World Journal of Engineering and Technology, 2023, 11, 902-916
https://www.scirp.org/journal/wjet
ISSN Online: 2331-4249
ISSN Print: 2331-4222

Acknowledging the Challenges of Constructing in Regions with Low Temperature

Md Ratan Bhuiyan[1*], Md Rabiul Azam[2], Badal Hossain[3], Md Taruk Aziz[3], Md Abdullah Al Galib[3]

[1]School of Civil Engineering, Hydraulic Engineering, Tianjin University, Tianjin, China
[2]School of Civil Engineering, Tianjin University, Tianjin, China
[3]College of Civil Engineering and Architecture, China Three Gorges University, Yichang, China
Email: *mdratanbhuiyan@tju.edu.cn, azam@tju.edu.cn, badal797@ctgu.edu.cn, tarukaziz7878@gmail.com, galib22@ctgu.edu.cn

How to cite this paper: Bhuiyan, M.R., Azam, M.R., Hossain, B., Aziz, M.T. and Galib, M.A.A. (2023) Acknowledging the Challenges of Constructing in Regions with Low Temperature. *World Journal of Engineering and Technology*, **11**, 902-916.
https://doi.org/10.4236/wjet.2023.114060

Received: October 26, 2023
Accepted: November 26, 2023
Published: November 29, 2023

Abstract

This research paper provides an overview of low-temperature construction processes with an emphasis on the challenges that the sector faces and the creative solutions created to deal with them. Low-temperature construction has particular challenges with regard to technology, materials, worker safety and technological development. It highlights the necessity of customized regulations and procedures aimed at improving the sustainability and efficiency of construction in regions with low temperatures.

Keywords

Construction, Low Temperature, Challenges, Materials, Safety & Technological Development

1. Introduction

Cold weather conditions can significantly affect the strength development of concrete [1]. Construction in low-temperature environments poses a variety of special obstacles in locations that are known for their extreme cold, necessitating creative thinking and careful design. This research is important because climatic variability is becoming more common and infrastructure development in cold climate areas is becoming more and more necessary. Prolonged winters and extreme cold place significant limitations on building operations that impact material characteristics, workability, and worker safety. Particularly in cold weather, and the effects can be significant when long distances separate concrete factories and construction sites, which is not uncommon in regions with cold climate. Delays in placing the concrete due to logistical challenges can exacerbate this issue, as the concrete may experience further temperature drops and reduced workability [2]. The present study explores the various facets of construction in low-temperature settings, emphasizing the critical problems related to this niche field. Through an examination of the unique climate and environmental characteristics of these places, together with the difficulties they present, this study seeks to clarify the crucial subtleties of construction in cold climates.

Consequently, it offers significant perspectives, useful suggestions, and a thorough comprehension of the instruments, technologies, and tactics utilized to surmount these obstacles and promote secure, effective, and environmentally friendly construction methods at extremely low temperatures.

2. Environmental and Climatic Factors

Low-temperature construction poses a distinct set of difficulties that are closely related to the local environment and climate. These regions differ from more temperate construction environments in that they experience prolonged periods of ice formation, frequent snowfall, and temperatures below freezing. To effectively overcome the challenges faced by construction professionals in these regions, it is imperative to comprehend the subtleties of these climate and environmental factors. Due to these harsh environmental conditions, structural adhesive bonding is not yet widely used in civil engineering structures, although it also offers many potential advantages in this field, the most important being the ease of joining different materials (e.g. steel to concrete) and components of complex forms and the rapidity of connection, which is beneficial in bridge construction to prevent extensive traffic interruptions [3].

First and foremost, areas with low temperatures are characterized by intense cold. These areas frequently experience extremely low temperatures during the winter, sometimes even reaching sub-zero levels. The behavior of workers, equipment, and construction materials can all be significantly impacted by such extreme temperatures. The performance of steel, concrete, and other construction materials can be impacted by low temperatures, and excavation and foundation work can be complicated by frozen ground. Cold weather can also lead to increased condensation and moisture accumulation within buildings and structures, potentially resulting in mold growth and structural damage [4]. Furthermore, extended exposure to cold can put construction workers' health and safety in jeopardy, calling for specific safety precautions.

