

Asphalt Concrete Modeling

Two Dimensional and Three Dimensional Discrete Element Modeling of Air Void Distribution for Asphalt Mixture

Sanjeev Adhikari, Ph.D. Student

Dr. Zhanping You, Advisor

Introduction

An asphalt mixture is a composite material of graded aggregates with asphalt binder plus a certain amount of air voids. Air voids play an important role in major pavement distresses including rutting, fatigue cracking, and low temperature cracking. Air voids also affect the durability of asphalt mixtures in terms of aging and stripping.

The amount of air voids in the asphalt concrete can be a detrimental effect if it is too high or too low. High air voids increases the asphalt stripping, accelerated oxidation, and rapid deterioration by development of rutting because of consolidation of wheel loading. Low air voids increases the likelihood of bleeding, shear flow, fatigue cracking and permanent deformation (i.e., rutting) in the wheel paths.

This study describes an idealized asphalt mixture as well as real microstructure of asphalt specimens. The asphalt mixture was modeled with the discrete element approach in both two dimensional and three dimensional approaches. The air voids were counted in the models by randomly generating within the models to reach a specific air void level. Two dimensional (2D) and three dimensional (3D) models were used to compute the strain and stress response when the specimens were subjected to compressive loads.

Objectives

- Use idealized mixture to compare for 2D and 3D modeling
- Develop 2D and 3D micromechanical discrete element models to simulate the modulus of an idealized asphalt mixture with air voids
- Investigate the differences to characterize the mixture modulus from 2D and 3D models with consideration of the air voids

Discrete Element Method: PFC 2D/3D

The discrete element approach is the complex constitutive behaviour of a material which is simulated by associating simple constitutive models with each particle contact. In this study, the commercial code from Itasca, Inc., called 'Particle Flow in Two Dimensions and Three Dimension,' or PFC2D and PFC3D are employed.

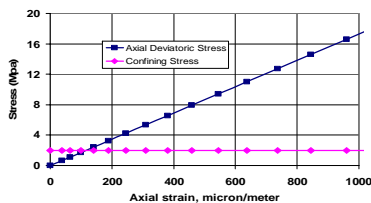


Fig 1: Axial deviator stress and confining stress versus axial strain in the 3D DEM simulation of an idealized mix with 4% air voids from one simulation. Modulus has been calculated 17.24GPa

Image

The rectangular shaped specimen with the a height of 80mm (0.08 m) and width of 40 mm (0.04 m) was generated for 2D. The height of 32mm is added for 3D. The radius of each ball (i.e., disk or discrete element) is 1mm. There are 800 balls in the 2D image and 12800 balls in the 3D image. Real image has 9680 balls for 2D and 9680*48 balls for 3D

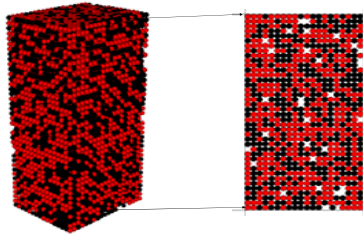


Fig 2: Image of air void (4%) and aggregate (53%) for 2D & 3D for idealized image

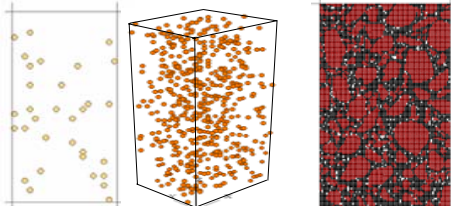


Fig 3: Image of air void (4%) distribution in 2D & 3D

Fig 4: Image of air void (4%) and aggregate (53%) for 2D real image

Real Vs. Idealized Microstructure

The real microstructure image is created from a lab sample using image-pro software to process the image to distinguish aggregate and mastic and further used for PFC 2D and PFC 3D. Air voids are randomly generated. This real sample has been compared with idealized 800 balls for 2D and 12800 balls for 3D.

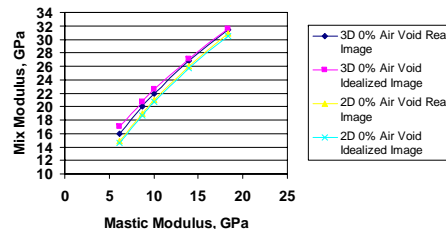


Fig 5: Comparing asphalt mix modulus for 2D and 3D modeling for 0% randomly generated air voids for real and idealized image.

Comparing 2D Image and 3D Image

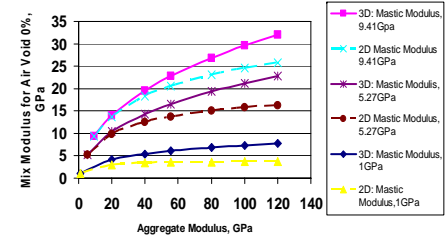


Fig 6: Comparing modulus for 2D and 3D 0% air voids by change in aggregate modulus.

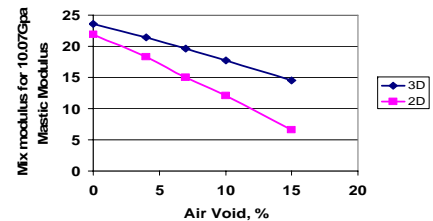


Fig 7: Comparing asphalt mix modulus for two dimensional and three dimensional modeling for different air voids

Conclusion

- It is found that the specimens have lower modulus when the air voids are higher in the specimens for both 2D and 3D models.
- When compared, the modulus predictions from the 2D and 3D models found the 3D models yield higher modulus than the 2D models. The average of the predicted modulus was 26% difference at 10% air voids and 7% at 4% air voids for the idealized asphalt mixture.
- When the air voids increase from 0% to 10%, the modulus decreased 30% in the 3D models compared with 48% in 2D models, even though both the 2D and 3D models yield same prediction when the air void is 0%. Therefore, the 2D models under-predicts the mixture modulus.
- At a certain air void level, the standard deviations from different randomly generated 2D models were much larger compared with the 3D.
- When compared real and idealized microstructure making similar percentage of mastic, aggregate and air voids, it predicts almost same modulus for 2D and 3D, but 3D predicts higher than 2D.