Review Article
ISSN 2658-5553
Received: January 25, 2025 Accepted: February 9, 2025 Published: February 27, 2025

Construction methods and challenges of reinforced concrete structures in Tehran, Iran

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Keywords:

Reinforced concrete structure; Protected building; Risk management; Contractor; Building code

Abstract:

The object of research is to investigate the challenges and methods of reinforced concrete structures in Tehran, Iran. The issues regarding contractors' obligations and Iran's construction challenges have been investigated. **Method**. Thus, the design of the Iranian code has been reviewed in this article, and similar international situations, the view of construction supervision, and the view of construction operations have also been analyzed. For field tests, two buildings with different contractors have been selected. **Results.** The results of the investigation show that the level of education, personality, and general knowledge of contractors are the key criteria for the correct implementation of buildings, which is the main construction problem in Tehran. In addition, the results show that improving the technology level of code design, etc., can increase the quality of construction after adapting the structures. The results obtained from the two buildings are compared, and the trend of the results is geared towards emphasizing the factors that were studied and mentioned that affect the construction. The factors indicate the social, scientific, and economic level of the contractors, which reflects their personality on the importance, health, and safety of the structure.

1 Introduction

The construction industry is considered a high-risk subject, so the high number of accidents is attributed to the construction industry [1], [2]. Some researchers believe that construction projects are risky among infrastructure projects such as roads, power plants, etc. [3]. The literature review of risk management studies illustrates that only a few studies, at least at the academic level, have concentrated on the risk of construction projects. For example, a lack of knowledge of the reasons for identifying weaknesses in project construction in the long and short term from an executive and supervisory point of view is one of the neglected parts of project management. Also, the lack of risk management knowledge, as well as the use of a systematic approach to identify and solve risk issues in the field of construction projects, is very evident in previous studies [4], [5].

The emergence of the Fourth Industrial Revolution had a direct impact on the construction method, building monitoring, and building protection after the construction process. One of the important factors in improving the construction method is the conditions of the contractors and contractors. Many factors can improve the quality of work at the construction site. For example, increasing the budget for tools and materials and reducing the labor force can increase the standard quality and reduce the construction time. It should be noted that the use of advanced technology is expensive. Still, it helps with product quality, time limits, and construction stability, so contractors must use advanced technology to improve the quality of construction [6], [7]. Othman et al. [8] analyzed many factors, from the personality of contractors to ages, years of experience, and education levels in Malaysia. They understood that more than 29 contractors out of 32 are younger than 39 years old. Twenty-two constrictors had less than 5 years of experience; 25 of them were male, and 23 of them had bachelor's degrees. One of the contractors' attractions of new technology and types of new buildings, including green buildings, is the economic justification of contractors. Another potential impact of project planning is the startup, shutdown, and post-occupancy phases [9], [10]. In addition, some studies show that government regulations have put more pressure on builders to improve the quality of buildings. For example, Qi et al. [11] found that there is a relationship in which the analyzed data set from the surveys shows that contractors only carry out green building practices out of necessity and not a personal urge or moral obligation to benefit the environment.

The quality of the contractors' work is directly related to the protection of the buildings against natural hazards after the completion of construction. Any type of natural disaster, such as climate change, earthquakes, and floods, has affected urban livelihoods, environmental degradation, socio-economic inequality, and finally, the quality and protection of buildings and urban [12]–[14]. Contractors play an important role in risk management during natural hazards [15]. For example, Zhu et al. [16] realized that contractors can reduce the project's risk of flooding. In addition, new technologies can improve contractors' view of operational capabilities and improve stakeholder engagement and efficient decision-making [17]. Results of some studies show that failure to apply risk management methods in the construction process through contractors has had negative consequences [18], [19].

