Editorial

Special Issue of Environment-Friendly Construction Materials

Shaopeng Wu 1, Inge Hoff 2, Serji Amirkhanian 3 and Yue Xiao 1,*

1 State Key Laboratory of Silicate Materials for Architectures, Wuhan University of Technology, Wuhan 430070, China; wusp@whut.edu.cn
2 Department of Civil and Environmental Engineering, Norwegian University of Science and Technology, Hogskolenringen 7A, NO-7491 Trondheim, Norway; Inge.Hoff@ntnu.no
3 Department of Civil Construction and Environmental Engineering, University of Alabama, Tuscaloosa, AL 35487, USA; samirkhanian@eng.ua.edu
* Correspondence: xiaoy@whut.edu.cn; Tel.: +86-1817-108-9165

Received: 18 March 2019; Accepted: 27 March 2019; Published: 3 April 2019

Abstract: This special issue, “Environment-Friendly Construction Materials”, has been proposed and organized as a means to present recent developments in the field of construction materials. For this reason, the articles highlighted in this editorial relate to different aspects of construction materials, from pavement materials to building materials, from material design to structural design, from self-healing to cold recycling, from asphalt mixture to cement concrete.

Keywords: construction materials; fatigue life; ageing resistance; modified asphalt materials; rejuvenator; self-healing asphalt; recycling; cold recycled asphalt mixture; ultra-high performance concrete

Construction materials are the most widely used materials for civil infrastructures in our daily life. However, from an environmental point of view, they consume a huge amount of natural resources and generate the majority of greenhouse gasses. Therefore, many new and novel technologies for designing environment-friendly construction materials have been developed recently. This special issue, “Environment-Friendly Construction Materials”, has been proposed and organized as a means to present recent developments in the field of construction materials. It covers a wide range of selected topics on construction materials. A brief summary of the articles is given in this editorial.

Service life prediction is essentially important in designing construction materials. Researchers all over the world are devoting themselves to life prediction analysis. Sun et al. [1,2] used a plateau value and permanent deformation ratio from three-point bending fatigue tests with cyclic loading to predict the fatigue life of asphalt mixture. The fatigue equation based on a plateau value can well predict the fatigue life. Wang et al. [3] studied the fatigue performance of combined structures with hot mix asphalt and cement emulsified asphalt mixtures. An artificial neural network was used and fatigue equations were established for fatigue life prediction. Residual fatigue properties of asphalt pavement after long-term field service [4], low-temperature performance [5] and damage characteristics [6] were reported. Eco-friendly fiber was used to improve the performance of mixtures. Sun et al. [7] studied the viscoelastic mechanical responses of high-modulus asphalt pavement by numerical simulation with a moving load. In three articles, ageing resistances of asphalt were reported, including ageing depth resulting from ultraviolet radiation [8], fluorescence spectrum ageing analysis [9], and ageing improvement by SBS/CRP (Styrene–butadiene–styrene polymer/crumb rubber powder) modification [10]. One research article focused on the chemical evolution and rheological properties of asphalt under water solute exposure [11]. Saturates and aromatics were partly dissolved in water and then moved out.
Modification on construction materials are being conducted in many research institutes to
design durable civil infrastructures. Fiber is a widely used strengthening additive in asphalt
mixtures. Eco–friendly basalt fiber was incorporated with SBS and diatomite by Wang et al. [12]
and Cheng et al. [13]. Another article by Yang et al. [14] presented improving mechanisms of diatomite
modified asphalt mixtures, by means of permanent deformation resistance and moisture resistance.
Aluminum hydroxide and layered double hydroxide were proposed by Li et al. [15] to improve the
fire resistance of asphalt. Another nanomaterial, named nanosilica, was evaluated by Guo et al. [16].

Improving the aggregate morphology characteristics is another effective way to get durable
asphalt mixtures. Xiao et al. [17] established the relationship between fine aggregate morphology and
skid-resistance of micro-surfacing, while Cheng et al. [18] and Wang et al. [19] reported the influence
of aggregate morphological characteristics on asphalt mixtures. The studied aggregate morphological
characteristics include roundness, perimeter index, erosion-dilation area ratio, angularity, and surface
texture. Influence of aggregate characteristics on the demulsification speed of asphalt emulsion was
presented by Tang et al. [20]. Furthermore, Liu et al. [21] proposed to use ash byproduct to improve
the asphalt-aggregate adhesion properties.

