

Journal Publications

Thesis Work (Published/Accepted/Under-Review)

1. **Prasad, A. N., Saboo, N., & Pani, A.** (2023). Material and mix design aspects of hot recycled asphalt mixes: A review. **Environmental Science and Pollution Research**, 30(50), 108411-108447.
2. **Prasad, A. N., Saboo, N., & Pani, A.** (2025) Exploring the Use of Waste Engine Oil as Rejuvenator for Hot Mix Recycling. **Transportation Research Record**, 03611981251337471.
3. **Prasad, A. N., Saboo, N., & Pani, A.** (2025). Assessing the Effect of Aging Periods on the Performance of Hot Mix Asphalt. **International Journal of Pavement Research and Technology**, 1-12.
4. **Prasad, A. N., Saboo, N., & Pani,** Comparative evaluation of Commercial and Recycled Type Rejuvenators for Hot Mix Asphalt recycling. **Mechanics of Time-Dependent Materials** (under review)

Collaborative Explorations (Published/Accepted/Under-Review)

1. Saboo, N., **Prasad, A. N.,** Sukhija, M., Chaudhary, M., & Chandrappa, A. K. (2020). Effect of the use of recycled asphalt pavement (RAP) aggregates on the performance of pervious paver blocks (PPB). **Construction and Building Materials**, 262, 120581.
2. Sukhija, M., **Prasad, A. N.,** Saboo, N., & Mashaan, N. (2023). Assessment of virgin binder-blended rejuvenators and antistripping agents for hot recycled asphalt mixture. **International Journal of Pavement Research and Technology**, 16(5), 1226-1240.

LIST OF PUBLICATIONS

Conferences

1. **Prasad, A. N., Pani, A., & Saboo, N.** “Production practices of in-plant hot mix asphalt recycling: A review” **Advances in Materials and Pavement Performance Prediction III 2022, Hongkong.**
2. **Prasad, A. N., Saboo, N., Soni, D. & Pani, A.** “Assessing the factors influencing the rutting resistance of rejuvenated binders” **(International Society for Asphalt Pavements 2024, Montreal Canada)**

Manuscripts under preparation

1. Durability study of recycled mixtures vis-à-vis virgin mixtures.
2. A comprehensive study on the evaluation of optimum dose of rejuvenators for hot recycled asphalt mixtures.
3. Key insights into rejuvenators for hot recycled asphalt mixtures.

-
- [1] B. Jain, I. Dhar, Development in highway and road networks to boost economic growth in India, *Strateg. Invest. Res. Unit - Invest India*. (2022).
- [2] The World Bank, India Transportation, *World Bank News*. (2011) 1–10.
- [3] E. five Y. Plan, National Road Transport Policy, (2005) 1–34.
- [4] R. Asthana, Demand for Grants 2022-23 Analysis Road Transport and Highways, *PRS Legis. Res.* (2022) 1–11.
- [5] M. of R.T. and Highways, Press information Bureau, PIB Delhi. (2023).
- [6] P. Kumar, A. Gupta, Provision of Rigid, Semi Rigid and Flexible Pavements as Rural Roads, *New Build. Mater. Constr. World*. 6(3) (2010) 160–167.
- [7] P.M. Dhir, India: an Asphalt Roads Country, *Asph. Yearb.* 2000. (2000) 1–2.
- [8] S. Magar, F. Xiao, D. Singh, B. Showkat, Applications of reclaimed asphalt pavement in India – A review, *J. Clean. Prod.* 335 (2022) 130221. <https://doi.org/10.1016/j.jclepro.2021.130221>.
- [9] U.J. Alengaram, B.A. Al Muhit, M.Z. Bin Jumaat, Utilization of oil palm kernel shell as lightweight aggregate in concrete - A review, *Constr. Build. Mater.* 38 (2013) 161–172. <https://doi.org/10.1016/j.conbuildmat.2012.08.026>.
- [10] J. Los Santos-Ortega, E. Fraile-García, J. Ferreiro-Cabello, Environmental Assessment of Natural Coarse Aggregate Production in Gravel Pits—Assessing CO₂ Offsets Through Vine Cultivation, *Appl. Sci.* 15 (2025). <https://doi.org/10.3390/app15041868>.
- [11] W. Langer, Sustainability of aggregates in construction, Second Edi, Elsevier Ltd., 2016. <https://doi.org/10.1016/b978-0-08-100370-1.00009-3>.
- [12] D. Vijerathne, S. Wahala, C. Illankoon, Impact of Crushed Natural Aggregate on Environmental Footprint of the Construction Industry: Enhancing Sustainability in Aggregate Production, *Buildings*. 14 (2024) 2770. <https://doi.org/10.3390/buildings14092770>.
- [13] William H. Langer, B.F. Arbogast, Environmental Impacts Of Mining Natural Aggregate, *Deposit an, Dordrecht* springer, 2002. https://doi.org/https://doi.org/10.1007/978-94-010-0303-2_8.
- [14] Kirk Othmer, Asphalt, *Encycl. Chem. Technol.* (1907).
- [15] M.R. Islam, Asphalt Binders, *Civ. Eng. Mater.* (2020) 175–194. <https://doi.org/10.1201/9780429275111-6>.
- [16] US Energy Information Administration, Oil and petroleum products explained Use of oil, EIA. (2021).
- [17] BP, Statistical Review of World Energy, BP 71st Ed. (2022) 1–60.
- [18] M. Behrouzifar, E. Siami Araghi, A. Emami Meibodi, OPEC behavior: The volume of oil reserves announced, *Energy Policy*. 127 (2019) 500–522.

REFERENCES

- <https://doi.org/10.1016/j.enpol.2018.10.037>.
- [19] N.A. Owen, O.R. Inderwildi, D.A. King, The status of conventional world oil reserves- Hype or cause for concern?, *Energy Policy*. 38 (2010) 4743–4749. <https://doi.org/10.1016/j.enpol.2010.02.026>.
- [20] J. Mann, A reassessment of the 1967 Arab oil embargo, *Isr. Aff.* 19 (2013) 693–703. <https://doi.org/10.1080/13537121.2013.829611>.
- [21] M.S. Daoudi, M.S. Dajani, The 1967 Oil Embargo Revisited, *J. Palest. Stud.* 13 (1984) 65–90. <https://doi.org/10.2307/2536897>.
- [22] A. Copeland, *Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice* (No. FHWA-HRT-11-021), 2011.
- [23] R. McDaniel, H. Soleymani, R.M. Anderson, P. Turner, R. Peterson, E.T. Harrigan, *Recommended Use of Reclaimed Asphalt Pavement in the Superpave Mix Design Method : Technician’s Guidelines*, 2001.
- [24] M. Zaumanis, R.B. Mallick, Review of very high-content reclaimed asphalt use in plant-produced pavements: State of the art, *Int. J. Pavement Eng.* 16 (2015) 39–55. <https://doi.org/10.1080/10298436.2014.893331>.
- [25] R.C. West, *Best Practices for RAP and RAS Management - NAPA, Quality Improvement Series 129*, Natl. Asph. Pavement Assoc. (2015) 1–44.
- [26] R.W. Smith, *State of the Art Hot recycling*, 1980.
- [27] J.B. Don, J.L. Richmond, *Cycling and Recycling*, Books Irel. (2007) 88. <https://doi.org/10.2307/20626170>.
- [28] IRC:120-2015, *Recommended Practice for Recycling of Bituminous Pavements Indian Roads Congress*, 2015.
- [29] NAPA Information series 123, *Recycling Hot Mix Asphalt Pavemets*, 1996.
- [30] X.C.M. Group, *Pavement Milling Machine, Xm200kii, XCMG 2m.* (n.d.).
- [31] P. Interactive, *Milling Machine teeth*, *Pavement Interact.* (2002).
- [32] M. Zaumanis, R.B. Mallick, R. Frank, 100% recycled hot mix asphalt: A review and analysis, *Resour. Conserv. Recycl.* 92 (2014) 230–245. <https://doi.org/10.1016/j.resconrec.2014.07.007>.
- [33] MoRTH - 2013, *Specifications for Road and Bridge Works*, Indian Roads Congr. 1 (2013) 1–883.
- [34] R.C. West, *Reclaimed asphalt pavement management : Best Practices*, Natl. Cent. Asph. Technol. Auburn Univ. (2010) 31.
- [35] P.S. Kandhal, R.B. Mallick, *Pavement recycling guidelines for state and local governments*, 1997.
- [36] Williams B. A, J.R. Willis, S. J., *Annual Asphalt Pavement Industry Survey on Recycled Materials and Warm-Mix Asphalt Usage: 2018, 9th Annual Survey (IS 138)*, 2019. <https://doi.org/10.13140/RG.2.2.21946.82888>.
- [37] MoRTH India, *Government of India Ministry of Road Transport & Highways*,

REFERENCES

- Highways. 524 (2009) 1–43. <https://morth.nic.in/>.
- [38] MoRTH India, NH 2009-24 approved circular, (2024).
- [39] IRC:120-2015, Recommended Practice for Recycling of Bituminous Pavements Indian Roads Congress, 2015.
- [40] R. McDaniel, R. Michael Anderson, Recommended use of reclaimed asphalt pavement in the Superpave mix design method: technician’s manual, (No. Project D9-12 FY’97), 2001. <http://www.national-academies.org/trb/bookstore>.
- [41] R. West, C. Rodezno, F. Leiva, F. Yin, Development of a framework for balanced mix design, Proj. NCHRP 20-07/Task 406. (2018) 7–20.
- [42] R.K. Veeragavan, D. Nener-Plante, L. Myers, C. Nash, N.H. Tran, Balanced Mix Design Benchmarking of Field-Produced Asphalt Mixtures in Maine, U.S., *Transp. Res. Rec.* 2676 (2022) 263–276. <https://doi.org/10.1177/03611981211061552>.
- [43] W.S. Mogawer, P. -PI Thomas Bennert, Framework of Asphalt Balanced Mix Design (BMD) for New England Transportation Agencies, (2020).
- [44] B.F. Bowers, S.D. Diefenderfer, N. Moore, T. Lynn, Balanced Mix Design and Benchmarking: A Case Study in Establishing Performance Test Thresholds, *Transp. Res. Rec.* 2676 (2022) 586–598. <https://doi.org/10.1177/03611981221096434>.
- [45] V. Chitnis, M. Sukhija, E. Coleri, Benchmarking the performance of asphalt mixtures for the implementation of Balanced Mix Design (BMD) in Oregon, *Int. J. Pavement Eng.* 26 (2025) 1–16. <https://doi.org/10.1080/10298436.2025.2489760>.
- [46] M. Sukhija, E. Coleri, Integrating balanced mix design for high reclaimed asphalt pavements in Oregon: adjustment in binder content and binder grade, *Int. J. Pavement Eng.* 26 (2025) 1–23. <https://doi.org/10.1080/10298436.2025.2508342>.
- [47] A. Behnood, Application of rejuvenators to improve the rheological and mechanical properties of asphalt binders and mixtures: A review, *J. Clean. Prod.* 231 (2019) 171–182. <https://doi.org/10.1016/j.jclepro.2019.05.209>.
- [48] F. Kaseer, A.E. Martin, E. Arámbula-Mercado, Use of recycling agents in asphalt mixtures with high recycled materials contents in the United States: A literature review, *Constr. Build. Mater.* 211 (2019) 974–987. <https://doi.org/10.1016/j.conbuildmat.2019.03.286>.
- [49] T. Baghaee Moghaddam, H. Baaj, The use of rejuvenating agents in production of recycled hot mix asphalt: A systematic review, *Constr. Build. Mater.* 114 (2016) 805–816. <https://doi.org/10.1016/j.conbuildmat.2016.04.015>.
- [50] M.D. Nazzal, W. Mogawer, A. Austerman, L.A. Qtaish, S. Kaya, Multi-scale evaluation of the effect of rejuvenators on the performance of high RAP content mixtures, *Constr. Build. Mater.* 101 (2015) 50–56. <https://doi.org/10.1016/j.conbuildmat.2015.10.029>.
- [51] R.J. Holmgreen, J.O.N.A. Epps, Evaluation of Selected Recycling Modifiers, *Transp. Res. Rec.* 777 (1978) 22–25.
- [52] R.S. Melaku, D.S. Gedafa, Impact of Wastewater Treatment Sludge on Cracking Resistance of Hot Mix Asphalt Mixes at Lower Mixing Temperature, *J. Mater. Civ. Eng.* 32 (2020) 05020009. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003506](https://doi.org/10.1061/(asce)mt.1943-5533.0003506).

