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Development of High Strength Concrete for Structural Application in Asia

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ABSTRACT

Due to its improved mechanical qualities and ability to reduce the size of structural parts, high-strength concrete (H.S.C.) has attracted much interest in structural engineering. This study article examines how high-strength concrete may be used in structural applications developed in Asia. The study's main objectives are to improve the mix design, add the appropriate admixtures, and evaluate the mechanical characteristics and durability of the resultant high-strength concrete. The development of High Strength Concrete (H.S.C.) material components for structural applications in Asia has been the subject of substantial research by several scholars. The findings of this study show that high-strength concrete breakthroughs and ground-breaking architectural icons have been built in Asia. For high-strength concrete to be used successfully and securely over the long term, proper mix design, quality control, and building techniques are essential.

Keywords- Admixtures, Compressive Strength, High-Strength Concrete, Mix Design, Structural Applications.

I. INTRODUCTION

HSC applications have recently increased in the construction industry due to various tailored benefits over traditional plain concrete, including excellent workability, increased compressive strength, and good durability. Increased public attention to environmental issues has led to greater use of “waste SCMs in HSC” construction in recent years [1]. Developing "smart construction" will significantly enhance the efficiency and caliber of construction firms. The term "smart construction" describes a system that uses wearables, mobile devices, and the Internet of Things (IoT) to control the whole building process in real-time. Due to challenges in implementing the Internet of Things, efficient and cost-effective mixing design development via data management is required in HSC mixing design [2].

In light of this, developed nations are investing heavily in creating manufacturing techniques and mixing design methodologies for high-strength concrete. More than 80 to 100 MPa of high-strength concrete have already been utilized to construct modern skyscrapers in China and other countries, while 78 of 125 or 62.4% of all buildings above 300 meters are located there [3]. This study describes how high-strength concrete was created in Asia for structural applications. Significant binders, such as aggregate kinds and hybrid materials, are learned when considering manufacturing high-strength concrete in Asia. Six to ten tests are then conducted after experimenting with various combinations while altering the quantity of usage [4].

II. METHODOLOGY

Several scholars have thoroughly studied the development of HSC material components for structural applications in Asia. The experimental technique describes the processes that are used to make high-strength concrete. It entails selecting locally accessible materials, maximizing mix design, and calculating the required water-cement ratio, aggregate grading, and cementations content. The research employs several admixtures, such as super plasticizers, silica fume, and fly ash, to enhance the workability and mechanical properties of the concrete. One of the critical study areas has been the HSC mixture ratio. Due to the high and low levels of preparation technologies, many parts of the globe have distinct characteristics regarding water quality, cement, silicon ash, other mixes, and steel fibers. The atmosphere in various locations may also impact the ideal HSC combination ratio. Therefore, finding the appropriate mixing ratio via tests in various locations is essential to achieve the ideal HSC material performance and prevent directly applying the current proportioning data. This problem could be among the most significant preventing widespread HSC usage in bridge engineering [5].

