Investigating Rutting Sensitivity of HMA and Appropriate Laboratory Test Methods:

Case Study - State of Qatar

14 November 2017

Make today matter

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Haissam Sebaaly, PhD Candidate

Supervisor: Prof James Maina, University of Pretoria

Co-Supervisor: Dr. Sudhir Varma, ANAS S.p.A., Qatar

Outline

- Background
  - Climate & Traffic
  - Asphalt Production
  - Research Objective
- Literature (*Texas, Kuwait, Abu Dhabi, New Zealand*)
- Laboratory Test Results
- Mix Design - Artificial Neural Network and Genetic Algorithm
- Future Work

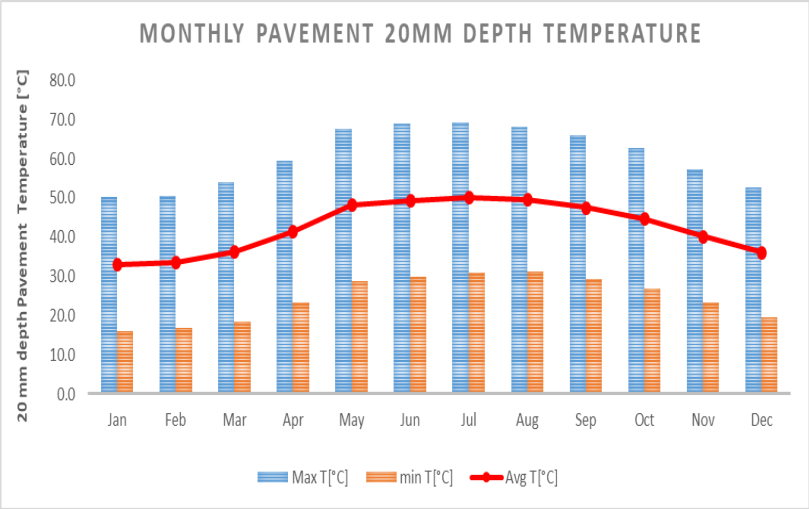
Background

The State of Qatar

- Gulf Cooperation Council (GCC) country
- 2022 world cup
- 2030 vision
- World highest per capita income (developing)
- 63 highway projects + local roads

Background

Climate



- Pen 60/70 ~ PG64-10
- PMB PG76E-10

Traffic

- Traffic congestion due to extreme construction activities

Background

Pavement Failures:

- Rutting
- Shoving
- Bleeding

Shoving

Bleeding

Rutting

Background

Different causes can lead to such pavement distresses:

- Unbalanced Mix Design
- Lack of criteria/requirements which give indication of potential permanent deformation failures
- HMA production issues

Shoving

Pavement Deformation

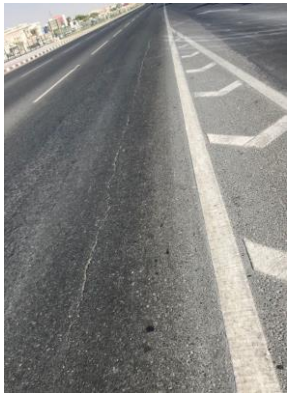
Bleeding

Background

- To address problems with permanent deformation failures, the industry has adopted the approach of minimizing binder content in asphalt mixes

- The combination of low binder content and Two other major factors:
  - ➢ No drainage system
  - ➢ High water table

  Resulted in other pavement distresses:
  - ➢ Premature fatigue cracking
  - ➢ Stripping



Background

Asphalt Production

- 33 Hot Mix Asphalt batch plants
- 9 Polymer Modified Binder plants
- All raw materials for asphalt mixes are imported (Aggregate and Binder)

QCS 2014 – Asphalt Mix Design Requirements:

- ➢ Marshall Mix Design – broadly used
  - ✓ 400 Blows
- ➢ Superpave Mix Design – not used yet
  - ✓ Nmax

