

Special Cements and Cement Concrete: Innovations and Applications

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ABSTRACT:

When compared to traditional cementitious materials, special cements and cement concrete offer superior performance and functionality, playing a critical role in the building sector. Special Class concrete is defined as having features or characteristics that vary from or are in addition to those of Normal Class concrete. Pre-cast panels, Green Star, Permeable Concrete, Low shrink pavements, post tension slabs, high strength 60MPa+ concrete, spray mixes, and other materials are examples. This chapter gives a general review of specific cements and cement concrete while stressing the distinctive qualities, uses, and advantages of each. It also examines the main difficulties in using them and outlines prospective new advancements in this area.

KEYWORDS:

Acid Resistant, Cement, Expanding, Fibre, Prestressed Concrete, Reinforced.

I. INTRODUCTION

In comparison to traditional cementitious materials, special cements and cement concrete offer improved performance, durability, and adaptability, revolutionizing the building sector. The properties, uses, advantages, drawbacks, and potential future advancements of special cements and cement concrete will be discussed in this article. Due to their specific compositions and qualities, special cements may be distinguished from regular Portland cement (OPC) [1], [2]. These cements have been created to adhere to strict performance standards in a variety of building applications. One such is high-strength cement, which is appropriate for constructions that need a higher load-bearing capacity and has a higher compressive strength than OPC. Rapid-setting cement is another type; it sets quickly and is frequently used in urgent repairs or other circumstances when a quick setting time is required. The enhanced durability of special cements is one of its major advantages. The tough environmental conditions, such as high temperatures, chemical assaults, and aggressive compounds, are better withstood by these cements.

They are therefore perfect for construction projects involving bridges, tunnels, and marine constructions in harsh conditions. Special cements also increase the durability of buildings by lowering maintenance needs and life-cycle expenses. Contrarily, cement concrete is a composite material made of cement, aggregates (such sand and gravel), water, and occasionally other additives. Due to its adaptability, simplicity of usage, and capacity for producing intricate forms and designs, it is extensively employed in the building sector. Concrete may be molded into many different shapes, making it ideal for building structures, pavements, and ornamental components. The performance and usefulness of cement concrete are improved by the use of specific cements. For example, silica fume or fly ash used as additional cementitious elements enhance the concrete's strength, longevity, and fracture resistance. By using industrial byproducts, these materials also help to lessen the environmental effect of the manufacture of concrete. Special cements and cement concrete also have advantages in terms of sustainability. One of the biggest sources of carbon dioxide (CO₂) emissions worldwide is the cement industry, however cutting-edge cements like low-carbon or carbon-neutral cements strive to lessen this effect. These cements assist address concerns about climate change by reducing the amount of CO₂ emitted during manufacture. By using less natural resources and creating less waste, the use of recycled aggregates and alternative binders in concrete manufacturing furthers sustainability.

The use of specialty cements and cement concrete, however, comes with certain difficulties. First off, these materials often cost more than conventional cementitious materials, mostly because of the specific production methods and the addition of cutting-edge additives. Their broad usage may be constrained by this economic aspect, especially in areas with tight budgets. Furthermore, it may be difficult to get particular cements and certain aggregates, which necessitates careful planning and sourcing for building projects [3], [4]. Additionally,

specialist knowledge and experience are necessary for the effective use of particular cements and cement concrete. To guarantee correct application and best performance, engineers, architects, and contractors must be aware with the qualities and handling traits of these materials. This knowledge gap may be filled and the efficient use of these cutting-edge products promoted with the aid of training programs and educational activities. Future-focused research and development aims to further enhance the characteristics and functionality of cement concrete and special cements. Scientists are investigating new varieties of cements with improved qualities, such as self-cleaning cements that prevent the buildup of dirt and pollutants on surfaces and self-healing cements that can automatically fix microcracks. These advancements have the potential to improve the cement-based constructions' sturdiness, upkeep, and aesthetics.

Cement production improvements that are sustainable are also being pursued. To lessen the carbon footprint connected with cement manufacture, this involves the creation of substitute binders and environmentally friendly manufacturing techniques. To reduce environmental impact and advance a circular economy in the building sector, researchers are looking into bio-based materials, geopolymers, and cutting-edge methods like carbon capture and use. In conclusion, better performance, durability, and adaptability of specific cements and cement concrete have revolutionized the building sector. These materials provide increased tensile strength, resilience to abrasive environments, and the capacity to produce complex patterns. However, there are obstacles including greater costs and a restricted supply, and specialist knowledge is required for their effective deployment. Nevertheless, efforts are being made to address these issues and progress the development of specific cements and cement concrete via continuing research and development. These materials will continue to aid in the development of long-lasting, sturdy, and aesthetically beautiful constructions in the future thanks to ongoing innovation [5], [6].