III. LITERATURE REVIEW

The application of artificial intelligence in the creation of the High-Strength Concrete Mixed Design System was investigated by Kim in 2022. After 28 days of using high-strength concrete, this may be verified using the compressive strength test, considered the most critical aspect of every high-strength concrete project's quality inspection. Improving the reliability of the mixed design, which impacts the manufacture of high-strength concrete, is crucial to provide high-quality commodities to ready-mixed concrete companies. The mixed design model presented in their research included "input and output variables, data gathering via learning, model structure determination, learning error, and recurrent phrase results." Matrix laboratory (MATLAB) with Deep learning was employed for their research since it is a language for matrix-based mathematics and engineering computations. Their findings suggest that high-strength concrete quality control may be reliably implemented via an AI-powered hybrid design system that is applied to all stages of production [6]. UHPC has been the single most revolutionary product in concrete technology. In cementitious composite materials, you can locate them. UHPC has been widely employed to build many different types of structures because of its higher mechanical endurance and strength, and research into its behaviour has grown quickly over the past decade. Since UHPC is so expensive, its bridge engineering (BE) application is restricted. Whether or whether UHPC is employed in other parts of BE remains to be seen. To assess the present state and prospects of UHPCs, a thorough assessment of current UHPC development patterns is necessary. This research looks at the state of the art in UHPC software for BE [7]. Amran et al.'s study shows that UHPC combines advanced cementitious material and fiber technology to create materials with high strengths and exceptional durability. Small holes in the material often prevent the passage of dangerous compounds, including water, gas, and chlorides. Their work offers a complete scientific study of the current status of UHPC, its capability to “capture carbon, sustainability aspects, challenges, and potential applications.” This survey of the current state of the art is meant to assist academics, designers, and professionals in the business world in expanding the usage of UHPCs for demanding infrastructure tasks. Their findings will inform the creation of industry standards for sustainable UHPC, paving the way for its widespread implementation. In this way, design engineers can make the most of UHPC's superior strength and other unique features and create predictive models that reliably predict UHPC sections' ultimate bearing capacity over various loading conditions [8]. Ali et al. explored the possibility of using coir as fiber-reinforcement materials in HSC using silica fume as an alternative for concrete. The criteria studied included compressible strength, shear capacity, breaking tensile force, ultrasonic pulses speed, retention of water, and sodium chloride penetration. “Scanning electron microscopy (SEM) was used to examine the CF-reinforced concrete's microstructure,” and including CF considerably reduced HSC's compressive strength while significantly increasing its “splitting tensile strength and shear strength.” The concrete's splitting tensile strength and shear strength were improved by 47% and 70%, respectively, when 1.5% CF and 5% silica fume were added, compared to the control mix. Water resistance in concrete is reduced due to the CF additive. The detrimental effects of CF on concrete's permeability resistance may be mitigated by combining the material with silica fume, as recommended. The SEM analysis revealed that CF diminised with time [9]. According to Akeed et al.'s research, UHPC is a "cement-based composite" utilized in the building of new buildings as well as in the rehabilitation of older buildings to increase their usable lives. It is a modern composite that can replace concrete structures in high-stress areas. While ultra-high performance concrete (UHPC) offers several advantages over regular concrete, its application is restricted by stringent design restrictions and expensive costs. Therefore, to increase its usefulness and offer crucial data for material testing needs and procedures, a comprehensive evaluation of UHPC's durability attributes is required. Researchers anticipate that sharing their findings might increase interest in UHPC and spur further study and implementation [10]. The thick framework of UHPC enhances the likelihood of explosive splitting. A lightweight ultra-high performance composite (L-UHPC) was developed due to their research, and a method was proposed to boost the material's performance and reduce the risk of explosive spalling. By mixing hollow glass microspheres, known for their exceptional "strength, with microscopic, lightweight aggregates, lightweight" and strong materials were produced. The amount of internal free water was decreased as a result of the heat-curing procedure, which helped to partially avoid the "thermal spelling of the L-UHPC under fire conditions." The silicate polymerization in the C-S-H structure and the micro hardness of the paste matrix are both accelerated by curing at higher temperatures, according to microstructural studies. The glass microspheres may have been broken, resulting in spaces that can withstand internal vapour pressure and limit the damage produced by the high temperatures. Low thermal conductivity achieved by dry heat curing and porous materials significantly improved the L-UHPC's material efficiency [11].

3.1 Importance of High Strength Concrete for structural application

Due to its many uses and benefits, high-strength concrete is an indispensable material for building modern buildings. This enables the construction of more muscular, more robust structures that can withstand heavier loads and pressures. High-strength concrete may achieve the same structural performance as regular concrete with less material. As a result, materials are used more efficiently; the building weighs less overall, money is saved, and ecologically friendly construction techniques are used [12].