By looking at issues related to Iran's construction industry and contractors' responsibilities, the paper's novelty focuses on a number of challenges and strategies pertaining to Tehran, Iran's reinforced concrete buildings. The paper focusses on several difficulties and approaches related to Tehran, Iran's reinforced concrete buildings. The investigations have been conducted into the problems associated with Iran's construction industry and contractors' responsibilities. Ultimately, these difficulties additionally present great opportunities for research and teaching for the upcoming generations of Iranian scholars studying reinforced concrete structures. This study analyzed the contractor's situation in Tehran, Iran, and its relationship with the quality of reinforced concrete structures and building protection after completing the structure. Due to the analysis of the construction in Tehran, the supervise and operation views have been considered and compared by international attempts. Finally, two case studies have been selected to find the effect of contractors on the quality of buildings.

2 Study Methodology

2.1 Iranian Building Execute Standard

The 9th Iranian building code design is applied as a verification required [20], [21] to obtain the appropriate constructed building. The 9th Iranian Building Design Codes is published on the design and construction of reinforcement concrete structures in 24 different chapters. The concrete mixing design, loading rebar, and concrete connections are considered as important to apply to the building's sections in the current study.

The Portland cement types, fine and coarse aggregates, and water are verified as the main components of the conventional concrete mixture's aggregates greater than 4.75 mm are defined as fine, and the aggregates smaller than 4.75 mm are explained as coarse aggregates. Moreover, the pozzolan cement, the chemical powders, and other materials are verified to be added to the concrete mixture. The concrete compressive strengths are classified by the C as the "compressive strength" and the number as the compressive strength (MPa). For example, C55 is explained for concrete with 55 MPa compressive strength [22].

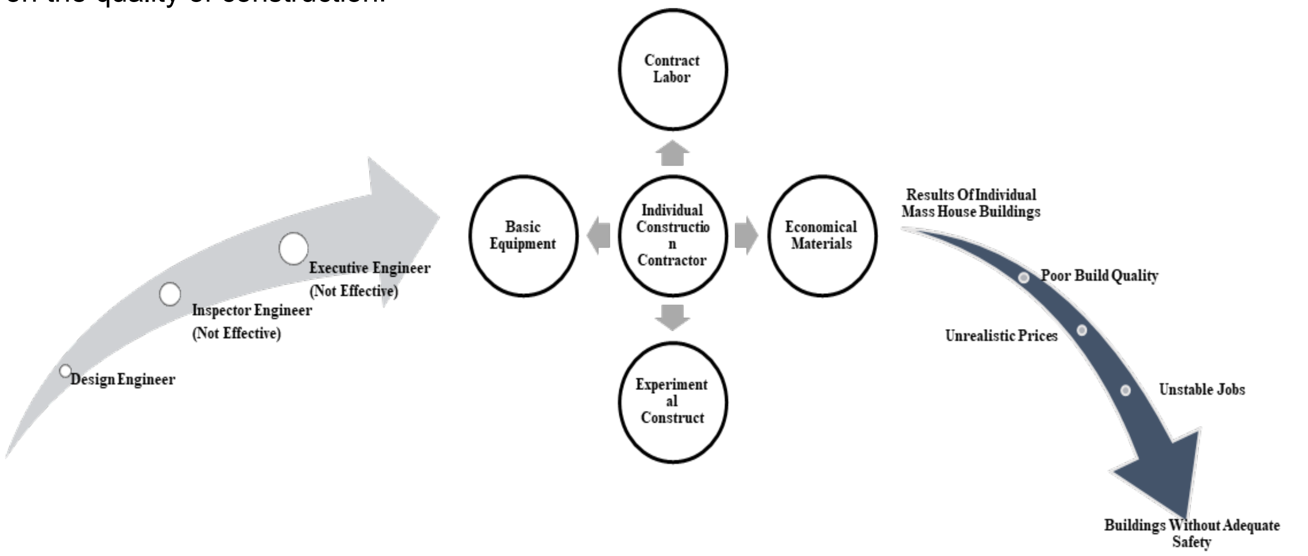
The classification of tensile strength defines four types of rebar steel. The "S" illustrates the name of "Steel", and the number after "S" is explained as the tensile strength (MPa). As an example, the S240 has defined the steel rebar as having 240 MPa tensile strength. Furthermore, the spiral-winding rib rebar type is only verified as the structural steel rebar in the 9th Iranian building design codes.