Acid Resistant Cement: A unique kind of cement created to withstand the corrosive effects of acids and other strong chemicals is known as acid-resistant cement, sometimes known as acid-proof cement or acid-resistant concrete. It is extensively utilized in fields where exposure to acids is common, including chemical factories, labs, sewage treatment facilities, and battery production facilities. The lifespan and durability of structures in these situations are ensured by the use of acid-resistant cement, which provides high resistance to acid assaults. Acid-resistant cement is made of a different material than regular cement. Typically, it is made up of a combination of Portland cement, silica aggregates, and additives resistant to acids. The high density and low porosity properties of the silica aggregates help to the cement's resistance to acid penetration. The cement's acid resistance qualities are further improved by the use of acid-resistant additives like potassium silicate or sodium silicate. Being able to tolerate a variety of acids, particularly powerful mineral acids like sulfuric acid, hydrochloric acid, and nitric acid, is one of the main benefits of acid-resistant cement. Additionally, it gives resistance to various corrosive chemicals, organic acids, and alkalis.

This resistance guards against structural damage, leaks, and potentially dangerous circumstances and stops the deterioration of concrete buildings. Construction of acid storage tanks, acid containment areas, acid pits, chemical storage spaces, and floors vulnerable to chemical spills frequently uses acid-resistant cement. It can be utilized as a lining material or to make concrete buildings that are acid-resistant. To maintain the efficacy and long-term performance of acid-resistant cement, thorough surface preparation, accurate mixing, and cautious curing are required. It is crucial to remember that while acid-resistant cement offers good defense against acid assaults, not all types or concentrations may be compatible with it. The right acid-resistant cement should be chosen based on the particular chemical environment, acid concentration, and acid temperature. To guarantee the proper selection and use of acid-resistant cement, consulting with specialists and adhering to industry standards are essential. Finally, acid-resistant cement is a unique substance created to withstand the corrosive impacts of acids and harsh chemicals. In industries where acid exposure is common, it provides exceptional resistance to acid penetration, preserving concrete buildings. Acid-resistant cement is frequently utilized in many different purposes, such as containment spaces, chemical storage facilities, and tanks for storing acids. The best performance and longevity of acid-resistant cement in corrosive settings depend on proper installation and selection based on individual needs [7], [8].

II. DISCUSSION

Expanding Cement: A unique kind of cement called expanding cement, often referred to as expansive cement or shrinkage-compensating cement, expands under regulated conditions as it hydrates. Expanding cement is intended to reverse the drying shrinkage that happens in concrete, as opposed to traditional cement, which shrinks as it dries. This will lessen or completely eliminate cracking and increase the overall longevity of constructions. The use of expansive agents during the production process allows expanding cement to expand. Most frequently, these substances consist of calcium sulfate or calcium sulfoaluminate compounds. The

expansive agents in cement react with the water to form ettringite crystals, which increase the cement's volume. By making up for the concrete's drying shrinkage, this expansion lowers the tensile stresses that might cause cracking. The main advantage of expanding cement is its capacity to reduce shrinkage-related concrete cracking. Concrete cracks may seriously jeopardize the strength and longevity of buildings by allowing moisture and other dangerous chemicals to enter.

Utilizing expanding cement lowers the risk of cracking, resulting in stronger, longer-lasting concrete. Many different building projects make use of expanding cement. It is frequently utilized in the construction of concrete structures including bridges, dams, tunnels, and high-rise buildings that are vulnerable to drying shrinkage. It is especially helpful when pouring huge amounts of concrete or when the concrete is exposed to temperature changes and drying conditions that might significantly cause shrinkage. Expanding cement has several positive qualities in addition to its ability to compensate for shrinkage. It keeps up strong workability and setting times, making building simple. It is appropriate for difficult conditions because it has good strength growth, durability, and resistance to chemical assaults. It is important to note that expanding cement needs to be handled carefully and installed correctly. To avoid overexpansion, which may have unfavorable effects, the expansion process must be under control. To achieve the best performance, proper curing processes and consideration of the temperature and moisture levels throughout the curing time are essential.