Rejuvenator, a healing agent to recover aged asphalt binder, is a widely used material in pavement
preventive maintenance. There are many different rejuvenators. For instance, soybean oil based [22],
dodecyl benzene sulfonic acid based [23], bio-oil based [24], petroleum based [25], isocyanate and epoxy
substances based [26] were detailed in this special issue. The interesting rejuvenation enhancement
was investigated and reported by these articles. Healing behavior of asphalt materials is another
key issue in the pavement preventive maintenance. Calcium alginate capsules were designed by
both Xu et al. [27] and Shu et al. [28]. The former article investigated the healing capacity of asphalt
mixture when calcium alginate capsules were used, while the second article presented a preparation
process for calcium alginate capsules with a multinuclear structure. In the study by Wan et al. [29],
self-healing properties of steel fiber and steel slag based ultra-thin wearing course were studied by a
semi-circular bending test under induction heating. Other researches focused on the healing agent
effect [30], induced healing efficiency of induction heating and microwave heating [31], and initial
self-healing temperature [32].

Andrzejuk et al. [33] and Ogrodnik et al. [34] reported their research on reusing the wastes of
sanitary ceramics as aggregates for asphalt mixture and cement concrete, respectively. Waste concrete
powder [35], low-grade aggregate [36], crumb rubber waste [37], and recycled concrete aggregate [38]
were also successfully reused as construction materials. In the study by Li et al. [39], the reclaimed
asphalt pavement was reused 100% in cold recycled asphalt mixtures. Asphalt emulsion and cement
were used to improve the interfacial bonding between binders and fillers, aiming to enhance the
moisture resistance and high temperature stability.

Several other studies involved the evaluation of eco-friendly railway concrete sleepers [40] and
engineered cementitious composites [41]. In the research of the former article, waste rubber was reused
for high-strength rubberized concrete. It was found that a decrease of compressive strength can be
expected when rubber content increased, and 10% was recommended as the optimal reuse content. In
the latter article, modified polyvinyl alcohol fiber was added into engineered cementitious composites to
enhance the mechanical performance. Research on self-compacting concrete [42], ultra-high performance
concrete [43], cement paste plasticized by polycarboxylate superplasticizer [44], and pozzolanic additive
in cement [45] were also discussed in this special issue.

Last, but not least, there are two articles focusing on functional construction materials, like phase
change materials for building energy conservation [46], and graphene-modulated removal performance
of nitrogen and phosphorus pollutants [47].

Funding: This research was funded by the National Natural Science Foundation of China (grant number U1733121,
51878526 and 51778515).

Conflicts of Interest: The authors declare no conflict of interest.
References

1. Sun, Y.; Fang, C.; Wang, J.; Yuan, X.; Fan, D. Method of Fatigue-Life Prediction for an Asphalt Mixture Based on the Plateau Value of Permanent Deformation Ratio. *Materials 2018*, 11, 722. [CrossRef] [PubMed]

2. Sun, Y.; Fang, C.; Wang, J.; Ma, Z.; Ye, Y. Energy-Based Approach to Predict Fatigue Life of Asphalt Mixture Using Three-Point Bending Fatigue Test. *Materials 2018*, 11, 1696. [CrossRef] [PubMed]

3. Wang, Z.; Cai, L.; Wang, X.; Xu, C.; Yang, B.; Xiao, J. Fatigue Performance of Different Thickness Structure Combinations of Hot Mix Asphalt and Cement Emulsified Asphalt Mixtures. *Materials 2018*, 11, 1145. [CrossRef] [PubMed]

4. Cui, P.; Xiao, Y.; Fang, M.; Chen, Z.; Yi, M.; Li, M. Residual Fatigue Properties of Asphalt Pavement after Long-Term Field Service. *Materials 2018*, 11, 892. [CrossRef] [PubMed]