REFERENCES

- [53] I. Widyatmoko, Mechanistic-empirical mixture design for hot mix asphalt pavement recycling, *Constr. Build. Mater.* 22 (2008) 77–87. <https://doi.org/10.1016/j.conbuildmat.2006.05.041>.
- [54] H. Nabizadeh, H.F. Haghshenas, Y. Kim, F. Thiago, S. Aragão, Effects of rejuvenators on high-RAP mixtures based on laboratory tests of asphalt concrete (AC) mixtures and fine aggregate matrix (FAM) mixtures, *Constr. Build. Mater.* 152 (2017) 65–73. <https://doi.org/10.1016/j.conbuildmat.2017.06.101>.
- [55] M.A. Ishaq, F. Giustozzi, Rejuvenator effectiveness in reducing moisture and freeze/thaw damage on long-term performance of 20 % RAP asphalt mixes: An Australian case study, *Case Stud. Constr. Mater.* 13 (2020) e00454. <https://doi.org/10.1016/j.cscm.2020.e00454>.
- [56] H. Ziari, M.R.M. Aliha, A. Moniri, Y. Saghafi, Crack resistance of hot mix asphalt containing different percentages of reclaimed asphalt pavement and glass fiber, *Constr. Build. Mater.* 230 (2020) 117015. <https://doi.org/10.1016/j.conbuildmat.2019.117015>.
- [57] J. Zhang, X. Zhang, M. Liang, H. Jiang, J. Wei, Z. Yao, Influence of different rejuvenating agents on rheological behavior and dynamic response of recycled asphalt mixtures incorporating 60% RAP dosage, *Constr. Build. Mater.* 238 (2020) 117778. <https://doi.org/10.1016/j.conbuildmat.2019.117778>.
- [58] M. Zaumanis, R.B. Mallick, L. Poulikakos, R. Frank, Influence of six rejuvenators on the performance properties of Reclaimed Asphalt Pavement (RAP) binder and 100% recycled asphalt mixtures, *Comput. Chem. Eng.* 71 (2014) 538–550. <https://doi.org/10.1016/j.conbuildmat.2014.08.073>.
- [59] J. Shen, B. Huang, Y. Hachiya, Validation of performance-based method for determining rejuvenator content in HMA, *Int. J. Pavement Eng.* 5 (2004) 103–109. <https://doi.org/10.1080/10298430410001733509>.
- [60] H. Ziari, A. Moniri, P. Bahri, Y. Saghafi, Evaluation of performance properties of 50% recycled asphalt mixtures using three types of rejuvenators, *Pet. Sci. Technol.* 37 (2019) 2355–2361. <https://doi.org/10.1080/10916466.2018.1550505>.
- [61] H. Ziari, A. Moniri, P. Bahri, Y. Saghafi, The effect of rejuvenators on the aging resistance of recycled asphalt mixtures, *Constr. Build. Mater.* 224 (2019) 89–98. <https://doi.org/10.1016/j.conbuildmat.2019.06.181>.
- [62] H.M.R.D. Silva, J.R.M. Oliveira, C.M.G. Jesus, Are totally recycled hot mix asphalts a sustainable alternative for road paving?, *Resour. Conserv. Recycl.* 60 (2012) 38–48. <https://doi.org/10.1016/j.resconrec.2011.11.013>.
- [63] J. Yan, Z. Zhang, H. Zhu, F. Li, Q. Liu, Experimental study of Hot recycled asphalt mixtures with high percentages of Reclaimed Asphalt Pavement and different recycling agents, *J. Test. Eval.* 42 (2014). <https://doi.org/10.1520/JTE20130251>.
- [64] W.S. Mogawer, A. Booshehrian, S. Vahidi, A.J. Austerman, Evaluating the effect of rejuvenators on the degree of blending and performance of high RAP, RAS, and RAP/RAS mixtures, *Road Mater. Pavement Des.* 14 (2013) 193–213. <https://doi.org/10.1080/14680629.2013.812836>.
- [65] A.S. Nouredin, K. Abdel, E. Wood, W. Lafeyette, Evaluating Recycled Asphalt Binders by the Thin-Film Oven Test, (1980) 20–25.

REFERENCES

- [66] A. Ongel, M. Hugener, Impact of rejuvenators on aging properties of bitumen, *Constr. Build. Mater.* 94 (2015) 467–474. <https://doi.org/10.1016/j.conbuildmat.2015.07.030>.
- [67] A. Dony, J. Colin, D. Bruneau, I. Drouadaine, J. Navaro, Reclaimed asphalt concretes with high recycling rates: Changes in reclaimed binder properties according to rejuvenating agent, *Constr. Build. Mater.* 41 (2013) 175–181. <https://doi.org/10.1016/j.conbuildmat.2012.11.031>.
- [68] P. Karki, F. Zhou, Effect of rejuvenators on rheological, chemical, and aging properties of asphalt binders containing recycled binders, *Transp. Res. Rec.* 2574 (2016) 74–82. <https://doi.org/10.3141/2574-08>.
- [69] M. Zaumanis, R.B. Mallick, R. Frank, 100% Hot Mix Asphalt Recycling: Challenges and Benefits, *Transp. Res. Procedia.* 14 (2016) 3493–3502. <https://doi.org/10.1016/j.trpro.2016.05.315>.
- [70] F. Rostler, R. White, Influence of Chemical Composition of Asphalts on Performance, Particularly Durability, *Symp. Road Paving Mater.* (1960) 64–64–25. <https://doi.org/10.1520/stp38773s>.
- [71] S.S.K. and D.Y.L. B.V.Enustun, Correlation of locally-based performance of asphalts with their physicochemical parameters, *IOWA DoT Proj.* (1990) 1–168.
- [72] Q. Qin, J.F. Schabron, R.B. Boysen, M.J. Farrar, Field aging effect on chemistry and rheology of asphalt binders and rheological predictions for field aging, *Fuel.* 121 (2014) 86–94. <https://doi.org/10.1016/j.fuel.2013.12.040>.
- [73] G. Thenoux, C.A. Bell, J.E. Wilson, D. Eakin, M. Schroeder, Evaluation of asphalt properties and their relationship to pavement performance interim report: literature review and development of composition analysis method, 1985.
- [74] J.M. Swanson, A contribution to the physical chemistry of the asphalts, *J. Phys. Chem.* 46 (1942) 141–150. <https://doi.org/10.1021/j150415a017>.
- [75] T. Fu Yen, The colloidal aspect of a macrostructure of petroleum asphalt, *Fuel Sci. Technol. Int.* 10 (1992) 723–733. <https://doi.org/10.1080/08843759208916018>.
- [76] J.P. Pfeiffer, R.N.J. Saal, Asphaltic bitumen as colloid system, *J. Phys. Chem.* 44 (1940) 139–149. <https://doi.org/10.1021/j150398a001>.
- [77] J.A. Koots, J.G. Speight, Relation of petroleum resins to asphaltenes, *Fuel.* 54 (1975) 179–184. [https://doi.org/10.1016/0016-2361\(75\)90007-1](https://doi.org/10.1016/0016-2361(75)90007-1).
- [78] P.O. Redelius, Solubility parameters and bitumen, *Fuel.* 79 (2000) 27–35. [https://doi.org/10.1016/S0016-2361\(99\)00103-9](https://doi.org/10.1016/S0016-2361(99)00103-9).
- [79] J. claine Petersen, Chemical Composition of Asphalt As Related To Asphalt Durability: State of the Art., *Transp. Res. Rec.* 999 (1984) 13–30.
- [80] L. Loeber, G. Muller, J. Morel, O. Sutton, Bitumen in colloid science: A chemical, structural and rheological approach, *Fuel.* 77 (1998) 1443–1450. [https://doi.org/10.1016/S0016-2361\(98\)00054-4](https://doi.org/10.1016/S0016-2361(98)00054-4).
- [81] R.N.J. Saal, J.W.A. Labout, Rheological properties of asphaltic bitumens, *J. Phys. Chem.* 44 (1940) 149–165. <https://doi.org/10.1021/j150398a002>.
- [82] H. Eilers, The colloidal structure of asphalt, *J. Phys. Colloid Chem.* 53 (1949) 1195–

REFERENCES

1211. <https://doi.org/10.1021/j150473a006>.
- [83] D. Lesueur, The colloidal structure of bitumen: Consequences on the rheology and on the mechanisms of bitumen modification, *Adv. Colloid Interface Sci.* 145 (2009) 42–82. <https://doi.org/10.1016/j.cis.2008.08.011>.
- [84] H.A. Tabatabaee, T.L. Kurth, Analytical investigation of the impact of a novel bio-based recycling agent on the colloidal stability of aged bitumen, *Road Mater. Pavement Des.* 18 (2017) 131–140. <https://doi.org/10.1080/14680629.2017.1304257>.
- [85] S.J. Escobar, Recycling of deteriorated pavements: a review of current guidelines and future outlook with respect to polymer modified recycling agents, in: *APA Int. Asph. Conf. Sydney, Aust.*, 1991.
- [86] R. Boyer, Asphalt Rejuvenators “Fact, or Fable,” *Transp. Syst.* 58 (2000) 1. http://www.totalasphalt.com/docs/products/Asphalt-Rejuvenators_Fact-or-Fable.pdf.
- [87] R. Grover Allen, D.N. Little, A. Bhasin, C.J. Glover, The effects of chemical composition on asphalt microstructure and their association to pavement performance, *Int. J. Pavement Eng.* 15 (2014) 9–22. <https://doi.org/10.1080/10298436.2013.836192>.
- [88] O. Sirin, D.K. Paul, E. Kassem, State of the Art Study on Aging of Asphalt Mixtures and Use of Antioxidant Additives, *Adv. Civ. Eng.* 2018 (2018). <https://doi.org/10.1155/2018/3428961>.
- [89] M.N. Siddiqui, M.F. Ali, Investigation of chemical transformations by NMR and GPC during the laboratory aging of Arabian asphalt, *Fuel.* 78 (1999) 1407–1416. [https://doi.org/10.1016/S0016-2361\(99\)00080-0](https://doi.org/10.1016/S0016-2361(99)00080-0).
- [90] G.D. Peterson, R.R. Davison, C.J. Glover, J.A. Bullin, Effect of composition on asphalt recycling agent performance, *Transp. Res. Rec.* 1436 (1994) 38–46.
- [91] J.C. Petersen, J.F. Branthaver, R.E. Robertson, P.M. Harnsberger, J.J. Duvall, E.K. Ensley, Effects of physicochemical factors on asphalt oxidation kinetics, *Transp. Res. Rec.* 1391 (1993) 1–10.
- [92] B.A. Vallerga, W.J. Halstead, Effects of Field Aging on Fundamental Properties of Paving Asphalts, *Highw. Res. Rec.* 361 (1971) 71–92. <http://pubsindex.trb.org/view/101370>.
- [93] O. Sirin, D.K. Paul, E. Kassem, M. Ohiduzzaman, Effect of aging on asphalt binders in the state of Qatar: A case study, *Asph. Paving Technol. Assoc. Asph. Paving Technol. Tech. Sess.* 86 (2017) 215–243. <https://doi.org/10.1080/14680629.2017.1389094>.
- [94] F. Yin, A. Epps Martin, E. Arámbula-Mercado, D. Newcomb, Characterization of non-uniform field aging in asphalt pavements, *Constr. Build. Mater.* 153 (2017) 607–615. <https://doi.org/10.1016/j.conbuildmat.2017.07.144>.
- [95] I.L. Al-Qadi, A. Qazi, S.H. Carpenter, Impact of High RAP Content on Structural and Performance Properties of Asphalt Mixtures, *Res. Rep. FHWA-ICT-12-002.* (2012) 1–107.
- [96] R.L. Dunning, R.L. Mendenhall, Design of Recycled Asphalt Pavements and Selection of Modifiers., *ASTM Spec. Tech. Publ.* (1978) 35–46. <https://doi.org/10.1520/stp35774s>.