Although shrinkage and cracking are significantly reduced when using expanding cement, it is not appropriate for all applications. Its application is often restricted to particular circumstances when shrinkage control is of utmost importance. Due to the added expansive agents, expanding cement may also cost more than normal cement. In conclusion, expanding cement is a unique type of cement that hydrates and expands, preventing concrete from drying out and shrinking, and minimizing cracking. In constructions that are subjected to shrinkage stresses, it offers enhanced durability and lower maintenance requirements. Various building projects often make use of expanding cement, especially when drying shrinkage is an issue. To get the best results, proper handling and installation methods are required. Expanding cement may greatly improve the performance and lifetime of concrete buildings, despite its greater price and more restricted uses [9], [10].

Oil Well Cement: Oil well cement is a particular kind of cement used in the oil and gas sector for the building and sealing of oil and gas wells. It is sometimes referred to as drilling cement or well cement. It is essential for maintaining the wellbore's stability and integrity, limiting fluid migration, and safeguarding the nearby formations. Oil well cement has a similar chemical make-up to regular Portland cement (OPC), but it frequently contains extra additives to improve its performance under the difficult environmental conditions present during oil well drilling and completion activities. Properties including density, setting time, strength development, and resilience to high temperatures and pressure differentials may all be improved by these additions. Oil well cement's main purpose is to create zonal isolation, which entails building a barrier between several geological strata to stop fluids like water, gas, or oil from migrating unintentionally across the formations.

It is essential for preserving the integrity of wells and averting any risks to the environment and public safety. Oil well cement is pumped down the wellbore and circulated through the annular area between the well casing and the formation during the drilling and completion process. The link between the casing and the wellbore walls is then allowed to cure and solidify, creating a firm, impenetrable bond. Fluids are kept within the confines of their specific formations thanks to the cement sheath's isolation from other zones and sealing off of the productive zones. For oil well cement to resist the harsh downhole conditions, it has to have a few essential qualities. To sustain the weight of the casing and survive the stress put on it during drilling, cementing, and production activities, it should have a high compressive strength. It must also have low permeability to stop fluid movement and preserve zonal isolation. Due to the harsh circumstances that oil and gas wells may endure over their operating lifetime, high temperature and pressure resistance are also crucial.

Oil well cement is divided into many classes or varieties according to its characteristics and intended uses. Each of these classes has distinct specifications for attributes including strength, setting time, and sulfate resistance. Examples of these classes are Class A, Class G, and Class H cements. Depending on the unique well circumstances, such as temperature, pressure, and the presence of corrosive fluids, the proper class of cement must be chosen. Industry standards and best practices are adhered to to guarantee the correct usage of oil well cement. Operations involving well cementing need meticulous planning, exact design, and precise execution. To confirm the characteristics and functionality of the cement, quality control methods, such as testing and monitoring, are put in place. In conclusion, oil well cement is a specific type of cement used to build and seal oil and gas wells. It offers zonal separation and restricts fluid movement among forms. The cement used in oil wells is made to endure extreme heat, pressure, and corrosive conditions. For the well's integrity and the secure and effective extraction of oil and gas resources, its appropriate selection and use are crucial.

Reinforced Cement Concrete: In order to increase the structural strength and durability of reinforced concrete, also known as reinforced cement concrete (RCC), reinforcing bars (rebars) are combined with concrete to create a composite material. In the construction sector, RCC is frequently utilized for a variety of purposes, including the foundations of buildings, columns, beams, slabs, bridges, and other structural components. Concrete, reinforcement, and formwork make up the three basic elements of RCC. Cement, aggregates (such as sand and gravel), water, and frequently extra additives to enhance workability, strength, or other desirable attributes make up concrete. The reinforcement, which is incorporated inside the concrete to give tensile strength and resistance against cracking and structural failure, is made up of steel bars or mesh that is generally composed of high-strength steel. Throughout the casting and curing processes, the formwork is employed to support and shape the concrete. Because steel is very resistant to tension and concrete is strong in compression but weak in tension, the combination of concrete and reinforcement in RCC has a synergistic effect. In order to resist these pressures and avoid failure or cracking, reinforcing bars are carefully positioned in regions where tensile forces are anticipated, such as the bottom of beams or the stress zone of slabs.

