Effect of Construction Delays and the Preventive Role of Concrete Works Optimization: Systematic Literature Review

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Abstract **– Delays in construction are a widespread global problem, leading to potential cost overruns and legal disputes. Additionally, delays can result in a decline in construction quality and loss of public trust. The aim of this study is to examine the effects of project delays in various regions and the preventive role of optimizing concrete works. Literature review and bibliometric analysis are carried out to determine global research trends. Findings show that optimizing concrete works can provide benefits such as cost savings, time savings, improved quality and safety, and environmental benefits. Optimization of concrete material composition is one of the most examined topics in this field. Based on the findings, construction firms have the potential to attain cost efficiencies while concurrently mitigating carbon emissions.**

Keywords **– Construction delays, concrete works optimization, cost saving, time saving, sustainability improvement.**

1. Introduction

A primary challenge encountered in developing nations, including Indonesia, are delays in construction projects, leading to potential losses and penalties [1].

DOI: 10.18421/TEM132-34
https://doi.org/10.18421/TEM132-34

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Received: 05 December 2023.
Revised: 22 March 2024.
Accepted: 29 March 2024.
Published: 28 May 2024.

Construction delays have become frequent in developed countries such as Nigeria, where most projects allocate 5%–10% of their budget for contingencies and unforeseen expenses [2]. Malaysia has also faced the same scenarios, where 55% of construction projects have faced cost overruns due to delays [3]. In India, 474 construction projects have suffered delays and 309 have suffered cost overruns according to the Ministry of Statistics and Programme Implementation [4]. This problem is not only experienced by developing countries. In Singapore, construction delays occur in 16% of conventional reinforced concrete building projects, of which 32% are green building projects [5]. Qatar, with the highest savings rate in the world, has also faced schedule and cost overruns. Almost 72% of their construction projects from 2000–2013 has suffered schedule delays [6]. In 2017, the Saudi Arabian Ministry of Municipal and Rural Affairs acknowledged that an estimated 75% of public construction projects experienced budget overruns and were behind schedule [7]. A survey with several contractors in Saudi Arabia in 2006 concluded that 76% of projects experienced delays of 10%–30% [8].

In construction projects throughout the world, concrete remains the dominant material used [9]. However, as the amount of concrete used in construction increases, global carbon emissions also increase [10]. In building projects, working with reinforced concrete structures work is considered a critical path. The average concrete work contributes to the project cost by 12% and reinforcing steel by 22% [11]. Any delay causes an increase in costs and other material losses. In addition, delays in construction projects therefore result in an increase in carbon emissions [11].

Several acceleration techniques have been used to avoid delays, such as fast-tracking or crashing as shown in Figure 1. This technique usually requires a cost allocation of 5%–10% of contingency costs [2]. An effective acceleration can be obtained by crashing on work that is considered a critical path [12].

In addition, optimization is believed to be a solution that produces not only acceleration but also efficiency. In concrete construction, optimization methods can be carried out to produce time and cost efficiencies [13]. Consequently, research is necessary to discover which specific optimization techniques can be utilized to effectively overcome delays.

Nowadays, sustainability has become a widely researched topic. 30%–40% of greenhouse gas emissions are contributed by the construction sector [11]. Gas released to the atmosphere during cement manufacturing contributes 8% of the total global greenhouse gases emission [14]. In 2021, developed nations, including the United States, manufactured one hundred million tons of cement for use in concrete building materials [14]. Although still considered costly, the use of more environmentally favorable materials or green materials is expected to decrease greenhouse gas (GHG) emissions [11].

This study aims to find gaps in previous literature that have discussed the various effects of construction delays and the role of optimizing concrete work as an alternative solution. The review of concrete work optimization does not only focus on time efficiency but also includes cost efficiency, safety improvement, and sustainability aspects.

2. Research Method

A literature review is conducted on a variety of articles for this investigation from several journals with the main focus on construction delays and concrete optimization. All keywords related to these topics have been collected to investigate the research trend and correlation between each keyword as shown in Figure 2. The selected papers are sorted by newest to oldest to determine the common and current studies.

From the several papers that have been collected, a review and analysis of the above-mentioned correlation is carried out to draw conclusions about the effect of construction delay and how concrete work optimization can be a preventive solution. Several recommendations obtained from several papers are then analyzed and compared, to determine opportunities for new innovative ideas that can be useful for solving cases related to construction delays. Data distribution including years and distribution in various countries are shown in Figure 3 and Figure 4.

China is the country with the most research related to concrete optimization, followed by India. In Middle Eastern countries, namely Egypt, Iran, and Saudi Arabia, the research topics of construction delay and concrete optimization are also quite popular. Meanwhile, in Indonesia, not many similar studies have been found.

