatures at a frequency range of 0-1Hz to 100Hz.Blackspace, Cole-Cole plot are drawn and a point parameter i.e. Glover Rowe Parameter are being find by using Modified Rowe Method. Following conclusion are drawn during the research

1) Graphical techniques shall help in determining the amount of aging in binder with the passage of time that are used in adverse weather conditions, indicate inaccuracy in data, rheological simple data and indicate threshold zone by using Glover Rowe parameter .
2) In Black Space Diagram addition of PMB in 60-70 grade bitumen indicates the shift of curves towards low phase angle by 3 to 4 degrees. It shows on addition of PMB to bitumen grade improves its behaviour from viscous to elastic.
3) The results of Cole-Cole plot shows the Linear viscoelastic behaviour of asphalt due to identical form of plot. Due to addition of PMB in 60-70 line of Cole-Cole move to upper right corner by 6 to 7 degrees.
4) The G-Rm parameter helps in evaluating and identify the cracking and aging susceptibility of asphalt mixtures with different mix variables. All Glover Rowe values lies below the damage zone and there is no possibility of block cracking.

Additional mixtures and binders that are extracted and recovered from aged mixtures will be evaluated to obtain a wider range of information about the effect of rheological behaviour on these diagrams and develop a database for future analysis.

VI. ACKNOWLEDGEMENT

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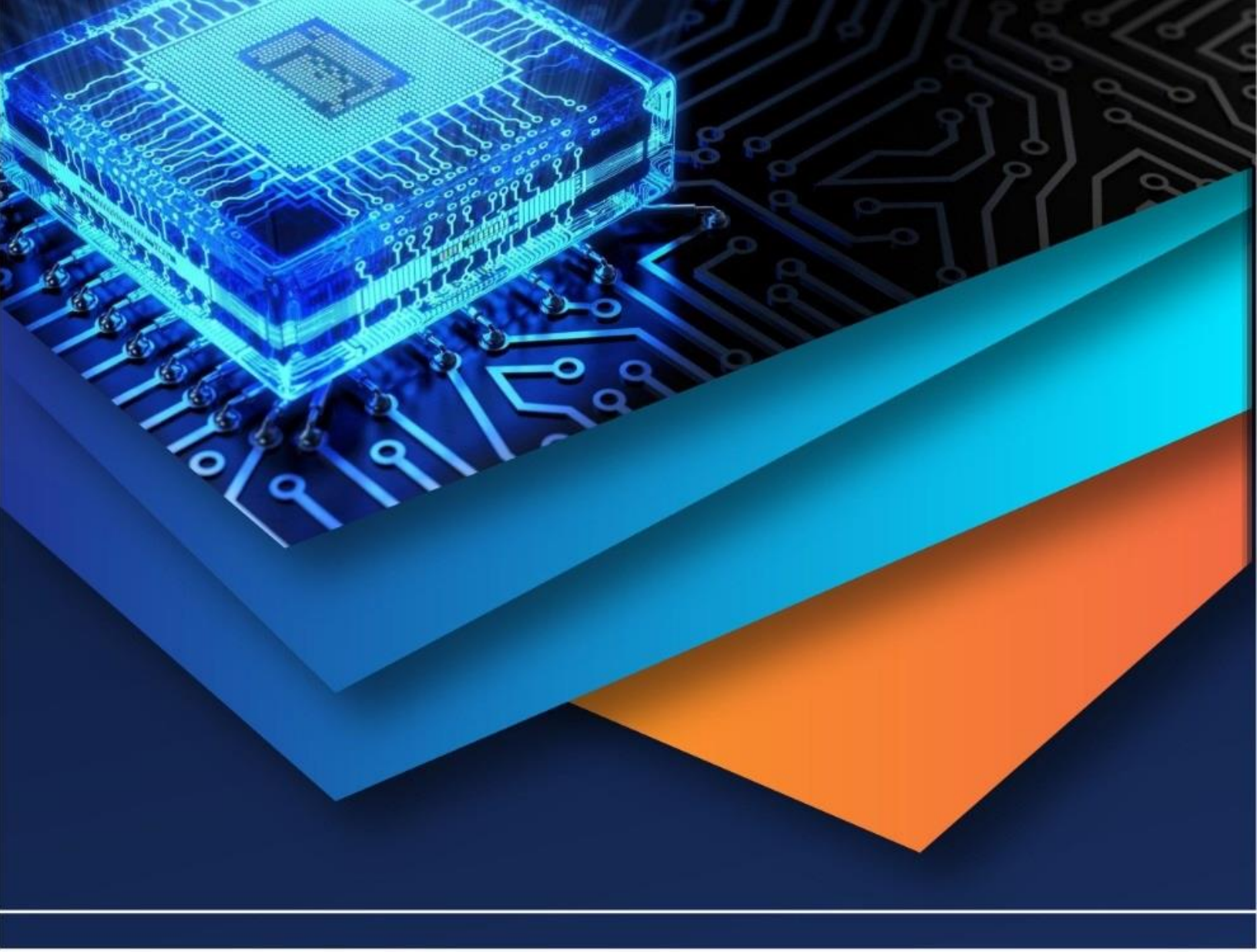

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