

Background

Roadway distresses are dramatically increasing and will continue to do so over the next decades. Factors such as rising traffic loads and extreme weather events have created a need for more durable asphalt pavement. One solution being implemented is the modification of



Fig. 1: Asphalt Binder Sample

asphalt binders (Figure 1) with reactive polymers to enhance pavement lifespan. Unlike conventional non-reactive modifiers that form physical networks through swelling, isocyanate-based reactive modifiers chemically interact with the components of the asphalt binder, as shown in Fig 2. This reaction creates a crosslinked network by forming a polyurethane structure within the binder, increasing pavement stiffness and stability at high temperatures. Likewise, since the modification is chemical rather than physical, it also helps solve common issues such as phase separation and workability reduction that often occur with conventional polymers.

The effectiveness of these modifiers, however, heavily depends on the pavement's base binder. This is because binders differ between crude oil sources and refining processes, resulting in high compositional variability among different binder groups. Therefore, developing a more complete understanding of potential modifier reactions means accounting for the changes in chemistry between different binder groups.

To accomplish this, this study utilizes the Strategic Highway Research Program (SHRP) reference binders, displayed in Table 1. These binders have been extensively characterized and represent a range of asphalt chemistries, making them ideal as base materials for evaluating the behavior of reactive polymer modifiers. Because SHRP binders are widely used as benchmark materials in asphalt research, their documented properties also enable comparison across different studies.

Research Objective

- Evaluate how a reactive polyisocyanate modifier influences the rheological behavior of SHRP reference binders using Dynamic Shear Rheometry (DSR).
- Identify chemical interactions between the modifier and binder components using Fourier Transform Infrared Spectroscopy (FTIR).
- Examine changes in molecular composition of the binders using FT-ICR Mass Spectrometry.