The industrial mixing concrete is just valid according to the 9th Iranian building code design to ensure the best qualification of concrete. The rebar connections are other important sections of the 9th Iranian building code design, which is analyzed in the current study.

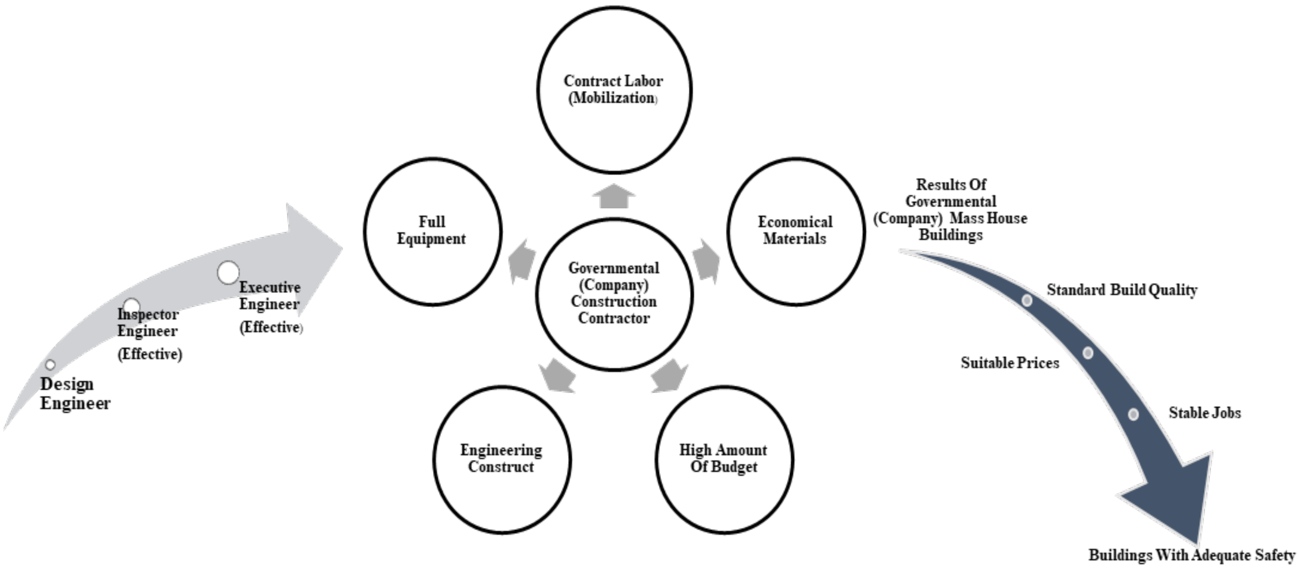
2.2 Iran Mass House Building Methods

The definition of mass house building condition is a complex subject in Iran, and there are different methods of building mass houses in Iran. In general, mass buildings branch out into two main branches: through construction companies (such as state companies, semi-state companies, and private companies) and individual constructors. On the one hand, mass government and corporate housing construction methods are affected by high budgets, equipment, labor, etc. Still, the value of the equipment depends on the types of companies, projects, budgets, and other aspects.

On the other hand, individual mass house buildings are affected by economic conditions, demand, population growth rate, and other social aspects. In this regard, two types of mass-building methods play an indirect role in Tehran's structural safety index. Increasing seismic hazards caused by natural faults around Tehran and the desire of mass builders to use reinforced concrete buildings for economic reasons are two important indicators that encourage engineers to study the impact of individual mass buildings on the quality of construction.