5. Cheng, Y.; Yu, D.; Tan, G.; Zhu, C. Low-Temperature Performance and Damage Constitutive Model of Eco-Friendly Basalt Fiber-Diatomite-Modified Asphalt Mixture under Freeze–Thaw Cycles. *Materials 2018*, 11, 2148. [CrossRef] [PubMed]

6. Cheng, Y.; Wang, W.; Gong, Y.; Wang, S.; Yang, S.; Sun, X. Comparative Study on the Damage Characteristics of Asphalt Mixtures Reinforced with an Eco-Friendly Basalt Fiber under Freeze-thaw Cycles. *Materials 2018*, 11, 2488. [CrossRef] [PubMed]

7. Sun, Y.; Gu, B.; Gao, L.; Li, L.; Guo, R.; Yue, Q.; Wang, J. Viscoelastic Mechanical Responses of HMAP under Moving Load. *Materials 2018*, 11, 2490. [CrossRef] [PubMed]

8. Hu, J.; Wu, S.; Liu, Q.; García Hernández, M.I.; Zeng, W.; Nie, S.; Wan, J.; Zhang, D.; Li, Y. The Effect of Ultraviolet Radiation on Bitumen Aging Depth. *Materials 2018*, 11, 747. [CrossRef] [PubMed]

9. Tang, N.; Yang, Y.-L.; Yu, M.-L.; Wang, W.-L.; Cao, S.-Y.; Wang, Q.; Pan, W.-H. Investigation of Ageing in Bitumen Using Fluorescence Spectrum. *Materials 2018*, 11, 1325. [CrossRef]

10. He, R.; Wu, S.; Wang, X.; Wang, Z.; Chen, H. Temperature Sensitivity Characteristics of SBS/CRP-Modified Bitumen after Different Aging Processes. *Materials 2018*, 11, 2136. [CrossRef]

11. Pang, L.; Zhang, X.; Wu, S.; Ye, Y.; Li, Y. Influence of Water Solute Exposure on the Chemical Evolution and Rheological Properties of Asphalt. *Materials 2018*, 11, 983. [CrossRef]

12. Wang, W.; Cheng, Y.; Tan, G. Design Optimization of SBS-Modified Asphalt Mixture Reinforced with Eco-Friendly Basalt Fiber Based on Response Surface Methodology. *Materials 2018*, 11, 1311. [CrossRef] [PubMed]

13. Cheng, Y.; Yu, D.; Gong, Y.; Zhu, C.; Tao, J.; Wang, W. Laboratory Evaluation on Performance of Eco-Friendly Basalt Fiber and Diatomite Compound Modified Asphalt Mixture. *Materials 2018*, 11, 2400. [CrossRef] [PubMed]

14. Yang, C.; Xie, J.; Zhou, X.; Liu, Q.; Pang, L. Performance Evaluation and Improving Mechanisms of Diatomite-Modified Asphalt Mixture. *Materials 2018*, 11, 686. [CrossRef]

15. Li, M.; Pang, L.; Chen, M.; Xie, J.; Liu, Q. Effects of Aluminum Hydroxide and Layered Double Hydroxide on Asphalt Fire Resistance. *Materials 2018*, 11, 1939. [CrossRef]

16. Guo, W.; Guo, X.; Chang, M.; Dai, W. Evaluating the Effect of Hydrophobic Nanosilica on the Viscoelasticity Property of Asphalt and Asphalt Mixture. *Materials 2018*, 11, 2328. [CrossRef]

17. Xiao, Y.; Wang, F.; Cui, P.; Lei, L.; Lin, J.; Yi, M. Evaluation of Fine Aggregate Morphology by Image Method and Its Effect on Skid-Resistance of Micro-Surfacing. *Materials 2018*, 11, 920. [CrossRef]

18. Cheng, Y.; Wang, W.; Tao, J.; Xu, M.; Xu, X.; Ma, G.; Wang, S. Influence Analysis and Optimization for Aggregate Morphological Characteristics on High- and Low-Temperature Viscoelasticity of Asphalt Mixtures. *Materials 2018*, 11, 2034. [CrossRef]

19. Wang, W.; Cheng, Y.; Tan, G.; Tao, J. Analysis of Aggregate Morphological Characteristics for Viscoelastic Properties of Asphalt Mixes Using Simplex Lattice Design. *Materials 2018*, 11, 1908. [CrossRef]