2.1. Challenges in Construction

Low-temperature construction poses a wide range of particular difficulties that have a big influence on project planning, execution, and completion. In **Figure 1**, constructing in regions that have severe winters, a lot of snowfall, cold air, rain, the main issues are snow loads, ice dams and insulation. The freezing of construction materials is one of the biggest problems. When the ambient temperature falls below the freezing point, the water within the concrete mix can freeze, interrupting the cement hydration process and affecting the concrete's strength development [5]. Water-based materials, mortar, and concrete can freeze in cold weather, compromising their structural integrity and making construction more difficult and taking longer than expected. Accelerators and insulating blankets are needed to keep concrete and other construction resources from freezing because their curing times lengthen with decreasing temperatures. Construction projects in cold climates are burdened with additional costs and logistical requirements as a result. A reduced curing rate in cold weather can lead to various challenges and consequences, including increased construction time, safety concerns, compromised durability, and increased costs [6]. Ice formation on construction areas can present a significant risk to worker safety by raising the possibility of mishaps. Maintaining worker safety in below-freezing temperatures is a complex task that calls for strict adherence to safety procedures, ongoing training, and protective gear. Curing of concrete is the process of maintaining proper moisture and temperature conditions within the concrete after it has been placed and finished [7]. Construction projects are more complex and expensive overall due to the requirement for specialized equipment and more man-hours devoted to safety in cold environments.

In low-temperature construction areas, another major challenge is reducing working hours due to extreme cold. Early freezing is a significant concern for concrete structures in cold climates, as it can lead to a reduction in strength, durability, and overall performance [8]. The number of operating hours available each day is limited by the short daylight window and inclement weather. The construction pace is impacted by this shorter workday, which results in longer project durations and higher labor costs. Additionally, it calls for the use of heating tools and makeshift enclosures to provide a controlled environment so that work can continue in below-freezing temperatures. These steps have a unique set of drawbacks, including higher fuel consumption, ventilation needs, and fire safety issues. Furthermore, the restricted working hours make the already strict construction schedules worse, which can lead to delays that affect the project as a whole.

One of the biggest challenges facing the construction industry in colder climates is ensuring that the built environment is durable and of high quality. Due to these harsh environmental conditions, structural adhesive bonding is not yet widely used in civil engineering structures, although it also offers many potential advantages in this field, the most important being the ease of joining different materials (e.g. steel to concrete) and components of complex forms and the rapidity of connection, which is beneficial in bridge construction to prevent extensive traffic interruptions [3]. The long-term structural integrity of infrastructure and constructions can be impacted by excessive cold. The thermal stress that materials experience when exposed to below-freezing temperatures can cause cracks and other weaknesses in the structure. Particularly in cold weather, the effects can be significant when long distances separate concrete factories and construction sites, which is not uncommon in regions with cold climate. Delays in placing the concrete due to logistical challenges can exacerbate this issue, as the concrete may experience further temperature drops and reduced workability [2]. Integrating adequate heating and insulation is necessary to preserve the structural integrity of constructions. Furthermore, winter weather can make it more difficult to complete important tasks that are necessary for precise construction, like precise surveying and ground testing. This reduces the built environment's accuracy and quality, raising maintenance costs and the possibility of structural problems in the future. To overcome these obstacles, constructing in cold climates necessitates sophisticated project planning, careful selection of materials, safety precautions, and specialized construction methods, all of which raise the process's complexity and expense.

Finally, it should be noted that constructing properties in cold climates comes with a variety of difficulties, such as frozen construction supplies, shortened workdays, and worries about the long-term strength and quality of the structures. Innovative solutions, specialized tools, strict safety precautions, and careful planning are needed to overcome these obstacles. Since construction in cold climates is still essential to the development of regions, the construction industry must successfully address these issues in order to ensure that projects that can withstand the harsh winter weather are completed.

Figure 1. Challenges in Construction (https://robertdebry.com/the-dangers-of-cold-weather-on-a-construction-site/).

2.2. Environmental Impact and Considerations

It is crucial to address the environmental impact of construction activities in low-temperature areas, in addition to the challenges unique to the construction industry. Extended usage of large machinery and generators for energy supply and heating may result in higher resource consumption and emissions. As a result, sustainability and ecologically friendly construction techniques are receiving more attention. To lessen the carbon footprint associated with construction in cold climates, researchers and practitioners are looking into creative solutions like using renewable energy sources and environmentally certified construction materials. Cold weather concrete construction has been an active area of research for several years, with numerous studies focusing on the challenges related to setting [9], curing [10], strength development [11], and drying [12], as well as frost damage [13], early freezing [14], and freeze-thaw cycles [15]. Additionally, the local ecosystems and wildlife can be greatly impacted by the environmental conditions in colder regions. Concerns include soil erosion, construction-related pollution, and disturbance of natural habitats. In order to reduce their ecological impact, construction projects in these areas must follow environmental regulations and use responsible construction practices.

To sum up, construction projects face distinct challenges due to the climate and environmental factors prevalent in regions with low temperatures. In order to ensure worker safety, address the ecological footprint of construction activities, and develop effective construction strategies, it is essential to comprehend the effects of extreme cold, snowfall, and their environmental impact. With this knowledge, creative solutions and environmentally friendly methods can be developed that are specifically suited to the challenges of construction in cold climates.

