

Quality control methods for epoxy asphalt road surfacing materials

Mehran Torbaghan & Esdras Ngezahayo | February 2022

This reading pack seeks to support the development of a quality control methodology and framework for the material and methods associated with constructing roads using epoxy bitumen. The readings identified existing quality control methods and their application in low and middle income settings. They describe the general components of a quality control system in the construction of road pavements comprising the following elements: Control of materials and methods; Control of end-product. This reading pack also explores experimental approaches to the characterisation of chemical and physical performance of epoxy modified bitumen.

A quality control system is essential during any road construction or maintenance activities to ensure an extended asset life and lower life cycle cost. Despite the importance of ensuring the quality of road surfacings, the literature suggests that there is a lack of quality control procedures for road surfacing material construction, especially in Low and Middle Income countries, which is leading to poor quality road surfaces. Further to this, there is a limited literature on the control of epoxy asphalt bitumen content. This is particularly important, as there are few suppliers of the material globally.

By developing a framework for quality control, higher durability and hence lower life cycle cost can be achieved for the epoxy bitumen road surfacings. This is essential to support the development of climate resilient and sustainable roads that are able to manage changes in climate, e.g., hotter seasons, more extreme precipitation events and sea level rise that impinge on road pavement performance in Low and Middle Income countries. Failure to account for such impacts in future road design, maintenance and operations planning could cause accelerated road deterioration and higher road use costs, thereby severely constraining socio-economic development.



Dr Mehran Torbaghan
(University of Birmingham)

Dr Mehran Torbaghan is a lecturer in infrastructure asset management at the Department of Civil Engineering with a Doctor of Philosophy (PhD) focused on Risk Management and Renewable Energy.



Dr Esdras Ngezahayo
(University of Birmingham)

Esdras has over 10 years of experience in Civil Engineering. He specialises in Geotechnical Engineering, with focus on sustainable and climate resilient materials for roads and railways.

Reading packs are commissioned by the University of Birmingham's CRISPS research team for independent study and professional development use. They are intended to be thought-provoking introductions to emerging issues and debates within the subject areas they cover.

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Key Readings

Reading 1: Velasquez, E.D.R. (2018). **A Quality Control Performance-Based Methodology for Pavement Management Systems**. Master's in Civil Engineering. The University of Texas at El Paso. <https://scholarworks.utep.edu/dissertations/AAI10929551/>

This thesis focuses on the development of a framework that incorporates a systematic quality control method in the pavement management process. The methodology includes quality control validation checks and statistical tests for data collection of the pavement inventory, condition assessment, and performance modelling. Transportation Asset Management is a decision-making process, which allocates available resources for operating, maintaining, enhancing, and expanding transportation infrastructure while considering its entire life cycle. Transportation infrastructure includes different types of assets and pavements are one of the main assets due to its social, economic, and environmental impacts to society. Transportation agencies implement Pavement Management Systems to support the pavement management process. While implementing and operating a Pavement Management System, one of the costliest procedures is collecting pavement condition data from the field. Good quality for pavement condition data is required to select the right preservation treatments, estimate the associated costs, model the pavement performance, justify budget needs, and apply well-timed maintenance and rehabilitation strategies. The results of this research contribute to the improvement of data quality used in the pavement management process by identifying poor quality data collected either manually or automatically. This methodology can be applied to training programs, certification programs, pre-collection sites, verification sites, control sites, and sample audits, among other quality control processes.

Reading 2: Weigel, S. and D. Stephan (2017). "The prediction of bitumen properties based on FTIR and multivariate analysis methods." **Fuel** 208: 655-661. <https://link.springer.com/article/10.1016/j.fuel.2017.05.017>