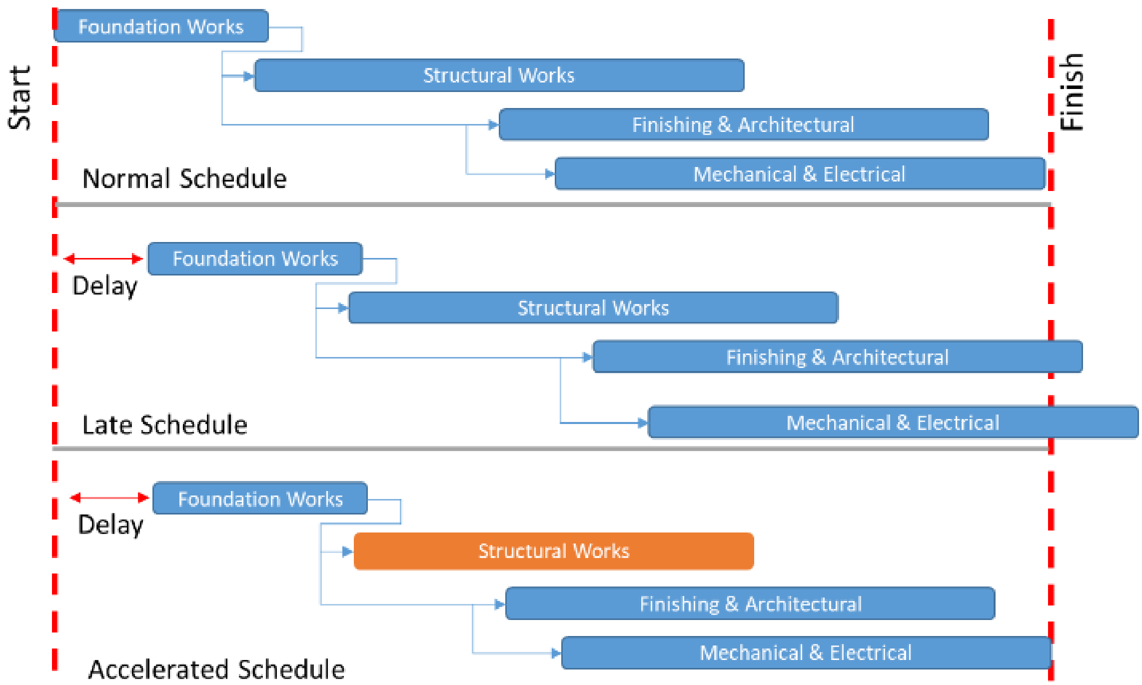


Figure 1. Construction delay and acceleration illustration in RC building project

