DESIGN MIX OF HIGH-STRENGTH CONCRETE USING ARTIFICIAL NEURAL NETWORK TECHNIQUES: A COMPREHENSIVE LITERATURE REVIEW.

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ABSTRACT

High-strength concrete (HSC) is essential in modern construction for its superior mechanical properties and durability. The design mix process is critical in achieving the desired performance of HSC. In recent years, neural network techniques have emerged as powerful tools for optimizing concrete mix designs. This literature review aims to provide a comprehensive overview of research studies focusing on the use of neural network techniques for designing high-strength concrete mixes.

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Introduction

High-strength concrete (HSC) is a critical material in modern construction, prized for its exceptional strength and durability. The design process for HSC involves intricate mix proportioning to achieve desired properties. Artificial Neural Networks (ANNs) have emerged as powerful tools for optimizing HSC mix designs due to their ability to capture complex relationships between input variables and concrete properties. This literature review aims to provide a comprehensive examination of research studies focusing on the use of ANNs in the design of high- strength concrete.

Literature review

Zhang and Yu (2017) provide an overview of the application of artificial neural networks (ANNs) in concrete mix design. The review discusses various aspects of ANN- based mix design methodologies, including input parameters, network architectures, training algorithms, and performance evaluation criteria. Mirzahosseini and Halid (2015) propose a novel approach for optimizing high-strength concrete mix designs using a combination of neural networks and the grey wolf optimizer algorithm. The study demonstrates the effectiveness of the proposed methodology in achieving desired strength and workability characteristics of HSC mixes.

Akçaözoğlu and Gürer develop an artificial neural network model for predicting the compressive strength of concrete based on mix proportions and constituent materials. The study highlights the potential of neural networks in accurately predicting mechanical properties of concrete mixes, including high-strength concrete Togay and Aladag propose a multi- objective optimization approach for high-strength concrete mixtures using artificial neural networks and genetic algorithms. The research demonstrates the capability of neural network models to simultaneously optimize multiple performance criteria, such as strength, workability, and durability.

Basha and Hashem (2017) propose a novel approach for optimizing the mix design of high-strength concrete using neural networks and hybrid optimization algorithms. The research demonstrates the effectiveness of this approach in achieving desired concrete properties while minimizing material costs, providing valuable insights for HSC mix design optimization.

Yeh (1998) presents a pioneering study on the use of artificial neural networks (ANNs) to model the compressive strength of high-performance concrete. The research demonstrates the ability of ANNs to predict concrete strength based on mix proportions, providing a valuable tool for optimizing HSC mix designs.

Shannag (2000) proposes a hybrid neural network model for predicting the modulus of elasticity of high-strength concrete. The model combines neural networks with statistical techniques to improve accuracy and reliability in predicting concrete properties, offering a robust approach for HSC mix design.

ANNs can accurately predict various concrete properties, such as compressive strength, modulus of elasticity, and durability parameters, based on input variables such as cement type, water-cement ratio, aggregate characteristics, and admixture dosage. By training ANNs with historical data from experimental tests, they can learn the complex relationships between these input variables and the desired concrete properties.

ANNs can be used in conjunction with optimization algorithms to find the optimal mix proportions that satisfy specific performance criteria. By defining objectives and constraints (e.g., target strength, workability requirements, cost limitations), ANNs can guide optimization algorithms to search for the most efficient mix designs. This approach enables engineers to achieve desired concrete properties while minimizing material usage and costs.

Concrete mix design involves numerous interrelated factors, and the relationships between these factors are often non-linear and complex. ANNs excel in capturing these non-linear relationships and can provide more accurate predictions compared to traditional empirical models or statistical approaches. This capability allows ANNs to adapt to diverse mix designs and varying material properties more effectively.

ANNs are capable of learning and adapting to new data over time, allowing them to continuously improve their predictive accuracy. As more experimental data becomes available or as new materials and mix designs are introduced, ANNs can be retrained to incorporate this information, ensuring that the predictive models remain up-to-date and reliable

Concrete properties are subject to inherent variability due to factors such as material variability, environmental conditions, and construction practices. ANNs can effectively handle this variability and uncertainty by learning from a diverse range of input data and generating probabilistic predictions with associated confidence intervals. This capability enables engineers to make informed decisions and account for uncertainties in concrete mix design.

Cheng Y. et al. (2019) explores the fatigue behavior, HSC specimens were subjected to cyclic loading experiments. The study looked at fatigue life, stiffness deterioration, and crack propagation properties of HSC under various loading amplitudes and frequencies. Li, X., et al. performs an experimental investigation looked into the effect of stress ratio on HSC fatigue behavior. The research looked at the impact of cyclic loading with different stress ratios on fatigue life, crack onset, and damage accumulation in HSC.

Wang et al.(2018) evaluate the progression of damage and failure modes in HSC subjected to cyclic stress, this work used sophisticated monitoring techniques like as acoustic emission analysis and digital image correlation. The study identified major damage mechanisms, including as microcracking, fracture propagation, and eventual failure, and investigated their consequences for structural performance. Cheng et al. (2021) studied the resistance of HSC to chloride penetration. They concluded that incorporating silica fume as a mineral admixture enhanced the resistance of HSC to chloride ingress significantly, improving its durability in marine environments (Cheng et al., 2021).

Li and Li (2018) investigated the sulfate resistance of HSC exposed to sulfate attack. Their findings suggested that proper mix design, including low water-to-cement ratios and appropriate mineral admixtures, could mitigate sulfate-induced deterioration effectively (Li & Li, 2018). Liang et al. (2019) conducted flexural tests on HSC beams reinforced with various types of fibers. They observed that the addition of steel fibers improved the flexural performance of HSC beams, delaying the onset of cracking and increasing ductility (Liang et al., 2019). Zhang et al. (2020) investigated the impact resistance of HSC using drop weight tests. Their results demonstrated that HSC incorporating high-strength aggregates exhibited superior impact resistance compared to conventional concrete mixes (Zhang et al., 2020). Zhang, et al. (2019). In their experimental investigation looked into the efficiency of fiber reinforcement in preventing fatigue damage in HSC. The study assessed the effect of different fiber types and doses in HSC mixes on fatigue life, crack bridging mechanisms, and residual strength under cyclic loading.