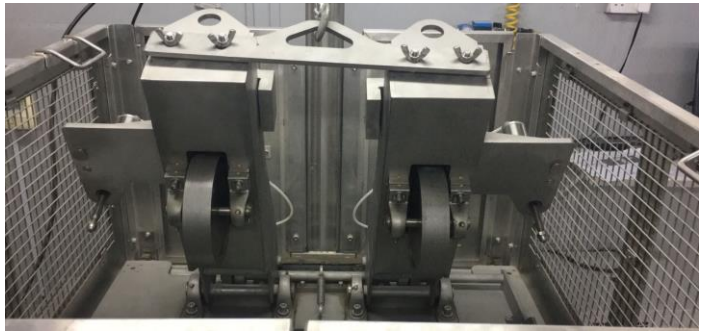
Research Objective

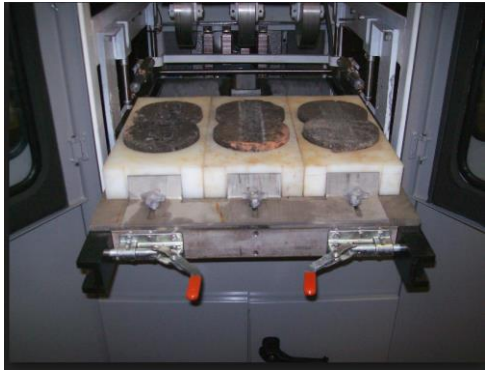
- Review current specs
- Identify gaps, specifically for permanent deformation
- Determine best lab tests
- Identify rutting criteria:
  - Enhancement of current methods and limits
  - Recommend tests & criteria

Literature

Performance tests that give indication of potential permanent deformation:

- Hamburg Wheel-Track Test (HWTT)
- Flow Number (FN)
- Asphalt Pavement Analyzer (APA)





Laboratory Test Results

Twelve asphalt mixtures were identified for this research purpose

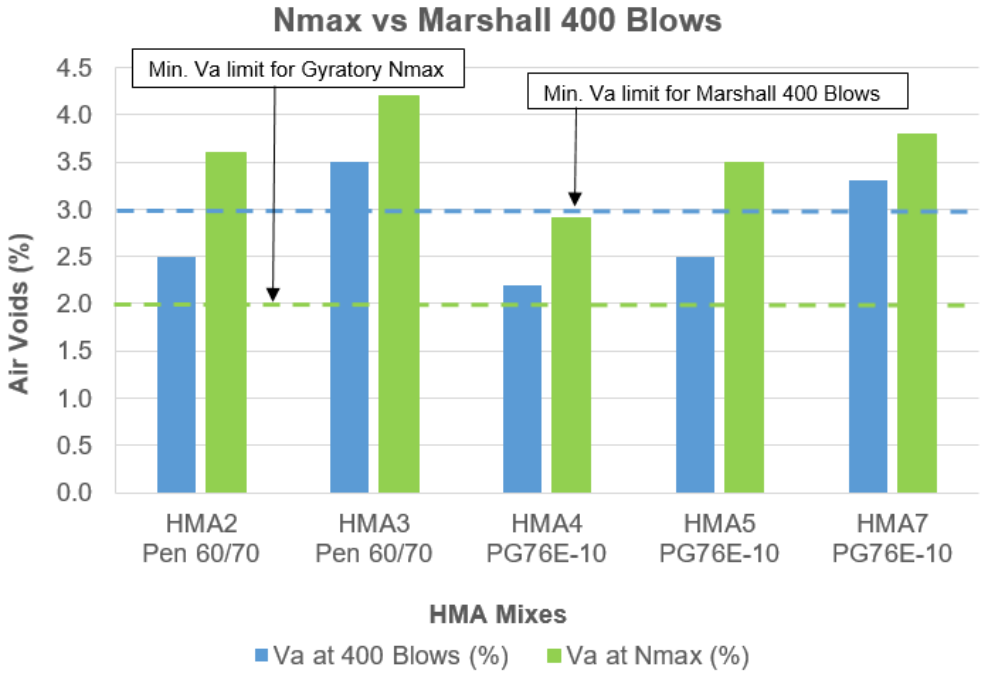
- Six surface course mixtures - Pen 60/70 (≅ PG64-10)
- Six surface course mixtures - PG76E-10