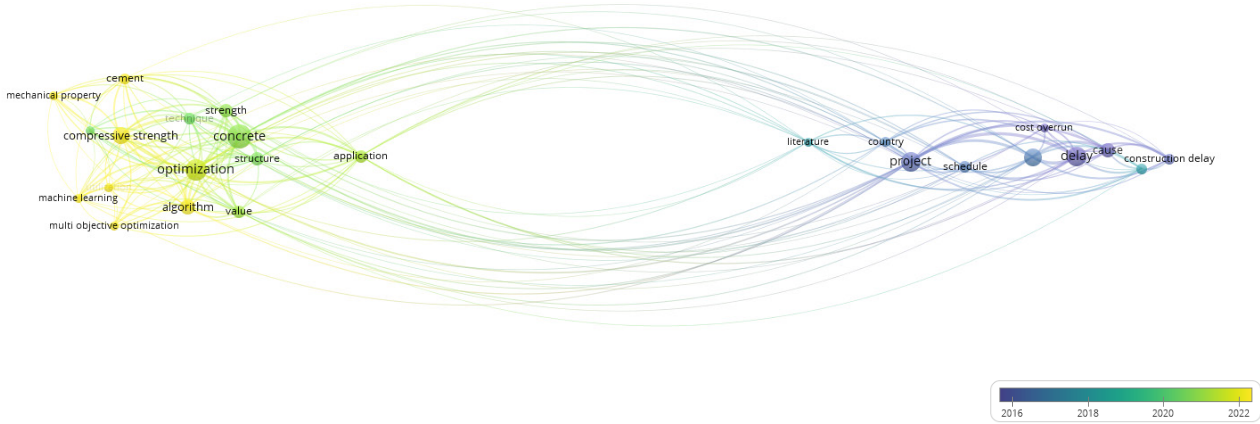


Figure 2. Bibliometric analysis on construction delays and concrete optimization

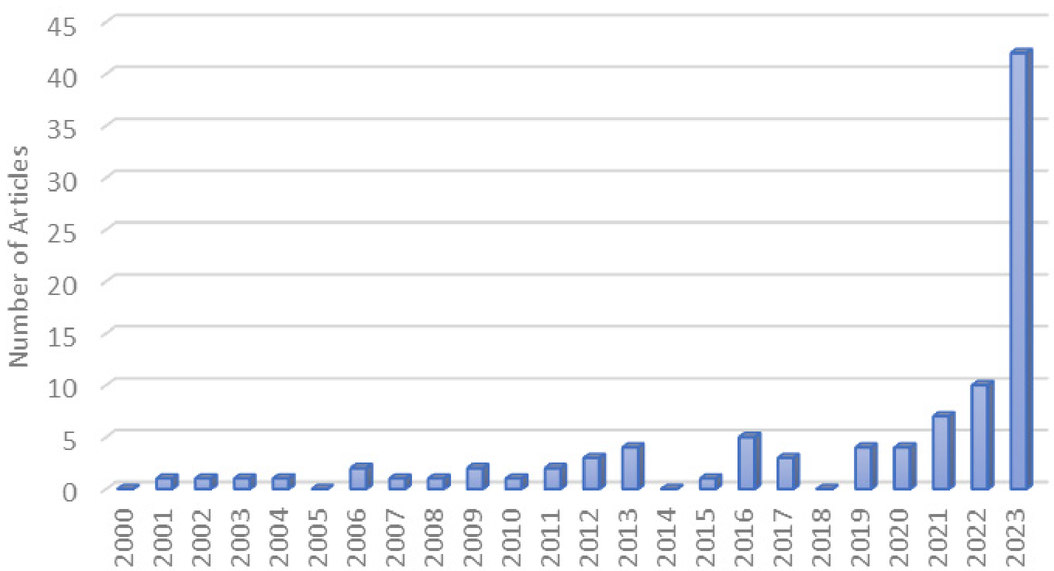


Figure 3. Yearly distribution of research articles regarding construction delays and concrete optimization

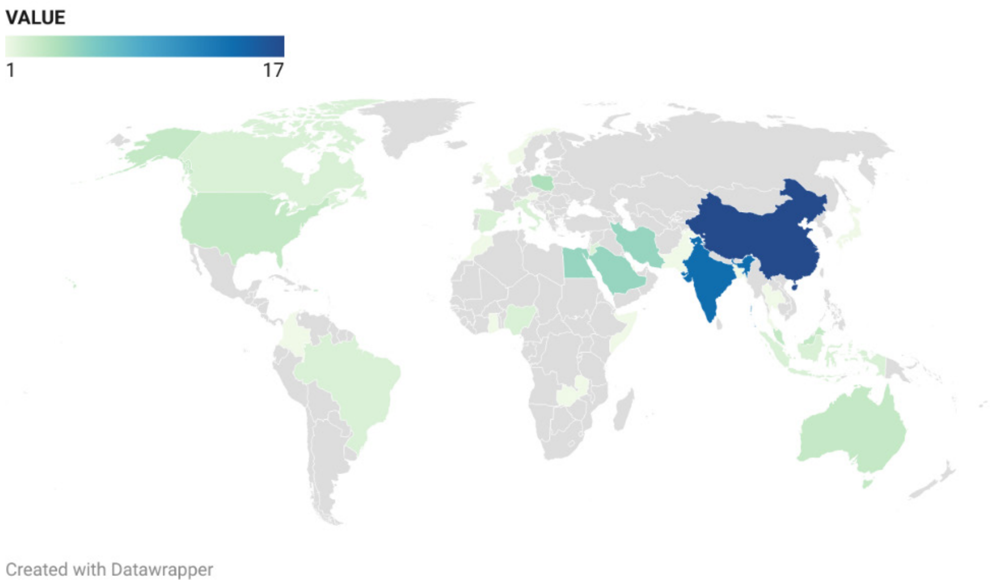


Figure 4. Country distribution of research on construction delays and concrete optimization

3. Discussion

On construction sites, concrete remains to be the most commonly used material. Delays are a significant obstacle in the execution of concrete structure projects. Cost implications and elevated carbon emissions are typical outcomes that ensue from construction project delays. Conversely, delays might be mitigated through the implementation of optimization strategies for concrete work. This chapter investigates a variety of optimization alternatives that can be implemented for concrete work in order to mitigate the negative effects of project delays. Optimization of concrete work includes structural design, concrete material, construction method, and schedule acceleration.

3.1. Construction Project Delays

The widespread problem of construction project delays requires a resolution. Therefore, considerable research has been carried out to map and classify the causes of these delays [15]. The majority of studies that investigate project delays focus on the causes [3], [7], [16], [17], [18]. Other literature reveals the consequences of such delays [4], [19], [20]. In addition to understanding the primary causes of construction project delays, their consequences must also be examined. According to numerous sources, among the consequences of delays are cost and schedule overruns [3], [8]. In addition, delays can lead to legal disputes that must be settled through arbitration or litigation [2], [15], [19]. Delays may also result in the project's termination, [15], [21] which affect the economic conditions of a region or nation [15].

Typically, research on project delays is carried out by creating and distributing a questionnaire to parties directly involved in construction. Then, statistical analysis is used to determine the impact factor for each cause. These factors considerably vary depending on the location of the study.

In Saudi Arabia, technically and financially inadequate contractor selection caused the most delays. This problem also occurs if the lowest bidder is selected as the winner [7]. In Egypt, the factor with the highest relative importance index (RII) that causes project delays is late progress payments [22], while in India, such factors are material delivery delays and late design drawing preparation [4]. In Malaysia, the factors with the highest RII are improper planning by contractors, poor project management governance, and inexperienced contractors [15]. In Indonesia, financial difficulties and delivery delays are also major contributors to project delays [1]. These various delay factors may result in a delayed start, and thus the real duration of a construction project has been significantly shortened in comparison to its originally planned schedule if the project is forced to meet its original deadline. In turn, such scenario can reduce quality and increase construction safety risks.