Experiments on the behavior of high- strength concrete under cyclic loading have revealed important information about fatigue behavior, damage mechanisms, and failure modes. These research advance understanding of HSC behavior and enhance the design and assessment of resilient concrete structures subjected to dynamic loading conditions by investigating the influence of loading factors and developing ways for increasing fatigue resistance.

By using ANNs to predict concrete properties, engineers can reduce the need for extensive experimental testing, saving time and resources. Once trained, ANNs can quickly generate predictions for a wide range of mix designs and scenarios, allowing engineers to explore alternative designs and optimize concrete performance more efficiently.

Test Setup

Testing of high-strength concrete (HSC) under cyclic loading normally comprises submitting concrete specimens to repeated loading and unloading cycles to simulate the impacts of dynamic or recurring loading situations that concrete structures may encounter during their service life. To explore the behavior of HSC under cyclic loading, a variety of assays can be performed, including:

3.1 Compressive Testing Machine A machine of 3000 KN capacity is used here to experimental study.

3.2 X-Y Plotter & LVDT

An XY plotter is a plotter that displays the relationship between two variables connected by the x and y axes. To obtain a plot between load and deflection, the output of the load meter was connected to the y-axis and the output of the LVDT was connected to the x-axis.

3.4 Dial Gauges

Its dial displays the value of deflection. It uses a mechanical augmentation principle.

Testing & Obvservation

About 54 Cubes & 81cylinders are casted and prepared in which minimum 3 set of various grade are cured and used for tensing for the development of neural network

The primary application of ANNs in concrete testing is to predict various concrete properties, such as compressive strength, modulus of elasticity, slump, and durability parameters. Once trained on a dataset comprising input variables (e.g., mix proportions, curing conditions) and corresponding concrete properties obtained from experimental tests, ANNs can accurately predict these properties for new or unseen concrete mixes.

Before deploying ANN models for predicting concrete properties in practice, it's essential to validate and verify their performance against experimental data. This involves comparing the predicted results from the ANN models with actual test results obtained from laboratory experiments. Validation ensures that the ANN models generalize well to unseen data and reliably predict concrete properties across different mix designs and conditions. Once validated, ANN models can be used to optimize concrete mix designs by iteratively adjusting input variables to achieve desired performance objectives. Engineers can employ optimization algorithms in conjunction with ANN models to search for the optimal mix proportions that satisfy specific criteria, such as target strength, workability, and durability requirements. This approach enables efficient exploration of the design space and identification of cost-effective mix designs.

ANNs can also be used to perform sensitivity analysis to identify the most influential factors affecting concrete properties. By analyzing the sensitivity of the ANN outputs to changes in input variables, engineers can gain insights into which factors have the most significant impact on concrete performance. This information can guide decision-making in mix design optimization and help prioritize factors for further investigation or control.

As new experimental data becomes available or as concrete properties evolve over time, ANN models can be continuously updated and refined to improve their predictive accuracy. By incorporating new data into the training process, engineers can ensure that ANN models remain relevant and reliable for predicting concrete properties under changing conditions. This iterative process of continuous improvement enhances the robustness and applicability of ANN-based testing

Microstructural Analysis Techniques

Microstructural analysis techniques, such as scanning electron microscopy (SEM) and X-ray computed tomography (CT), can be employed to examine the internal structure and damage evolution in HSC specimens before and after cyclic loading tests.

Conclusions and Outcomes

Neural network techniques offer promising avenues for optimizing high-strength concrete mix designs by leveraging their capabilities in modeling complex relationships and patterns in large datasets. Through a comprehensive literature review, this study has highlighted the application of neural networks in various aspects of concrete mix design, including optimization, prediction of mechanical properties, and multi-objective optimization. By integrating findings from these research studies, engineers and practitioners can harness the power of neural network techniques to develop efficient and robust high-strength concrete mixes tailored to specific project requirements.

Overall, the effective use of ANNs in concrete mix design offers significant benefits in terms of accuracy, efficiency, and adaptability. By harnessing the power of ANNs, engineers can optimize mix proportions, predict concrete properties, and design high-performance concrete mixes tailored to specific project requirements and performance objectives.

Testing methods help researchers and engineers understand various aspects of HSC behavior under cyclic loading, including fatigue life, stiffness degradation, crack initiation and propagation, energy dissipation, and ultimate failure modes. By analyzing the results of these tests, insights can be gained into the performance of HSC in real-world applications and strategies can be developed to enhance its durability and resilience.

In summary, testing concrete using Artificial Neural Networks (ANNs) enables accurate prediction of concrete properties, validation against experimental data, optimization of mix designs, sensitivity analysis, and continuous improvement of predictive models. By leveraging the capabilities of ANNs, engineers can enhance their understanding of concrete behavior, optimize mix designs, and design high- performance concrete structures tailored to specific project requirements.

References

1. Al-hamrani, A., and W. Alnahhal. 2023. “Bond durability of sand coated and ribbed basalt FRP bars embedded in high-strength concrete.” *Constr. Build. Mater.*, 406 (April): 133385. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat .2023.133385.
2. Awasthy, N., E. Schlangen, D. Hordijk, B. Savija, and M. Lukovi. 2023. “Developments in the Built Environment The role of eigen- stresses on apparent strength and stiffness of normal , high strength , and ultra-high performance fibre reinforced concrete.” 16 (September). https://doi.org/10.1016/j.dibe.2023.100277.

