SUMMARY OF EVIDENCE ON BENEFICIAL EFFECTS OF HYDRATED LIME IN SLOWING THE OXIDATION OF ASPHALT MIXTURES

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Prepared by: Rebecca Hooper, British Lime Association
Reviewed by: Didier Lesueur, European Lime Association

INTRODUCTION

The British Lime Association (BLA) has received requests from stakeholders to summarise the evidence related to the beneficial effects of hydrated lime additions in reducing the oxidation of asphalt mixtures in service. The evidence available to the BLA is summarised in this paper.

Oxidation of bitumen within asphalt mixtures by exposure to atmospheric oxygen is known to affect the durability of asphalt pavements, as the bitumen usually becomes harder and more brittle increasing the risks of, for example, surface cracking and ravelling[a]. This is widely referred to as oxidative ageing. Oxidation of bitumen is also undertaken, in some cases, as part of the bitumen manufacturing process to alter its physical properties to meet product specifications[b].The open nature of porous asphalts makes them even more prone to oxidative ageing and complementary evidence on the effects of hydrated lime on porous asphalt durability is also included in this paper.

HYDRATED LIME EFFECTS ON BITUMEN OXIDATION

The anti-oxidising properties of hydrated lime additions have been known for almost 50 years. Prompted by the observed 'softening' benefits in asphalt mixtures laid in Utah when hydrated lime had been added as an anti-strip agent, a three year study from 1968-1971 examined the viscosity and penetration of binders recovered from previously constructed pavements (up to six years old) and pavements especially constructed for the trial[c]. The study demonstrated that the viscosities were lower, and the ductility increased, for binders with hydrated lime additions compared to those without hydrated lime. The researchers concluded that the addition of one percent hydrated lime to bituminous mixtures was beneficial because it reduced the hardening rate of the asphalts.

A further investigation, reported in 1976, was undertaken to better understand the mechanisms through which hydrated lime additions reduce oxidative ageing[d]. The study demonstrated that hydrated lime additions reduce the viscosity increases associated with laboratory ageing by:

- Adsorbing reactive polar compounds already present in the bitumen which influence its viscosity; and
- Reducing the formation of carbonyl-type oxidation products during ageing which affect bitumen viscosity.

Similar results have been obtained by other researchers[e,f,g,h,i].

Recent research at the University of Nottingham on UK materials[j] tested mastics containing granite or limestone fillers and mastics where hydrated lime replaced a portion of the filler. Samples were laboratory aged using thin film oven testing and pressure ageing vessels. In all cases, the ageing of the mastics containing hydrated lime was lower than the ageing of mastics with filler alone:

- Fewer carbonyl groups were formed on ageing in granite filler mastics containing hydrated lime (Figure 1[j]) – noted above as the products of oxidative ageing;
- The stiffness of mastics increased less on ageing when hydrated lime was included – that is, the ratio of the complex shear modulus (G*) before and after ageing was closer to 1 with hydrated lime additions than with granite or limestone filler alone (Figure 2[j]).

DURABILITY IMPROVEMENTS IN POROUS ASPHALT

A Local Authority stakeholder highlighted to the BLA that the widespread specification and use of hydrated lime in the Netherlands[k], where porous asphalt is the dominant road surfacing material, may be a useful field indicator of the durability benefits of hydrated lime by enhancing the resistance to oxidative hardening.

Porous asphalts rely on the open structure of the asphalt to lower noise from vehicle traffic, promote surface drainage and reduce road spray during wet conditions. However, this means that the porous surfacings are more prone to moisture damage and oxidative ageing. As a result, the service life of porous asphalts is known to be lower than denser alternatives[l] or stone mastic asphalts[m] – 8 to 10 years compared to 12 years for dense asphalt, or compared to 15 years for stone mastic asphalts. Current Dutch porous asphalts are expected to achieve service lives of 11 (slow lane) to 17 (fast lane) years and require the selection of fillers with the correct quantities of hydrated lime and the use of unmodified 70/100 binder[k].