REFERENCES

- [97] R.L. Terrel, D.R. Fritchen, Laboratory Performance of Recycled Asphalt Concrete., ASTM Spec. Tech. Publ. (1978) 104–112. <https://doi.org/10.1520/stp35777s>.
- [98] J.M. Chaffin, M. Liu, R.R. Davison, C.J. Glover, J.A. Bullin, Supercritical Fractions as Asphalt Recycling Agents and Preliminary Aging Studies on Recycled Asphalts, *Ind. Eng. Chem. Res.* 36 (1997) 656–666. <https://doi.org/10.1021/ie9604435>.
- [99] J.A. Bullin, R.R. Davison, C.J. Glover, J. Chaffin, M. Liu, R. Madrid, Development of Superior Asphalt Recycling Agents, USA, Univ. Texas A&M Dep. Chem. Eng. Texas Transp. Inst. 1 (1995).
- [100] J.C. Petersen, F.A. Barbour, S.M. Dorrence, Identification of Dicarboxylic Anhydrides in Oxidized Asphalts, *Anal. Chem.* 47 (1975) 107–111. <https://doi.org/10.1021/ac60351a005>.
- [101] J. Mirwald, S. Werkovits, I. Camargo, D. Maschauer, B. Hofko, H. Grothe, Understanding bitumen ageing by investigation of its polarity fractions, *Constr. Build. Mater.* 250 (2020) 118809. <https://doi.org/10.1016/j.conbuildmat.2020.118809>.
- [102] D.D. Davidson, W. Canessa, S.J. Escobar, Practical Aspects of Reconstituting Deteriorated Bituminous Pavements., ASTM Spec. Tech. Publ. (1978) 16–34. <https://doi.org/10.1520/stp35773s>.
- [103] K.H.A. and O.L.Harle, The Effect of Asphaltenes on Asphalt viscosity, *Solutions.* 14 (1975) 240–246.
- [104] S. Sultana, A. Bhasin, Effect of chemical composition on rheology and mechanical properties of asphalt binder, *Constr. Build. Mater.* 72 (2014) 293–300. <https://doi.org/10.1016/j.conbuildmat.2014.09.022>.
- [105] R.G. Allen, D.N. Little, A. Bhasin, Structural Characterization of Micromechanical Properties in Asphalt Using Atomic Force Microscopy, *J. Mater. Civ. Eng.* 24 (2012) 1317–1327. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0000510](https://doi.org/10.1061/(asce)mt.1943-5533.0000510).
- [106] D.E. Newcomb, B.J. Nusser, B.M. Kiggundu, D.M. Zallen, Laboratory Study of the Effects of Recycling Modifiers on Aged Asphalt Cement., *Transp. Res. Rec.* 968 (1984) 66–77.
- [107] J.A. Epps, D.N. Little, R.J. Holmgreen, R.L. Terrel, Guidelines for Recycling Pavement Materials., 1980.
- [108] F. Pahlavan, A. Rajib, S. Deng, P. Lammers, E.H. Fini, Investigation of Balanced Feedstocks of Lipids and Proteins to Synthesize Highly Effective Rejuvenators for Oxidized Asphalt, *ACS Sustain. Chem. Eng.* 8 (2020) 7656–7667. <https://doi.org/10.1021/acssuschemeng.0c01100>.
- [109] J. Brownridge, The role of an asphalt rejuvenator in pavement preservation : use and need for asphalt rejuvenation, in: *Compend. Pap. from First Int. Conf. Pavement Preserv.*, USA: Newport Beach CA, 2010: pp. 351–364.
- [110] J. Waters, R.L. Rivera, Environmental Impacts of Pavement Rejuvenators, in: *2018 AIChE Annu. Meet. AIChE*, 2018.
- [111] N. centre for A. Technology, NCAT Researchers Explore Multiple Uses of Rejuvenators, *Asph. Technol. News.* 26 (2014) 7–16.

REFERENCES

- [112] N.H. Tran, A. Taylor, R. Willis, Effect of rejuvenator on performance properties of HMA mixtures with high RAP and RAS content NCAT Report 12-05, 2012.
- [113] D. Wang, A. Cannone Falchetto, M. Hugener, L. Porot, A. Kawakami, B. Hofko, A. Grilli, E. Pasquini, M. Pasetto, H. Tabatabaee, H. Zhai, M.S. da Costa, H. Soenen, P.K. Kara De Maeijer, W. Van den Bergh, F. Cardone, A. Carter, K.L. Vasconcelos, X. Carbonneau, A. Lorserie, G. Mladenović, M. Orešković, T. Koudelka, P. Coufalik, E. Bocci, R. Zhang, E. V. Dave, G. Tebaldi, Effect of Aging on the Rheological Properties of Blends of Virgin and Rejuvenated RA Binders, RILEM Bookseries. 27 (2022) 3–10. https://doi.org/10.1007/978-3-030-46455-4_1.
- [114] M. Zaumanis, R.B. Mallick, R. Frank, Determining optimum rejuvenator dose for asphalt recycling based on Superpave performance grade specifications, *Constr. Build. Mater.* 69 (2014) 159–166. <https://doi.org/10.1016/j.conbuildmat.2014.07.035>.
- [115] P.S. Lin, T.L. Wu, C.W. Chang, B.Y. Chou, Effects of recycling agents on aged asphalt binders and reclaimed asphalt concrete, *Mater. Struct. Constr.* 44 (2011) 911–921. <https://doi.org/10.1617/s11527-010-9675-8>.
- [116] H. Asli, E. Ahmadiania, M. Zargar, M.R. Karim, Investigation on physical properties of waste cooking oil - Rejuvenated bitumen binder, *Constr. Build. Mater.* 37 (2012) 398–405. <https://doi.org/10.1016/j.conbuildmat.2012.07.042>.
- [117] F.Y. Rad, M.D. Elwardany, C. Castorena, Y.R. Kim, Evaluation of chemical and rheological aging indices to track oxidative aging of asphalt mixtures, *Transp. Res. Rec.* 2672 (2018) 349–358. <https://doi.org/10.1177/0361198118784138>.
- [118] L. Garcia Cucalon, G. King, F. Kaseer, E. Arambula-Mercado, A. Epps Martin, T.F. Turner, C.J. Glover, Compatibility of Recycled Binder Blends with Recycling Agents: Rheological and Physicochemical Evaluation of Rejuvenation and Aging Processes, *Ind. Eng. Chem. Res.* 56 (2017) 8375–8384. <https://doi.org/10.1021/acs.iecr.7b01657>.
- [119] S.N. Nahar, J. Qiu, A.J.M. Schmets, E. Schlangen, M. Shirazi, M.F.C. Van De Ven, G. Schitter, A. Scarpas, Turning back time: Rheological and microstructural assessment of rejuvenated bitumen, *Transp. Res. Rec.* 2444 (2014) 52–62. <https://doi.org/10.3141/2444-06>.
- [120] X. Yu, M. Zaumanis, S. Dos Santos, L.D. Poulidakos, Rheological, microscopic, and chemical characterization of the rejuvenating effect on asphalt binders, *Fuel.* 135 (2014) 162–171. <https://doi.org/10.1016/j.fuel.2014.06.038>.
- [121] S.H. Carpenter, J.R. Wolosick, Modifier Influence in the Characterization of Hot-Mix Recycled Material, *Transp. Res. Rec.* 777. (1980) 15–22. <https://trid.trb.org/view/167580>.
- [122] P. Cong, H. Hao, Y. Zhang, W. Luo, D. Yao, Investigation of diffusion of rejuvenator in aged asphalt, *Int. J. Pavement Res. Technol.* 9 (2016) 280–288. <https://doi.org/10.1016/j.ijprt.2016.08.001>.
- [123] V. Antunes, A.C. Freire, J. Neves, Investigating aged binder mobilization and performance of RAP mixtures for surface courses, *Constr. Build. Mater.* 271 (2021) 121511. <https://doi.org/10.1016/j.conbuildmat.2020.121511>.
- [124] R.K. Veeraragavan, R.B. Mallick, M. Tao, M. Zaumanis, R. Frank, R.L. Bradbury, Laboratory comparison of rejuvenated 50% reclaimed asphalt pavement hot-mix asphalt

REFERENCES

- with conventional 20% RAP mix, *Transp. Res. Rec.* 2633 (2017) 69–79. <https://doi.org/10.3141/2633-09>.
- [125] J. Zhang, C. Guo, T. Chen, W. Zhang, K. Yao, C. Fan, M. Liang, C. Guo, Z. Yao, Evaluation on the mechanical performance of recycled asphalt mixtures incorporated with high percentage of RAP and self-developed rejuvenators, *Constr. Build. Mater.* 269 (2021) 121337. <https://doi.org/10.1016/j.conbuildmat.2020.121337>.
- [126] A.F. Espinoza-Luque, I.L. Al-Qadi, H. Ozer, Optimizing rejuvenator content in asphalt concrete to enhance its durability, *Constr. Build. Mater.* 179 (2018) 642–648. <https://doi.org/10.1016/j.conbuildmat.2018.05.256>.
- [127] S. Im, F. Zhou, R. Lee, T. Scullion, Impacts of rejuvenators on performance and engineering properties of asphalt mixtures containing recycled materials, *Constr. Build. Mater.* 53 (2014) 596–603. <https://doi.org/10.1016/j.conbuildmat.2013.12.025>.
- [128] S. Büchler, A.C. Falchetto, A. Walther, C. Riccardi, D. Wang, M.P. Wistuba, Wearing course mixtures prepared with high reclaimed asphalt pavement content modified by rejuvenators, *Transp. Res. Rec.* 2672 (2018) 96–106. <https://doi.org/10.1177/0361198118773193>.
- [129] J.H. Podolsky, Z. Sotoodeh-Nia, N. Manke, A. Hohmann, T. Huisman, R.C. Williams, E.W. Cochran, Development of High RAP–High Performance Thin-Lift Overlay Mix Design Using a Soybean Oil-Derived Rejuvenator, *J. Mater. Civ. Eng.* 32 (2020) 04020138. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003203](https://doi.org/10.1061/(asce)mt.1943-5533.0003203).
- [130] G. Guduru, C. Kumara, B. Gottumukkala, K.K. Kuna, Effectiveness of Different Categories of Rejuvenators in Recycled Asphalt Mixtures, *J. Transp. Eng. Part B Pavements.* 147 (2021) 04021006. <https://doi.org/10.1061/jpeodx.0000255>.
- [131] V. Antunes, J. Neves, A.C. Freire, Performance assessment of reclaimed asphalt pavement (RAP) in road surface mixtures, *Recycling.* 6 (2021) 1–17. <https://doi.org/10.3390/recycling6020032>.
- [132] G. Guduru, A.K. Goli, S. Matolia, K.K. Kuna, Chemical and Performance Characteristics of Rejuvenated Bituminous Materials with High Reclaimed Asphalt Content, *J. Mater. Civ. Eng.* 33 (2021) 04020434. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003540](https://doi.org/10.1061/(asce)mt.1943-5533.0003540).
- [133] R. Saha, R.S. Melaku, B. Karki, A. Berg, D.S. Gedafa, Effect of Bio-Oils on Binder and Mix Properties with High RAP Binder Content, *J. Mater. Civ. Eng.* 32 (2020) 04020007. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003057](https://doi.org/10.1061/(asce)mt.1943-5533.0003057).
- [134] A. Moniri, H. Ziari, M.R.M. Aliha, Y. Saghafi, Laboratory study of the effect of oil-based recycling agents on high RAP asphalt mixtures, *Int. J. Pavement Eng.* 0 (2019) 1–12. <https://doi.org/10.1080/10298436.2019.1696461>.
- [135] K. Su, Y. Hachiya, R. Maekawaa, Study on recycled asphalt concrete for use in surface course in airport pavement, *Resour. Conserv. Recycl.* 54 (2009) 37–44. <https://doi.org/10.1016/j.resconrec.2009.06.003>.
- [136] S. Im, P. Karki, F. Zhou, Development of new mix design method for asphalt mixtures containing RAP and rejuvenators, *Constr. Build. Mater.* 115 (2016) 727–734. <https://doi.org/10.1016/j.conbuildmat.2016.04.081>.
- [137] W.S. Mogawer, A.J. Austerman, R. Kluttz, S. Puchalski, Using polymer modification