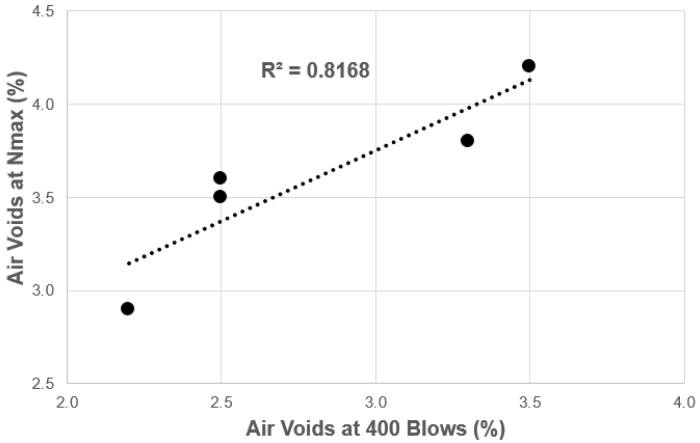
Currently, the only permanent deformation indicator at the mix design stage is the Air Voids at 400 Blows compaction

Samples for five mixes were prepared and tested as follows:

- Marshall samples compacted at 400 Blows, and
- Gyratory samples compacted at Nmax gyrations.

Laboratory Test Results

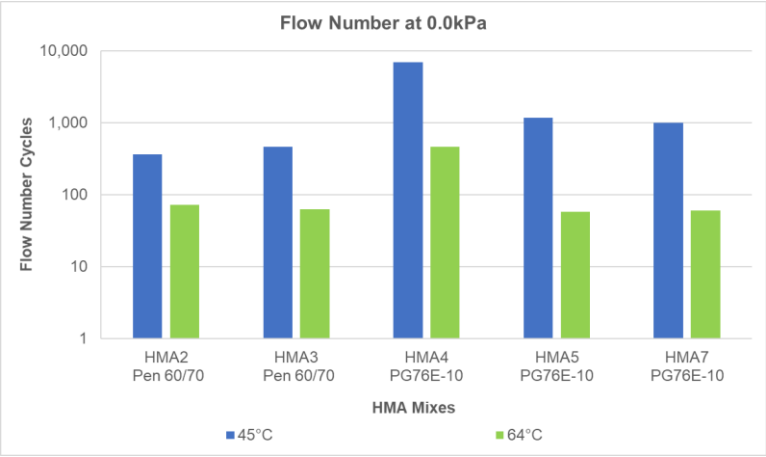


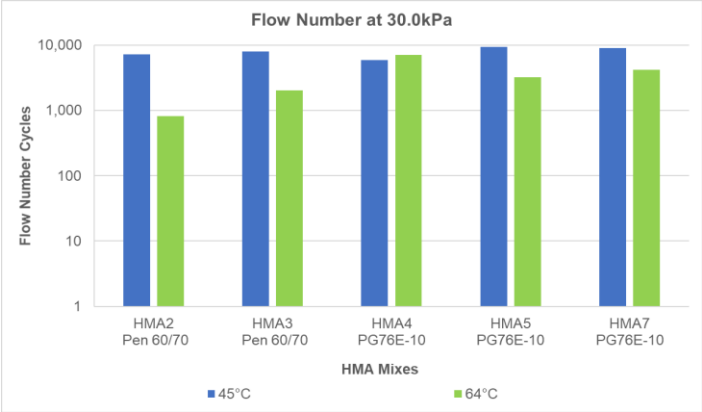


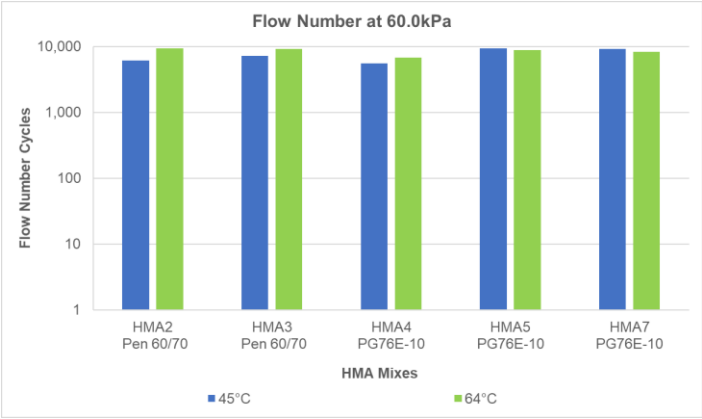
Laboratory Test Results

Flow Number Tests were conducted on five mixes at three different confining pressures and two different temperatures:

- 0.0 kPa, 30.0 kPa, 60.0 kPa
- 45°C, 64°C

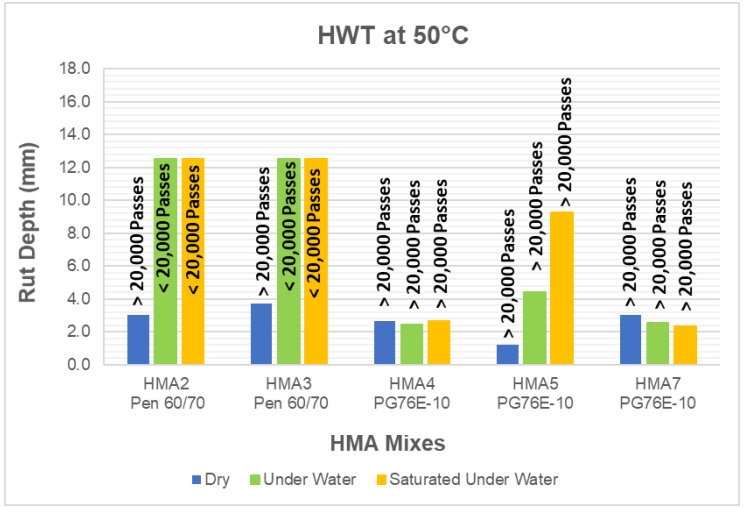


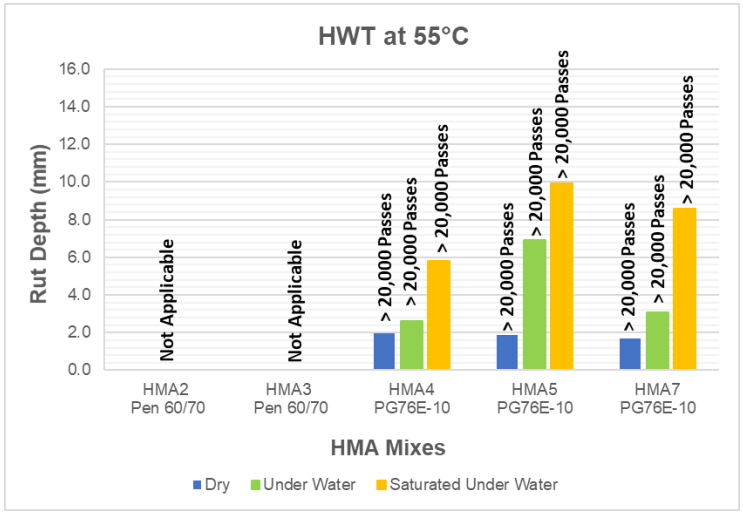




Laboratory Test Results

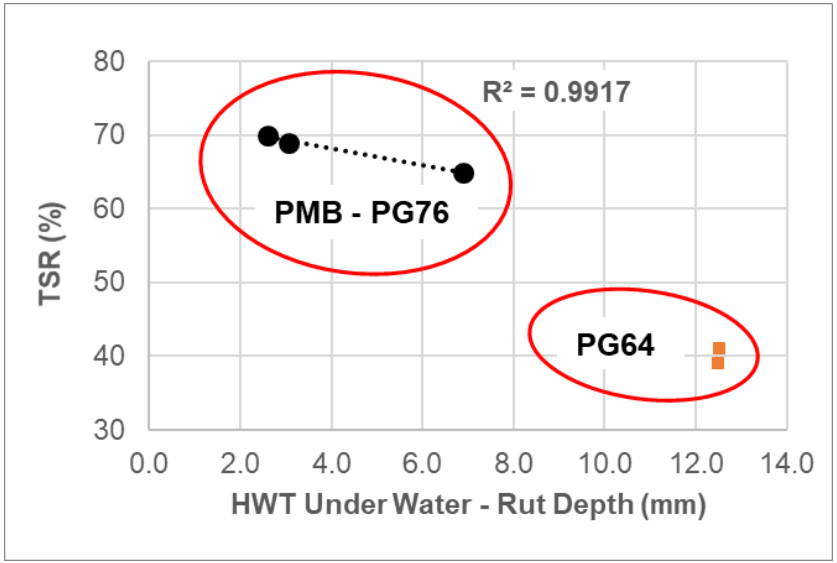
Hamburg Wheel-Track Tests were conducted on five mixes at two different temperatures: 50°C, 55°C