(a)



(b)

Fig.1 - The Mass House Buildings Methods in Iran; (a) Individual Construction Contractor; (b) Governmental (Company) Construction Contractor

The differences and comparison between Individual Construction Contractor and Governmental (Company) Construction Contractor in the Iranian Mass House Buildings System are given in figure. 1. Figure 1 (a), defines the Individual Construction Contractor methods in Iran. The Individual Construction Contractors consist of experimental or engineering contractors who, with the prior agreement of the landowner, begin construction of the building. The contract between contractors and landowners includes many items such as the number of floors, the types of structural materials (reinforced concrete structure or steel frame structure), the types of architectural materials, the percentages of the division of classes according to the percentage of participation of individuals, etc. At the same time, state construction companies are made up of government engineers and they are supported by government funds and equipment (Figure 1 b). Individual construction contractors make up more than fifty percent of mass house buildings. Therefore, this study concentrates on the methods of individual construction contractors and individual mass house buildings in Tehran, Iran.

2.3 Method of the study

In the first step, the influence of the operator and supervision of civil engineers in Tehran city is investigated. The main purpose of studying the effect of monitoring and operators on civil engineering is to find the appropriate relationship between monitoring structures and building operations. In the second step, two buildings in Tehran are selected as the study factor for the actual condition analysis, and the display and reports are expanded with actual observation.

Figure 2 defines the entire algorithm of the study. In the first part (the third section of the article), Tehran was analyzed as the first cause of the study, according to previous studies. The real cases are analyzed in the Results section. In this section, two buildings in the east of Tehran have been selected and analyzed as the real causes. Finally, in the Discussion, the results were compared in order to find the relationship between the challenges, mistakes, and causes of construction accidents in Tehran. In the final section, the main issues are presented, and suggestions are made to find the relationship between challenges, mistakes, and problems.

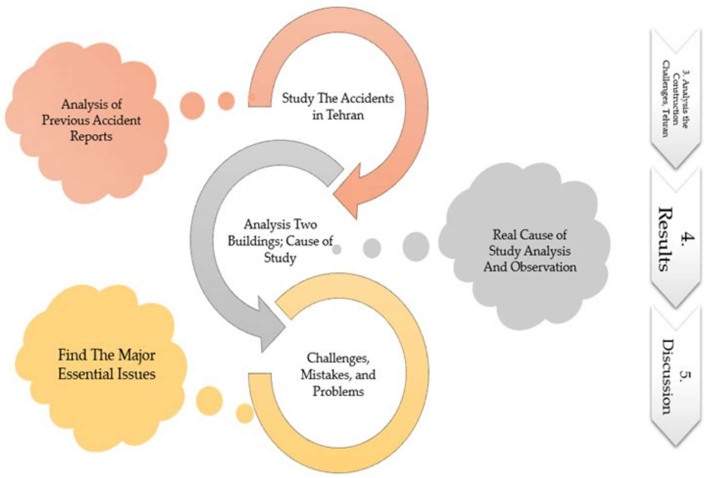


Fig. 2 - Algorithm of the research method

2.3.1 Location of Study

In the first step, Tehran is selected as the capital of Iran. Tehran's population is a city living in 22 urban areas. According to the latest census of 2010, Tehran has a population of 8,151,898 people. As a metropolis, due to its diverse centrality, Tehran has been able to accommodate the entire country in its political, administrative, and socio-political spheres and can accommodate a large population from the whole country [22].

The second step, Ghanat Kowsar, Forth District, Tehran, Iran, was chosen as the second cause of study. All two locations are selected in Ghanat Kowsar, in the east of Tehran. Moreover, both buildings are on the same street for better comparison.

2.3.2 Tehran Faults

Tehran is surrounded by eight large faults, including active faults inside the city (Figure (1)). These faults threaten Tehran every day. North Tehran, Mosha, Kahrizak–South Rey–North Rey, Parchin, Pishva, Garmsar, Taleghan, and Pardisan faults are nearest close to Tehran. These eight faults threaten Tehran every moment. Given Tehran's population of more than 8 million, Tehran is a dangerous city in Iran.