Construction project delays also frequently result in cost increases [23]. Cost overruns can be caused by idle equipment and personnel, significant additional resources to make up for delays, and various claims and penalties from both the owner and the contractor. This delay also results in financial and economic losses at the macro level. Delayed should-be-operational structures are unable to generate revenue [1]. Furthermore, the increase in construction costs causes a delay in the return of capital to property owners and investors [23]. These additional costs may also increase if the delay leads to a dispute between the contractor and the owner. In dispute resolution, several cases can be resolved through mediation between the parties; if this fails, arbitration can be pursued; if arbitration fails, litigation is pursued [22]. Given that the project has not been completed and the owner/investor funds for resolving the dispute have run out, this dispute has the potential to result in the project's abandonment or even termination [19].

Figure 5 shows the most common consequences of delays, including time overruns, cost overruns, and legal disputes, according to various literature reviews [1], [2]. However, several studies indicate that delays can also diminish the quality of work outcomes [24]. Projects with cost overruns inevitably go over budget by the end of the project. Moreover, the contractor inevitably has to complete the remaining work on a very limited budget, consequently leading to a high probability of decline in quality. Other additional costs are associated with resolving disputes, paying late fees, and extending performance guarantees.

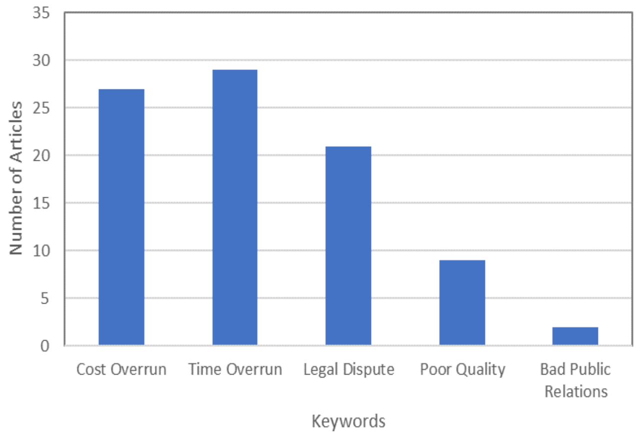
Various studies have analyzed and described the effect of delays, particularly the negative ones. Aibinu [2] concluded six negative effects of project delays, namely, schedule overruns, cost overruns, disputes, arbitration, litigation, and total abandonment. Similar research has been carried out in Zambia, where delays in construction projects result in poor client–contractor relations and cash flow issues in addition to the previously mentioned effects [23]. However, research has rarely examined the scope of case studies and the quantitative effect of project delays, which is necessary to determine the overall impact on the project performance. A substantial impact indicates that the issue of delays requires the immediate attention of stakeholders to be resolved. Moreover, few studies examine in depth the impact of project delays on environmental and sustainability factors, despite the current research trend on sustainable topics.

The issues of global warming and environmental damage are among the most important problems in the world that need urgent solutions, and therefore contributions to research on this subject are very important.

3.2. Concrete Works Optimization

Project management decisions significantly impact the achievement of a project [25].

In turn, for optimal decision-making, an optimization procedure is required. Optimization of concrete works has become a topic of international research interest, considering that concrete is the most prevalent building material in many countries [10]. A literature review shows that optimization of concrete works can be carried out on four aspects, namely, schedule, construction method, structural design, and material composition.



Description of impact	Source
Cost Overrun	[1],[2],[3],[4],[5],[6],[7],[8],[15],[16],[17],[18],[19],[21],[22],[23],[24],[26],[27],[28],29],[30],[31],[32],[33],[34], [35],[36]
Time Overrun	[1],[2],[3],[4],[5],[6],[7],[8],[15],[16],[17],[18],[19],[20],[21],[22],[23],[24],[26],[27],[28],[29],[30],[31],[32],[33],[34],[35],[36],[37]
Legal Dispute	[1],[2],[3],[4],[5],[6],[7],[8],[15],[16],[19],[21],[22],[23],[24],[27],[28],[29], [31],[32],[33]
Poor Quality	[1],[4],[18],[19],[23],[24],[28],[33],[36]
Bad Public Relations	[3], [28]

Figure 5. Effects of construction delays from the literature review

The purpose of optimization is to achieve optimal performance with efficient resources [38] and the most common parameters are quality and cost. Optimization contributes not only to cost and resource efficiency but also to environmental protection. In 66 papers, the current research trend in optimization of the abovementioned aspects and their benefits are shown in Figure 6.