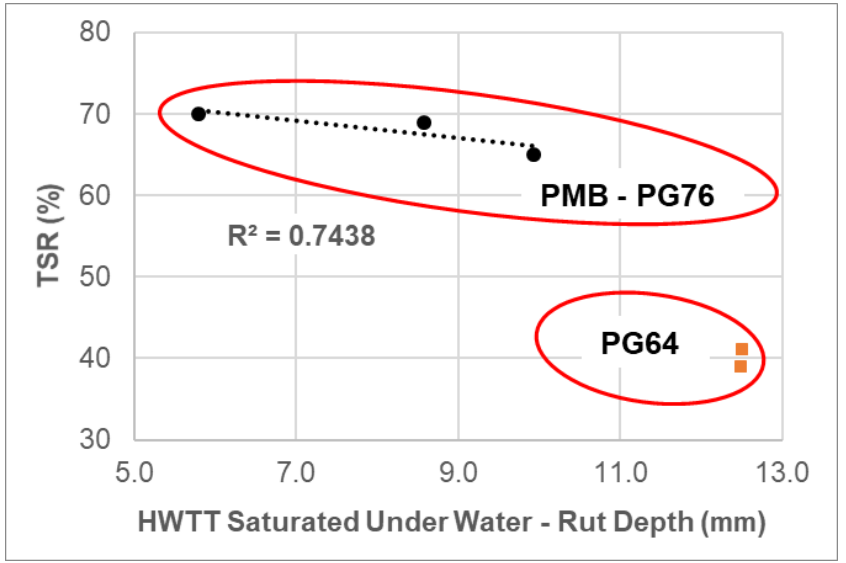




Laboratory Test Results

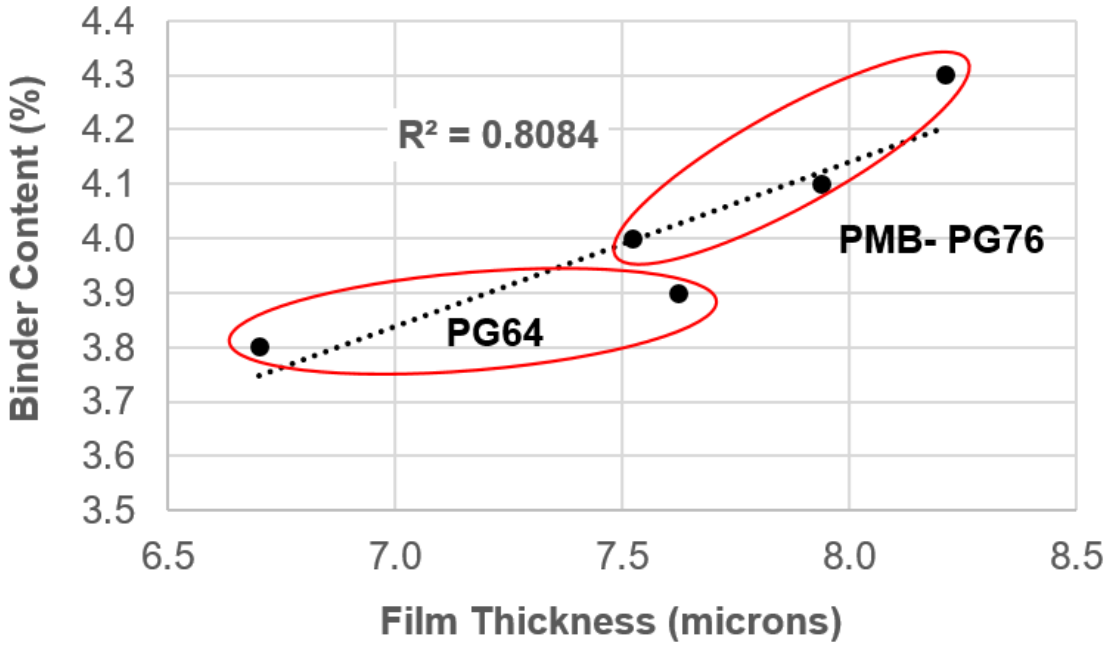
Tensile Strength Ratio Tests (Modified Lottman Tests) were conducted on five mixes