3. Bheel, N., I. Mir, A. Ali, A. Abbasi, E. M. Tag-eldin, H. R. Almujibah, M. Ahmad, O. Benjeddou, and R. A. Gonzalez-lezcano. 2024. "Case Studies in Construction Materials Synergistic effect of recycling waste coconut shell ash , metakaolin , and calcined clay as supplementary cementitious material on hardened properties and embodied carbon of high strength concrete." *Case Stud. Constr. Mater.*, 20 (March 2023): e02980. Elsevier Ltd. https://doi.org/10.1016/j.cscm.2024.e 02980.
4. Bremner, T. W., and M. D. A. Thomas. 2017. "Effects of corrosion inhibiting admixtures and supplementary cementitious materials combinations on the strength and certain durability properties of HPC." 926 (July): 918–926.
5. Effects, A., A. Effects, and T. Serviceability. n.d. "Department of civil engineering."
6. Faridmehr, I., M. L. Nehdi, A. F. Nejad, M. A. Sahraei, and K. A. Valerievich. 2024. "l P re." *Int. J. Light. Mater. Manuf.* China Aerotime Media Co., Ltd. https://doi.org/10.1016/j.ijlmm.2024. 01.004.
7. Guang, C., and C. Guang. 2024. "Applications in Engineering Science Shear capacity evaluation of studs in steel-high strength concrete composite structures." *Appl. Eng. Sci.*, 17 (September 2023): 100150. Elsevier Ltd. https://doi.org/10.1016/j.apples.2023 .100150.
8. Hamada, H., F. Abed, A. Alattar, F. Yahaya, B. Tayeh, and Y. I. Abu. 2023. "Engineering Science and Technology , an International Journal Influence of palm oil fuel ash on the high strength and ultra-high performance concrete : A comprehensive review." *Eng. Sci. Technol. an Int. J.*, 45 (March): 101492. Karabuk University. https://doi.org/10.1016/j.jestch.2023 . 101492.
9. Hirata, N., X. Huang, T. Obara, S. Kono, and Y. Ota. 2023. "Axial behavior of square steel-tubed ultra-high-strength reinforced concrete columns." *Eng. Struct.*, 294 (January): 116762. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2 0 23.116762.
10. Hong, S., J. Choi, S. Yoo, and Y. Yoon. 2023. "Developments in the Built Environment Structural benefits of using carbon nanotube reinforced high-strength lightweight concrete beams." *Dev. Built Environ.*, 16 (June): 100234. ElsevierLtd. https://doi.org/10.1016/j.dibe.2023.1 00234.
11. Hong, S., J. Choi, T. Yuan, and Y. Yoon. 2022. "A review on concrete creep characteristics and its evaluation on high-strength lightweight concrete." *J. Mater. Res. Technol.*, 22: 230–251. The Author(s). https://doi.org/10.1016/j.jmrt.2022.1 1.125.
12. " HSC_ce papers - 2023 - Ali - Influence of the load frequency and moisture content on fatigue deterioration of high-strength.pdf." n.d.
13. Huang, Y., J. Fu, R. Wang, R. Rao, and N. Ma. 2024a. "Case Studies in Construction Materials Experimental study on creep behavior of high- strength concrete filled steel tubular (HSCFST) columns." 20 (August

2023). Elsevier Ltd.
14. Huang, Z. C., J. J. Liu, F. M. Ren, J. Cui, Z. Song, D. H. Lu, and M. H. Lai. 2024b. "Case Studies in Construction Materials Behavior of SSFA high-strength concrete at ambient and after exposure to elevated temperatures." 20 (January). https://doi.org/10.1016/j.cscm.2024.e02946.
15. Ikhlasi, Z., and T. Vincent. 2023. "Materials Today : Proceedings Experimental study on the behavior of CFRP-high strength concrete-steel double skin tubular columns subjected to axial compression." *Mater. Today Proc.*, 85: 79–82. Elsevier Ltd. https://doi.org/10.1016/j.matpr.2023.05.264.
16. Jiang, F., R. Liu, Z. Mao, and M. Deng. 2023. "The combined effect of steel fiber and MgO on the deformation and mechanical properties of high- strength concrete." *J. Mater. Res. Technol.*, 26: 4296–4309. The Author(s). https://doi.org/10.1016/j.jmrt.2023.08.153.
17. Kadhar, S. A., E. Gopal, V. Sivakumar, and N. A. Anbarasu. 2024. "Optimizing flow , strength , and durability in high-strength self-compacting and self-curing concrete utilizing lightweight aggregates."
18. Kanagaraj, B., N. Anand, R. Jerry, R. S. Raj, and E. Lubloy. 2023. "Axial compressive behaviour and physical characteristics of high strength self-compacting geopolymer concrete (HSGC) columns exposed to elevated temperature." *Constr. Build. Mater.*, 401 (March): 132866. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat.2023.132866.
19. Liao, J., J. Zeng, H. Xiang, H. Dai, and W. Zeng. 2023. "Behavior of hybrid FRP-concrete-steel double- skin tubular beams with ultra-high strength concrete and PBL shear connectors under bending." *Eng. Struct.*, 295 (July): 116865. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.20 23.116865.
20. Liu, G., G. Liu, and W. Jiang. 2024. "Modeling and calculation of shear capacity of prestressed high strength concrete beams with web reinforcement based on BIM." *Ain Shams Eng. J.*, 15 (1): 102360. Faculty of Engineering, Ain Shams University. https://doi.org/10.1016/j.asej.2023.102360.
21. Meng, L., C. Zhang, J. Wei, L. Li, and J. Liu. 2023. "Case Studies in Construction Materials Mechanical properties and microstructure of ultra-high strength concrete with lightweight aggregate." *Case Stud. Constr. Mater.*, 18 (November 2022): e01745. Elsevier Ltd. https://doi.org/10.1016/j.cscm.2022.e 01745.
22. Montuori, R., E. Nastri, V. Piluso, and P. Todisco. 2024. "Experimental and analytical study on the behaviour of circular concrete filled steel tubes in cyclic bending." *Eng. Struct.*, 304 (January): 117610. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.20 24.117610.
23. Pang, S., Y. Huang, Z. Chen, and P. Ye. 2023. "Case Studies in Construction Materials Bond-slip performance of water cooling steel-reinforced high-strength concrete after high temperature." *Case Stud. Constr. Mater.*, 19 (January): e02271. Elsevier Ltd.

https://doi.org/10.1016/j.cscm.2023.e02271.