The use of RCC has many advantages. Reinforcement allows RCC constructions to endure greater weights and to more successfully withstand bending, shear, and other external forces than plain concrete. This makes it possible to build bigger, more durable structures that can support enormous loads and withstand adverse weather conditions. Due to the inherent fire resistance of concrete and the protective layer that the reinforcement provides, RCC also delivers good fire resistance. To guarantee safety and structural integrity, RCC structures are designed and built in accordance with recognized engineering principles and norms. Based on the predicted loads and structural requirements, the amount and location of reinforcement are calculated as part of the design process. To provide the RCC components the proper strength and longevity, appropriate compaction, curing, and quality control are required throughout construction. RCC has gained popularity as a building technique because of its adaptability, affordability, and long-term durability. It may be shaped into many different sizes and forms, enabling imaginative architectural ideas and adaptable building techniques.

RCC is a practical option for a variety of building projects due to the accessibility and affordability of cement and steel reinforcement. RCC does, however, have certain restrictions. Compared to other building materials, it is particularly heavy, which could need greater structural support and foundations. Additionally, the presence of reinforcement might make the construction process more difficult and drive up labor and material expenses. RCC constructions can also be vulnerable to corrosion of the reinforcement if they are not correctly planned and built, which reduces their endurance and raises the possibility of structural problems. Finally, reinforced cement concrete (RCC) is a composite material that blends cement and reinforcing bars to produce sturdy constructions. In building applications, RCC offers better strength, resistance to outside influences, and adaptability. In order to guarantee the structural integrity and long-term performance of RCC constructions, proper design, building methods, and adherence to technical standards are essential.

Prestressed Concrete: Pre-applied internal stresses are incorporated into reinforced concrete to increase strength and performance in prestressed concrete. It is frequently used to make tanks, bridges, and other structures with long spans, great load bearing capacity, and resistance to cracking and deformation. The idea behind prestressed concrete is to apply compressive stresses to the concrete before the predicted external loads are applied to it. By balancing out the tensile stresses that develop when the structure is stressed, these compressive stresses improve structural performance and boost load-bearing capacity. Prestressing tendons, which might be high-strength steel cables, bars, or strands, are used to create prestressed concrete. Compressive stresses are applied to the structure by these tendons, which are tensioned and fastened to the concrete. Pre-tensioning and post-tensioning are the two most often used techniques for prestressing. Before the concrete is cast, the tendons are tensioned during pre-tensioning.

Typically, the tendons are positioned in a predetermined arrangement, or precast bed, and then tensioned with hydraulic jacks. The concrete is cast all the way around the tendons after they have been tensioned, allowing the two materials to bind. The tendons are released once the concrete has hardened, transferring the compressive stresses they had on the concrete. The tendons are inserted inside the concrete during post-tensioning after the concrete has been poured and hardened. The tendons are accommodated via ducts or sleeves built into the concrete. The tendons are run through the ducts and tensioned with hydraulic jacks once the concrete has attained the required strength. The prestressing pressures are then applied to the concrete by installing anchors at the ends of the tendons to secure them. There are various benefits to using prestressing in concrete. The structure's ability to handle more weight is greatly increased in the first place, enabling longer spans and shallower structures. Costs are reduced as a result, and resources are used more effectively. Second, since the compressive stresses balance out the tensile stresses brought on by the applied loads, prestressed concrete demonstrates better resilience to cracking and deformation.

The structure's strength and service life are improved as a result. Additionally, prestressed concrete buildings are more resilient to seismic stresses and may withstand huge deflections without suffering major strength losses. Prestressed concrete has many different uses. Prestressed concrete is frequently utilized in bridge building because of the lengthy spans and high load requirements. Precast concrete has advantages for structures with extensive floor surfaces, such as parking garages and industrial buildings. Water tanks, silos, and other constructions requiring great structural strength and stability also use prestressed concrete. For prestressed concrete to be used successfully, certain design and construction methods are required. To achieve the intended structural performance, the design procedure takes into account the projected loads, tendon arrangement, and prestressing force. The integrity and long-term durability of prestressed concrete buildings depend on quality control throughout fabrication and construction. prestressed concrete is a reinforced concrete construction technique that makes use of internal stresses that have already been imposed to increase structural performance and strength. Compared to traditional reinforced concrete, it has a higher load-bearing capacity, a better resistance to cracking, and a shallower structural depth. Wherever exceptional strength and durability are required, such as in bridges, buildings, and storage facilities, prestressed concrete is frequently employed. For prestressed concrete to perform to its full potential, proper design and construction techniques are essential.