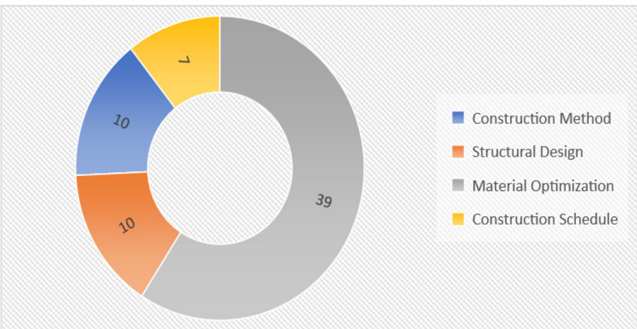


Figure 6. Concrete optimization studies and their focus

Other articles on concrete optimization address issues of sustainability, demonstrating that such techniques have the potential to produce more environmentally friendly structures. Savings are not only realized through the use of more eco-friendly materials, but also through the reduction of construction-related resource needs.

3.2.1. Benefits of Concrete Optimization

The construction industry is commonly acknowledged as the primary driver of the worldwide gross domestic product (GDP) expansion. In fact, the construction sector is a substantial contributor to the gross domestic product of the majority of nations. As an illustration, this sector supports over 2.6 million enterprises in the United Kingdom, 8% of Australia's gross domestic product, and 17% of enterprises in developing economies like Iran [13]. Consequently, construction sector efficacy may have a positive impact on the economy. As depicted in Table 1. statistics on the benefits of optimizing concrete work are derived from various sources of information.

In terms of performance, construction optimization techniques such as concrete maturity method has shown both financial and overall time savings during structure development [39]. In addition, the mix proportion optimization technique can be used to increase concrete durability, while enhancing the economic and environmental benefits of concrete production, safety performance, and service life [40]. In addition, the correct use of waste materials in concrete mixtures improves the performance of concrete. For example, utilization of scrap timber as an adhesive shows a significant effect on improving the bending capacity of concrete.

The partial substitution of fine or coarse aggregates with recycled materials, including plastics and pulverized concrete, serves to mitigate the depletion of natural resources. Although pulverized concrete does not compromise compressive strength, its weak adhesion to cement may restrict the plastic content [14].

Apart from the performance aspect, the sustainability aspect is a major concern. The entire globe is gradually confronted with temperature rise and more harsh climates, which pose a threat to civilizations via impacts including torrential floods, droughts, and surges of mass migration. Most of researchers consider anthropogenic, or human-caused, causes of climate change such as prevalent emissions of greenhouse gases, including carbon dioxide, from industrialized and developing nations. Societies characterized by a high level of consumption. The construction materials industry has been recognized as the third largest contributor to carbon dioxide emissions among industrial sectors globally [9]. Although the industrial sector is the second-largest consumer of water, there remains a scarcity of product-specific water footprint assessments, especially in the construction sector. Each year, billions of tons of cement, concrete, and steel are produced throughout the world, with water being consumed and polluted along the production chain [13].

In 2021, more than 100 million tons of cement were manufactured in the United States for the production of concrete, and consequently, the cement industry contributes to the emission of greenhouse gases in the millions of tons, representing a sizable portion of the carbon footprint of the nation [14]. Concrete optimization has been proven to not only affect cost efficiency, but also make a real contribution to sustainability. For example, by optimizing using green lightweight concrete in an integrated manner, an efficient structure can be produced and the need for concrete and reinforcing steel can be reduced. Thus, apart from cost efficiency, the effect on environment (emissions) and construction waste can be minimized [48].

Several studies have specifically stated the percentage of efficiency generated in terms of costs, carbon emissions and performance. Brief information on percentage sizes is present in Table 2. From the table above, it can be seen that the element that has the most significant optimization impact is the structural design. From previous research, optimization of structural design can provide cost savings of up to 50% in quantity and a reduction of embodied energy significantly. After the structural design elements, the next step is material optimization which can also provide significant cost savings, namely 23.8-40% and can provide a reduction in GHG emissions of 41.57% - 60%.

Table 1. Benefits of concrete optimization

No	Benefit	Source	Frequency
1	Cost Saving	[9], [13], [38], [39], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76], [77], [78]	44
2	Time Saving	[12], [25], [39], [42], [43], [44], [45], [46], [47], [48], [56], [61], [62], [71], [74], [75], [79], [80], [81]	19
3	Quality/ Performance Improvement	[40], [52], [58], [59], [63], [65], [66], [70], [72], [73], [74], [78], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [92]	24
4	Safety Improvement	[40], [51], [75], [78]	4
5	Reduce Environmental Impact	[9], [13], [38], [49], [50], [53], [54], [55], [57], [60], [63], [64], [65], [66], [67], [68], [70], [91], [92], [93], [94], [95], [96], [97]	24
6	Reduce Waste/ Resources	[13], [46], [49], [54], [57], [76], [77], [82]	8

The next element is a construction method that can provide cost efficiency in terms of execution and resource requirements. The difference in significance of each optimization element is also influenced by the location where the research is carried out. In developed countries, where construction technology is advanced, efficiency tends to be higher.

Therefore, concrete optimization research remains highly relevant to our present needs.