20. Tang, F.; Xu, G.; Ma, T.; Kong, L. Study on the Effect of Demulsification Speed of Emulsified Asphalt based on Surface Characteristics of Aggregates. *Materials 2018*, 11, 1488. [CrossRef] [PubMed]

21. Liu, Z.; Huang, X.; Sha, A.; Wang, H.; Chen, J.; Li, C. Improvement of Asphalt-Aggregate Adhesion Using Plant Ash Byproduct. *Materials 2019*, 12, 605. [CrossRef] [PubMed]

22. Kuang, D.; Jiao, Y.; Ye, Z.; Lu, Z.; Chen, H.; Yu, J.; Liu, N. Diffusibility Enhancement of Rejuvenator by Epoxidized Soybean Oil and Its Influence on the Performance of Recycled Hot Mix Asphalt Mixtures. *Materials 2018*, 11, 833. [CrossRef] [PubMed]
23. Kuang, D.; Ye, Z.; Yang, L.; Liu, N.; Lu, Z.; Chen, H. Effect of Rejuvenator Containing Dodecyl Benzene Sulfonic Acid (DBSA) on Physical Properties, Chemical Components, Colloidal Structure and Micro-Morphology of Aged Bitumen. *Materials* 2018, 11, 1476. [CrossRef] [PubMed]

24. Yang, T.; Chen, M.; Zhou, X.; Xie, J. Evaluation of Thermal-Mechanical Properties of Bio-Oil Regenerated Aged Asphalt. *Materials* 2018, 11, 2224. [CrossRef]

25. Pan, P.; Kuang, Y.; Hu, X.; Zhang, X. A Comprehensive Evaluation of Rejuvenator on Mechanical Properties, Durability, and Dynamic Characteristics of Artificially Aged Asphalt Mixture. *Materials* 2018, 11, 1554. [CrossRef] [PubMed]

26. Li, Z.; Xu, X.; Yu, J.; Wu, S. Assessment on Physical and Rheological Properties of Aged SBS Modified Bitumen Containing Rejuvenating Systems of Isocyanate and Epoxy Substances. *Materials* 2019, 12, 618. [CrossRef] [PubMed]

27. Xu, S.; Liu, X.; Tabakovic, A.; Schlangen, E. Investigation of the Potential Use of Calcium Alginate Capsules for Self-Healing in Porous Asphalt Concrete. *Materials* 2019, 12, 168. [CrossRef]

28. Shu, B.; Wu, S.; Dong, L.; Wang, Q.; Liu, Q. Microfluidic Synthesis of Ca-Alginate Microcapsules for Self-Healing of Bituminous Binder. *Materials* 2018, 11, 630. [CrossRef] [PubMed]

29. Wan, J.; Xiao, Y.; Song, W.; Chen, C.; Pan, P.; Zhang, D. Self-Healing Property of Ultra-Thin Wearing Courses by Induction Heating. *Materials* 2018, 11, 1392. [CrossRef] [PubMed]

30. Pan, C.; Tang, P.; Riara, M.; Mo, L.; Li, M.; Guo, M. Effect of Healing Agents on Crack Healing of Asphalt and Asphalt Mortar. *Materials* 2018, 11, 1373. [CrossRef] [PubMed]

31. Liu, Q.; Chen, C.; Li, B.; Sun, Y.; Li, H. Heating Characteristics and Induced Healing Efficiencies of Asphalt Mixture via Induction and Microwave Heating. *Materials* 2018, 11, 913. [CrossRef] [PubMed]

32. Li, C.; Wu, S.; Tao, G.; Xiao, Y. Initial Self-Healing Temperatures of Asphalt Mastics Based on Flow Behavior Index. *Materials* 2018, 11, 917. [CrossRef] [PubMed]

33. Andrzejuk, W.; Barnat-Hunek, D.; Siddique, R.; Zegardło, B. Application of Recycled Ceramic Aggregates for the Production of Mineral-Asphalt Mixtures. *Materials* 2018, 11, 658. [CrossRef] [PubMed]

34. Ogrodnik, P.; Szulej, J.; Franus, W. The Wastes of Sanitary Ceramics as Recycling Aggregate to Special Concretes. *Materials* 2018, 11, 1275. [CrossRef] [PubMed]