3. Components and Constructing Strategies

A deliberate approach to material selection, construction techniques, and creative adjustments is necessary for construction in low-temperature environments. Construction methods should be adapted to the particular difficulties presented by low temperatures, and the materials utilized must be able to tolerate extremely cold temperatures. The creation of robust infrastructure and structures in these difficult settings is ultimately facilitated by the constant exploration of innovations and adaptations aimed at improving the effectiveness, safety, and sustainability of construction in cold climates.

3.1. Materials Used in Construction

The best building materials for cold climates are not always the most durable. If you live in a cold environment, then you know that it's important to build with durable materials. **Figure 2** is the Building Materials—Brick, Stone, Concrete, Plastic, Wood & Metal (Best Building Materials for Cold Climates (http://constrofacilitator.com/)). Concrete is a most commonly used construction material [16] [17]. Choosing the right materials for a construction project in a low-temperature region is essential to guaranteeing the long-term stability, safety, and durability of the infrastructure and constructions. Conventional construction products face particular challenges in these regions due to the extreme cold and unfavorable weather. Therefore, it's usually preferred to use specialized materials that can endure the harsh climate while maintaining their structural integrity. The main material used is concrete, but it needs to be altered in order to successfully withstand cycles of freezing and thawing. Repeated freezing and thawing cycles can have significant adverse effects on the performance and durability of concrete structures in cold climates [18].

To increase the durability of concrete, mixtures containing air-entraining agents and additional cementitious materials, like fly ash or slag, are frequently used. Although it is susceptible to freezing temperatures, steel is still another essential component of construction. Therefore, to shield steel components from the corrosive effects of low temperatures, galvanization or corrosion-resistant coatings may be applied. In order to stop heat loss and keep a comfortable interior temperature, high-performance insulation materials like expanded or extruded polystyrene must be used for thermal insulation in walls and roofs.

Figure 2. Building materials for cold climates—(Best Building Materials for Cold Climates (http://constrofacilitator.com/)).

3.2. Constructing Strategies

Construction methods in low-temperature regions must consider the difficulties presented by cold weather, short days, and snow buildup. The organizing and timing of construction operations is one crucial component. By ensuring proper curing, contractors can optimize the performance, durability, and service life of concrete structures, making it a critical aspect of the overall construction process [2]. Project schedules in cold climates with shortened workdays in the winter should be carefully designed to account for variations in temperature and seasonal shifts. For example, scheduling the construction can take advantage of the best weather and daylight throughout the warmer months. In addition, insulation and temporary heating are frequently used to keep workers' working conditions as good as possible. By taking these precautions, construction efficiency is increased while simultaneously ensuring worker safety and comfort. To minimize problems like cracking and decreased structural integrity, specialized construction equipment is utilized to shield materials from freezing temperatures. Implementing appropriate preventive measures and strategies can help mitigate the risks of frost damage, ensuring the durability, performance, and longevity of the concrete structures [19]. One example of this equipment is heated enclosures for concrete drying. Lastly, it's crucial to maintain and cure construction parts properly. For instance, to maintain the required temperature for curing, insulated blankets or heating components are frequently used in cold-weather concrete curing situations.

3.3. Advancements and Modifications

Innovative modifications and solutions have been created recently to enhance the construction process in cold climates. To prevent issues related to longer setting and slower curing of concrete in cold weather, various measures can be implemented to ensure the quality, performance, and durability. Chemical admixtures, such as accelerators, can be added to the concrete mix to accelerate the hydration process and reduce the setting time. These admixtures can help the concrete to achieve the desired strength faster, minimizing the impact of cold weather [20]. Prefabricated or modular components, for example, are becoming more and more common because they enable regulated manufacture in indoor spaces, minimizing exposure to cold weather. Cutting-edge construction technology, including Building Information Modeling (BIM), has been used to improve project coordination and planning, which has increased project efficiency and decreased rework. In order to lessen the environmental effect of construction in cold areas, green construction approaches are also becoming more common. These practices include the integration of renewable energy systems, energy-efficient construction envelopes, and sustainable construction materials.

In addition, The creation of concrete that has the ability to mend tiny fractures brought on by freeze-thaw cycles holds potential for increasing the longevity of constructions in cold climates.

4. Safety Considerations

In the construction industry, safety is crucial, especially in cold with windy climates where workers are exposed to more risks and difficulties which one shown in **Figure 3**. Windy conditions on the construction site can create safety hazards, reduce worker productivity, and cause damage to structures and materials. Erecting wind barriers, such as windbreaks or temporary enclosures, can help protect the construction site and its occupants from the effects of strong winds [21]. In these kinds of settings, protecting the health and safety of construction workers is not only required by law but also crucial to the accomplishment of projects. This section will examine the safety factors unique to construction in cold climates, emphasizing important problems and precautions.