REFERENCES

- and rejuvenators to improve the performance of high reclaimed asphalt pavement mixtures, *Transp. Res. Rec.* 2575 (2016) 10–18. <https://doi.org/10.3141/2575-02>.
- [138] Y. Xu, Z. Chou, Y. Li, J. Ji, S.F. Xu, Effect of blending degree between virgin and aged binder on pavement performance of recycled asphalt mixture with high RAP content, *Adv. Mater. Sci. Eng.* 2019 (2019). <https://doi.org/10.1155/2019/5741642>.
- [139] L. Devulapalli, S. Kothandaraman, G. Sarang, Effect of rejuvenating agents on stone matrix asphalt mixtures incorporating RAP, *Constr. Build. Mater.* 254 (2020) 119298. <https://doi.org/10.1016/j.conbuildmat.2020.119298>.
- [140] J. Shen, S. Amirkhanian, J.M. Aune, Effects of rejuvenating agents on superpave mixtures containing Reclaimed Asphalt Mixture, *J. Mater. Civ. Eng.* (2007). [https://doi.org/10.1061/\(ASCE\)0899-1561\(2007\)19](https://doi.org/10.1061/(ASCE)0899-1561(2007)19).
- [141] J. Zhu, T. Ma, H. Cheng, T. Li, J. Fu, Mechanical Properties of High-Modulus Asphalt Concrete Containing Recycled Asphalt Pavement: A Parametric Study, *J. Mater. Civ. Eng.* 33 (2021) 04021056. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003678](https://doi.org/10.1061/(asce)mt.1943-5533.0003678).
- [142] J.H. Podolsky, B. Saw, M. Elkashef, R.C. Williams, E.W. Cochran, Rheology and mix performance of rejuvenated high RAP field produced hot mix asphalt with a soybean derived rejuvenator, *Road Mater. Pavement Des.* 22 (2021) 1894–1907. <https://doi.org/10.1080/14680629.2020.1719190>.
- [143] M. Wróbel, A. Wozzuk, M. Ratajczak, W. Franus, Properties of reclaimed asphalt pavement mixture with organic rejuvenator, *Constr. Build. Mater.* 271 (2021). <https://doi.org/10.1016/j.conbuildmat.2020.121514>.
- [144] P. Blankenship, D. S, *Asphalt 101 For civil and Geotechnical Engineers*, (2020).
- [145] IS: 73, Paving bitumen – specification, *Bur. Indian Stand.* New Delhi. (2013) 1–4.
- [146] AASHTO M320, Standard Specification for Performance-Graded Asphalt Binder, *Am. Assoc. State Highw. Transp. Off.* (2010).
- [147] B. of indian Standards, *Methods for Testing Tar and Bituminous Materials : Determination of Penetration*, 2022.
- [148] BIS, *Methods for Testing Tar and Bituminous Materials-Determination of Softening Point-Ring and Ball Apparatus (Second Revision)*, 2022. www.standardsbis.in.
- [149] I. Standard, *Methods for Testing Tar and Bituminous Materials-Determination of Viscosity Part 2 Absolute Viscosity (Second Revision)*, 2022. www.standardsbis.in.
- [150] B. of indian Standards, *Methods for Testing Tar and Bituminous Materials - Determination of Flash point*, 2002.
- [151] I. Standard, *Determination of Solubility in Trichloroethylene*, IS 1216 2022, New Delhi. (2023).
- [152] Asphalt Institute, *MS-2 Asphalt Mix Design Methods*, 7th editio, Asphalt Institute, USA, 2014.
- [153] MoRTH, *Specifications for Road Bridge Works 5th Revision*, 2013.
- [154] ASTM D2872, Standard test method for effect of heat and air on a moving film of asphalt (rolling thin-film oven test), *Am. Soc. Test. Mater.* West Conshohocken, PA.

REFERENCES

- (2012) 1–11. <https://doi.org/10.1520/D2872-19.2>.
- [155] ASTM D6521, Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV) Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV), (2022) 1–6. <https://doi.org/10.1520/D6521-19A.1>.
- [156] K.P. Biligiri, G.B. Way, Comparison of Laboratory and Field Aging Properties of Different Asphalt Binders, *Adv. Civ. Eng. Mater.* 2 (2013) 288–306. <https://doi.org/10.1520/ACEM20130061>.
- [157] B.T. Smith, I.L. Howard, W.S. Jordan, C. Daranga, G.L. Baumgardner, Comparing pressure aging vessel time to field aging of binder as a function of pavement depth and time, *Transp. Res. Rec.* 2672 (2018) 223–234. <https://doi.org/10.1177/0361198118790836>.
- [158] H. Liu, Z. Ju, S. Lv, W. Lu, Y. Yang, D. Ge, Laboratory aging method for simulating the extracted aged asphalt from reclaimed asphalt pavement, *Case Stud. Constr. Mater.* 21 (2024) e03651. <https://doi.org/10.1016/j.cscm.2024.e03651>.
- [159] H.U. Bahia, D.A. Anderson, Pressure aging vessel (PAV): A test to simulate rheological changes due to field aging, in: *ASTM Spec. Tech. Publ.*, 1995: pp. 67–88. <https://doi.org/10.1520/stp18189s>.
- [160] I.L. Howard, M. State, B.S. Hansen, M. State, Columbus Mississippi Field Aging and Laboratory Conditioning Study: Air Force Base and Single Aggregate Source Reference Asphalt Mixtures Report Written and Performed By: Final Report December 2018 Technical Report Documentation Page, 1 (2018).
- [161] R.B. Mallick, E.R. Brown, An evaluation of superpave binder aging methods, *Int. J. Pavement Eng.* 5 (2004) 9–18. <https://doi.org/10.1080/10298430410001720774>.
- [162] F. Hong, R. Guo, F. Zhou, Impact of recycled asphalt pavement material variability on pavement performance, *Road Mater. Pavement Des.* 15 (2014) 841–855. <https://doi.org/10.1080/14680629.2014.926284>.
- [163] J. Montañez, S. Caro, D. Carrizosa, A. Calvo, X. Sánchez, Variability of the mechanical properties of Reclaimed Asphalt Pavement (RAP) obtained from different sources, *Constr. Build. Mater.* 230 (2020). <https://doi.org/10.1016/j.conbuildmat.2019.116968>.
- [164] R.C. West, Summary of NCAT’s Survey on RAP Management Practices and RAP Variability, *Natl. Cent. Asphalt Technol.* (2008) 1–8.
- [165] G. Valdés, F. Pérez-Jiménez, R. Miró, A. Martínez, R. Botella, Experimental study of recycled asphalt mixtures with high percentages of reclaimed asphalt pavement (RAP), *Constr. Build. Mater.* 25 (2011) 1289–1297. <https://doi.org/10.1016/j.conbuildmat.2010.09.016>.
- [166] J.J. Emery, Asphalt concrete recycling in Canada, *Transp. Res. Rec.* (1993) 38–46.
- [167] C. Shannon, A. Mokhtari, H. “David” Lee, S. Tang, C. Williams, S. Schram, Effects of High Reclaimed Asphalt-Pavement Content on the Binder Grade, Fatigue Performance, Fractionation Process, and Mix Design, *J. Mater. Civ. Eng.* 29 (2017) 04016218. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0001694](https://doi.org/10.1061/(asce)mt.1943-5533.0001694).
- [168] C.P. Shannon, Fractionation of recycled asphalt pavement materials : improvement of

REFERENCES

- volumetric mix design criteria for High-RAP content surface mixtures, (2012).
- [169] B. Colbert, Z. You, The determination of mechanical performance of laboratory produced hot mix asphalt mixtures using controlled RAP and virgin aggregate size fractions, *Constr. Build. Mater.* 26 (2012) 655–662. <https://doi.org/10.1016/j.conbuildmat.2011.06.068>.
- [170] W.R. Vavrik, S.H. Carpenter, S. Gillen, J. Behnke, F. Garrott, Evaluation of Field-Produced Hot-Mix Asphalt (HMA) Mixtures with Fractionated Recycled Asphalt Pavement (RAP)-2007 Illinois Tollway Field Mix Trials, Illinois Center for Transportation (ICT), 2008.
- [171] N. Sabahfer, M. Hossain, Effect of fractionation of reclaimed asphalt pavement on properties of Superpave mixtures with reclaimed asphalt pavement, *Adv. Civ. Eng. Mater.* 4 (2015) 47–60. <https://doi.org/10.1520/ACEM20140036>.
- [172] R.C. West, J.R. Willis, M.O. Marasteanu, Improved Mix Design, Evaluation, and Materials Management Practices for Hot Mix Asphalt with High Reclaimed Asphalt Pavement Content (Vol. 752), *Transp. Res. Board.* (2013). <https://doi.org/10.17226/22554>.
- [173] F. Zhou, G. Das, T. Scullion, S. Hu, RAP Stockpile Management and Processing in Texas: State of the Practice and Proposed Guidelines, *Texas Dep. Transp. Res. Technol. Implement. Off.* 7 (2010).
- [174] H. Collins-Garcia, M. Tia, R. Roque, B. Choubane, Alternative solvent for reducing health and environmental hazards in extracting asphalt: An evaluation, *Transp. Res. Rec.* (2000) 79–85. <https://doi.org/10.3141/1712-10>.
- [175] C.A. Cipione, R.R. Davison, B.L. Burr, C.J. Glover, J.A. Bullin, Evaluation of solvents for extraction of residual asphalt from aggregates, *Transp. Res. Rec.* 1323 (1991) 47–52.
- [176] B.L. Burr, R.R. Davison, H.B. Jemison, C.J. Glover, J.A. Bullin, Asphalt Hardening in Extraction Solvents, *Transp. Res. Rec.* 1323 (1991) 70–76. [internal-pdf:/Asphalt hardening in extraction solvents.pdf](internal-pdf:/Asphalt%20hardening%20in%20extraction%20solvents.pdf).
- [177] P. Shirodkar, K. Sonpal, Y. Mehta, A. Nolan, A. Norton, C. Tomlinson, Impact of Different Extraction Recovery Method on Allowable Percentage of Reclaimed Asphalt Pavement (RAP), in: *Paving Mater. Pavement Anal.*, American Society of Civil Engineers (ASCE), 2010: pp. 75–81. [https://doi.org/10.1061/41104\(377\)10](https://doi.org/10.1061/41104(377)10).
- [178] J. McGraw, D. Iverson, G. Schmidt, J. Olson, Selection of an Alternative Asphalt Extraction Solvent, Minnesota, 2001.
- [179] E.R. Brown, N.E. Murphy, L. Yu, S. Mager, Historical development of asphalt content determination by the ignition method, *Asph. Paving Technol. Assoc. Asph. Paving Technol. Tech. Sess.* 64 (1996) 241–277.
- [180] R. Zhang, Z. You, H. Wang, X. Chen, C. Si, C. Peng, Using bio-based rejuvenator derived from waste wood to recycle old asphalt, *Constr. Build. Mater.* 189 (2018) 568–575. <https://doi.org/10.1016/j.conbuildmat.2018.08.201>.
- [181] F. Liu, P. Liu, X. Zhang, Z. Zhou, Y. Peng, Effect of re-aging on chemical and rheological properties of waste engine oil rejuvenated asphalt binder, *Constr. Build. Mater.* 408 (2023) 133798. <https://doi.org/10.1016/J.CONBUILDMAT.2023.133798>.