At present, countries around the world continue to prioritize economic growth while attempting to minimize carbon emissions to the greatest extent. Concrete optimization techniques have been evaluated through various studies using diverse methodologies and is found capable of delivering cost efficiencies ranging from 1.2%–33%. In addition, concrete optimization also shows the potential to reduce GHG emissions by up to 49.10%.

With increasing innovation and research in order to minimize the environmental effects of construction, the massive impact of this industry on global warming may also be reduced. Thus, the primary objective of sustainable construction can be attained.

3.2.2. Structural Design

Concerning structural optimization, an increasing number of studies are incorporating environmental impact as a variable. The multi-objective optimization technique and genetic algorithm (GA) have been used to optimize the structure of reinforced concrete buildings using the parameters of beam and column cross-sectional capacity, cost, and water footprint; the findings indicate that the optimization method is highly useful for obtaining an efficient structure that still meets the requirements [13].

Table 2. Percentage of efficiency from concrete optimization

No	Method	Cost Saving	Reduce Environmental Impact	Quality & Safety Improvement	Source	Country
1	Structural Design Shape Optimization	40%-50% quantities efficiencies; 3.8%-15.8% cost saving	23.7%-49.1% reduction in embodied energy	14%-19% higher structural efficiency ratio	[53], [51], [93]	UK, Australia, Bahrain
2	Material Optimization using GA	23.8%-30.25% of cost savings; Up to 40% cost saving	2.63%-41.57% GHG emission savings; Up to 60% Global Warming Potential (GWP) reduction		[67], [68]	Australia
3	Construction Method & Material Optimization using GA	5% cost efficiency per floor			[48]	Saudi Arabia
4	Construction Method, Striking Optimization	6%-33% of equipment & labor cost			[71]	Columbia
5	BIM Implementation Survey Questionairre	1.2% cost saving			[18]	Eqypt

Similar investigations have been conducted in the United States, where main beam elements are optimized using a topology optimization mechanism to determine the maximum safe load for concrete tensile elements [50]. In addition to beams, floor plates can also be optimized to produce efficient structures. A study was carried out to develop a design for an efficient floor plate structure, ribbed one-way concrete floor configuration is optimized to reduce construction costs and embodied energy (EE), which reduced the floor plate's embodied energy by 48%–64% [49]. A new floor plate design, namely, the T-beam grillage, has also been observed to be an efficient alternative design, resulting in material quantity reductions of 40%–50% compared with flat slab [53]. Using Australian standards and codes, optimization of floor plate and beam elements was also performed in other research to reduce the EE of the whole structural system, and consequently, achieve a 23.7%–49.1% reduction [51] .

In addition to buildings, structural optimization is also used to create efficient bridge designs. In Austria, bridge girders are optimized to produce the smallest amount of total material, with laboratory tests as evidence [52]. The results indicate that a design with the smallest volume of concrete and reinforcement can be obtained by optimization, and thus, the impact of potential global warming can also be reduced [52]. Additionally, comparable research was carried out in Bahrain. The prestressed concrete I (PCI) girder structure was optimized to obtain a structure that meet the requirements at the lowest possible cost, and as a result, the optimized PCI girder achieves 13%–17% higher structural efficiency and 14%–19% higher structural efficiency ratio than the Caltrans and AASHTOO PCI Girder [93].

Optimization of structural design has a greater effect when combined with the utilization of eco-friendly materials. In addition to optimizing the structural design, a study in Saudi Arabia compared the use of conventional concrete, recycled plastic aggregate concrete, and lightweight concrete, the framework considers possibilities which include safety of design, architectural specification, material's efficacy, cost-efficiency, and ecological consequence [48]. The present study assesses four distinct concrete aggregate materials, specifically natural weight aggregate, lightweight volcanic aggregate, and plastic-based green lightweight aggregates.

When compared to conventional concrete mix, these materials offer potential cost reductions of up to 5% per floor [48].

3.2.3. Concrete Material

The construction material industry has been recognized as the third largest industrial sector in the world [9]. Therefore, research into the optimization of construction materials is crucial. One of them pertains to concrete technology. Numerous investigations have been conducted regarding the optimization of concrete materials to obtain concrete materials with improved performance, lower costs, and fewer environmental impacts. Using 892 design mix data, an investigation was carried out to optimize concrete composition using artificial intelligence (AI) and GA, The impact of various factors on global warming potential (GWP) is investigated in five case studies: the chemical properties of cement and supplementary cementitious materials (SCM), the minimal cement dosage, regional transportation, emissions level, and type of binder. The results indicate that the developed tool can reduce GWP by as much as 60% and costs by as much as 40% compared to outcomes from experiments of comparable intensity, with regard to the cost of optimal mix designs [68].

In addition to sustainability considerations, material performance requires special attention. In several countries with cold climates, extreme temperature fluctuations or freeze–thaw cycles can damage concrete structures and diminish their durability. Utilizing the Random Forest model and NSGA-II, the optimal durability is obtained to ensure the safety performance and service life of the structure, the chloride ion permeability coefficient of concrete is decreased by 47.9% following optimization, while the relative dynamic elastic modulus increases by 4.07% and the cost decreases by 2.4% [40].