24. Qayyum, A., H. Ahmad, M. Rasul, and Z. Ahmad. 2023. "Optimized artificial neural network model for accurate prediction of compressive strength of normal and high strength concrete." *Clean. Mater.*, 10 (October): 100211. Elsevier Ltd. https://doi.org/10.1016/j.clema.2023.100211.
25. Qin, X., X. Huang, Y. Li, and S. Kaewunruen. 2024. "Sustainable design framework for enhancing shear capacity in beams using recycled steel fiber-reinforced high-strength concrete." *Constr. Build. Mater.*, 411 (December 2023): 134509. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat.2023.134509.
26. Rajkohila, A., and S. P. Chandar. 2024. "Assessing the effect of natural fiber on mechanical properties and microstructural characteristics of high strength concrete." *Ain Shams Eng. J.*, (January): 102666. Faculty of Engineering, Ain Shams University. https://doi.org/10.1016/j.asej.2024.102666.
27. Tan, K., T. Zhang, W. Zhu, D. Yang, D. Lin, H. Wang, J. Wei, and Q. Yu. 2024. "Case Studies in Construction Materials Innovative high-strength , high-permeability concrete for large-scale applications in permeable subgrade of highway tunnel." *Case Stud. Constr. Mater.*, 20 (January): e02977. Elsevier Ltd. https://doi.org/10.1016/j.cscm.2024.e02977.
28. Tran, H., and V. T. Phan. 2024. "Case Studies in Construction Materials Potential usage of fly ash and nano silica in high-strength concrete : Laboratory experiment and application in rigid pavement." *Case Stud. Constr. Mater.*, 20 (January): e02856. Elsevier Ltd. https://doi.org/10.1016/j.cscm.2024.e 02856.
29. Wei, Y., S. Liang, and W. Guo. 2017. "Decoupling of Autogenous Shrinkage and Tensile Creep Strain in High Strength Concrete at Early Ages." 475–485. https://doi.org/10.1007/s11340-016- 0249-8.
30. Zhang, J., Y. Shao, M. F. Hassanein, K. A. Cashell, and M. Hadzima-. 2024. "Behaviour of ultra-high strength concrete-filled dual- stiffened steel tubular slender columns." *Eng. Struct.*, 300 (September 2023): 117204. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2 0 23.117204.
31. Zhu, Y., L. Gardner, and H. Yang. 2023. "Thin-Walled Structures Experimental investigation into the transverse impact performance of high-strength circular CFST members." *Thin-Walled Struct.*, 189 (March): 110923. Elsevier Ltd. https://doi.org/10.1016/j.tws.2023.1 1 0923.
32. Christy,F., Tensing,D., and Mercy.S.R.,"In –plane shear behaviour of Brick Masonry-A literature review on experimental study", International journal of Civil and Structural Engineering Vol.2, No.4, 2012, pp 1144-1152,.
33. Choubey,U.B. and Sinha, S.N.,"Cyclic Compressive response of brick masonry", Journal of Masonry International London , Vol.4,1991.

34. Choubey, U.B., “A Mathematical Model of Loading and Unloading Curves of Brick Masonry” Paper presented in All India Civil Engineering Meet, 31 Oct – 2 Nov 1991, BITS, Pilani.
35. Choubey,U.B.,Gupta.U.,and Gangrade.S.D.,“An Experimental Study of Flexural Tensile Strength of Brick Masonry” Journal of Institution of Engineers, India Vol. 74, Nov. 1993, pp 135-140.
36. Choubey,U.B. and Sinha,S.N.,“Cyclic Response of Infilled Frames” Journal of Structural Engineering, Madras, Vol. 21, No. 3, Oct.1994,pp 203-211.
37. Choubey, U.B., Gupta,U.,and Mayadasani,A.,“An Experimental Study of Flexural Tensile Strength of Calcium Silicate Brick Masonry” Journal of Structural Engineering, Madras, Vol. 26, No. 2 July,1999.
38. Choubey,U.B., Gupta,U,.and Shukla,M.,“Equations of Cyclic Reloading and Unloading Curves of SFRC” Journal of Structural Engineering, Vol. 30 No. 4, Jan – March 2003.
39. Choubey,U.B., and Shukla,M,“Stress – Strain Behavior of Steel Fiber Reinforced Concrete under Cyclic Compressive Loading” Journal of Structural Engineering, Vol. 31, No. 2 July – Sept., 2004.
40. Choubey,U.B., Gupta,U.,and Shukla,M.,“Low Cyclic Fatigue Behavior of SFRC in Compression” Journal of Structural Engineering Vol. 31, No. 3 Oct – Dec., 2004.
41. E.Reyes et al. “Cohessive Crack model for mixed mode fracture of brick masonry” Springer, July, 2008.
42. “Indian Standard Code of Practice for Brick Work”, IS 2212:1991, Bureau of Indian Standards”, New Delhi
43. “Indian Standard Code of Practice for Brick masonry pier”, IS 1905:1992, Bureau of Indian Standards, New Delhi.
44. “Indian Standard Code of specification for fly ash for use as pozzolana and admixture”, IS 3812:1992, Bureau of Indian Standards, New Delhi.
45. “Indian Standard Code of Practice for fly ash brick work”, IS 3495:1992, Bureau of Indian Standards, New Delhi.
46. “Indian Standard Code of specification for Burnt clay fly ash building brick”,

IS 13757:1998 Bureau of Indian Standards, New Delhi.
47. “Indian Standard Code of specification of cement mortar”, IS 2386:1999, Bureau of Indian Standards, New Delhi.
48. “Indian Standard Code of specification For Portland Pozzolana Cement”, IS 1489:2002, Bureau of Indian Standards, New Delhi.
49. “Indian Standard Code of specification of Pulverized fuel ash-lime bricks”,IS 12894:2002, Bureau of Indian Standards, New Delhi.
50. Kato,H.,Goto,T., and Liba,M., “Cyclic loading test of confined fly ash brick masonry”, Material and Structures, Vol. 35, 2012,pp 280-291,.
51. Maidasani,A.J.,D.,“

A

n Experimental study of Flexural tensile strength of Calcium-Silicate brick masonry". A dissertation work of M.E. guided by Dr.U.B.Choubey and Prof. Dr. U.Gupta at S.G.S.I.T.S. Indore.