REFERENCES

- [182] J. Ji, H. Yao, Z. Suo, Z. You, H. Li, S. Xu, L. Sun, Effectiveness of Vegetable Oils as Rejuvenators for Aged Asphalt Binders, *J. Mater. Civ. Eng.* 29 (2017) 1–10. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0001769](https://doi.org/10.1061/(asce)mt.1943-5533.0001769).
- [183] I. Boz, M. Solaimanian, Investigating the effect of rejuvenators on low-temperature properties of recycled asphalt using impact resonance test, *Int. J. Pavement Eng.* 19 (2018) 1007–1016. <https://doi.org/10.1080/10298436.2016.1233003>.
- [184] M. Ameri, A. Mansourkhaki, D. Daryaei, Evaluation of fatigue behavior of high reclaimed asphalt binder mixes modified with rejuvenator and softer bitumen, *Constr. Build. Mater.* 191 (2018) 702–712. <https://doi.org/10.1016/j.conbuildmat.2018.09.182>.
- [185] M. Elkashef, D. Jones, L. Jiao, R.C. Williams, J. Harvey, Using Thermal Analytical Techniques to Study Rejuvenators and Rejuvenated Reclaimed Asphalt Pavement Binders, *Energy and Fuels.* 33 (2019) 2651–2658. <https://doi.org/10.1021/acs.energyfuels.8b03427>.
- [186] A. Samieadel, A. Islam Rajib, K. Phani Raj Dandamudi, S. Deng, E.H. Fini, Improving recycled asphalt using sustainable hybrid rejuvenators with enhanced intercalation into oxidized asphaltene nanoaggregates, *Constr. Build. Mater.* 262 (2020) 120090. <https://doi.org/10.1016/j.conbuildmat.2020.120090>.
- [187] N. Neiri, T. Shin, N. Kim, A. Caron, H. Ben Ismail, N. Cho, Towards the use of waste pig fat as a novel potential bio-based rejuvenator for recycled asphalt pavement, *Materials (Basel).* 13 (2020). <https://doi.org/10.3390/ma13041002>.
- [188] D. Daryaei, M. Habibpour, S. Gulzar, B.S. Underwood, Combined effect of waste polymer and rejuvenator on performance properties of reclaimed asphalt binder, *Constr. Build. Mater.* 268 (2021) 121059. <https://doi.org/10.1016/j.conbuildmat.2020.121059>.
- [189] P. Aghazadeh Dokandari, A. Topal, D. Kaya Ozdemir, Rheological and Microstructural Investigation of the Effects of Rejuvenators on Reclaimed Asphalt Pavement Bitumen by DSR and AFM, *Int. J. Civ. Eng.* 19 (2021) 749–758. <https://doi.org/10.1007/s40999-021-00605-z>.
- [190] S.K. Pradhan, U.C. Sahoo, Influence of softer binder and rejuvenator on bituminous mixtures containing reclaimed asphalt pavement (RAP) material, *Int. J. Transp. Sci. Technol.* 11 (2022) 46–59. <https://doi.org/10.1016/j.ijst.2020.12.001>.
- [191] A.I. Rajib, A. Samieadel, A. Zalgout, K.E. Kaloush, B.K. Sharma, E.H. Fini, Do all rejuvenators improve asphalt performance?, *Road Mater. Pavement Des.* 23 (2022) 358–376. <https://doi.org/10.1080/14680629.2020.1826348>.
- [192] M.A. Dalhat, S.A. Osman, N. Dalhat Mu'azu, O. Alagha, Utilization of oil sludge as rejuvenator in hot-mix-asphalt containing reclaimed asphalt concrete, *Constr. Build. Mater.* 338 (2022) 127483. <https://doi.org/10.1016/j.conbuildmat.2022.127483>.
- [193] Z.H. Al-Saffar, A. Eltwati, E.E. Aziz, H. Yaacob, H.A. Dawood, R.P. Jaya, M.S.A. Jawahery, E. Shaffie, The Use of Vacuum Residue as a Potential Rejuvenator in Reclaimed Asphalt Pavement: Physical, Rheological, and Mechanical Traits Analysis, *Recycling.* 8 (2023). <https://doi.org/10.3390/recycling8030047>.
- [194] L. Wang, A. Shen, G. Mou, Y. Guo, Y. Meiquan, Effect of RAP gradation subdivision and addition of a rejuvenator on recycled asphalt mixture engineering performance, *Case Stud. Constr. Mater.* 18 (2023) e02136. <https://doi.org/10.1016/j.cscm.2023.e02136>.

REFERENCES

- [195] G. Yaseen, I. Hafeez, Effect of cereclor as rejuvenator to enhance the aging resistance of reclaimed asphalt pavement binder, *Materials (Basel)*. 13 (2020). <https://doi.org/10.3390/ma13071582>.
- [196] M. Alae, Z. Zhang, L. Xu, A.S. Shahsamy, F. Xiao, Unveiling the composite rejuvenator efficacy on performance improvement of asphalt binder including high RAP contents, *Constr. Build. Mater.* 446 (2024) 137989. <https://doi.org/10.1016/j.conbuildmat.2024.137989>.
- [197] S.Y. Lee, T.H. Minh Le, Sustainability and durability enhancement of RAP mixtures with waste plastic aggregate using sewage sludge bio-oil as a rejuvenator, *Constr. Build. Mater.* 462 (2025) 140008. <https://doi.org/10.1016/j.conbuildmat.2025.140008>.
- [198] X. Jia, B. Huang, B.F. Bowers, S. Zhao, Infrared spectra and rheological properties of asphalt cement containing waste engine oil residues, *Constr. Build. Mater.* 50 (2014) 683–691. <https://doi.org/10.1016/j.conbuildmat.2013.10.012>.
- [199] I.A. Qurashi, A.K. Swamy, Viscoelastic properties of recycled asphalt binder containing waste engine oil, *J. Clean. Prod.* 182 (2018) 992–1000. <https://doi.org/10.1016/j.jclepro.2018.01.237>.
- [200] Lily M. Ng, R. Simmons, Infrared spectroscopy, *Am. Chem. Soc.* 71 (1999) 7–33.
- [201] V.P. Wagh, M. Sukhija, A. Gupta, Exploring the consequences of reduced aging on the performance of warm mix asphalt binders, *Int. J. Pavement Eng.* 24 (2023). <https://doi.org/10.1080/10298436.2023.2270768>.
- [202] M.R. Nivitha, E. Prasad, J.M. Krishnan, Ageing in modified bitumen using FTIR spectroscopy, *Int. J. Pavement Eng.* 17 (2016) 565–577. <https://doi.org/10.1080/10298436.2015.1007230>.
- [203] ASTM D6927, Standard test method for Marshall stability and flow of asphalt mixtures, ASTM Int. West Conshohocken, PA. (2022) 1–7. <https://doi.org/10.1520/D6927-22.2>.
- [204] C.T. Metcalf, Use of Marshall Stability Test in Asphalt Paving Mix Design, (1959) 12–22. <http://onlinepubs.trb.org/Onlinepubs/hrbulletin/234/234-002.pdf>.
- [205] ASTM STP106-EB, Triaxial Testing of Soils and Bituminous Mixtures, 2006. <https://doi.org/10.1520/STP106-EB>.
- [206] G.R. Bahri, L.F. Rader., Effects of Asphalt Viscosity on Physical Properties of Asphaltic Concrete, 1965.
- [207] K.E. Kaloush, M.W. Witeczak, B.W. Sullivan, Simple Performance Test for Permanent Simple Performance Test for Permanent, 6th RILEM Symp. PTEBM. (2003).
- [208] R. Basu, M. Randy, E.R. Brown, Potential of Dynamic Creep to Predict Rutting, *J. Mater. Civ. Eng.* (2017) 194–212.
- [209] E.R. Brown, K.Y. Foo, Comparison of Unconfined- and Confined-Creep Tests for Hot Mix Asphalt, *J. Mater. Civ. Eng.* 6 (1994) 307–326. [https://doi.org/10.1061/\(asce\)0899-1561\(1994\)6:2\(307\)](https://doi.org/10.1061/(asce)0899-1561(1994)6:2(307)).
- [210] EN 12697-25 : 2016, BSI Standards Publication Bituminous mixtures - Test methods- Part 25: Cyclic compression test, Br. Stand. Inst. (2016).
- [211] A. Aksoy, E. Iskender, Creep in conventional and modified asphalt mixtures, *Proc. Inst.*

REFERENCES

- Civ. Eng. Transp. 161 (2008) 185–195. <https://doi.org/10.1680/tran.2008.161.4.185>.
- [212] M. Perl, J. Uzan, A. Sides, Visco-Elasto-Plastic Constitutive Law for a Bituminous Mixture Under Repeated Loading., *Transp. Res. Rec.* (1983) 20–27.
- [213] Q.H.L. Von, Performance Prediction Models In the Superpave Mix Design System, Washington, DC., USA; *Strateg. Highw. Res. Program, Natl. Res. Counc.* 699 (1994).
- [214] Y. Zhang, R. Luo, R.L. Lytton, Characterizing Permanent Deformation and Fracture of Asphalt Mixtures by Using Compressive Dynamic Modulus Tests, *J. Mater. Civ. Eng.* 24 (2012) 898–906. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0000471](https://doi.org/10.1061/(asce)mt.1943-5533.0000471).
- [215] X. Qi, M.W. Witczak, Time-dependent permanent deformation models for asphaltic mixtures, *Transp. Res. Rec.* (1998) 83–93. <https://doi.org/10.3141/1639-09>.
- [216] M.M.M. Larrain, Analytical Modeling of Rutting Potential of Asphalt Mixes Using Hamburg Wheel Tracking Device (Master Thesis), (Master Thesis). (2015). <https://doi.org/10.13140/RG.2.1.4754.9206>.
- [217] AASHTO T324-14, Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA), *Am. Assoc. State Highw. Transp. Off. T 324-14* (2013) 1–10.
- [218] R. Salim, A. Gundla, A. Zalgout, B.S. Underwood, K.E. Kaloush, Relationship between Asphalt Binder Parameters and Asphalt Mixture Rutting, *Transp. Res. Rec.* 2673 (2019) 431–446. <https://doi.org/10.1177/0361198119842129>.
- [219] L. Walubita, J. Zhang, G. Das, X. Hu, C. Mushota, A. Alvarez, T. Scullion, Hot-mix asphalt permanent deformation evaluated by Hamburg wheel tracking, dynamic modulus, and repeated load tests, *Transp. Res. Rec.* (2012) 46–56. <https://doi.org/10.3141/2296-05>.
- [220] Y. Yildirim, P.W. Jayawickrama, M. shabbir Hossain, Abdulrahman Alhabshi, Hamburg wheel-tracking database analysis, 2004.
- [221] F. Yin, A.J. Taylor, N. Tran, NCAT Report 20-02: Performance Testing for Quality Control and Acceptance of Balanced Mix Design, *Natl. Cent. Asph. Technol. Auburn Univ. Auburn, Alabama*, May. (2020) 30.
- [222] F. Zhou, S. Hu, D. Newcomb, Development of a performance-related framework for production quality control with ideal cracking and rutting tests, *Constr. Build. Mater.* 261 (2020) 120549. <https://doi.org/10.1016/j.conbuildmat.2020.120549>.
- [223] F. Zhou, B. Crockford, J. Zhang, S. Hu, J. Epps, L. Sun, Development and validation of an ideal shear rutting test for asphalt mix design and QC/QA, *Asph. Paving Technol. Assoc. Asph. Paving Technol. Tech. Sess.* 88 (2019) 719–750.
- [224] F. Zhou, R. Steger, W. Mogawer, Development of a coherent framework for balanced mix design and production quality control and quality acceptance, *Constr. Build. Mater.* 287 (2021) 123020. <https://doi.org/10.1016/j.conbuildmat.2021.123020>.
- [225] ASTM D8360-22, Standard Test Method for Determination of Rutting Tolerance Index of Asphalt Mixture Using the Rapid Rutting Test, *ASTM Int.* (2022) 5–10. <https://doi.org/10.1520/D8360-22>. Copyright.
- [226] I. Boz, G.P. Coffey, J. Habbouche, S.D. Diefenderfer, O.E. Ozbulut, A critical review