A Transport Research Laboratory (TRL) review of UK trials of porous asphalts from 1967 to 1984 noted an average service life of 8 years, with a range from 0 to 15 years[n]. The review highlighted that binder hardening and brittle failure tend to govern the ultimate life achieved by porous asphalts and that hydrated lime additions tended to reduce binder hardening rates.

Historically, Highways Agency specifications for porous asphalt required the addition of 2% hydrated lime. Whilst acknowledging that porous asphalts that contain hydrated lime have lower hardening rates, and hence increased durability, a 2001 TRL report[o] recommended that the hydrated lime requirement was removed to allow suppliers to meet aggregate/binder adhesion requirements by other means. The report noted that some suppliers believe that hydrated lime additions complicate asphalt mixing and suggests that hydrated lime is difficult to handle. A later TRL report reviewing the feasibility of introducing two-layer porous asphalt systems into the UK notes that a good quality filler improves both adhesion and resistance to ageing, mentioning hydrated lime in this context[p]. The current Highways England specification for porous asphalt[q] refers to the equivalent European Standard, based on a performance specification approach such that the use of hydrated lime is not mandated[r].

The BLA dispute that hydrated lime is difficult to handle as it is material widely used across the construction sector, in waste water treatment, and in the manufacturing, food and drink, and environmental services sector. As with any material, appropriate handling is vital, as are effective health and safety procedures on site. BLA Members provide Safety Data Sheets for their products and are happy to support suppliers to address any concerns they may have.

CONCLUSION

There is a substantial body of evidence indicating that additions of hydrated lime to asphalt will reduce the oxidative hardening of the bitumen that occurs as a result of exposure to air in service. Oxidative hardening makes the binder more brittle and the asphalt more prone to failure, for example, by ravelling. Hence, by reducing oxidative hardening, hydrated lime additions have been seen to increase the service life of pavements.

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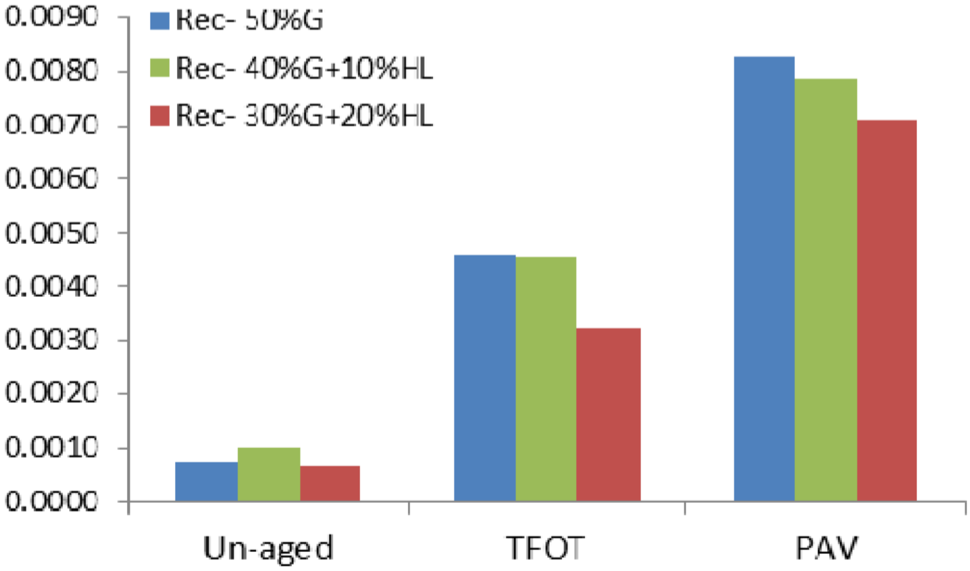
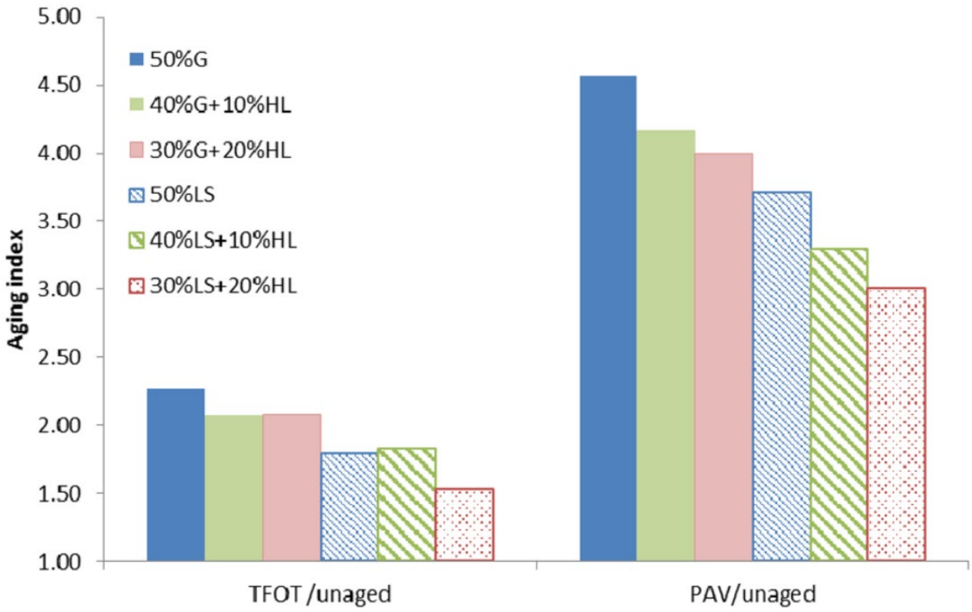
Figure 1: Carbonyl Ageing Index for binder recovered from mastics containing granite (G) and hydrated lime (HL) fillers