One of the main issues for safety in low-temperature settings is the possibility of cold-related diseases and injuries. Long-term exposure to very low temperatures can result in frostbite, hypothermia, and cold stress. Inadequate protection can cause workers to lose dexterity, make worse decisions, and respond more slowly, all of which can lead to mishaps on the job site. Accumulated snow and ice can pose significant safety risks and impede construction operations. Implementing a comprehensive snow and ice removal plan, including the use of snowplows, snow blowers, and de-icing agents, can help ensure a safe and efficient construction site [22]. Thus, it is essential that construction businesses that work in cold areas have strong worker protection policies into place. This entails bringing the proper gear and apparel, planning regular warm-up breaks, and providing hot drinks and shelter while on the job. Employees may take the necessary precautions and identify the early symptoms of cold-related diseases with the support of training and awareness campaigns.

The handling and operation of machinery and equipment is a crucial aspect of low-temperature construction safety. When workers come into close touch with extremely cold metal equipment and machinery, it can cause pain and, in severe situations, frostbite. Furthermore, at low temperatures, hydraulic and lubricating fluids in heavy machinery may lose some of their effectiveness, which might result in equipment failures. Construction organizations need to make sure that workers have access to heated tool handles and insulated gloves in order to reduce these dangers. To keep machinery functioning safely and effectively, routine equipment maintenance and appropriate winterization methods are also necessary.

Another major worry in chilly climates is slip-and-fall incidents. Walking surfaces that have accumulated snow and ice may become slick, raising the possibility of accidents and injury. Maintaining de-icing products and plowing as needed will be essential in keeping construction sites free of snow and ice. In order to lower the risk of accidents, workers should be given anti-slip footwear, and specific pathways should be created and maintained. In order to improve visibility and lower the chance of trips and falls during the gloomy winter months, adequate lighting is also crucial.

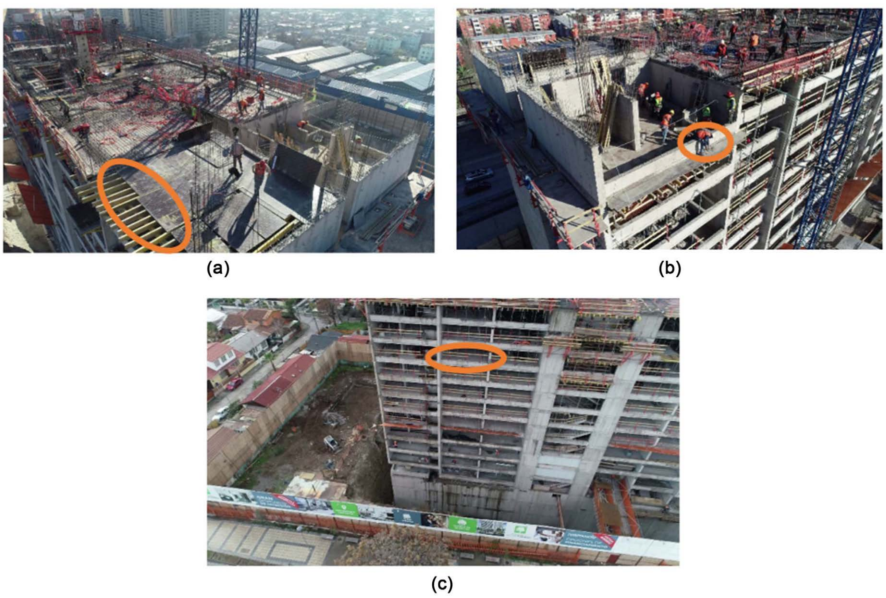

Figure 3. UAV images for safety monitoring at a construction site in Chile: (a) lack of guardrails; (b) worker without safety rope; and (c) lack of guardrails (Images by Jhonattan G. Martinez) [23].

In summary, there are many different aspects to safety concerns while constructing in cold climates, and a thorough and proactive approach is needed. Protecting employees from cold-related diseases and injuries should be a primary focus since worker well-being is so important. This entails supplying the appropriate attire, tools, and instruction in addition to establishing a setting that promotes safety and awareness. To further avoid malfunctions and mishaps, proper maintenance and winterization of machinery and equipment are essential. Finally, maintaining a safe working environment requires managing the hazards of slips and falls through appropriate snow and ice removal, anti-slip devices, and suitable illumination. Construction organizations may optimize worker welfare and project performance in low-temperature environments by taking these safety issues into account.

5. Construction's Effect on the Environment in Low-Temperature Areas

The effects of construction on the environment are only one of the particular difficulties and factors that come with constructing in cold climates we can see in **Figure 4**. The growth of construction processes in cold areas necessitates an awareness of the environmental repercussions. This section explores how development in low-temperature places affects the environment, covering issues such as energy use, pollution, and ecological damage.