Because of high-strength concrete's increased strength and durability, engineers and architects can construct structures with more innovative and intricate layouts. Greater architectural flexibility makes constructing higher structures with greater spans and smaller columns possible. This increases the usable interior space of a building and broadens design options. Constructing thinner structural elements like beams, slabs, and walls is possible because high-strength concrete can carry higher weights. This reduces the overall weight of the building and increases the floor space that may be used for people or other purposes [13].

3.2 History of development and application

Compressive strengths of up to 800 N/mm2 were achieved in concretes developed and produced in the 1960s under controlled laboratory conditions. After being heavily compressed, they underwent heat treatment. Due to their small grain size (less than 1 mm) and excellent packing density (thanks to other inert or reactive mineral additions), this concrete was dubbed Reactive Powder Concrete. The first widespread commercial applications appeared in the 1980s, thanks to the advent of so-called DSP mortars in Asia. Vaults, strong rooms, and other forms of secure storage and fortifications were its primary uses. The first studies on the potential benefits of HSC in construction started about 1985 [14]. Offshore bucking foundations and other precast components may employ it, with or without "passive" reinforcement. Engineers developed coarse-grained HSC made from synthetic or natural high-strength aggregates for very tall buildings and heavily laden columns. These days, it is possible to tailor a formula to the specifics of a project's layout, building materials, and style of construction or design [15].

3.3 Reason of developing High-strength concrete in Asia

Rapid urbanization and population growth in many Asian countries have driven the extensive use of High-Strength Concrete in construction, particularly for tall buildings and infrastructure projects. This type of concrete is essential for supporting greater loads and providing resilience against natural disasters such as strong winds and earthquakes. As a result, significant investments have been made in developing highways, dams, and other critical infrastructure throughout the continent. High-strength concrete plays a crucial role in these large-scale projects, ensuring both structural integrity and long-term durability. Advances in concrete technology have facilitated the incorporation of various ingredients, including fly ash, slag, and silica fume, along with chemical admixtures, which enhance the strength, adaptability, and longevity of the concrete [16] [17].

In Asia, there has been extensive research and development focused on improving concrete mix designs, exploring innovative materials, and analyzing the behavior of HSC under different conditions. This collaborative effort has yielded positive outcomes, prompting several Asian nations to adopt stricter construction codes that mandate the use of high-strength concrete. These standards and testing processes are designed to ensure the effectiveness and quality of HSC for structural applications. engineering projects requiring concrete components to withstand significant compressive loads, HSC is indispensable, particularly in the construction of high-rise buildings, where it is commonly used in foundations, shear walls, and columns—especially on lower floors where stress levels are highest. In certain instances, it is also employed in the construction of highway bridges, enabling longer spans with reinforced or pre stressed concrete girders compared to those made with normal strength concrete. [18] [19].

The enhanced load-bearing capacity of high-strength concrete allows for fewer girders, providing a financial advantage to concrete producers by reducing the need for steel in specific bridge projects. Overall, the findings indicate that breakthroughs in high-strength concrete have led to the creation of architectural icons across Asia. To ensure the successful and safe long-term utilization of HSC, it is vital to focus on proper mix design, quality control, and effective construction techniques [20].