Materials

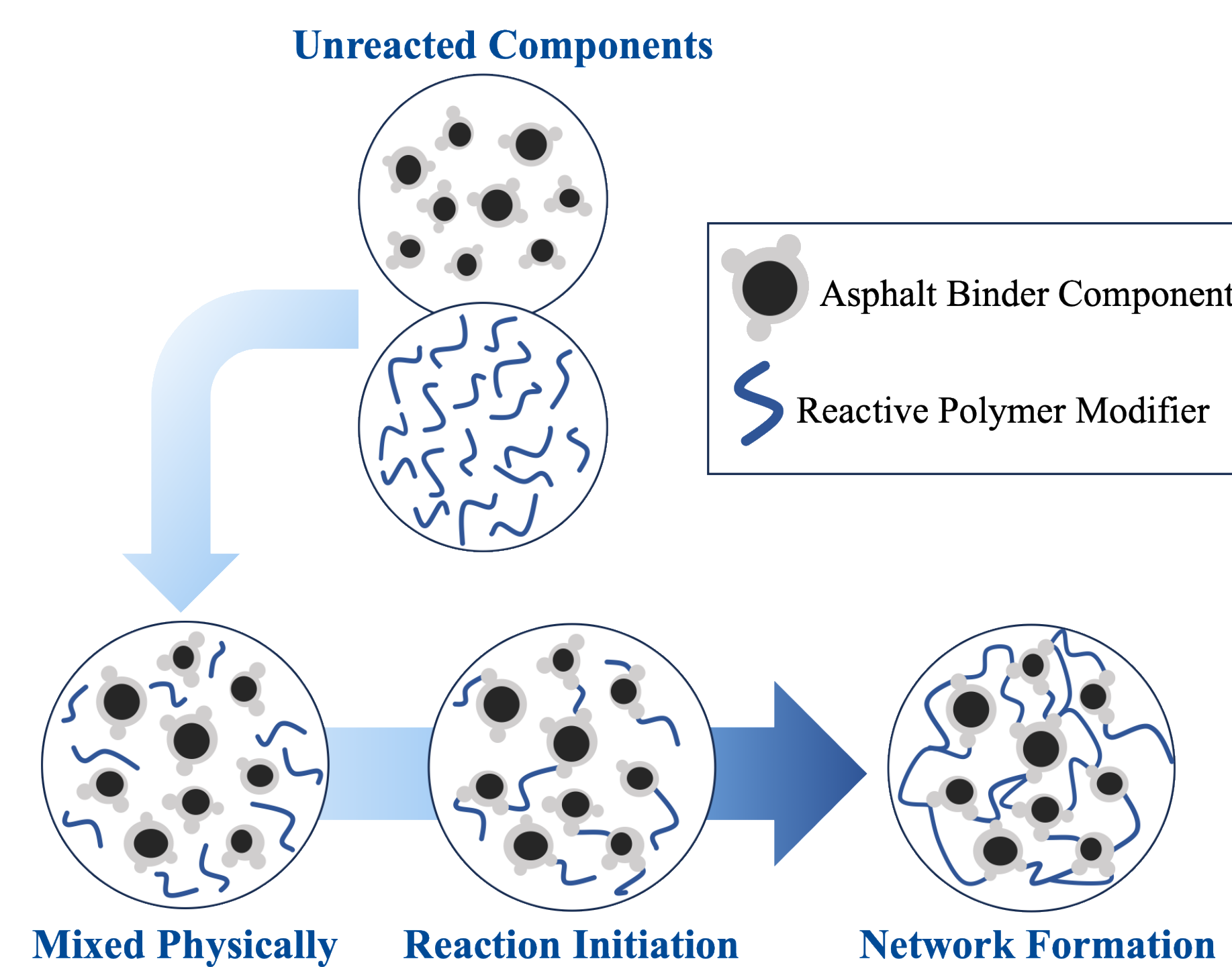


Fig. 2: Conceptual illustration of reactive polymer interaction and network formation in asphalt binder.

Table 1. SHRP Binders Used in Study

SHRP Binder	Crude Oil Source
AAA-1	Lloydminster
AAB-1	Wyoming High Sulfur
AAC-1	Redwater
AAD-1	California Coastal
AAF-1	West Texas Sour
AAG-1	California Valley
AAK-1	Boscan
AAM-1	West Texas Intermediate

Analytical Methods

Dynamic Shear Testing using a Rheometer (Figure 3) will be used to characterize the viscoelastic behavior of the samples. This test evaluates binder stiffness and relaxation across controlled temperatures and loading frequencies. From this information, the potential mechanical performance of the binder can be derived, specifically its resistance to rutting at high temperatures and fatigue cracking at intermediate temperatures.



Fig. 3: Dynamic Shear Rheometer

As for the DSR parameters, both parallel plate and concentric cylinder geometries (Figure 4) will be used to characterize asphalt binder performance across a wider range of temperatures and viscosities. This is because although the parallel plate geometry is more standardized for binder testing, at elevated temperatures when binders become highly fluid, edge loss and sample slippage can reduce measurement reliability. The concentric cylinder geometry, however, confines the binder within a narrow cylindrical gap, preventing material loss and providing more stable measurements for low-viscosity conditions. By combining both geometries, rheological properties can be measured more reliably across a larger performance range.