Figure 4. Spalling of concrete due to cracking and corrosion in a cold climate [24].

5.1. Energy Consumption and Emissions

Increased energy usage is one major environmental issue related to construction in cold climates. Construction projects' carbon footprint is directly impacted by cold temperatures, which require more energy for heating. Fossil fuel consumption increases greenhouse gas emissions, which exacerbates climate change when it comes to heating and mechanical functioning. An array of energy-efficient technology, solar or geothermal heating alternatives, and insulating materials are examples of environmentally friendly construction approaches that may help lessen the impact on the environment. Construction projects may save money in the long run by implementing energy-efficient measures, which can also cut emissions. In order to reduce the carbon footprint in cold-weather construction, it is essential that legislators and the construction industry work together to promote energy-efficient alternatives.

5.2. Ecological Disruption

Low-temperature construction frequently necessitates excavation, which modifies the surrounding environment and disrupts local ecosystems. Excavation can seriously disturb the ground's stability in northern areas where permafrost is common, which could result in long-term harm. Permafrost may thaw as constructing continues, releasing strong greenhouse gas methane into the sky. Furthermore, in frigid regions, migration patterns can be disrupted and wildlife habitats might be fragmented by road construction and other infrastructure projects. Construction projects can incorporate mitigating measures, such as animal corridors, replanting, and decreasing the footprint of infrastructure, to solve these ecological problems. Planning ahead and following environmental laws will assist in lessening the impact on nearby ecosystems.

5.3. Sustainable Practices

There are initiatives afoot to improve the sustainability of structures constructed in regions with low temperatures. Reducing environmental impact and promoting resilience are the goals of these activities. Prefabrication and modular construction, for instance, can cut down on energy use and on-site trash. Reducing transportation emissions can be achieved by using locally sourced resources. Furthermore, the environmental impact may be reduced by using less intrusive construction methods, including using lightweight materials. Sustainable construction practices also include appropriate waste and water management. Adoption of eco-friendly practices can be stimulated by promoting certifications that are environmentally friendly, such as LEED (Leadership in Energy and Environmental Design), for cold-weather construction. All things considered, it is critical that the construction sector give top priority to environmentally friendly methods that simultaneously protect the long-term viability of the ecosystems in regions with low temperatures.

In conclusion, there are environmental effects associated with constructing in cold climates; however, they may be minimized by careful planning, the use of sustainable practices, and the use of energy-efficient technology. It is critical to recognize the environmental impact of the construction industry's growth and expansion into colder climates, and to strive toward more conscientious and environmentally conscious construction techniques. Construction in low-temperature settings may live with nature while lowering its carbon footprint and ecological damage by taking into account the long-term environmental impacts and putting mitigation measures in place.

6. Technological Developments in Low-Temperature Construction

Although there are particular difficulties when construction is in cold climates, technological developments have greatly increased the productivity, security, and caliber of projects carried out in these conditions. This section will examine significant technical developments that have been instrumental in resolving the difficulties associated with cold-weather construction.

6.1. Modern Heating and Insulation Systems

Preserving a workable atmosphere and avoiding material freezing are two of the most important components for constructing in cold climates. Technological advancements in heating systems and insulation have completely transformed the sector. While portable heating systems provide a regulated environment within construction zones, insulated forms and panels offer an efficient defense against extremely cold temperatures. Proper winterization applications, including engine block heaters, antifreeze, and cold-weather lubricants, can help protect equipment and machinery from the effects of low temperatures [25]. One important factor in lowering energy use has been the use of polystyrene foam boards, which block heat escape through walls and foundations. Furthermore, subterranean radiant heating systems not only keep workers comfortable, but they help quicken the curing process for concrete and keep water-based products from freezing. Because these devices are remotely controllable, constructing may continue even in extremely frigid temperatures while assuring efficient energy consumption. Consequently, and due to the normal large scale of the structural components, cold-curing adhesives can be used, unlike in other fields where hot-curing adhesives are applied indoors [26].

6.2. Modular Construction and Prefabrication

The use of prefabrication and modular construction technologies has become more common in cold climates because of its effectiveness and capacity to reduce exposure to inclement weather. Using these techniques, construction components are assembled in controlled industrial settings before being transported to the construction site.

In **Figure 5**, Building Information Modeling (BIM) has made it possible to manufacture components precisely, guaranteeing that they will fit together perfectly when assembled on-site. This cuts down on the amount of time construction workers must spend in bitter cold in addition to cutting down on construction time. Modular construction techniques also cut down on material waste since leftover materials may be sent back to the producer to be utilized in other projects. This method is especially sustainable in colder climates where trash disposal and transportation might be difficult.