IV. RESULTS

For the development of HSC for structural applications, Asia has been a persistent focus. High-strength concrete generally has compressive strengths more than 50 MPa compared to standard concrete mixtures. Because of the increased strength, structures may be planned and constructed to be thinner and sturdier [21].High-strength concrete produces significant heat during the first three days following placement due to the vast paste volume and high cement content. The temperature increase of high-strength concrete at an early age may be as high as 60o C, depending also on the mass of the concrete pour. It has been suggested that grade 100 concrete poured in a 2.3 m square column mould might reach a peak temperature that is extremely near the water's boiling point without any active temperature control. While liquid nitrogen or water cooling may be used to maintain the temperature of the concrete at a manageable level, these active measures are cumbersome and costly. According to the author, the best technique to manage the temperature is to change the mix proportions to produce less heat. However, a proper laboratory test procedure for determining how a concrete mix's temperature develops is needed to achieve this. The bulk of the concrete pour, the shape of the component being cast, and the formwork's insulation all affect how hot a concrete pour becomes during actual casting. The laboratory test should be carried out so that heat dispersion is not permitted, i.e. under adiabatic conditions, to remove such fluctuations and imitate the state in the center of a significant pour. Even with excellent insulation, there will be some heat loss, making reaching the adiabatic curing condition impossible. We also need to reduce the temperature difference between the concrete and the surroundings to stop heat loss entirely. This may be accomplished by placing the concrete in a climate-controlled chamber with its mould and insulation, monitoring the temperature at the core of the concrete, and adjusting the chamber temperature such that it is always equal to the temperature of the concrete, as illustrated in Figure1[22] [23].

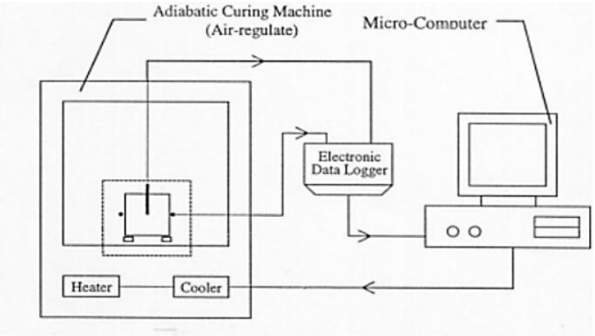

Figure 1: Set up for adiabatic curing test of concrete

Depending on the precision of the temperature measurement device and the quality of the chamber, the active value control of the temperature in the surrounding environment can reduce the variation in temperature within the concrete and the environment to approximately 0.5 degrees Celsius and the degree of heat dispersion can be reduced to almost nothing at all. Figure 8 depicts a temperature-time curve derived from a typical experiment carried out at the University of Asia. By doing adiabatic drying experiments on various types of hsc, it may be possible to examine the effects of various mix variables on the rise in concrete heat. The preliminary research has revealed that using PFA and CSF instead of some cement in concrete may significantly reduce the temperature increase that the concrete experiences. An important factor in determining the rise in temperature of the concrete mix, in along with the quantity of concrete there is also the amount of water present, particularly at high water/binder ratios. After the conclusion of the research, a thorough report of the findings will be made public. In the long term, it has been recommended that the aerodynamic curing test be implemented as an established procedure for grade 60 or above concretes [24] [25].