52. Milad,M.A., and Sinha,S.N.,"Stress-Strain Characteristics of Brick Masonry under Uniaxial Cyclic Loading" ASCE, Vol. 395, 2012,pp 1126-1139.

53. Mistry.S.,et al., "Fly Ash Bricks Masonry: An Experimental Study" National Conference on Recent Trends in Engineering and Technology , 13-14 May 2011., B.B.M. Engg. College. Gujarat, India.

54. Munasamy,D., (1998), " Experimental Stress-Strain Analysis of Sand-Lime Brick Under cyclic compressive loading". A dissertation work of M.E. guided by Dr.U.B.Choubey and Prof. Dr. U.Gupta at S.G.S.I.T.S. Indore.

55. Narain, K.S. and Sinha, S.N. "Behaviour of brick masonry Under Cyclic Compressive Loading". Journal of Construction Engineering and Management, ASCE, Vol.115, 1989, pp 1432-1445.

56. Nazar,M., and Sinha,S.N.,(2007), "Behaviour of Interlocking grouted stabilized sand fly ash brick masonry under uniaxial cyclic compressive loading"., Journal of material in Civil Engineering,ASCE, Nov. 2007,Vol.19, pp947-956.

57. Obada,K., (2010), "Advantages of Fly ash brick over clay brick" Journal of Construction Engineering and Management, ASCE, Vol.215, 2010, pp 1152-1165.

58. Palanisamy,M., and Premalatha,J.," Experimental study on masonry infill material properties" International Journal of Scientific and Engineering Research, Vol. 3, Issue 7, July, 2012.

59. Papa,E., and Nappi, A.," A test rig for the application of biaxial cyclic loads to structural models", Material and Structures , Vol. 28, 1995, pp 299-307,.

60. Patidar.V. (2011), "Experimental Behaviour of Slabs with Circular Opening under cyclic loading". A dissertation work of M.E. guided by Dr.U.B.Choubey and Prof. Dr. U.Gupta at S.G.S.I.T.S. Indore

61. Powell, B. and Hodgkinson, H.R. (1997) "Determination of Stress-Strain Relationship of brick work". British Ceramic Research Association, Stoke –on –Trend, London

62. Prasad, B.K., Gupta, U. and Choubey, U.B., "Slow Cycle Fatigue Response of Latex Modified Concrete in Compression", Accepted for publication in Journal of Structural Engineering, SERC, Chennai.

63. Bashir, R. H., B. S. Hamad, and G. R. Chehab. 2024. "Assessment of External and Internal Geogrid Confinement of Reinforced Concrete Columns Case Studies in Construction Materials Assessment of external and internal geogrid confinement of reinforced concrete columns." *Case Stud. Constr. Mater.*, 20 (February): e02974. ElsevierLtd. https://doi.org/10.1016/j.cscm.2024.e02974.

64. Effect, T. H. E., O. F. Cyclic, S. Treatment, T. On, T. H. E. Marginal, G. A. P. Of, I. Retained, F. Partial, W. Three, and D. Designs. 2024.

"THE EFFECT OF CYCLIC LOADING AND SURFACE TREATMENT TECHNIQUES ON THE MARGINAL GAP OF ZIRCONIA."

65. El-naqeeb, M. H., T. Ghanbari-ghazijahani, A. Gholampour, R. Hassanli, Y. Zhuge, X. Ma, and A. Manalo. 2024. "Cyclic behaviour of an innovative cap beam to column pocketless connection in GFRP-RC precast structures." *Structures*, 61 (January): 106003. Elsevier Ltd. https://doi.org/10.1016/j.istruc.2024.106003.
66. Gudzulic, V., and K. Daadouch. 2023. "Modelling Of Damage Processes In Concrete Under Monotonic And Cyclic Loading MODELLING OF DAMAGE PROCESSES IN CONCRETE UNDER." (January 2024). https://doi.org/10.21012/FC11.092312.
67. Hung, C., and C. Chueh. 2016. "Cyclic behavior of UHPFRC flexural members reinforced with high-strength steel rebar." *Eng. Struct.*, 122: 108–120. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2016.05.008.
68. Jeyapandian, S. E., T. Dharmaraj, V. S. Jebadurai, and D. Cruze. 2023. "INFLUENCE OF CYCLIC LOADING ON THE BEHAVIOR OF COMPOSITE FRAME ENCASED WITH MILD STEEL." 12 (10): 1347–1356. https://doi.org/10.48047/ecb/2023.12.si10.00162.
69. Liu, J. 2024. "Experimental Investigation of H-beam to Recycled Aggregate Concrete Column Edge Connections under Cyclic Loading." 0–20."No Title." n.d.
70. Patel, N. M. 2023. "Study of PET Fiber Concrete in Beam-Column Joint under Cyclic Loading Using Finite Element Analysis." 13 (5): 38–47. https://doi.org/10.5815/ijem.2023.05.05.
71. Rajeshguna, R., M. Mariappan, A. Raju, and K. Suguna. 2021. "Cyclic response of high strength fibre reinforced concrete beams with fibre reinforced polymer (FRP) laminates."
72. Sadoon, A. A., M. A. Al-shugaa, M. K. Rahman, A. Al-fakih, and M. A. Al-osta. 2023. "Case Studies in Construction Materials Enhancing unreinforced masonry wall resilience through nano-silica modified steel fiber reinforced mortar : A study on in-plane cyclic loading." *Case Stud. Constr. Mater.*, 19 (July): e02358. ElsevierLtd. https://doi.org/10.1016/j.cscm.2023.e02358.
73. Science, E. n.d. "Nonlinear analysis of interior and exterior beam- column connections under reversed cyclic loading Nonlinear analysis of interior and exterior beam-column connections under reversed cyclic loading." https://doi.org/10.1088/1755-1315/1195/1/012018.
74. Sciences, P. 2023. *University of Southampton Research Repository*.
75. Shcc, C. C. 2024. "Influence Of Fiber Orientation On The Cyclic Behavior Of Strain-Hardening INFLUENCE OF FIBER ORIENTATION ON THE CYCLIC BEHAVIOR OF STRAIN-HARDENING CEMENT-BASED COMPOSITES." (January). https://doi.org/10.21012/FC11.092318.
76. Xie, G., X. Zhang, H. Hao, and J.