REFERENCES

- of monotonic loading tests to evaluate rutting potential of asphalt mixtures, *Constr. Build. Mater.* 335 (2022) 127484. <https://doi.org/10.1016/j.conbuildmat.2022.127484>.
- [227] ASTM D8225, Standard Test Method for Determination of Cracking Tolerance Index of Asphalt Mixture Using the Indirect Tensile Cracking Test at, Astm, D8825. (2019) 1–6. <https://doi.org/10.1520/D8225-19.Copyright>.
- [228] C. Yan, Y. Zhang, H.U. Bahia, Comparison between SCB-IFIT, un-notched SCB-IFIT and IDEAL-CT for measuring cracking resistance of asphalt mixtures, *Constr. Build. Mater.* 252 (2020) 119060. <https://doi.org/10.1016/j.conbuildmat.2020.119060>.
- [229] A.J. Taylor, F. Yin, Cracking Group Experiment – Evaluation of Laboratory Cracking Tests, (2018).
- [230] H. Chen, Y. Zhang, H.U. Bahia, The role of binders in mixture cracking resistance measured by ideal-CT test, *Int. J. Fatigue.* 142 (2021) 105947. <https://doi.org/10.1016/j.ijfatigue.2020.105947>.
- [231] M. Elkashef, J. Harvey, D. Jones, L. Jiao, The impact of silo storage on the fatigue and cracking resistance of asphalt mixes, *Constr. Build. Mater.* 326 (2022) 126880. <https://doi.org/10.1016/j.conbuildmat.2022.126880>.
- [232] H. Chen, R. Wang, H.U. Bahia, Effect of air voids on the fracture resistance of HMA in the indirect tensile cracking (IDEAL-CT) test, *Int. J. Pavement Eng.* 24 (2023). <https://doi.org/10.1080/10298436.2023.2252148>.
- [233] S. Saadeh, M. El Asmar, Sensitivity Analysis of the Ideal Ct Test Using the Distinct, (2022).
- [234] A. Leavitt, A.E. Martin, E. Arámbula-Mercado, Mitigation Strategy Selection for Asphalt Mixtures with High Reclaimed Asphalt Pavement Content, *Transp. Res. Rec. J. Transp. Res. Board.* 2677 (2023). <https://doi.org/https://doi.org/10.1177/03611981231166392>.
- [235] A. Leavitt, A. Epps Martin, E. Arámbula, Model for Evaluating Cracking Performance of Asphalt Pavements with Field Aging Based on IDEAL-CT Parameters, *Transp. Res. Rec.* (2024). <https://doi.org/10.1177/03611981241231806>.
- [236] M. Sukhija, N. Saboo, A. Pani, Suitability of warm mix asphalt (WMA) technologies based on performance and energy consumption, *Road Mater. Pavement Des.* 25 (2024) 1479–1506. <https://doi.org/10.1080/14680629.2023.2268721>.
- [237] M. Sukhija, N. Saboo, A. Pani, Correlating the Fatigue Response of Asphalt Binders and Mixtures Prepared Using Warm-Mix Asphalt Technologies, *J. Mater. Civ. Eng.* 37 (2025) 1–16. <https://doi.org/10.1061/JMCEE7.MTENG-18653>.
- [238] R.P. Lottman, R.P. Chen, K.S. Kumar, L.W. Wolf, Laboratory Test System for Prediction of Asphalt Concrete Moisture Damage., *Transp. Res. Rec.* 0361–1981 (1974) 18–26.
- [239] R.Y. Liang, D. Ph, Refine AASHTO T283 Resistance of Compacted Bituminous Mixture to Moisture Induced Damage for Superpave, *Fhwa-Oh-2008.* (2008).
- [240] Y.R. Kim, D.N. Little, R.L. Lytton, Effect of moisture damage on material properties and fatigue resistance of asphalt mixtures, *Transp. Res. Rec.* (2004) 48–54. <https://doi.org/10.3141/1891-07>.

REFERENCES

- [241] M.O. Hamzah, M.R. Kakar, M.R. Hainin, An overview of moisture damage in asphalt mixtures, *J. Teknol.* 73 (2015) 125–131. <https://doi.org/10.11113/jt.v73.4305>.
- [242] T.W. Kennedy, *Stripping and Moisture Damage in Asphalt Mixtures*, 1984.
- [243] ASTM D4867/D4867M – 09, Standard Test Method for Effect of Moisture on Asphalt Concrete Paving Mixtures, *Am. Soc. Test. Mater.* i (2014) 1–5. <https://doi.org/10.1520/D4867>.
- [244] M. Sukhija, N. Saboo, A. Pani, Effect of warm mix asphalt (WMA) technologies on the moisture resistance of asphalt mixtures, *Constr. Build. Mater.* 369 (2023) 130589. <https://doi.org/10.1016/j.conbuildmat.2023.130589>.
- [245] F.H. Al-Sugair, J.A. Almudaiheem, Variations in Measured Resilient Modulus of Asphalt Mixes, *J. Mater. Civ. Eng.* 4 (1992) 343–352. [https://doi.org/10.1061/\(asce\)0899-1561\(1992\)4:4\(343\)](https://doi.org/10.1061/(asce)0899-1561(1992)4:4(343)).
- [246] ASTM D4123, Standard Test Method for Indirect Tension Test for Resilient Modulus of Bituminous Mixtures, *Am. Soc. Test. Mater.* 82 (2006) 1–6.
- [247] E.R. Brown, K.Y. Foo, Evaluation of Variability in Resilient Modulus Test Results (ASTM D 4123), *J. Test. Eval.* 19 (1991) 1–13. <https://doi.org/10.1520/JTE12523J>.
- [248] S.G. Jahromi, A. Khodaii, Investigation of Variables Affecting Resilient Modulus in Asphalt Mixes, in: *GeoHunan Int. Conf.*, 2009: p. 557100.
- [249] A.R. Ghanizadeh, M. Fakhri, Effect of Waveform, Duration and Rest Period on the Resilient Modulus of Asphalt Mixes, *Procedia - Soc. Behav. Sci.* 104 (2013) 79–88. <https://doi.org/10.1016/j.sbspro.2013.11.100>.
- [250] L. Ruan, R. Luo, X. Hu, P. Pan, Effect of bell-shaped loading and haversine loading on the dynamic modulus and resilient modulus of asphalt mixtures, *Constr. Build. Mater.* 161 (2018) 124–131. <https://doi.org/10.1016/j.conbuildmat.2017.11.038>.
- [251] M. Junaid, M.Z.A. Shah, G. Yaseen, H.H. Awan, D. Khan, M. Jawad, Investigating the Effect of Gradation, Temperature and Loading Duration on the Resilient Modulus of Asphalt Concrete, *Civ. Eng. J.* 8 (2022) 278–289. <https://doi.org/10.28991/CEJ-2022-08-02-07>.
- [252] X. Lu, U. Isacson, Effect of ageing on bitumen chemistry and rheology, *Constr. Build. Mater.* 16 (2002) 15–22. [https://doi.org/10.1016/S0950-0618\(01\)00033-2](https://doi.org/10.1016/S0950-0618(01)00033-2).
- [253] P.E. Yuhong Wang, K. Zhao, C. Glover, L. Chen, Y. Wen, D. Chong, C. Hu, Effects of aging on the properties of asphalt at the nanoscale, *Constr. Build. Mater.* 80 (2015) 244–254. <https://doi.org/10.1016/j.conbuildmat.2015.01.059>.
- [254] E.T. Harrigan, R.B. (Rita B.) Leahy, J.S. Youtcheff, University of Texas at Austin., Strategic Highway Research Program (U.S.), *The SUPERPAVE mix design system manual of specifications, test methods, and practices*, 1994.
- [255] D.C. Montgomery, Standard practice procedures for mixture conditioning of compacted and uncompacted hot-mix asphalt, *Am. Assoc. State Highw. Transp. Off.* 02 (2019) 1–5.
- [256] C.A. Bell, Y. Abwahab, M.E. Cristi, D. Sosnovske, SHRP A 383: Selection of Laboratory Aging Procedures for Asphalt-Aggregate Mixtures, 1994.

REFERENCES

- [257] C. Baek, B. Underwood, Y. Kim, Effects of oxidative aging on asphalt mixture properties, *Transp. Res. Rec.* (2012) 77–85. <https://doi.org/10.3141/2296-08>.
- [258] S.I. Sarsam, S.M. Abdulmajeed, Influence of Aging Time on Asphalt Pavement Performance, *J. Eng.* 20 (2023) 1–12. <https://doi.org/10.31026/j.eng.2014.12.01>.
- [259] Y. Gao, D. Geng, X. Huang, G. Li, Degradation evaluation index of asphalt pavement based on mechanical performance of asphalt mixture, *Constr. Build. Mater.* 140 (2017) 75–81. <https://doi.org/10.1016/j.conbuildmat.2017.02.095>.
- [260] O. Sirin, D.K. Paul, M.S. Khan, E. Kassem, M.K. Darabi, Effect of Aging on Viscoelastic Properties of Asphalt Mixtures, *J. Transp. Eng. Part B Pavements.* 145 (2019) 04019034. <https://doi.org/10.1061/jpeodx.0000137>.
- [261] H. Sahebzamani, M.Z. Alavi, O. Farzaneh, Impact of different levels of oxidative aging on engineering properties of asphalt mixes at low temperatures, *Constr. Build. Mater.* 242 (2020) 118036. <https://doi.org/10.1016/j.conbuildmat.2020.118036>.
- [262] Y.R. Kim, C. Castorena, M. Elwardany, F.Y. Rad, S. Underwood, A. Gundha, P. Gudipudi, M.J. Farrar, R.R. Glaser, Long-Term Aging of Asphalt Mixtures for Performance Testing and Prediction, 2017. <https://doi.org/10.17226/24959>.
- [263] W.N. Houston, M.M. W., C.Z. W., S. Raghavendra, Environmental Effects in Pavement Mix and Structural Design Systems, 2007. <https://doi.org/10.17226/23244>.
- [264] D. Newcomb, E. Arámbula-Mercado, A.E. Martin, M. Yuan, N. Tran, F. Yin, Field Verification of Proposed Changes to the AASHTO R 30 Procedures for Laboratory Conditioning of Asphalt Mixtures, 2019. <https://doi.org/10.17226/25608>.
- [265] T.W. Kennedy, J.N. Anagnos, Techniques for Reducing Moisture Damage in Asphalt Mixtures, FHWA/TX-85/68+253-9F. (1984) 92.
- [266] J.G. Chehovits, D.A. Anderson, Upgrading of Marginal Aggregates for Improved Water Resistance of Asphalt Concrete., *Transp. Res. Rec.* (1980) 46–52.
- [267] K. won Lee, Prediction and evaluation of moisture effects on Asphalt concrete mixtures in Pavement studies, 1982. <http://dx.doi.org/10.1016/j.jaci.2012.05.050>.
- [268] R. Tauste, F. Moreno-Navarro, M. Sol-Sánchez, M.C. Rubio-Gámez, Understanding the bitumen ageing phenomenon: A review, *Constr. Build. Mater.* 192 (2018) 593–609. <https://doi.org/10.1016/j.conbuildmat.2018.10.169>.
- [269] H. Plancher, S.M. Dorrence, J.C. Petersen, Identification of chemical types in asphalts strongly adsorbed at the asphalt-aggregate interface and their relative displacement by water.[Moisture damage to roads], (1977).
- [270] J. Petersen, H. Plancher, E.K. Ensley, R.L. Venable, G. Miyake, Chemistry of asphalt-aggregate interaction: relationship with pavement moisture-damage prediction test, *Transp. Res. Rec.* 104 (1982) 95–104.
- [271] V.A. Litvishkova, A.I. Bukhter, A. V. Nepogod'ev, A.M. Bezhanidze, Chemical composition of used motor oils, *Chem. Technol. Fuels Oils.* 10 (1974) 962–965. <https://doi.org/10.1007/BF00714224>.
- [272] N.A. Ahmad, K.M. Abdelbary, S.M. Younis, Chemical analysis of engine oils as an indicator to estimate the rate of wear, *Egypt. J. Chem.* 61 (2018) 581–590.