Polymer Concrete: A polymer binder, such as epoxy or polyester resin, is mixed with particles to create polymer concrete, a form of composite material. Compared to conventional cement-based concrete, it offers improved mechanical qualities, chemical resistance, and durability. Construction, infrastructure, and industrial settings are just a few sectors where polymer concrete is used. A polymer resin, aggregate materials such as sand, gravel, or crushed stone, and additives are the usual components of polymer concrete. The aggregate particles are held together by the polymer resin, which serves as a binder. Depending on the particular needs of the application, a variety of polymers, such as epoxy, polyester, vinyl ester, or furan resins, can be utilized. Comparing polymer concrete to regular concrete, there are various benefits. It is excellent for applications that call for a high load-bearing capacity as well as resistance to heavy traffic or dynamic loads due to its first-rate strength and impact resistance.

Second, polymer concrete is very resistant to chemicals and can endure exposure to salts, acids, alkalis, and other corrosive materials. This makes it perfect for settings including industrial flooring, wastewater treatment facilities, and containment structures where chemical resistance is required. A further benefit of polymer concrete is that it has low permeability, which minimizes the entry of water and other things that might deteriorate or harm the structure. The polymer resin, particles, and additives are mixed during the production of polymer concrete. The subsequent steps involve casting the slurry into molds or covering already-existing surfaces. Construction timeframes can be shortened since polymer concrete cures more quickly than conventional concrete does. Numerous applications for polymer concrete exist. It is used for architectural details, façade panels, countertops, and flooring systems in the building sector. Due to its great strength and chemical resistance, polymer concrete is employed in infrastructure projects for drainage systems, road repairs, and bridge decking.

For tanks, pipelines, and linings in industrial environments where resistance to strong chemicals is essential, it is also used. While polymer concrete provides a number of benefits, it also has significant drawbacks. Due to the costlier polymer resins and sophisticated production techniques, it may be more expensive than conventional concrete. To ensure compatibility and obtain the necessary qualities, it is crucial to choose the right polymer resin and aggregate mix. For polymer concrete constructions to operate well over time and be durable, proper installation methods and quality control procedures are crucial. In summary, polymer concrete is a composite material that blends aggregates with a polymer binder to produce a material that is high-strength and resistant to chemicals. Compared to conventional cement-based concrete, it offers better mechanical qualities, chemical resistance, and durability. Applications for polymer concrete may be found in the industrial, infrastructural, and construction sectors where high strength and chemical resistance are necessary. To provide ideal performance, it may have greater expenditures and need careful material selection and installation techniques.

Fibre Reinforced Concrete: A type of concrete known as fiber-reinforced concrete (FRC) uses fibers to enhance its performance and mechanical qualities. The concrete matrix gains improved tensile strength, fracture resistance, impact resistance, and durability with the inclusion of fibers. Steel, glass, synthetic polymers like polypropylene or nylon or natural fibers like sisal or jute can all be used to create fibers. Fibers added to concrete produce a three-dimensional reinforcing system that more evenly distributes applied stresses, preventing fracture development and spread. By bridging the fissures that form when the concrete is loaded and increasing the overall toughness of the material, the fibers serve as secondary reinforcement. As a result, the material has improved tensile stress and deformation resistance, improving structural performance.

Different manufacturing processes can be used to create fiber-reinforced concrete. The fibers can be included into the concrete mix as it is being mixed, either directly or by utilizing a pre-blended fiber-reinforced concrete mix. As they are evenly dispersed throughout the concrete matrix, the fibers serve as reinforcement in every direction. Based on the intended qualities and performance demands of the concrete, the fiber content and type are carefully chosen. Increased fracture resistance, higher impact resistance, and improved durability are all advantages of fiber-reinforced concrete. It is especially helpful in reducing drying shrinkage, thermal cracking, and plastic shrinkage cracking, which can happen during the early phases of concrete curing. FRC is frequently utilized in applications including pavements, industrial floors, precast parts, and shotcrete uses where crack control and improved durability are crucial. Based on the particular application and performance demands, the kind and percentage of fibers used in FRC are chosen. To improve the tensile strength and impact resistance of the concrete, steel fibers are frequently utilized. Glass fibers are ideal for applications exposed to severe chemical conditions and have a good resilience to alkalis.