On an infrared spectrum, carbonyl groups formed by oxidative ageing (C=O groups) appear at around wavenumber 1700cm^{-1}. The Carbonyl Ageing Index is the ratio of the carbonyl infrared response to the total infrared response. Fewer carbonyl groups are formed on ageing in mastics containing hydrated lime. Ageing was conducted by Thin Film Oven Testing (TFOT) or Pressure Ageing Vessel (PAV).

Figure 2: G* Ageing Index of mastics containing granite (G), limestone (LS) and hydrated lime (HL) fillers



G* is the complex shear modulus for the mastic specimens and the G* Ageing Index is the ratio of G* (aged) over G* (unaged). No change in G* would have an Ageing Index = 1. The closer the Ageing Index is to 1, the smaller the change in G* experienced upon ageing.

REFERENCES

[a] H. Soenen, X. Lu & O-V Laukkanen. (2016). Oxidation of bitumen: molecular characterization and influence on rheological properties. Rheologica Acta. 55. 315-326. https://www.researchgate.net/publication/296336122_Oxidation_of_bitumen_molecular_characterization_and_influence_on_rheological_properties"

[b] The Asphalt Institute & Eurobitume (2015). The Bitumen Industry – A Global Perspective. Third Edition. https://www.eurobitume.eu/public_downloads/General/The%20Bitumen%20Industry%203rd%20edition.pdf

[c] C. V. Chachas, W. J. Liddle, D. E. Peterson, & M. L. Wiley. (1971). Use of Hydrated Lime in Bituminous Mixtures to Decrease Hardening of the Asphalt Cement - Final Report, Utah State Department of Highways Materials and Tests Division. http://digitallibrary.utah.gov/awweb/guest.jsp?smd=1&cl=all_lib&lb_document_id=83649

[d] H. Plancher, E. L. Green & J. C. Petersen. (1977). Paving Asphalts: Reduction of Oxidative Hardening of Asphalts by Treatment with Hydrated Lime - A Mechanistic Study, FHWA-RD-77-l47. https://rosap.ntl.bts.gov/view/dot/921

[e] A. C. Edler, M. M. Hattingh, V. P. Servas & C. P. Marais. (1985). Use of Aging Tests to Determine the Efficacy of Hydrated Lime Additions to Asphalt in Retarding its Oxidative Hardening. Proceedings of Association of Asphalt Paving Technologists. Volume 54, pp 118-139.