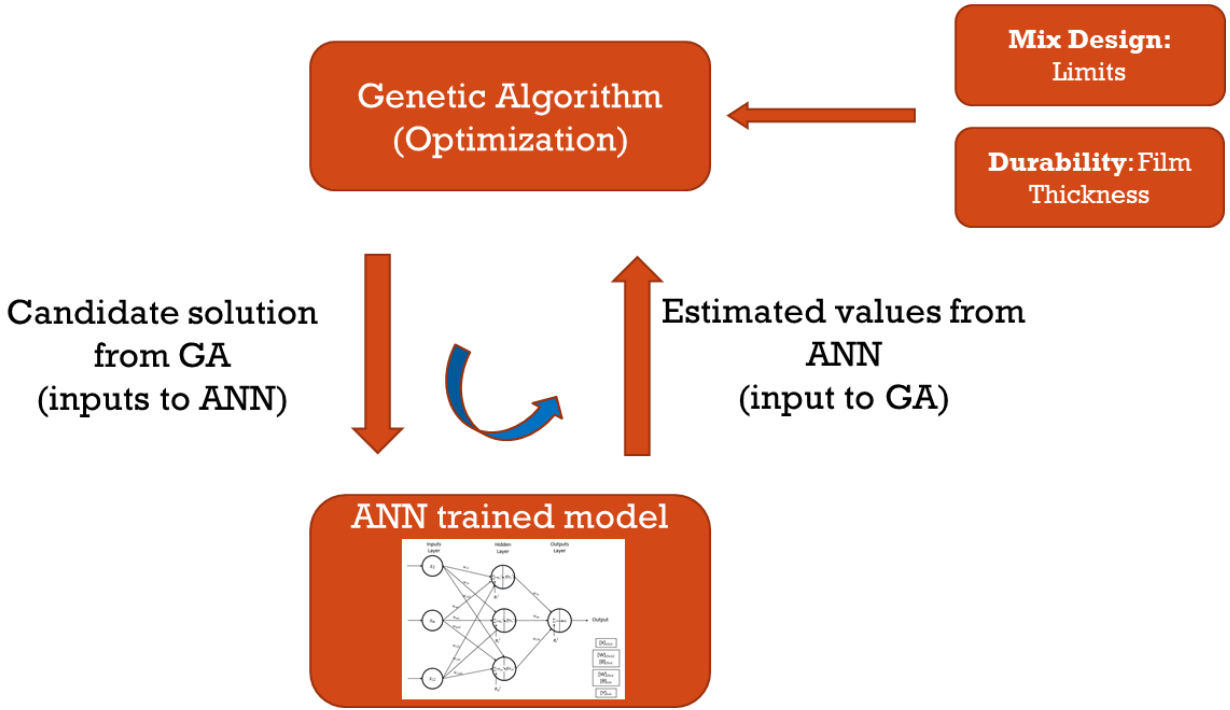
Laboratory Test Results

The Film Thickness of each mix was calculated to check if the durability was maintained



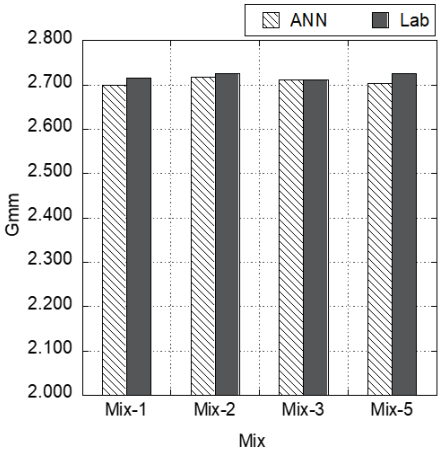
Marshall Mix Design – ANN & GA

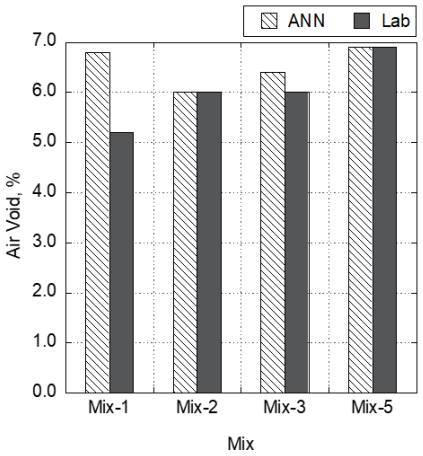
- Asphalt mix properties from construction projects were used in developing ANN model.
- The ANN & GA models were used to automate mix design procedure and obtain optimum design that meets al the criteria.
- Film thickness was checked as a measure of durability.