Thomas. 2024. "Parametric study of reinforced interlocking brick wall under cyclic loading." *J. Build. Eng.*, 83 (December 2023): 108415. Elsevier Ltd. https://doi.org/10.1016/j.jobe.2023.108415.

77. Alavi-dehkordi, S., D. Mostofinejad, and P. Alaee. 2019. "Effects of high-strength reinforcing bars and concrete on seismic behavior of RC beam-column joints." *Eng. Struct.*, 183 (January): 702–719. Elsevier. https://doi.org/10.1016/j.engstruct.2019.01.019.
78. Azad, A. K., I. Hakeem, and S. Ahmad. 2013. "Effect of cyclic exposure and fibre content on tensile properties of ultra-high- performance concrete." 25 (5): 273–281.
79. Bae, B., J. Chung, H. Choi, H. Jung, and C. Choi. 2018. "Experimental study on the cyclic behavior of steel fi ber reinforced high strength concrete columns and evaluation of shear strength." *Eng. Struct.*, 157 (September 2017): 250–267. Elsevier. https://doi.org/10.1016/j.engstruct.2017.11.072.
80. Bai, Z. Z., and F. T. K. Au. 2010. "Flexural ductility design of high-strength concrete columns." 1–24. https://doi.org/10.1002/tal.
81. Baktheer, A., H. Spartali, J. Hegger, and R. Chudoba. 2021. "High-cycle fatigue of bond in reinforced high-strength concrete under push- in loading characterized using the modified beam-end test High-cycle fatigue of bond in reinforced high-strength concrete under push-in loading characterized using the modified beam-end test." (February). https://doi.org/10.1016/j.cemconcomp.2021.103978.
82. Boulekbache, B., M. Hamrat, M. Chemrouk, and S. Amziane. 2016. "Flexural behaviour of steel fibre-reinforced concrete under cyclic loading." *Constr. Build. Mater.*, 126: 253–262. ElsevierLtd. https://doi.org/10.1016/j.conbuildmat .2016.09.035.
83. Caballero-morrison, K. E., J. L. Bonet, J. Navarro-gregori, and P. Serna-ros. 2013. "An experimental study of steel fiber-reinforced high-strength concrete slender columns under cyclic loading." *Eng. Struct.*, 57: 565–577. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.20 12.06.052.
84. Campian, C., Z. Nagy, and M. Pop. 2015. "Behavior of Fully Encased Steel-Concrete Composite Columns Subjected to Monotonic and Cyclic Loading." *Procedia Eng.*, 117: 439–451. Elsevier B.V. https://doi.org/10.1016/j.proeng.2015.08.193.
85. Campione, G., and M. L. Mangiavillano. 2008. "Fibrous reinforced concrete beams in flexure : Experimental investigation , analytical modelling and design considerations." 30 (11): 2970–2980. ElsevierLtd. https://doi.org/10.1016/j.engstruct.2008.04.019.
86. Daud, S. A., J. P. Forth, and N. Nikitas. 2018. "Time-dependent behaviour of cracked , partially bonded reinforced concrete beams under repeated and sustained loads." *Eng. Struct.*, 163 (December 2017): 267–280. Elsevier. https://doi.org/10.1016/j.engstruct.2018.02.054.

87. Deng, F., Y. Chi, L. Xu, L. Huang,

and X. Hu. 2021. "Constitutive behavior of hybrid fiber reinforced concrete subject to uniaxial cyclic tension : Experimental study and analytical modeling." *Constr. Build. Mater.*, 295: 123650. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat.2021.123650.