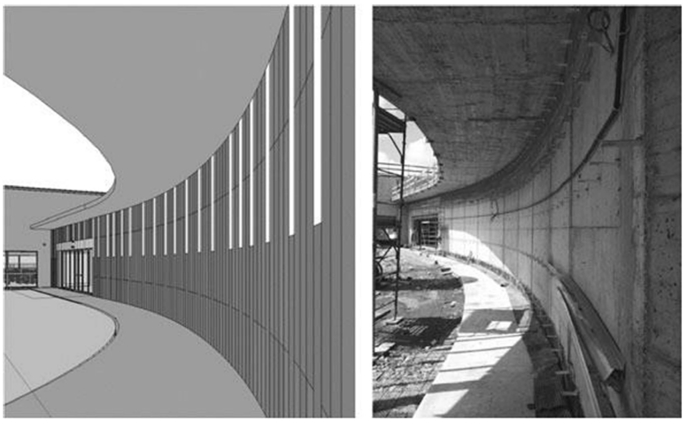

Figure 5. Contribution of BIM in the construction phase [27].

6.3. Remote Sensing and Drones

In cold-weather construction operations, drones and remote sensing technology have become essential instruments. Drones have rapidly evolved from being mere novelties to indispensable tools in the construction sector. By utilizing different types of drones, construction professionals can optimize their workflow, improve project coordination, and mitigate risks [28] [29].

In **Figure 6**, drones using thermal imaging cameras may detect heat loss in structures fast, allowing for timely repairs and avoiding freezing. They also lessen the need for people to be on-site all the time by helping with surveying, site inspections, and construction progress monitoring. Regularly or continuously monitoring the temperature and strength development of the concrete is crucial during cold weather construction [30]. Additionally, subsurface studies are aided by remote sensing technology like ground-penetrating radar and LiDAR (Light Detection and Ranging), which may discover possible dangers like subterranean ice formations. These technologies improve efficiency and safety by offering useful information for project planning and implementation.

The field of low-temperature constructing has seen a dramatic change as a result of technology breakthroughs. Construction efficiency, safety, and sustainability have all increased thanks to the employment of drones and remote sensing technologies, prefabrication and modular construction, and sophisticated insulation and heating systems. These developments not only lessen the particular difficulties presented by cold climates, but also pave the way for more ambitious and environmentally friendly construction initiatives in these areas. Even in the worst winter weather, the construction sector is expected to prosper as long as it adopts this technology.

7. Conclusion

Low-temperature constructing has a distinct set of difficulties that need creative fixes and modifications. The unique challenges brought about by extremely cold temperatures have been brought to light by this research, including material freezing, shortened workdays, and safety issues. However, the constructing

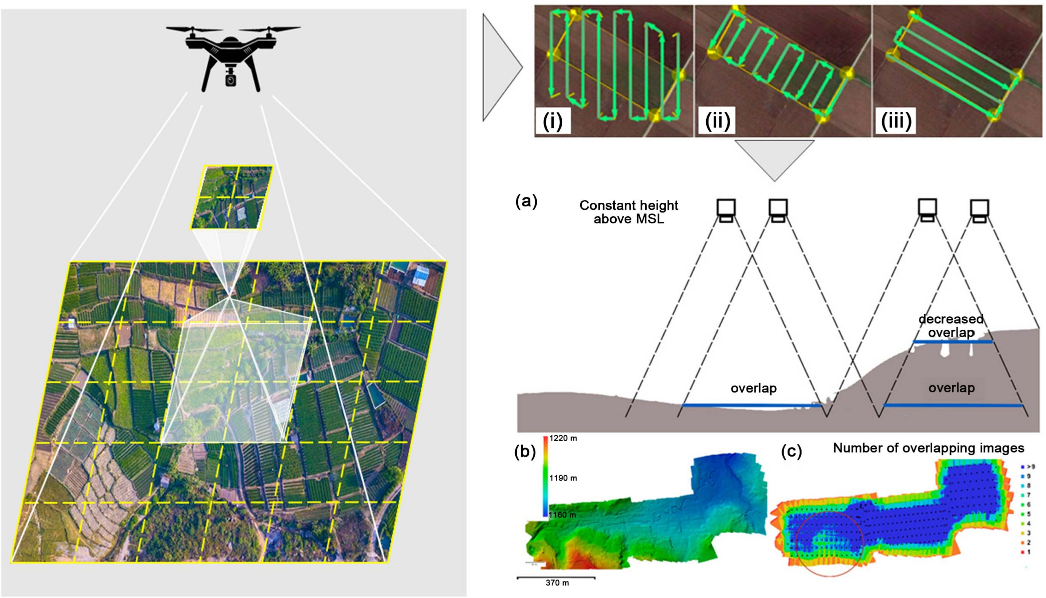

Figure 6. A general process for generating a digital terrain model with a drone [31].