Plastic waste causes severe environmental problems in Morocco. In a study to determine the effects of partially substituting PVC-U waste for sand in concrete mixtures, the PVC-U waste dosage ranges from 5%–50% [65]. Utilizing optimal percentages, water was poured to examine the fresh and hardened behavior of concrete containing plastic waste, with an emphasis on its workability, fresh and dry density, compressive strength, tensile strength, modulus young, ductility, and ultrasonic pulse velocity (UPV). The findings suggest that the incorporation of plastic waste into the concrete resulted in a reduction in slump and fresh and dry density, while the mechanical properties were enhanced [65].

In Egypt, an examination was conducted to determine the performance of concrete with SCM addition. The SCMs contained varying proportions of silica fume, glass powder, and marble dust (MD) (0%, 15%, and 20%), the findings suggest that the compressive strength can be enhanced to 28 day by integrating SCM and a finer sand particle size distribution compared to the grain sizes of natural sand [83]. Rice husk ash (RHA) is also used as a concrete mixture. RHA is an agricultural byproduct that can be utilized to obtain the optimum mix design considering strength, cost, and carbon footprint. A combination of the algorithm and eXtreme Gradient Boosting (ALO-XGB) is used for optimization, by substituting conventional concrete in bridge and residential structures, RHA concrete may decrease Italy's carbon emissions by 12.2–17.5 kg CO_2 equivalents per square meter [92]. Table 3. presents the numerous options for optimizing concrete materials. In the present study, the majority of the literature relies on machine learning techniques and standard algorithms to achieve optimization (i.e., ANN, Box-Behken). GA can also be used to make predictions based on historical data. Using GA in mixing design is also extremely useful for determining the optimal mix proportions [63]. By using this method, the concrete mix design can be accurately predicted at low cost, with low carbon emissions, and while still meeting the required compressive strength criteria [82]. Less than 5% relative error is observed between experimental and predicted optimized values [86].

3.2.4. Construction Method

Conventional onsite concrete construction methods for buildings have faced criticism due to their lengthy duration, lack of productivity, worrying safety records, and plenty of waste [74]. Innovation and optimization in the implementation of concrete construction continue to be researched and developed to enhance its performance and productivity. The optimization can aid in deciding which method to implement.

Optimization has been carried out using GAs to determine the optimal method for implementing mass concrete works. In one study with the optimization parameter of construction cost and selection variables of material types, placement temperature, height of lift, and lift spacing, the outcomes indicate that the proposed method can be effectively implemented in the design of enormous concrete structures [76]. A similar method is also used to optimize the choice of prefabricated or precast construction methods.

The construction method selection model is intended to support building teams in the initial phases of a project in evaluating the viability of prefabrication and determining the optimal strategy for applying prefabrication to concrete buildings. For the optimization and adoption of prefabrication in concrete buildings, the proposed model was determined to be a valuable and effective decision-making instrument [74].

Other research also involves precast optimization-related optimization utilizing non-dominated sorting genetic algorithm II and great deluge algorithm (NSGA-II-GD). Building information modeling was used to obtain data and criteria, and then construction costs, precast dimensions, and reinforcement were optimized. The results indicate a balance between cost of construction and standardization, specifically for components exposed to comparable stresses [78]. However, the implementation of prefabricated construction in developing nations has been inadequate, considering a dearth of adequate technology and qualified technicians. In a few instances, the implementation of precast construction actually results in quality issues.

The acceleration of concrete cycles through faster release of formwork and shoring is an intriguing topic that may be applicable in developing nations. The concrete formwork is an essential element of construction management since failure to achieve the required concrete strength can result in rework and, as a result, cost and schedule overruns [79].

Table 3. Various article keywords regarding concrete materials optimization

Keywords 1	**Keywords 2**	**Source**	**frequency**
Curing Method	Rapid curing	[61]	1
Composite Material		[38], [66]	2
Self-healing		[70], [89]	2
Supplementary Material	fly ash	[55], [58], [66], [67], [72], [73], [88], [96]	9
Supplementary Material	rice husk ash	[54], [59], [60], [70]	4
Supplementary Material	limestone	[56], [68]	2
Supplementary Material	silicafume	[9], [60], [83]	3
Supplementary Material	superplasticizer	[40],[55],[56],[57],[58], [67], [70], [72], [73],[96]	10
Supplementary Material	steel fiber	[9], [38], [57], [70], [85], [97]	6
Supplementary Material	geopolimer	[82], [83]	2
Recycle Material	recycle coarse aggregate	[58], [63], [68], [84], [85], [91], [94]	7
Recycle Material	recycle fine aggregate	[63], [84], [86], [91]	4
Recycle Material	recycle water	[64]	1
Recycle Material	slag	[62], [67], [86], [88], [92], [94], [96]	7
Recycle Material	glass powder	[82], [83]	2
Recycle Material	plastic recycle	[87], [95]	2

Early removal of the formwork can result in extreme deflections or potential collapse on the contrary, late removal further causes construction to experience a delay, which has financial repercussions. The removal of formwork is typically governed by the ratio of its strength to its self-weight and transient construction-related loads [80]. An approach that is used to approximate the strength of concrete is the maturity method. It is a widely recognized approach utilized to determining the mechanical properties of concrete (e.g., compressive strength) by monitoring the temperature progression throughout the hardening process. The necessary striking time of the formwork can be determined using the compressive strength of the concrete. Utilizing this approach for this objective is economical and provides the necessary safety precautions.