88. Elghazouli, A. Y., D. V Bompa, B. Xu, A. M. R. Teran, and P. J. Sta. 2018. "Performance of rubberised reinforced concrete members under cyclic loading." 166 (November 2017): 526–545. https://doi.org/10.1016/j.engstruct.2018.03.090.
89. Faisal, M., N. H. R. Sulong, and S. Ali. 2017. "Thin-Walled Structures FE modelling of the fl exural behaviour of square and rectangular steel tubes fi lled with normal and high strength concrete." *Thin Walled Struct.*, 119 (June): 470–481. Elsevier Ltd. https://doi.org/10.1016/j.tws.2017.06.025.
90. Fan, W., B. Liu, X. Huang, and Y. Sun. 2019. "Efficient modeling of flexural and shear behaviors in reinforced concrete beams and columns subjected to low-velocity impact loading." *Eng. Struct.*, 195 (June): 22–50. Elsevier. https://doi.org/10.1016/j.engstruct.2019.05.082.
91. Gajalakshmi, P., and H. J. Helena. 2012. "Behaviour of concrete- fi lled steel columns subjected to lateral cyclic loading." *JCSR*, 75: 55–63. Elsevier Ltd. https://doi.org/10.1016/j.jcsr.2012.03.006.
92. Galal, K. E., and A. Ghobarah. 2003. "Flexural and shear hysteretic behaviour of reinforced concrete columns with variable axial load." 25: 1353–1367. https://doi.org/10.1016/S0141 - 0296(03)00111-1.
93. Ganesan, N., P. V Indira, and R. Abraham. 2007. "STEEL FIBRE REINFORCED HIGH PERFORMANCE CONCRETE BEAM-COLUMN JOINTS SUBJECTED TO CYCLIC LOADING." 44 (3): 445–456.
94. Ganesan, N., P. V Indira, and M. V Sabeena. 2014. "Behaviour of hybrid fibre reinforced concrete beam – column joints under reverse cyclic loads." *Mater. Des.*, 54: 686–693. Elsevier Ltd. https://doi.org/10.1016/j.matdes.2013.08.076.
95. Guo, Y., X. Chen, X. Li, S. Li, and S. Guo. 2019. "Experimental study on fracture behavior of three-graded concrete under cyclic loading after initial static loading." *Theor. Appl. Fract. Mech.*, 103 (June): 102272. Elsevier. https://doi.org/10.1016/j.tafmec.2019.102272.
96. Hasan, A., H. Karim, M. N. Sheikh, and M. N. S. Hadi. 2019. "Moment-Curvature Behavior of Glass Fiber-Reinforced Polymer Bar-Reinforced Normal-Strength Concrete and High- Strength Concrete Columns." (116): 51715573. https://doi.org/10.14359/51715573.
97. Hou, L., J. Wang, T. Huang, C. Shen, F. Aslani, and D. Chen. 2019. "Flexural behaviour of corroded reinforced concrete beams repaired with ultra-high toughness cementitious composite." *Constr. Build. Mater.*, 211: 1127–1137. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat.2019.03.214.
98. Hung, C., and C. Chueh. 2016.

"Cyclic behavior of UHPFRC flexural members reinforced with high-strength steel rebar." *Eng. Struct.*, 122: 108–120. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2016.05.008.

99. Hung, C., and F. Hu. 2018. "Behavior of high-strength concrete slender columns strengthened with steel fibers under concentric axial loading." *Constr. Build. Mater.*, 175: 422–433. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat.2018.04.201.

100. Jin, L., D. Li, and X. Du. 2016. "Mechanical behavior and size effect of moderate high- strength RC columns under monotonic and cyclic axial compression." *Eng. Struct.*, 124: 269–285. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2016.06.030.

101. Kwan, A. K. H., F. T. K. Au, and S. L. Chau. 2004. "Theoretical study on effect of confinement on flexural ductility of normal and high-strength concrete beams." (5): 299–309.

102. Kwan, J. Y. K. L. Æ. J. C. M. H. Æ. A. K. H. 2009. "Flexural ductility of high-strength concrete columns with minimal confinement." 909–921. https://doi.org/10.1617/s11527-008-9431-5.

103. Makita, T., and E. Bru. 2013. "Tensile fatigue behaviour of ultra- high performance fibre reinforced concrete (UHPFRC)." https://doi.org/10.1617/s11527-013-.2019.06.038.

105. Mohammadhassani, M., S. Akib, M. Shariati, M. Suhatril, and M. M. A. Khanouki. 2014. "An experimental study on the failure modes of high strength concrete beams with particular references to variation of the tensile reinforcement ratio." 41: 73–80.

106. Naaman, A. E., and H. Hammoud. 1998. "Fatigue Characteristics of High Performance Fiber-reinforced Concrete." 20: 353–363.

107. Pourbaba, M., H. Sadaghian, and A. Mirmiran. 2019. "A comparative study of flexural and shear behavior of fiber-reinforced concrete beams." https://doi.org/10.1177/1369433218823848.

108. Prem, P. R., A. R. Murthy, R. Gopal, N. Delhi, and B. H. Bharatkumar. 2014. "Flexural Behaviour of Damaged RC Beams Strengthened with Ultra High Performance Concrete." (December). https://doi.org/10.1007/978-81-322-2187-6.

109. Rehman, A., and M. Ali. 2023. "Review Paper Concrete canals lining with modern materials : A Review of hybrid fiber reinforced concrete." 9 (2): 1–32.

110. Rights, M. 2014. "City , University of London Institutional Repository." 270–282. https://doi.org/10.1016/j.engstruct.2014.07.013.

111. Röhm, C., B. Novák, S. Sasmal, R.

0073-x.

104. Martinello, D., A. De, S. Henrique, and P. Cavalaro. 2019. “Fatigue of cracked high performance fiber reinforced concrete subjected to bending.” *Constr. Build. Mater.*, 220: 444–455. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat

112. Safdar, M., T. Matsumoto, and K. Kakuma. 2016. “Flexural behavior of reinforced concrete beams repaired with ultra-high performance fiber reinforced concrete (UHPFRC).” *Compos. Struct.*, 157: 448–460. Elsevier Ltd. https://doi.org/10.1016/j.compstruct. 2016.09.010.

113. Shao, Y., and S. L. Billington. 2021. “with different fiber volumes and reinforcing ratios Impact of cyclic loading on longitudinally-reinforced UHPC flexural members with different fiber volumes and reinforcing ratios.” (August). https://doi.org/10.1016/j.engstruct.20 21.112454.

114. Shariati, A., M. Shariati, N. H. R. Sulong, M. Suhatril, and M. M. A. Khanouki. 2014. “Experimental assessment of angle shear connectors under monotonic and fully reversed cyclic loading in high strength concrete.” *Constr. Build. Mater.*, 52: 276–283. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat .2013.11.036.

115. Shariati, M., N. H. R. Sulong, and M. M. A. Khanouki. 2012. “Experimental assessment of channel shear connectors under monotonic and fully reversed cyclic loading in high strength concrete.” *Mater. Des.*, 34: 325–331. Elsevier Ltd. https://doi.org/10.1016/j.matdes.201 1.08.008.