35. Wang, K.; Ren, L.; Yang, L. Excellent Carbonation Behavior of Rankinite Prepared by Calcining the C-S-H: Potential Recycling of Waste Concrete Powders for Prefabricated Building Products. *Materials* 2018, 11, 1474. [CrossRef] [PubMed]

36. Zhang, X.; Zhang, B.; Chen, H.; Kuang, D. Feasibility Evaluation of Preparing Asphalt Mixture with Low-Grade Aggregate, Rubber Asphalt and Desulphurization Gypsum Residues. *Materials* 2018, 11, 1481. [CrossRef]

37. Li, H.; Jiang, H.; Zhang, W.; Liu, P.; Wang, S.; Wang, F.; Zhang, J.; Yao, Z. Laboratory and Field Investigation of the Feasibility of Crumb Rubber Waste Application to Improve the Flexibility of Anti-Rutting Performance of Asphalt Pavement. *Materials* 2018, 11, 1738. [CrossRef]

38. Hou, Y.; Ji, X.; Li, J.; Li, X. Adhesion between Asphalt and Recycled Concrete Aggregate and Its Impact on the Properties of Asphalt Mixture. *Materials* 2018, 11, 2528. [CrossRef]

39. Li, Y.; Lyu, Y.; Fan, L.; Zhang, Y. Effects of Cement and Emulsified Asphalt on Properties of Mastics and 100% Cold Recycled Asphalt Mixtures. *Materials* 2019, 12, 754. [CrossRef]

40. Kaewunruen, S.; Li, D.; Chen, Y.; Xiang, Z. Enhancement of Dynamic Damping in Eco-Friendly Railway Concrete Sleepers Using Waste-Tyre Crumb Rubber. *Materials* 2018, 11, 1169. [CrossRef]

41. Sun, M.; Chen, Y.; Zhu, J.; Sun, T.; Shui, Z.; Ling, G.; Zhong, H.; Zheng, Y. Effect of Modified Polyvinyl Alcohol Fibers on the Mechanical Behavior of Engineered Cementitious Composites. *Materials* 2018, 12, 37. [CrossRef] [PubMed]

42. Ling, G.; Shui, Z.; Sun, T.; Gao, X.; Wang, Y.; Sun, Y.; Wang, G.; Li, Z. Rheological Behavior and Microstructure Characteristics of SCC Incorporating Meta kaolin and Silica Fume. *Materials* 2018, 11, 2576. [CrossRef] [PubMed]

43. Liu, K.; Yu, R.; Shui, Z.; Li, X.; Ling, X.; He, W.; Yi, S.; Wu, S. Effects of Pumice-Based Porous Material on Hydration Characteristics and Persistent Shrinkage of Ultra-High Performance Concrete (UHPC). *Materials* 2018, 12, 11. [CrossRef] [PubMed]

44. Ma, B.; Peng, Y.; Tan, H.; Lv, Z.; Deng, X. Effect of Polyacrylic Acid on Rheology of Cement Paste Plasticized by Polycarboxylate Superplasticizer. *Materials* 2018, 11, 1081. [CrossRef]
45. Xu, W.; Wei, J.; Chen, J.; Zhang, B.; Xu, P.; Ren, J.; Yu, Q. Comparative Study of Water-Leaching and Acid-Leaching Pretreatment on the Thermal Stability and Reactivity of Biomass Silica for Viability as a Pozzolanic Additive in Cement. *Materials* 2018, *11*, 1697. [CrossRef]

46. Zhang, D.; Chen, M.; Liu, Q.; Wan, J.; Hu, J. Preparation and Thermal Properties of Molecular-Bridged Expanded Graphite/Polyethylene Glycol Composite Phase Change Materials for Building Energy Conservation. *Materials* 2018, *11*, 818. [CrossRef]

47. Xia, G.; Xu, W.; Fang, Q.; Mou, Z.; Pan, Z. Graphene-Modulated Removal Performance of Nitrogen and Phosphorus Pollutants in a Sequencing Batch Chlorella Reactor. *Materials* 2018, *11*, 2181. [CrossRef] [PubMed]