industry has made great strides toward resolving these issues with a mix of cutting-edge materials, construction methods, and technology breakthroughs. It is clear that in low-temperature construction, efficiency, sustainability, and safety must always come first. Future study and ongoing adaption strategy development will be essential to guarantee the successful completion of construction projects in these difficult situations.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Bagheri-Zadeh, S.H., Kim, H., Hounsell, S., Wood, C.R., Soleymani, H. and King, M. (2007) Field Study of Concrete Maturity Methodology in Cold Weather. *Journal of Construction Engineering and Management*, **133**, 827-835. https://doi.org/10.1061/(ASCE)0733-9364(2007)133:11(827)

[2] Nilimaa, J. and Zhaka, V. (2023) An Overview of Smart Materials and Technologies for Concrete Construction in Cold Weather. *Eng*, **4**, 1550-1580. https://doi.org/10.3390/eng4020089

[3] Motavalli, M., Terrasi, G.P. and Meier, U. (1997) On the Behaviour of Hybrid Aluminium/CFRP Beams at Low Temperatures. *Composites Part A*: *Applied Science and Manufacturing*, **28**, 121-129. https://doi.org/10.1016/S1359-835X(96)00100-5

[4] Brambilla, A. and Sangiorgio, A. (2020) Mould Growth in Energy Efficient Buildings: Causes, Health Implications and Strategies to Mitigate the Risk. *Renewable and Sustainable Energy Reviews*, **132**, Article ID: 110093. https://doi.org/10.1016/j.rser.2020.110093

[5] Jamolovich, T.U. (2022) Modern Methods for Controlling the Strength of Concrete in the Structures of Monolithic Buildings. *Academicia Globe*: *Inderscience Research*,

3, 588-595.

[6] Yu, K., Jia, M., Yang, Y. and Liu, Y. (2023) A Clean Strategy of Concrete Curing in Cold Climate: Solar Thermal Energy Storage Based on Phase Change Material. *Applied Energy*, **331**, Article ID: 120375. https://doi.org/10.1016/j.apenergy.2022.120375

[7] Taylor, P.C. (2013) Curing Concrete. CRC Press, Boca Raton, 7-10.

[8] Wang, R., Zhang, Q. and Li, Y. (2022) Deterioration of Concrete under the Coupling Effects of Freeze-Thaw Cycles and Other Actions: A Review. *Construction and Building Materials*, **319**, Article ID: 126045. https://doi.org/10.1016/j.conbuildmat.2021.126045

[9] Ryou, J.S. and Lee, Y.S. (2012) Properties of Early-Stage Concrete with Setting-Accelerating Tablet in Cold Weather. *Materials Science and Engineering: A*, **532**, 84-90. https://doi.org/10.1016/j.msea.2011.10.066

[10] Liu, Y., Tian, W. and Ma, G. (2023) Electric Activation Curing Behaviour of Reinforced Concrete Beam under Severely-Cold Environment: Breakthrough of Rapid Concrete Manufacturing at Cold Region. *Construction and Building Materials*, **384**, Article ID: 131443. https://doi.org/10.1016/j.conbuildmat.2023.131443

[11] Ortiz, J., Aguado, A., Agulló, L. and Garcia, T. (2005) Influence of Environmental Temperatures on the Concrete Compressive Strength: Simulation of Hot and Cold Weather Conditions. *Cement and Concrete Research*, **35**, 1970-1979. https://doi.org/10.1016/j.cemconres.2005.01.004

[12] Nilimaa, J. and Zhaka, V. (2023) Material and Environmental Aspects of Concrete Flooring in Cold Climate. *Construction Materials*, **3**, 180-201. https://doi.org/10.3390/constrmater3020012

[13] Şahin, Y., Akkaya, Y. and Taşdemir, M.A. (2021) Effects of Freezing Conditions on the Frost Resistance and Microstructure of Concrete. *Construction and Building Materials*, **270**, Article ID: 121458. https://doi.org/10.1016/j.conbuildmat.2020.121458

[14] Sang, Y. and Yang, Y. (2020) Assessing the Freezing Process of Early Age Concrete by Resistivity Method. *Construction and Building Materials*, **238**, Article ID: 117689. https://doi.org/10.1016/j.conbuildmat.2019.117689

[15] Wang, R., Hu, Z., Li, Y., Wang, K. and Zhang, H. (2022) Review on the Deterioration and Approaches to Enhance the Durability of Concrete in the Freeze-Thaw Environment. *Construction and Building Materials*, **321**, Article ID: 126371. https://doi.org/10.1016/j.conbuildmat.2022.126371

[16] Statista. Global Cement Production from 1995 to 2022. https://www.statista.com/statistics/219343/cement-production-worldwide/

[17] Monteiro, P.J., Miller, S.A. and Horvath, A. (2017) Towards Sustainable Concrete. *Nature Materials*, **16**, 698-699. https://doi.org/10.1038/nmat4930