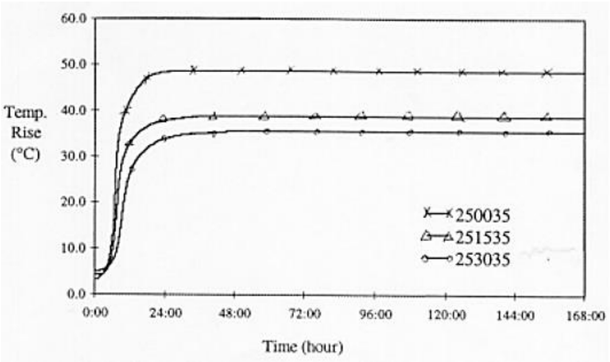

Figure 2: Typical Temperature-time curve obtained by adiabatic curing test

V. CONCLUSION

Due to rapid urbanization and population growth in many Asian countries, high-strength concrete has been produced and is widely utilized throughout the continent. In order to construct tall buildings that can support greater loads and withstand natural disasters like strong winds and earthquakes, high-strength concrete is often used. Asia has spent much money on highways, dams, and other infrastructure development. High-strength concrete is crucial for these vast projects because it guarantees structural integrity and long-term durability. Improvements in concrete technology have allowed for using high-strength concrete ingredients, including “fly ash, slag, and silica fume, in addition to chemical admixtures.” These additives enhance the concrete's strength, adaptability, and longevity. There has been a lot of research and development (R&D) in Asia aimed at bettering concrete mix designs, exploring innovative materials, and analyzing the behavior of high-strength concrete in different situations. The results of this collaborative effort have been positive. Several Asian nations have adopted new, more stringent construction codes that call for the use of high-strength concrete. The specific standards and testing processes outlined in these guidelines guarantee the efficacy and quality of high-strength concrete used for structural purposes. As a result of Asia's advancements in high-strength concrete, groundbreaking architectural icons have been erected there. Successful use of high-strength concrete relies on good mix design, quality assurance, and construction procedures to ensure its long-term effectiveness and security.

REFERENCES

[1] Cogurcu, M. T. “Investigation of mechanical properties of red pine needle fiber reinforced self-compacting ultra-high performance concrete.” Case Studies in Construction Materials, Volume 16, June 2022,pp.1-13, doi.org/10.1016/j.cscm.2022.e00970

[2] Hakeem, I. Y., Althoey, F., & Hosen, A.Mechanical and durability performance of ultra-high-performance concrete incorporating SCMs. Construction and Building Materials, Volume 359, 12 December 2022, pp.1-14, doi.org/10.1016/j.conbuildmat.2022.129430

[3] Wang, P., Fu, H., Zuo, W., Luo, S., Zhao, H., Feng, P., & Wang, H. Effect of n-CSH-PCE and slag powder on the autogenous shrinkage of high-strength steam-free pipe pile concrete. Construction and Building Materials, Volume 325, 28 March 2022, pp.1-31 doi.org/10.1016/j.conbuildmat.2022.126815

[4] Tipu, R. K., Panchal, V. R., & Pandya, K. S. An ensemble approach to improve BPNN model precision for predicting compressive strength of high-performance concrete. In Structures Vol. 45, pp. 500-508, doi.org/10.1016/j.istruc.2022.09.046

[5] Wang, Y. S., Lee, H. S., Lin, R. S., & Wang, X. Y. Effect of silicate-modified calcium oxide-based expansive agent on engineering properties and self-healing of ultra-high-strength concrete. Journal of Building Engineering, 50, 2022. doi.org/10.1007/s44290-024-00130-7

[6] Kim, D. G. Development of High-Strength Concrete Mixed Design System Using Artificial Intelligence. Webology, Volume 19, No. 1, 2022, pp.4268-4285.

[7] Abdal, S., Mansour, W., Agwa, I., Nasr, M., Abadel, A., Onuralp Özkılıç, Y., & Akeed, M. H. Application of ultra-high-performance concrete in bridge engineering: current status, limitations, challenges, and future prospects. *Buildings*, 13(1), 185, pp.1-24.2023

[8] Amran, M., Huang, S. S., Onaizi, A. M., Makul, N., Abdelgader, H. S., & Ozbakkaloglu, T. Recent trends in ultra-high performance concrete (UHPC): Current status, challenges, and future prospects. Construction and Building Materials, 352,2022, 129029.

[9] Ali, B., Fahad, M., Ullah, S., Ahmed, H., Alyousef, R., & Deifalla, A. Development of ductile and durable high strength concrete (HSC) through interactive incorporation of coir waste and silica fume. Materials, 15(7),2022, pp.1-21,doi.org/10.3390/ma15072616

[10] Akeed, M. H., Qaidi, S., Ahmed, H. U., Faraj, R. H., Mohammed, A. S., Emad, W., & Azevedo, A. R. Ultra-high-performance fiber-reinforced concrete. Part IV: Durability properties, cost assessment, applications, and challenges. Case Studies in Construction Materials, Volume 17, December 2022,pp.1-20 doi.org/10.1016/j.cscm.2022.e01271

[11] Lu, J. X., Shen, P., Sun, Y., & Poon, C. S. Strategy for preventing explosive spalling and enhancing material efficiency of lightweight ultra high-performance concrete. Cement and Concrete Research, 158,2022, 106842.