Having knowledge of the maturity method, the compressive strength of concrete can be estimated. If concrete possesses the necessary strength, formwork removal and striking time can be reduced. Thus, the overall construction costs can also be reduced. The more concrete work performed during the construction phase, the greater the savings generated [39]. The time of opening the formwork has been determined using a sensor connected with a BIM model and experiments. These sensors can provide a real-time assessment of the concrete’s maturity, to allow for the determination of when the formwork can be safely removed, and thus allows for potential reduction in the duration of formwork release and generates time savings [79]. The same scenario is also executed using the UPV instrument, which can determine the shortest time during which the formwork can be removed and the structure can safely withstand the loads [80].

In addition to the duration of formwork release, the maturation method may also be employed to ascertain the duration of shoring/striking release. In regard to the striking of formwork, current scientific research and technical standards provide varying estimates. The primary structural components require 14–21 days to be established. For main elements including slabs or beams with a span above 6 m, the standards require at least 70%–85% of their design strength to dismantle the formwork [39].

A study on the duration of striking release in 10 European cities has shown that, due to higher ambient temperature, concrete acquires the necessary strength for striking the formwork more quickly during the summer months [39]. In a study carried out in Bogota, Columbia, optimizing the shoring (striking) release cycle can reduce costs by 6%–33% due to staff and equipment rental savings [71]. In a separate study, not only the cycle, but also the number and placement of shoring, were investigated and optimized to achieve a structure’s safety that satisfies the requirements with a minimal number of shoring. As a result of calculations with finite elements and optimization with GAs, the number of shorings can be reduced and the actual shorings can be released sooner [43]. Thus, optimizing the formwork release and shoring cycle has the potential to increase project efficiency and to positively affect the economy. New approaches and innovations are needed to increase the construction efficacy. However, of the numerous papers on optimizing construction methods, few have addressed sustainability. The effect of optimization on the environment therefore requires further investigation.

3.2.5. Schedule

Efforts to overcome delays may include schedule optimization. Crashing can be utilized to shorten the duration of a construction project, but additional costs must be considered. A study on schedule optimization was carried out using numerical simulation with the crashing method, and the model was designed to optimize between accelerated schedule and lowest cost [25]. Crashing is found effective if combined with the critical path method, which is frequently used to plan and manage short-duration projects. In addition, crashing using program evaluation and review technique concept is developed, and is proven effective in reducing the duration of a project, reduce variance, and potentially reduce tardiness [12].

Optimization is a useful basis for making decisions.

Mixed integer programming and GA is also utilized to determine the most cost-effective scheduling scenario, and results show that optimizing specific work sequences by factoring in the time/cost of relocating resources can provide additional scheduling flexibility for construction projects that span multiple locations [44]. This GA can considerably expedite simulations and iterations, but requires validation using multiple existing case studies.

4. Conclusion

Construction delays have become a widespread global problem, as observed in developed and developing countries. According to the search results, the effects of this problem include not only time overruns but also cost overruns and legal disputes. In addition, the deterioration of building quality and the erosion of public trust are potential consequences. Therefore, future efforts are required to minimize such construction delays.

Concrete optimization is found to provide several benefits that help address this problem. Depending on the findings of the investigation, concrete work can be optimized in terms of several aspects, including structural design, schedule, construction method, and materials. Various optimizations of concrete work result in time and cost savings, improved quality (including durability), increased safety, and reduced waste and greenhouse gas emissions. This literature review shows that optimization of structural design has the potential to produce cost efficiency of 3.8%–15.8%, material quantities efficiency of 40%–50%, and emission reduction of 23.7%–49.1%. Meanwhile, optimization of construction methods has the capacity to generate 6%–33% cost saving and optimization of concrete materials can produce cost savings of 23.8%–30.25% and reduce GHG emissions by 2.63%–41.57%. Thus, efficiency can be enhanced through the integration of multiple approaches that have been implemented in numerous prior investigations, given the wide variety of opportunities presented.

Material optimization is the topic that receives the most attention from scholars around the world. Construction materials can be optimized by adding supplements or substitution with recycled materials such that the concrete becomes more cost-effective without sacrificing quality. In addition, modifying and optimizing the material can lead to reduced carbon emissions, a positive outcome in light of the growing efforts to achieve sustainable construction.

Acknowledgements

The authors express gratitude for the financial support granted by the Engineering Faculty of University of Gadjah Mada. The research grants and scholarships awarded by the Engineering Faculty of University of Gadjah Mada have enabled the realization of this project and have alleviated the financial constraints associated with conducting research.

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