[18] Qiu, W.L., Teng, F. and Pan, S.S. (2020) Damage Constitutive Model of Concrete under Repeated Load after Seawater Freeze-Thaw Cycles. *Construction and Building Materials*, **236**, Article ID: 117560. https://doi.org/10.1016/j.conbuildmat.2020.120720

[19] Kurihashi, Y., Konno, H. and Hama, Y. (2021) Effects of Frost-Damaged Reinforced Concrete Beams on Their Impact Resistance Behavior. *Construction and Building Materials*, **274**, Article ID: 122089. https://doi.org/10.1016/j.conbuildmat.2020.122089

[20] Ren, G., Tian, Z., Wu, J. and Gao, X. (2021) Effects of Combined Accelerating Admixtures on Mechanical Strength and Microstructure of Cement Mortar. *Construc-*

tion and Building Materials, **304**, Article ID: 124642. https://doi.org/10.1016/j.conbuildmat.2021.124642

[21] Shin, Y.S. and Kim, G.H. (2014) A Comparison of the Economic Feasibility of the Protecting Tent Method and SCSFM Method for Heat Curing of Cold-Weather Concrete. *Applied Mechanics and Materials*, **651**, 1311-1314. https://doi.org/10.4028/www.scientific.net/AMM.651-653.1311

[22] Rahman, M.L., Malakooti, A., Ceylan, H., Kim, S. and Taylor, P.C. (2022) A Review of Electrically Conductive Concrete Heated Pavement System Technology: From the Laboratory to the Full-Scale Implementation. *Construction and Building Materials*, **329**, Article ID: 127139. https://doi.org/10.1016/j.conbuildmat.2022.127139

[23] Martinez, J.G., Gheisari, M. and Alarcón, L.F. (2020) UAV Integration in Current Construction Safety Planning and Monitoring Processes: Case Study of a High-Rise Building Construction Project in Chile. *Journal of Management in Engineering*, **36**, Article ID: 05020005. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000761

[24] Adachi, Y., Hirakawa, H., Fukushima, A., Uematsu, T., Kikuta, K. and Taniguchi, M. (2022) Investigation of the Deterioration of Medium-Rise-Wall Type Reinforced Concrete Buildings with External Insulation in Snowy Cold Districts. *Buildings*, **12**, Article No. 2048. https://doi.org/10.3390/buildings12122048

[25] Huang, D., Chen, Z. and Zhou, S. (2022) Self-Powered Heating Strategy for Lithium-Ion Battery Pack Applied in Extremely Cold Climates. *Energy*, **239**, Article ID: 122095. https://doi.org/10.1016/j.energy.2021.122095

[26] Moussa, O., Vassilopoulos, A.P. and Keller, T. (2012) Effects of Low-Temperature Curing on Physical Behavior of Cold-Curing Epoxy Adhesives in Bridge Construction. *International Journal of Adhesion and Adhesives*, **32**, 15-22. https://doi.org/10.1016/j.ijadhadh.2011.09.001

[27] Toyin, J.O. and Mewomo, M.C. (2022) Overview of BIM Contributions in the Construction Phase: Review and Bibliometric Analysis. *Journal of Information Technology in Construction*, **28**, 500-514. https://doi.org/10.36680/j.itcon.2023.025

[28] Shanti, M.Z., Cho, C.S., de Soto, B.G., Byon, Y.J., Yeun, C.Y. and Kim, T.Y. (2022) Real-Time Monitoring of Work-at-Height Safety Hazards in Construction Sites Using Drones and Deep Learning. *Journal of Safety Research*, **83**, 364-370. https://doi.org/10.1016/j.jsr.2022.09.011

[29] Zhang, Y. and Zhang, K. (2021) Design of Construction Site Dust Detection System Based on UAV Flying Platform. 2021 *IEEE International Conference on Control Science and Electric Power Systems* (*CSEPS*), Shanghai, 28-30 May 2021, 148-151. https://doi.org/10.1109/CSEPS53726.2021.00036

[30] Huang, H., Huang, T., Yuan, Q., Zhou, D., Deng, D. and Zhang, L. (2019) Temperature Dependence of Structural Build-Up and Its Relation with Hydration Kinetics of Cement Paste. *Construction and Building Materials*, **201**, 553-562. https://doi.org/10.1016/j.conbuildmat.2018.12.226

[31] Jiménez-Jiménez, S.I., Ojeda-Bustamante, W., Marcial-Pablo, M.D.J. and Enciso, J. (2021) Digital Terrain Models Generated with Low-Cost UAV Photogrammetry: Methodology and Accuracy. *ISPRS International Journal of Geo-Information*, **10**, Article No. 285. https://doi.org/10.3390/ijgi10050285