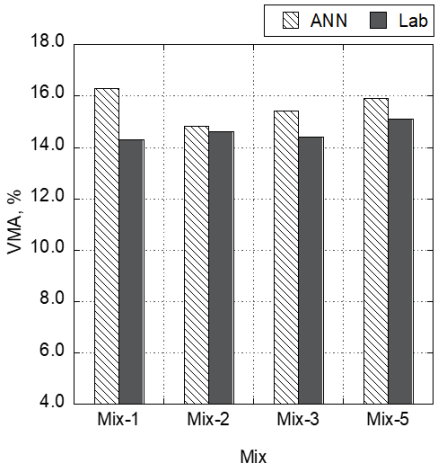


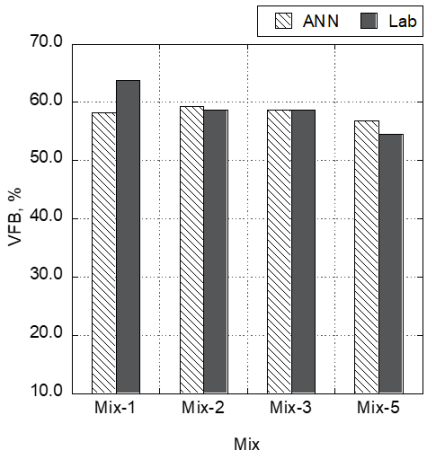
Marshall Mix Design – ANN & GA

End results were successful and fresh mixes were verified through lab testing









A paper was submitted to (Journal of Construction & Building Materials)

Future Work

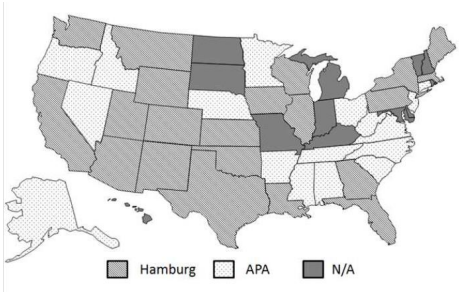
- Testing matrix will be finalized within approx. 12 months
- Testing of cores from construction sites
- Monitoring of pavement sections to assess short to medium term performance of the mixes (*for PhD purpose*)
- Conclusion and recommendations will be drawn after finalizing all analyses including statistical evaluations

Thank You

Literature

In the USA each State has its own specifications and criteria for permanent deformation.

DoT	PG 58	PG 64	PG 70	PG 76
California	45	50	55	
Montana	44	50	56	
Colorado	45	50	55	55
Utah	46	50	54	
Iowa	50 for all tests			
Texas	50 for all tests			
Wisconsin	50 for all tests			
Oklahoma	50 for all tests			
Washington	50 for all tests			
Illinois	50 for all tests			
Louisiana	50 for all tests			
Massachusetts	45			

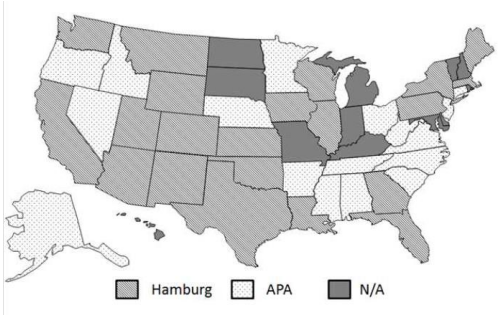


DoT	PG 58	PG 64	PG 70	PG 76
California (12.5mm)	10,000	15,000	20,000	25,000 (or higher PG)
Montana (12.5mm)	1000 for Plant Produced Mix			-
	1500 for Lab Produced Mix			-
Colorado	Maximum rut depth > 4mm before 10,000 passes is considering a failure			
Utah	Maximum rut depth > 20mm before 20000 passes is considered failure			-
Texas (12.5mm)	10000	10000	15000	20000 (or higher PG)
Wisconsin (12.5mm)	5000	10000	15000	20000
Illinois (12.5mm)	5000 (or lower PG)	7500	15000	20000 (or higher PG)
Louisiana (12.5mm)	12000	20000	7500 (OGFC)	