[12] Qaidi, S., Al-Kamaki, Y., Hakeem, I., Dulaimi, A. F., Özkılıç, Y., Sabri, M., & Sergeev, V. Investigation of the physical-mechanical properties and durability of high-strength concrete with recycled PET as a partial replacement for fine aggregates. Frontiers in Materials, Volume 10, 2023, pp.1-17, doi.org/10.3389/fmats.2023.1101146

[13] Hamzah,N., Mohd Saman,H.,Baghban, M.H., Mohd Sam, A. R., Faridmehr, I., Jones, M. R., & McCarthy, A. Preliminary views on the potential of foamed concrete as a structural material. Magazine of Concrete Research, 2005,57(1), pp.21–31.

[14] Anas, S. M., Alam, M., Isleem, H. F., Najm, H. M., & Sabri, M. M. S. Ultra high performance concrete and C-FRP tension Re-bars: A unique combinations of materials for slabs subjected to low-velocity drop impact loading. Frontiers in Materials, 9,2022, 1061297, doi.org/10.3389/fmats.2022.1061297

[15] Trivedi, A., Ojha, P. N., Singh, A., Singh, B., Bansal, S., & Sengupta, L. Experimental investigations on mechanical properties of normal and high strength high calcium geopolymer concrete. Journal of Asian Concrete Federation, 8(1), 2022, pp.16-25.

[16] Shah, A. A., & Ribakov, Y. Recent trends in steel fibered high-strength concrete. Materials & Design, 32(8-9),2011, pp.4122–4151

[17] [17] Song, G., Gu, H., & Mo, Y.-L Smart aggregates: multi-functional sensors for concrete structures—a tutorial and a review. Smart Materials and Structures, 17(3),2008, 033001, doi.org/10.1088/0964-1726/17/3/033001

[18] Michels, J., Sena-Cruz, J., Czaderski, C., & Motavalli, M. Structural Strengthening with Prestressed CFRP Strips with Gradient Anchorage. Journal of Composites for Construction, 17(5),2013, pp. 651–661.

[19] Zhong, R., & Wille, K. Material design and characterization of high performance pervious concrete. Construction and Building Materials, 98(14),2015, pp. 51–60.

[20] Cao, X., Ren, Y. C., Zhang, L., Jin, L. Z., & Qian, K. Flexural behavior of ultra-high-performance concrete beams with various types of rebar. Composite Structures, 292,2022, 115674. doi.org/10.1016/j.compstruct.2022.115674 ·

[21] Chen, S., Zhang, R., Jia, L.-J., Wang, J.-Y., & Gu, P. Structural behavior of UHPC filled steel tube columns under axial loading. Thin-Walled Structures, 130(54),2018, pp. 550–563.

[22] Lim, J. C., & Ozbakkaloglu, T. Stress–strain model for normal- and light-weight concretes under uniaxial and triaxial compression. Construction and Building Materials, 71(12),2014, pp.492–509

[23] Muhd Sidek, M. N., and Huseien, G. F. A review on the use of self-curing agents and its mechanism in high-performance cementitious materials. Buildings, 12(2), 152, 2022, doi.org/10.3390/buildings12020152

[24] Wu, Y., Wang, J.-Y., Monteiro, P. J. M., & Zhang, M.-H. Development of ultra-lightweight cement composites with low thermal conductivity and high specific strength for energy efficient buildings. Construction and Building Materials, 87(25), 2015, pp.100–112.

[25] Memon, S. A., Cui, H., Lo, T. Y., & Li, Q. (2015). Development of structural–functional integrated concrete with macro-encapsulated PCM for thermal energy storage. Applied Energy, 150(24) ,2015, pp.245–257.