This article aimed to demonstrate that the combination of Fourier transform infrared (FTIR) spectroscopy with attenuated total reflexion (ATR) technique and multivariate evaluation is a very well-suited method to reliably identify and quantify additives in bituminous binders. Bitumen is a crucial building material in road construction, which is exposed to continuously higher stresses due to higher traffic loads and changing climatic conditions. Therefore, various additives are increasingly being added to the bitumen complicating the characterisation of the bituminous binder, especially concerning the reuse of reclaimed asphalt. For this research, various unmodified and modified binders, directly and extracted from laboratory and reclaimed asphalts, were investigated with FTIR-ATR spectroscopy. The determined spectra, pre-processed by standard normal variate (SNV) transformation and the determination of the 1st derivation, were evaluated using factor analysis (FA), linear discriminant analysis (LDA) and partial least square regression (PLSR). With this multivariate evaluation, first, a significant model with a very high hit rate of over 90% was developed allowing for the identification of styrene-butadiene copolymers (SBC), ethylene-copolymer bitumen (ECB) and different waxes (e.g., amide and Fischer-Tropsch wax) even if the additives do not show any additional peaks or the samples are multi-modified. Second, a quantification of the content is

possible for SBC, ECB, and amide wax with a mean error of $RMSE \leq 0.4$ wt% and a coefficient of determination of $R^2 > 90\%$. Based on these results, FTIR identification and quantification of additives in bituminous binders is a very promising method with a great potential.

Reading 3: Pipintakos, G. (2018). **Experimental characterization of chemical and physical performance of epoxy modified bitumen.** TUDelft. <https://repository.tudelft.nl/islandora/object/uuid%3A6f6740a0-1e69-4fed-bf39-a880d8ea4e06>

This paper provides an experimental characterisation of chemical and physical performance of epoxy modified bitumen. The increasing traffic load has led to the use of polymer modifiers in bituminous mixes in order to improve the performance and the durability of the pavement structures. Epoxy is a thermoset material which ensures enhanced fatigue performance and improved mechanical characteristics when used to modify bituminous materials. However, unlike conventional modification techniques, a series of experimental methods have to be conducted to evaluate the chemical-related phenomena occurring during the binder production and their effects on the performance of the epoxy modified bitumen. For this reason, in this thesis, the utilisation of epoxy modifiers was investigated at binder level.

Initially, the chemical hardening (curing) process of epoxy modified bitumens (EMBs) was investigated by means of Fourier Transform Infrared (FT-IR) spectrometer and Dynamic Shear Rheometer (DSR). Different combinations of hardening conditions for three epoxy modification levels were studied. Properties, such as modulus and viscosity, were utilised to determine the workability of EMB. At the same time, by using the FT-IR spectrometer, the functional groups of EMBs during the chemical reactions were identified for the understanding of polymerization in the epoxy components.

Additionally, the DSR device was utilised to determine the fatigue and tensile strength of EMBs. It was found that, with increasing the content of epoxy modifier, the fatigue life and tensile strength were increased significantly compared to an unmodified binder. Finally, the age hardening (aging) of EMBs was evaluated at different time intervals. For the simulation of short-term aging on EMBs, a short-term oven aging method (STOA) was used. For long-term aging, simulations were performed in a pressure aging vessel (PAV) under constant pressure and temperature. The results of chemical characterisation and rheological properties of the aged EMBs were obtained by using DSR and FT-IR and were compared to the unmodified bitumen.

Reading 4: Achampong, F., F. Boadu, P.K. Agbeko and R.A. Anum (2013). "Post construction failure analysis of road pavements in Ghana." **Civil and Environmental Research** 3(7): 74-78. <https://www.iiste.org/Journals/index.php/CER/article/view/6119>

The objectives of this research were to investigate the causes leading to the early deterioration of the road pavement and recommend remedial approach to ameliorate the current situation. The paper employed a desk study of contract

documents, as built drawings, visual road condition survey, structured questionnaire, in situ field tests and laboratory tests were conducted.

Premature road pavement failure occurs when it can no longer perform its traditional function of carrying vehicles and people from one location to another in safety and comfort before the anticipated design life. Usually, premature pavement failure of Ghana roads results in frequent road accidents with loss of life and properties, high transportation costs of goods and services, high maintenance costs of vehicles and increase in travel time.

The forensic studies revealed that the premature pavement failure was due to lack of geotechnical investigation, insufficient drainage system, poor construction methods, the inclusion of substandard materials, inadequate quality control and quality assurance program. It was recommended that the design phase should provide adequate drainage system for the roadway. Where poor to marginal construction material do not meet the specifications, it should be stabilized. Proper construction methods should be employed and dedicated personnel are needed to monitor the QC/QA program.