Literature

Texas DOT Specifications for HWTT (50°C)

High-Temperature Binder Grade	Minimum Number of Passes @ 0.5 inch Rut Depth
PG 64	10,000
PG 70	15,000
PG 76 or Higher	20,000

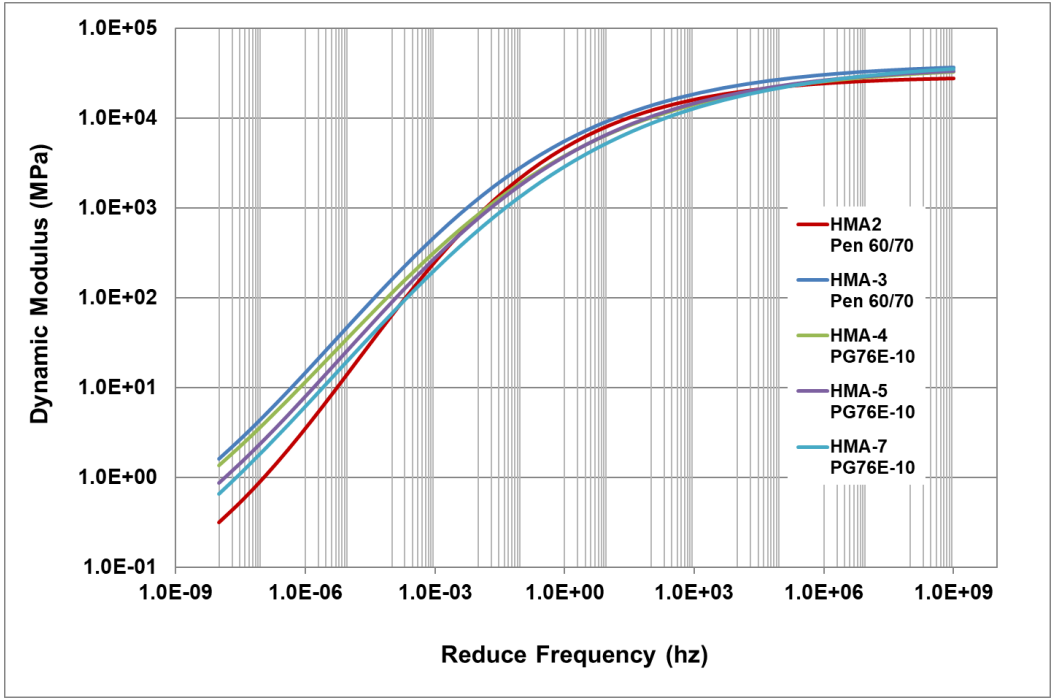


- In New Zealand, HWTT is used for measuring permanent deformation. Test is conducted Dry at 60°C and the max. rut depth allowed is 6.0mm

- In Kuwait & Abu Dhabi (GCC), the rutting indicator is the Marshall specimens compacted at 400 Blows and min. air voids required is 3.0%

Laboratory Test Results

- The Dynamic Modulus test was conducted for five mixes
- E* will be used as an input for the me-GAMES to determine the pavement confinement pressure in the top 100mm for different pavement structures
- The analysis of me-GAMES will be used to determine the optimum FN confinement pressure



Marshall Mix Design - ANN

- The goal of this ANN is to develop an optimization model which assists in automating mix design procedure.

- Based on the existing literature despite successful demonstration of possible advantageous ANN implementation in pavement engineering, it has not been adopted in practice.

- The main obstacles in adopting ANN in practice is lack of background information and complex architecture of ANN models.

Marshall Mix Design - ANN

- An optimization scheme was developed using Genetic Algorithm to automate mix design procedure

- Durability of each mix was checked through the Film Thickness calculation (min. 8.0 microns)