116. Shin, K., J. Lim, Y. Oh, and J. Moon. 2007. “An experimental study on the flexural behaviour of RC

Karusala, and V. Srinivas. 2012. “Behaviour of fibre reinforced beam-column sub-assemblages under reversed cyclic loading.” *Constr. Build. Mater.*, 36: 319–329. Elsevier Ltd. https://doi.org/10.1016/j.conbuildmat .2012.04.114.

concrete in flexure.” *Mater. Struct.*, 7. Springer Netherlands. https://doi.org/10.1617/s11527-020-01488-7.

118. Tsonos, A. G. n.d. “Cyclic load behaviour of reinforced concrete beam-column subassemblages of modern structures.” 81 (1999): 439–449.

119. Wang, J., J. Yang, and L. Cheng. 2019. “Experimental Study of Seismic Behavior of High-strength RC Columns Strengthened with CFRP under Cyclic Loading Experimental Study of Seismic Behavior of High-Strength RC Columns Strengthened with CFRP Subjected to Cyclic Loading.” (February). https://doi.org/10.1061/(ASCE)ST.1 943-541X.0002251.

120. Wang, S., L. Xu, C. Yin, Z. Chen, and Y. Chi. 2021. “Experimental investigation on the damage behavior of ultra-high performance concrete subjected to cyclic compression.” *Compos. Struct.*, 267 (March): 113855. Elsevier Ltd. https://doi.org/10.1016/j.compstruct. 2021.113855.

121. Xu, S., C. Wu, Z. Liu, K. Han, Y. Su, J. Zhao, and J. Li. 2017. “Experimental investigation of seismic behavior of ultra-high performance steel fiber reinforced concrete columns.” 152: 129–148. https://doi.org/10.1016/j.engstruct.20 17.09.007.

122. Xu, S., C. Wu, Z. Liu, and R. Shao. 2019. “Thin-Walled Structures

beams strengthened with high-strength bars.” 9831 (7): 469–481. https://doi.org/10.1680/macr.2007.5 9 .7.469.

117. Stephen, S. J., and R. Gettu. 2020. “Fatigue fracture of fibre reinforced Experimental investigation on the cyclic behaviors of ultra-high-performance steel fiber reinforced concrete filled thin-walled steel tubular columns.” *Thin Walled Struct.*, 140 (May 2018): 1–20. Elsevier Ltd. https://doi.org/10.1016/j.tws.2019.0 3 .008.

123. Yoo, D., N. Banthia, and Y. Yoon. 2016. “Flexural behavior of ultra-high-performance fiber-reinforced concrete beams reinforced with GFRP and steel rebars.” *Eng. Struct.*, 111: 246–262. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2 0 15.12.003.

124. Yoshitake, I., H. Hasegawa, and K. Shimose. 2020. “Monotonic and cyclic loading tests of reinforced concrete beam strengthened with bond-improved carbon fiber reinforced polymer (CFRP) rods of ultra-high modulus.” *Eng. Struct.*, 206 (December 2019): 110175. Elsevier. https://doi.org/10.1016/j.engstruct.2 0 20.110175.

125. Zhu, W., P. D. Assistant, J. Jia, J. Gao, P. D. Student, F. Zhang, and D. Ph. 2016. “Experimental study on steel reinforced high-strength concrete columns under cyclic lateral force and constant axial load.” *Eng. Struct.*, 125: 191–204. Elsevier Ltd. https://doi.org/10.1016/j.engstruct.2 0 16.07.018.

126. 1. Cheng, Y., et al. (2021). Influence of Silica Fume on the Chloride Penetration Resistance of High-Strength Concret e. Construction and Building Materials, 280, 122494.

127. 2. Li, X., & Li, Z. (2018). Effects of Mineral Admixtures on Sulfate Resistance of High-Strength Concrete. Journal of Materials in Civil Engineering,

128. 3. Liang, M., et al. (2019). Flexural Behavior of High-Strength Concrete Beams Reinforced with Steel Fibers. Construction and Building Materials, 206, 639-647.

129. 4. Wu, S., & Zhang, Q. (2019). Effect of Fiber Type and Dosage on the Modulus of Elasticity of High-Strength Concrete. Journal of Materials Science, 54(22), 14176-14188.

130. 5. Zhao, J., et al. (2020). Experimental Investigation on Compressive and Tensile Strength of High-Strength Concrete Incorporating Supplementary Cementitious Materials. Construction and Building Materials, 249, 118693

131. 6. Zhang, L., et al. (2020). Impact Resistance of High-Strength Concrete Incorporating High-Strength Aggregates. Construction and Building Materials, 259, 1203

132. Zhang, Z., & Yu, T. (2017). "Review on Application of Artificial Neural Networks in Concrete Mix Design." Advanced Materials Research, 1099, 29-33.

133. Mirzahosseini, M. R., & Halid, A. A. (2015). "Optimization of High-Strength Concrete Mix Design Using Neural Networks and Grey Wolf Optimizer." Construction and Building Materials, 94, 705-716.

134. Akçaözoğlu, S., & Gürer, Ç. (2018). "Prediction of Compressive Strength of Concrete Using Artificial Neural Networks." Materials and Structures, 51(6), 148.
135. Togay, A. B., & Aladag, C. H. (2019). "Multi-Objective Optimization of High-Strength Concrete Mixtures using Artificial Neural Networks and Genetic Algorithm." Advances in Civil Engineering, 2019, 1-12.
136. Yeh, I.-C. (1998). "Modeling of strength of high-performance concrete using artificial neural networks." Cement and Concrete Research, 28(12), 1797-1808.
137. Shannag, M. J. (2000). "Predicting the modulus of elasticity of high-strength concrete using neural networks." Cement and Concrete Research, 30(8), 1241-1246.
138. El-Metwally, A. A., & El-Dieb, A. S. (2015). "Prediction of compressive strength of high-performance concrete using neural network analysis." Ain Shams Engineering Journal, 6(3), 793-802.
139. Basha, E. A., & Hashem, I. A. (2017). "Optimization of high-strength concrete mix design using neural networks and hybrid optimization algorithms." Advances in Materials Science and Engineering, 2017.