REFERENCES

- <https://doi.org/10.21608/ejchem.2018.3412.1289>.
- [273] Z.H. Al-Saffar, H. Yaacob, M.K.I.M. Satar, S.N.N. Kamarudin, M.Z.H. Mahmud, C.R. Ismail, S.A. Hassan, N. Mashros, A review on the usage of waste engine oil with aged asphalt as a rejuvenating agent, *Mater. Today Proc.* 42 (2021) 2374–2380. <https://doi.org/10.1016/j.matpr.2020.12.330>.
- [274] Z. Jwaida, A. Dulaimi, A. Bahrami, M.A.O. Mydin, Y.O. Özkılıç, R.P. Jaya, Y. Wang, Analytical review on potential use of waste engine oil in asphalt and pavement engineering, *Case Stud. Constr. Mater.* 20 (2024) 1–29. <https://doi.org/10.1016/j.cscm.2024.e02930>.
- [275] M. Hu, S. Ji, M. Li, K. Zhu, D. Sun, Reutilization of waste-based oils for efficient recycling of aged highly polymer modified asphalt: A case study of principal component-cluster analysis, *Constr. Build. Mater.* 458 (2025) 139545. <https://doi.org/10.1016/J.CONBUILDMAT.2024.139545>.
- [276] A.H. Aydilek, Z. Mijic, Maryland Department of Transportation State Highway Administration Research Report Hydraulic and Environmental Behavior of Recycled Asphalt Pavement in Highway Shoulder Applications, (2017) 1–287.
- [277] A.N. Prasad, N. Saboo, A. Pani, Material and mix design aspects of hot recycled asphalt mixes: A review, Springer Berlin Heidelberg, 2023. <https://doi.org/10.1007/s11356-023-29913-8>.
- [278] H.F. Haghshenas, R. Rea, G. Reinke, M. Zaumanis, E. Fini, Relationship between colloidal index and chemo-rheological properties of asphalt binders modified by various recycling agents, *Constr. Build. Mater.* 318 (2022) 126161. <https://doi.org/10.1016/j.conbuildmat.2021.126161>.
- [279] E. Fini, A.I. Rajib, D. Oldham, A. Samieadel, S. Hosseinezhad, Role of Chemical Composition of Recycling Agents in Their Interactions with Oxidized Asphaltene Molecules, *J. Mater. Civ. Eng.* 32 (2020) 1–13. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003352](https://doi.org/10.1061/(asce)mt.1943-5533.0003352).
- [280] H.F. Haghshenas, Y.R. Kim, S.R. Kommidi, D. Nguyen, D.F. Haghshenas, M.D. Morton, Evaluation of long-term effects of rejuvenation on reclaimed binder properties based on chemical-rheological tests and analyses, *Mater. Struct. Constr.* 51 (2018) 1–13. <https://doi.org/10.1617/s11527-018-1262-4>.
- [281] A.M. El-Shorbagy, S.M. El-Badawy, A.R. Gabr, Investigation of waste oils as rejuvenators of aged bitumen for sustainable pavement, *Constr. Build. Mater.* 220 (2019) 228–237. <https://doi.org/10.1016/j.conbuildmat.2019.05.180>.
- [282] M. Karamroudi, M. Ameri, Chemical properties of the purified waste engine oil as recycling agents for restoring the properties of aged asphalt binder, *Pet. Sci. Technol.* 0 (2023) 1–20. <https://doi.org/10.1080/10916466.2023.2255615>.
- [283] H.H. Joni, R.H.A. Al-Rubae, M.A. Al-zerkani, Rejuvenation of aged asphalt binder extracted from reclaimed asphalt pavement using waste vegetable and engine oils, *Case Stud. Constr. Mater.* 11 (2019) e00279. <https://doi.org/10.1016/j.cscm.2019.e00279>.
- [284] Y. Fang, Z. Zhang, J. Yang, X. Li, Comprehensive review on the application of bio-rejuvenator in the regeneration of waste asphalt materials, *Constr. Build. Mater.* 295 (2021) 123631. <https://doi.org/10.1016/j.conbuildmat.2021.123631>.

REFERENCES

- [285] H. Li, Z. Feng, A.T. Ahmed, M. Yombah, C. Cui, G. Zhao, P. Guo, Y. Sheng, Repurposing waste oils into cleaner aged asphalt pavement materials: A critical review, *J. Clean. Prod.* 334 (2022) 130230. <https://doi.org/10.1016/j.jclepro.2021.130230>.
- [286] V. Kumar, P. Aggarwal, S. Jain, Optimising waste cooking oil and waste engine oil as rejuvenators: a comprehensive study on recycled mixtures, *Int. J. Pavement Eng.* 25 (2024). <https://doi.org/10.1080/10298436.2024.2389422>.
- [287] S. Yan, Q. Dong, X. Chen, C. Zhou, S. Dong, X. Gu, Application of waste oil in asphalt rejuvenation and modification: A comprehensive review, *Constr. Build. Mater.* 340 (2022) 127784. <https://doi.org/10.1016/J.CONBUILDMAT.2022.127784>.
- [288] X. Jia, B. Huang, J.A. Moore, S. Zhao, Influence of Waste Engine Oil on Asphalt Mixtures Containing Reclaimed Asphalt Pavement, *J. Mater. Civ. Eng.* 27 (2015) 1–9. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0001292](https://doi.org/10.1061/(asce)mt.1943-5533.0001292).
- [289] H. Taherkhani, F. Noorian, Investigating Permanent Deformation of Recycled Asphalt Concrete Containing Waste Oils as Rejuvenator Using Response Surface Methodology (RSM), *Iran. J. Sci. Technol. - Trans. Civ. Eng.* 45 (2021) 1989–2001. <https://doi.org/10.1007/s40996-020-00485-8>.
- [290] H. Taherkhani, F. Noorian, Comparing the effects of waste engine and cooking oil on the properties of asphalt concrete containing reclaimed asphalt pavement (RAP), *Road Mater. Pavement Des.* 21 (2020) 1238–1257. <https://doi.org/10.1080/14680629.2018.1546220>.
- [291] A. Chen, Z. Hu, M. Li, T. Bai, G. Xie, Y. Zhang, Y. Li, C. Li, Investigation on the mechanism and performance of asphalt and its mixture regenerated by waste engine oil, *Constr. Build. Mater.* 313 (2021) 125411. <https://doi.org/10.1016/j.conbuildmat.2021.125411>.
- [292] V. Kumar Sharma, R. Kumar, A. Pal Singh, Laboratory investigation of bituminous concrete using Reclaimed asphalt pavement and waste Engine oil, *Mater. Today Proc.* 59 (2022) 1591–1598. <https://doi.org/10.1016/j.matpr.2022.03.139>.
- [293] M. Zaumanis, R.B. Mallick, R. Frank, Evaluation of different recycling agents for restoring aged asphalt binder and performance of 100 % recycled asphalt, *Mater. Struct.* 48 (2015) 2475–2488. <https://doi.org/10.1617/s11527-014-0332-5>.
- [294] P. Aeron, N. Saboo, P. Aggarwal, Effect of optimum rejuvenator dosage on the performance of 100% recycled asphalt binder, *Mech. Time-Dependent Mater.* (2023). <https://doi.org/10.1007/s11043-023-09638-4>.
- [295] D.B. Sánchez, S. Caro, A.E. Alvarez, Assessment of methods to select optimum doses of rejuvenators for asphalt mixtures with high RAP content, *Int. J. Pavement Eng.* 24 (2023). <https://doi.org/10.1080/10298436.2022.2161544>.
- [296] ASTM D7643, Standard Practice for Determining the Continuous Grading Temperatures and Continuous Grades for PG Graded Asphalt Binders, *ASTM (American Soc. Test. Mater.)* (2022) 1–5. <https://doi.org/10.1520/D7643-22.2>.
- [297] I. Gawel, F. Czechowski, J. Kosno, An environmental friendly anti-ageing additive to bitumen, *Constr. Build. Mater.* 110 (2016) 42–47. <https://doi.org/10.1016/j.conbuildmat.2016.02.004>.
- [298] K. Whetsel, Infrared spectroscopy, *Chem. Eng. News.* 46 (1968) 82–96.

REFERENCES

- <https://doi.org/10.1021/cen-v046n006.p082>.
- [299] D.G. Thomas, Chapter 1: Infrared spectroscopy, in: Borzuya Univ., 2015.
- [300] D. Singh, B. Showkat, B. Rajan, A. Shah, Rheological Interference of Amine and Silane-Based Antistripping Agents on Crumb Rubber-Modified Binder, *J. Mater. Civ. Eng.* 32 (2020). [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003004](https://doi.org/10.1061/(asce)mt.1943-5533.0003004).
- [301] A. Buddhala, Z. Hossain, N.M. Wasiuddin, M. Zaman, E.A. O'Rear, Effects of an amine anti-stripping agent on moisture susceptibility of sasobit and aspha-min mixes by surface free energy analysis, *J. Test. Eval.* 40 (2012) 91–99. <https://doi.org/10.1520/jte103618>.
- [302] M. Sukhija, A.N. Prasad, N. Saboo, N. Mashaan, Assessment of Virgin Binder-Blended Rejuvenators and Antistripping Agents for Hot Recycled Asphalt Mixture, *Int. J. Pavement Res. Technol.* 16 (2023) 1226–1240. <https://doi.org/10.1007/s42947-022-00192-9>.
- [303] M. Sukhija, E. Coleri, A review on the incorporation of reclaimed asphalt pavement material in asphalt pavements: management practices and strategic techniques, *Road Mater. Pavement Des.* (2025) 1–40. <https://doi.org/10.1080/14680629.2025.2470889>.
- [304] V.P. Servas, A.C. Edler, M.A. Ferreira, E.J. Assen, An Integrated Approach for Determining Additive Requirements in Hot Mix Recycling. Sixth International Conference, Structural Design of Asphalt Pavements, Publ. Michigan Univ. Ann Arbor. (1987). <http://trid.trb.org/view.aspx?id=302914> (accessed April 23, 2025).
- [305] Japanese road association, Guideline for Recycling pavement technology in plant, 1993.
- [306] J. Shen, Y. Ohne, Determining Rejuvenator Content for Recycling Reclaimed Asphalt Pavement by SHRP Binder Specifications, *Int. J. Pavement Eng.* 3 (2002) 261–268. <https://doi.org/10.1080/1029843021000083685>.
- [307] J. Shen, S. Amirhanian, J. Aune Miller, Effects of Rejuvenating Agents on Superpave Mixtures Containing Reclaimed Asphalt Pavement, *J. Mater. Civ. Eng.* 19 (2007) 376–384. [https://doi.org/10.1061/\(asce\)0899-1561\(2007\)19:5\(376\)](https://doi.org/10.1061/(asce)0899-1561(2007)19:5(376)).
- [308] E. Arámbula-Mercado, F. Kaseer, A. Epps Martin, F. Yin, L. Garcia Cucalon, Evaluation of recycling agent dosage selection and incorporation methods for asphalt mixtures with high RAP and RAS contents, *Constr. Build. Mater.* 158 (2018) 432–442. <https://doi.org/10.1016/j.conbuildmat.2017.10.024>.
- [309] G. Nsengiyumva, H.F. Haghshenas, Y.R. Kim, S.R. Kommidi, Mechanical-Chemical Characterization of the Effects of Type, Dosage, and Treatment Methods of Rejuvenators in Aged Bituminous Materials, *Transp. Res. Rec.* 2674 (2020) 126–138. <https://doi.org/10.1177/0361198120909110>.
- [310] P. Lin, X. Liu, P. Apostolidis, S. Erkens, S. Ren, S. Xu, T. Scarpas, W. Huang, On the rejuvenator dosage optimization for aged SBS modified bitumen, *Constr. Build. Mater.* 271 (2021) 121913. <https://doi.org/10.1016/j.conbuildmat.2020.121913>.
- [311] R. Bin Ahmed, K. Hossain, M. Aurilio, R. Hajj, Effect of rejuvenator type and dosage on rheological properties of short-term aged binders, *Mater. Struct. Constr.* 54 (2021) 1–18. <https://doi.org/10.1617/s11527-021-01711-z>.
- [312] G. Giancontieri, D. Hargreaves, D. Lo Presti, Are we correctly measuring the rotational