Reading 5: Olutaiwo, A. and A. Adanikin (2020). "Evaluating the Quality Assurance and Control of Hot-Mix Asphalt from Selected Plants in South West, Nigeria." **Nigerian Journal of Technological Development** 17(3): 217-222. <https://doi.org/10.4314/njtd.v17i3.8>

The authors of this paper assert that roads are essential necessity of every nation and it is possible that even with proper designs, the roads might not be constructed to the design standard due to poor quality assurance and control resulting in poor pavement quality. This study presents experimental results carried out on various hot - mix asphalt (HMA) samples obtained across different Asphalt plants in South West Nigeria. This was done to determine the extent to which the HMA used in the construction and rehabilitation of Nigerian roads affect their service life. Six samples of the asphalt binder (bitumen) were obtained from each plant over a period of six months and tested. The tested properties were assessed based on the level of conformance with the specifications and requirements from the FMWH General Specification (Roads and Bridges). The results revealed that HMA from plant B had a specific gravity of 1.01, penetration of 65.00 mm, softening point of 53 °C, flash point of 237.00 °C, peak Marshall Stability of 18.25 kN, flow of 3.87 mm and voids in total mixture peak value of 5.08 %. HMA from plant E had a specific gravity of 1.03, penetration of 65.00 mm, softening point of 51 °C, flash point of 239.00 °C, peak Marshall stability of 18.26 kN, flow of 3.67 mm and voids in total mixture peak value of 4.99 % and these were adjudged the best in conformance with the FMWH specifications. Adequate monitoring of HMA quality for either binder or wearing courses by carrying out quality control and assurance tests is thereby recommended as it affects pavement durability and performance.

Standards

British Standards Institution (BSI): BSI, the British Standards company, has facilitated the drafting of a revision to the British Standard series on the design of pavements using modular paving. The Standard British Standard provides recommendations and guidance on the design of pavements surfaced with modular paving units produced in accordance with BS EN 1338, BS EN 1339, BS EN 1340, BS EN 1341, BS EN 1342, BS EN 1343, and BS EN 1344 respectively for concrete, clay, and stone products.

For more information see: <https://www.bsigroup.com/en-GB/industries-and-sectors/construction-and-the-built-environment/british-standard-revision-on-the-design-of-pavements-constructed-with-natural-stone-or-concrete-published-for-public-comment/>

American Society for Testing and Materials (ASTM): ASTM is a developer of international voluntary consensus standards. ASTM standards are developed by committees of relevant industry professionals who meet regularly in an open and transparent process to deliver standards, test methods, specifications, guides, and practices. ASTM creates many standard procedures governing environmental and engineering services.

For more information see: <https://www.partneresi.com/resources/glossary/american-society-testing-and-materials-astm>

Questions to guide reading

1. What elements constitute a quality control performance-based methodology for pavement management systems?
2. What methods are available to predict bitumen properties?
3. What are the latest innovations in characterising the chemical and physical performance of epoxy modified bitumen?
4. What evidence exists of the performance of road pavement surfacings in Africa?

References

Achampong, F., F. Boadu, P.K. Agbeko and R.A. Anum (2013). "Post construction failure analysis of road pavements in Ghana." **Civil and Environmental Research** 3(7): 74-78.

Olutaiwo, A. and A. Adanikin (2020). "Evaluating the Quality Assurance and Control of Hot-Mix Asphalt from Selected Plants in South West, Nigeria." **Nigerian Journal of Technological Development** 17(3): 217-222.

Pipintakos, G. (2018). **Experimental characterization of chemical and physical performance of epoxy modified bitumen**. TUDelft.

Velasquez, E.D.R. (2018). **A Quality Control Performance-Based Methodology for Pavement Management Systems**. Master's in Civil Engineering The University of Texas at El Paso.

Weigel, S. and D. Stephan (2017). "The prediction of bitumen properties based on FTIR and multivariate analysis methods." **Fuel** **208**: 655-661.