Nylon and polypropylene are examples of synthetic polymer fibers that offer high durability and fracture control. Natural fibers are frequently employed in non-structural applications because they are environmentally friendly and attractive. It is crucial to highlight that, especially for structural parts subjected to heavy stresses, fiber-reinforced concrete does not completely replace the requirement for traditional reinforcing, such as steel reinforcement bars (rebars). The synergistic reinforcing system created by the use of fibers and rebars enhances the performance of the concrete construction. Structures made of fiber-reinforced concrete are designed and built in accordance with defined norms and guidelines. Engineering study and consideration of the unique project needs are used to establish the fiber type, content, and distribution. To provide the intended performance and longevity of the FRC, proper mix design, placement, and curing processes are crucial. fiber-reinforced concrete is a composite material that uses fibers to improve the mechanical characteristics, fracture resistance, impact resistance, and durability of the material. In comparison to traditional concrete, it provides better tensile strength and fracture management. FRC is applied in a variety of ways to increase the durability and performance of concrete buildings. The use of fiber-reinforced concrete requires careful material selection, mix design, and building techniques.

III. CONCLUSION

In the construction business, special cements and cement concrete have several benefits over conventional cementitious materials. These materials have special qualities that enable better functioning and performance in a variety of applications. Strength, durability, and resistance to environmental conditions like high temperatures and chemical assaults may all be improved with the use of specific cements. On the other hand, cement concrete offers adaptability and enables the production of intricate forms and patterns. Despite its benefits, using unique cements and cement concrete has drawbacks, such as increased costs, a restricted supply, and a requirement for specialist knowledge while building. Nevertheless, efforts are still being made in research and development to overcome these problems and raise the materials' availability and cost. Further developments in cement concrete and special cements are predicted in the future. In addition to examining sustainable solutions to lessen the environmental effect of cement production, researchers are investigating innovative additives and mix designs to improve their characteristics and performance. Another area of ongoing study is to increase the lifetime and maintenance of cement-based buildings by creating self-healing and self-cleaning features. Overall, the development and use of unique cements and cement concrete will help to build strong, inventive, and sustainable structures in the future. These materials have enormous promise for the construction sector.

REFERENCES

- [1] C. Zhu et al., Dark, heat-reflective, anti-ice rain and superhydrophobic cement concrete surfaces, *Constr. Build. Mater.*, 2019, doi: 10.1016/j.conbuildmat.2019.05.188.
- [2] S. Pilehvar et al., Effect of freeze-thaw cycles on the mechanical behavior of geopolymer concrete and Portland cement concrete containing micro-encapsulated phase change materials, *Constr. Build. Mater.*, 2019, doi: 10.1016/j.conbuildmat.2018.12.057.
- [3] M. Gou, L. Zhou, and N. W. Y. Then, Utilization of tailings in cement and concrete: A review, *Science and Engineering of Composite Materials*. 2019. doi: 10.1515/secm-2019-0029.
- [4] J. Huo, Z. Wang, H. Chen, and R. He, Impacts of low atmospheric pressure on properties of cement concrete in plateau areas: A literature review, *Materials (Basel)*, 2019, doi: 10.3390/ma12091384.
- [5] P. C. Hewlett and M. Liska, *Lea's chemistry of cement and concrete*. 2019. doi: 10.1016/C2013-0-19325-7.
- [6] S. Yousuf, L. F. M. Sanchez, and S. A. Shammeh, The use of particle packing models (PPMs) to design structural low cement concrete as an alternative for construction industry, *J. Build. Eng.*, 2019, doi: 10.1016/j.jobe.2019.100815.
- [7] T. R. Praveenkumar, M. M. Vijayalakshmi, and M. S. Meddah, Strengths and durability performances of blended

cement concrete with TiO₂ nanoparticles and rice husk ash, *Constr. Build. Mater.*, 2019, doi: 10.1016/j.conbuildmat.2019.05.045.

- [8] D. Shen, Corrosion resistance of carbon steel reinforced solidia cement concrete in corrosive waters: An electrochemical impedance spectroscopy study, *Int. J. Electrochem. Sci.*, 2019, doi: 10.20964/2019.07.20.
- [9] T. Sonal, D. Urmil, and P. Jay, Effect of high temperature on fly ash-based alkali activated concrete compared to Portland cement concrete, *Int. J. Mater. Struct. Integr.*, 2019, doi: 10.1504/IJMSI.2019.103212.
- [10] H. L. Nguyen, C. T. Pham, D. L. Pham, T. A. Pham, D. P. Pham, and B. T. Pham, Designing of concrete pavement expansion joints based on climate conditions of Vietnam, *J. Mech. Behav. Mater.*, 2019, doi: 10.1515/jmbm-2019-0007.