[f] J. C. Petersen, H. Plancher & P.M. Harnsberger. (1987). Lime Treatment of Asphalt to Reduce Age Hardening and Improve Flow Properties. Proceedings of Association of Asphalt Paving Technologists. Volume 56, pp 632-653.

[g] M. Iwańskia & G. Mazurekb. (2013). Hydrated Lime as the Anti-aging Bitumen Agent. 11th International Conference on Modern Building Materials, Structures and Techniques. Procedia Engineering. Volume 57, pp 424 – 432. https://www.sciencedirect.com/science/article/pii/S1877705813007881

[h] J. Zou, M. Isola, R. Roque, S. Chun, C. Koh & G. Lopp. (2013). Effect of hydrated lime on fracture performance of asphalt mixture. Construction and Building Materials. Volume 44, pp 302-308. https://www.sciencedirect.com/science/article/abs/pii/S0950061813002249

[i] A. G. Banja et al. (2018). Optimal hydrated lime concentration in asphalt binder to improve photo degradation resistance. REM, Int. Eng. J., vol.71, n.2. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S2448-167X2018000200225&lng=en&nrm=iso

[j] G. Airey, R. Alfaqawi, B. Zaidi & J. Grenfell. (2017). Effects of Hydrated Lime on Ageing and Moisture Damage of Asphalt Mastics and Mixtures. Presentation to British Lime Association 'Lime in Road Solutions Conference. https://britishlime.org/documents/06_2017-11-16_UniNott-MoistDamageAgeing.pdf

[k] I. van Vilsteren. (2017). Porous Asphalt - Dutch Experiences with Porous Asphalt Pavements. CEDR Symposium Road Traffic Noise Management and Abatement. https://www.cedr.eu/download/other_public_files/2017_road__traffic_noise_symposium/2-6-Inge-van-Vilsteren-Porous-Asphalt-in-the-Netherlands.pdf

[l] J. T. Van der Zwan, T. Goeman, H. J. A. J Gruis, J. H. Swart & R. H. Oldenburger. (1990). Porous Asphalt Wearing Courses in the Netherlands: State of the Art Review. Transportation Research Record No. 1265. Porous Asphalt Pavements: An International Perspective, pp 95-110. http://onlinepubs.trb.org/Onlinepubs/trr/1990/1265/1265-011.pdf

[m] A. de Bondt, K. Plug, J. van de Water, P. The & J. Voskuilen. (2016). Development of a durable third generation Porous Asphalt with a high noise reduction. Proceedings of the 6th Eurasphalt and Eurobitume Congress. https://www.h-a-d.hr/pubfile.php?id=1000

[n] J. C. Nicholls. (1997) Review of UK Porous Asphalt Trials – TRL Report 264. https://trl.co.uk/sites/default/files/TRL264.pdf

[o] J. C. Nicholls & I. G. Carswell. (2001). The design of porous asphalt mixtures to performance-related criteria - TRL Report 497. https://trl.co.uk/sites/default/files/TRL497.pdf

[p] P. A. Morgan, R. E. Stait, S. Reeves & M. Clifton. (2007). The feasibility of using twin-layer porous asphalt surfaces on England's strategic road network – PPR 433. https://trl.co.uk/sites/default/files/PPR433_new.pdf

[q] Highways England. (2018). Manual Of Contract Documents For Highway Works. Volume 1 - Specification For Highway Works. Series 900 - Road Pavements – Bituminous Bound Materials. Clause 938 - Porous Asphalt. http://www.standardsforhighways.co.uk/ha/standards/mchw/vol1/

[r] British Standards. (2016). BS EN 13108-7: 2016 - Bituminous mixtures. Material specifications. Porous Asphalt. https://shop.bsigroup.com/ProductDetail/?pid=000000000030278727