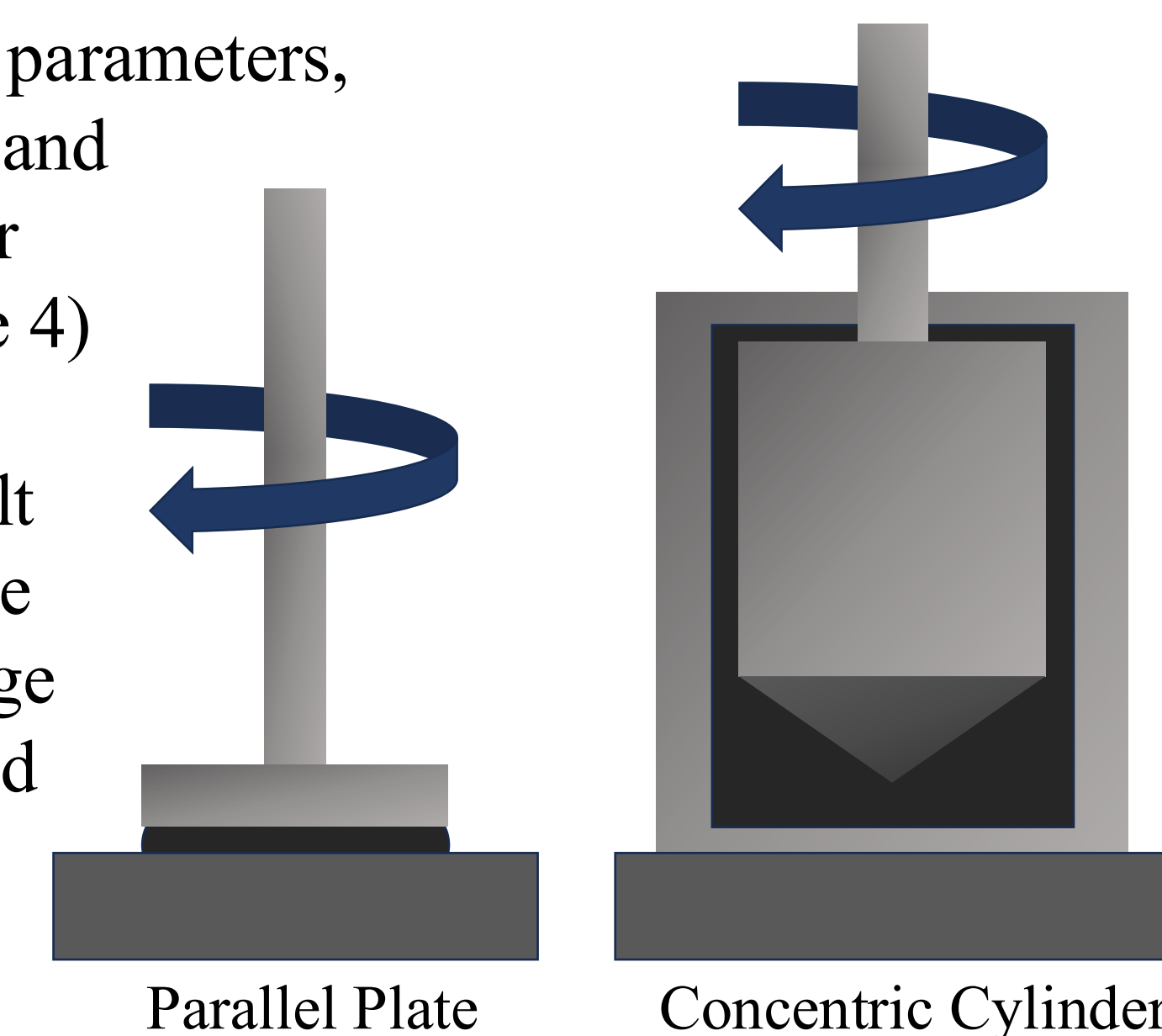


Fig. 4: DSR Geometries

In addition, Fourier Transform Infrared Spectroscopy (FTIR) will be used to examine chemical interactions between the reactive polymer modifier and asphalt binder components (Figure 5). This is done by identifying changes in functional groups and bond formations for each sample.