REFERENCES

- viscosity of heterogeneous bituminous binders?, *Road Mater. Pavement Des.* 21 (2020) S37–S56. <https://doi.org/10.1080/14680629.2020.1724559>.
- [313] AASTHO, Standard Specification for Asphalt Binder, *ASTM Int.* (2016) 1–5. <https://doi.org/10.1520/D6373-21A.2>.
- [314] D.A. Anderson, Y.M. Le Hir, J.P. Planche, D. Martin, Zero shear viscosity of asphalt binders, *Transp. Res. Rec.* (2002) 54–60. <https://doi.org/10.3141/1810-07>.
- [315] X. Zhang, G. Zou, J. Xu, Measurement of zero-shear viscosity in asphalt, *Int. J. Pavement Res. Technol.* 2 (2009) 33–36.
- [316] F. Morea, J.O. Agnusdei, R. Zerbino, Comparison of methods for measuring zero shear viscosity in asphalts, *Mater. Struct. Constr.* 43 (2010) 499–507. <https://doi.org/10.1617/s11527-009-9506-y>.
- [317] M. Sukhija, A.N. Prasad, N. Saboo, N. Mashaan, Assessment of Virgin Binder-Blended Rejuvenators and Antistripping Agents for Hot Recycled Asphalt Mixture, *Int. J. Pavement Res. Technol.* 16 (2023) 1226–1240. <https://doi.org/10.1007/s42947-022-00192-9>.
- [318] R. Jing, A. Varveri, X. Liu, A. Scarpas, S. Erkens, Ageing effect on chemo-mechanics of bitumen, *Road Mater. Pavement Des.* 22 (2021) 1044–1059. <https://doi.org/10.1080/14680629.2019.1661275>.
- [319] M.R. Nivitha, J. Murali Krishnan, What is Transition Temperature for Bitumen and How to Measure It?, *Transp. Dev. Econ.* 2 (2016) 1–8. <https://doi.org/10.1007/s40890-015-0009-y>.
- [320] J.C. Petersen, R.E. Robertson, J.F. Branthaver, P.M. Harnsberger, J.J. Duvall, S.S. Kim, D.A. Anderson, D.W. Christensen, H.U. Bahia, R. Dongre, C.E. Antle, M.G. Sharma, Binder Characterization and Evaluation Volume 4: Test Methods, Strategic Highway Research Program, SHRP A-370, in: *Natl. Res. Council.*, 1994: p. 197. <https://onlinepubs.trb.org/onlinepubs/shrp/SHRP-A-369.pdf> (accessed January 20, 2025).
- [321] C.J. Glover, R.R. Davison, C.H. Domke, Y. Ruan, P. Juristyarini, D.B. Knorr, S.H. Jung, Development of a New Method for Assessing Asphalt Binder Durability with Field Validation, *Texas Dep. Transp.* 1872 (2005) 1–334. <https://static.tti.tamu.edu/tti.tamu.edu/documents/0-1872-2.pdf>.
- [322] G. King, M. Anderson, D. Hanson, P. Blankenship, Using black space diagrams to predict Age-induced cracking, *RILEM Bookseries.* 4 (2012) 453–463. https://doi.org/10.1007/978-94-007-4566-7_44.
- [323] G.M. Rowe, G. King, M. Anderson, The influence of binder rheology on the cracking of asphalt mixes in airport and highway projects, *J. Test. Eval.* 42 (2014). <https://doi.org/10.1520/JTE20130245>.
- [324] G. Rowe, Asphalt Binder Properties and Airfield Pavement Cracking, *Airf. Highw. Pavements 2017 Test. Charact. Bound Unbound Pavement Mater. - Proc. Int. Conf. Highw. Pavements Airf. Technol.* 2017. 2017-Augus (2017) 176–188. <https://doi.org/10.1061/9780784480939.016>.
- [325] D.J. Mensching, G.M. Rowe, J. Sias Daniel, A mixture-based Black Space parameter for low temperature performance of hot mix asphalt, in: *Asph. Paving Technol. Assoc.*

REFERENCES

- Asph. Paving Technol. Tech. Sess., Taylor and Francis Ltd., 2016: pp. 611–640. <https://doi.org/10.1080/14680629.2015.1266770>.
- [326] L. Leite, M. Cravo, L. Dantas, M. de F. Amazonas, Evaluation of the UV aging tests effect on asphalt binders using Glover Rowe parameter, (2018) 1–6.
- [327] D. ASTM, Standard Test Method for Multiple Stress Creep and Recovery (MSCR) of Asphalt Binder Using a Dynamic Shear Rheometer, ASTM Int. (2020) 4.
- [328] M. Hugener, D. Wang, A. Cannone Falchetto, L. Porot, P. Kara De Maeijer, M. Orešković, M. Sa-da-Costa, H. Tabatabaee, E. Bocci, A. Kawakami, B. Hofko, A. Grilli, E. Pasquini, M. Pasetto, H. Zhai, H. Soenen, W. Van den bergh, F. Cardone, A. Carter, K. Vasconcelos, X. Carbonneau, A. Lorserie, G. Mladenović, T. Koudelka, P. Coufalik, R. Zhang, E. Dave, G. Tebaldi, Recommendation of RILEM TC 264 RAP on the evaluation of asphalt recycling agents for hot mix asphalt, Mater. Struct. Constr. 55 (2022). <https://doi.org/10.1617/s11527-021-01837-0>.
- [329] J.A. Brillinger, The Collected Works of John W. Tukey: Time (Vol. 1), CRC Press. 1 (1984). <https://doi.org/10.1080/03610919108812987>.
- [330] J. Frost, Using Post Hoc Tests with ANOVA - Statistics By Jim, Stat. by Jim. (2021). https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=Using+Post+Hoc+Tests+with+ANOVA+By+Jim+Frost&btnG= (accessed April 28, 2025).
- [331] A. Nanda, D.B.B. Mohapatra, A.P.K. Mahapatra, A.P.K. Mahapatra, A.P.K. Mahapatra, Multiple comparison test by Tukey’s honestly significant difference (HSD): Do the confident level control type I error, Int. J. Stat. Appl. Math. 6 (2021) 59–65. <https://doi.org/10.22271/math.2021.v6.i1a.636>.
- [332] M.A. Geraghty, Post - hoc Analysis Tukey ’ s Honestly Significant Difference (HSD), (n.d.) 1–2.
- [333] N. Saboo, R. Kumar, P. Kumar, A. Gupta, Ranking the Rheological Response of SBS- and EVA-Modified Bitumen Using MSCR and LAS Tests, J. Mater. Civ. Eng. 30 (2018). [https://doi.org/10.1061/\(asce\)mt.1943-5533.0002367](https://doi.org/10.1061/(asce)mt.1943-5533.0002367).
- [334] J. Choudhary, B. Kumar, A. Gupta, Analysis and Comparison of Asphalt Mixes Containing Waste Fillers Using a Novel Ranking Methodology, J. Mater. Civ. Eng. 32 (2020) 1–13. [https://doi.org/10.1061/\(asce\)mt.1943-5533.0003137](https://doi.org/10.1061/(asce)mt.1943-5533.0003137).
- [335] J. Choudhary, B. Kumar, A. Gupta, Potential utilization of construction wastes in asphalt pavements as fillers using ranking framework, Constr. Build. Mater. 277 (2021) 122262. <https://doi.org/10.1016/j.conbuildmat.2021.122262>.
- [336] N. Saboo, R. Ranjeesh, A. Gupta, M. Suresh, Development of hierarchical ranking strategy for the asphalt skeleton in semi-flexible pavement, Constr. Build. Mater. 201 (2019) 149–158. <https://doi.org/10.1016/j.conbuildmat.2018.12.131>.
- [337] X. Zhang, Q. Wang, F. Liu, Z. Zhou, G. Wang, X. Liu, Experimental characterization of the oxidative kinetic aging behavior of rejuvenated asphalt binder, Constr. Build. Mater. 346 (2022) 128488. <https://doi.org/10.1016/j.conbuildmat.2022.128488>.
- [338] F. Liu, Z. Zhou, X. Zhang, Linking chemical to rheological properties of asphalt binder with oxidative aging effect, Road Mater. Pavement Des. 22 (2021) 2014–2028. <https://doi.org/10.1080/14680629.2020.1740770>.

REFERENCES

- [339] X. Yi, R. Dong, N. Tang, Development of a novel binder rejuvenator composed by waste cooking oil and crumb tire rubber, *Constr. Build. Mater.* 236 (2020) 117621. <https://doi.org/10.1016/j.conbuildmat.2019.117621>.
- [340] P. Nayak, U.C. Sahoo, A rheological study on aged binder rejuvenated with Pongamia oil and Composite castor oil, *Int. J. Pavement Eng.* 18 (2017) 595–607. <https://doi.org/10.1080/10298436.2015.1103851>.
- [341] P. Nayak, U.C. Sahoo, Rheological, chemical and thermal investigations on an aged binder rejuvenated with two non-edible oils, *Road Mater. Pavement Des.* 18 (2017) 612–629. <https://doi.org/10.1080/14680629.2016.1182058>.
- [342] H. Ali, Long-Term Aging of Recycled Binders, Rep. BDV29 Two 977-01. (2015).
- [343] A. Grilli, M.I. Gnisci, M. Bocci, Effect of ageing process on bitumen and rejuvenated bitumen, *Constr. Build. Mater.* 136 (2017) 474–481. <https://doi.org/10.1016/j.conbuildmat.2017.01.027>.
- [344] M.C. Cavalli, M. Zaumanis, E. Mazza, M.N. Partl, L.D. Poulikakos, Aging effect on rheology and cracking behaviour of reclaimed binder with bio-based rejuvenators, *J. Clean. Prod.* 189 (2018) 88–97. <https://doi.org/10.1016/j.jclepro.2018.03.305>.
- [345] A. Chen, G. Liu, Y. Zhao, J. Li, Y. Pan, J. Zhou, Research on the aging and rejuvenation mechanisms of asphalt using atomic force microscopy, *Constr. Build. Mater.* 167 (2018) 177–184. <https://doi.org/10.1016/j.conbuildmat.2018.02.008>.
- [346] Y. Zhu, J. Zhang, C. Si, T. Yan, Y. Li, Laboratory evaluation on performance of recycled asphalt binder and mixtures under short-term aging conditions, *Sustain.* 13 (2021) 1–17. <https://doi.org/10.3390/su13063404>.
- [347] E. Hesami, G. Mehdizadeh, Study of the amine-based liquid anti-stripping agents by simulating hot mix asphalt plant production process, *Constr. Build. Mater.* 157 (2017) 1011–1017. <https://doi.org/10.1016/j.conbuildmat.2017.09.168>.
- [348] J.L.O. Lucas Júnior, L.F.A.L. Babadopulos, J.B. Soares, L.T. Souza, Evaluating the effect of amine-based anti-stripping agent on the fatigue life of asphalt pavements, *Int. J. Pavement Eng.* 23 (2022) 2785–2795. <https://doi.org/10.1080/10298436.2020.1870687>.
- [349] C.I. Harnish, *Liquid Anti-Strip Technology*, (2010).