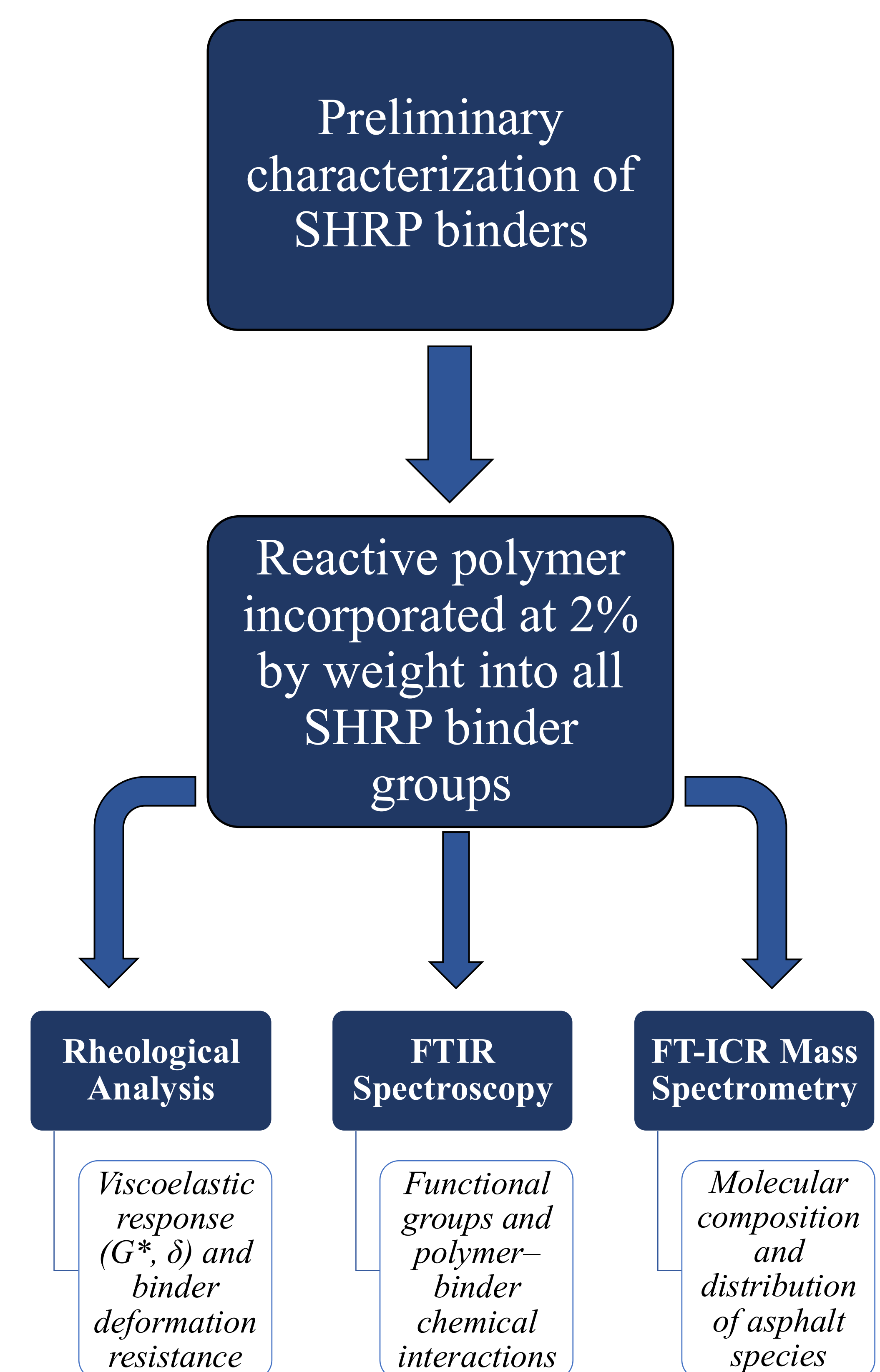
Fig. 5: FTIR spectrometer

Finally, Fourier Transform Ion Cyclotron Resonance Mass Spectrometry (FT-ICR MS), shown in Figure 6, will be performed with the National High Magnetic Field Laboratory (MagLab) to characterize the molecular composition of the samples. Asphalt is composed of thousands of different molecular species, making it difficult for conventional analytical techniques to clearly separate individual components. FT-ICR MS, however, works well because of its ultrahigh mass resolution, allowing molecules with minuscule mass differences to be separated and detected. This enables detailed identification of molecular species, providing insight into how reactive polymers influence binder compositional fractions at the molecular scale.



Fig. 6: 21-Tesla Bruker FT-ICR

Experimental Workflow



Acknowledgments

This project is conducted in collaboration with the National High Magnetic Field Laboratory and BASF. The author gratefully acknowledges the FAMU–FSU College of Engineering, particularly the EUREKA Program, for supporting this research. Special thanks are extended to my mentor and the graduate students in the PRISM Laboratory for their guidance and assistance.

References

- Pan, Wang; Guan, Hongxin; Deng, Jie; Yang, Hairong. (2026). Rigid–Flexible Interpenetrating Network: Performance Regulation and Multi-Scale Mechanism of Lignin–Polyurethane Composite Asphalt. Case Studies in Construction Materials.
- Anderson, David A.; et al. (1994). SHRP Asphalt Binder Characterization and Evaluation, Volume 3: Physical Characterization. Strategic Highway Research Program, National Research Council.
- Zhang, Zengping; Sun, Jia; Jia, Meng; Ban, Xiaoyi; Wang, Li; Chen, Liqi; Huang, Ting; Liu, Hao. (2021). Effects of polyurethane thermoplastic elastomer on properties of asphalt binder and asphalt mixture. Journal of Materials in Civil Engineering, 33(3), 04020477.
- Carreno Gómez, Nicolás Héctor; Oeser, Markus; Fleischel, Olivier. (2021). Chemical modification of bitumen with novel isocyanate-based additive to enhance asphalt performance. Construction and Building Materials, 301, 124128.
- Wiebelhaus, Dag. (2023). Building better roads. BASF Research Press Conference, December 1, 2023. BASF SE.