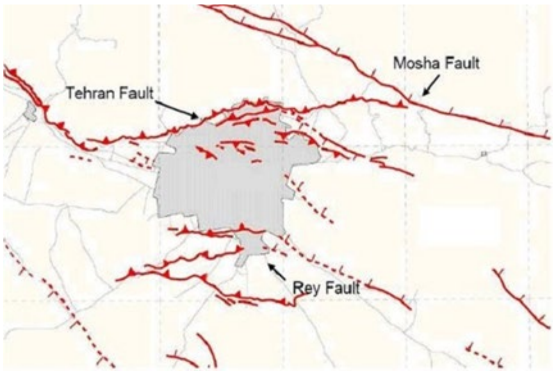


Fig. 3 - All of 8 faults close to Tehran

3 Analysis the Construction Challenges, Tehran

3.1 Construction Operation View

In construction management, the construction operation is a key step that is used to adapt the construction operation parameters considering the 9th Iranian building code design with reality. The influence of building excavation, constructing lateral brace, constructing the foundation, casting, and installing concrete (columns, beams, and roofs) are effective in the collapse of the structures in Tehran. Meanwhile, building excavation and lateral brace installation are the riskiest subjects in Tehran. The last studies proved that the neglect of appropriate building excavation was a great problem at any construction site. In this case, Mohseni et al. [1] proved that more than 90 percent of workers' safety problems are related to excavation problems. Also, the reports show that the number of excavation problems is significantly increasing every year. A governmental report illustrates one building excavation accident per day in 2008, while the statistics show one and a half building excavation accidents per day in 2009 in Tehran [1]. The depth of excavation, the weakness of lateral buildings, and the types of ground are cited factors in the evidence. Depth of excavation and the pressure of dynamic and static loads from the lateral structures were the most important problems in the current years. For example, Figure 4 (a) shows the soil settlement problem in a construction site.

The accident occurred in Talegani Street, Tehran, in 2019. The pressure of dynamic and static loads from the street and the depth of excavation were the major problems at this construction site. Furthermore, the weakness of lateral buildings is another problem for excavation due to the urban decay of Tehran. Figure 4 (b) shows an excavation accident in A.Kashain Street, Tehran, 2021. The lateral building weakness and a load of the external wall caused this incident. These problems are repeated in Figure 4 (c), and Figure 4 (d) as well. Figure 4 (c) illustrates the soil settlement accidents caused by the dynamic and static load pressure from the lateral street above the excavation construction site in Saadatabad Province, Tehran, 2016 as well as Figure 4 (d) illustrates the collapse of a lateral building due to the depth of excavation in West of Tehran, 2018.

(a)

(b)

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2025; AlfaBuild; **33** Article No 3302. doi: 10.57728/ALF.33.2

(c)

(d)

Fig. 4 - Excavation accidents in Tehran: (a) Talegani Street, Tehran, 2019; (b) A. Kashain Street, Tehran, 2021; (c) Saadatabad Province, Tehran, 2016; (d) West of Tehran, 2018

Casting and installing concrete are other essential issue in most construction workshops in Tehran. This problem is related to workers, equipment, improper design, improper casting and installation of concrete, and the technology gap between the knowledge of traditional and new construction technologies. Issues related to building installation and casting operations are analyzed from short-term and long-term perspectives. Short-term problems are often solved on construction sites. Figure 5 can be cited as examples of short-term issues.

On the one hand, problems are focused on reinforced concrete columns and beams. For example, Figure 5(a) shows a punch failure on the second and third floors due to the use of weak steel rebar in the columns and beams. Columns and beams are a problem. In fact, the failure of columns and beams includes a wide range of reinforced concrete problems such as connections, thickness of rebar, weakness in the mechanical properties of concrete, lack of attention to construction operations, etc. On the other hand, installing reinforced concrete slabs is another problem at any construction site. In this regard, Figure 5 (b) shows the failure caused by the non-implementation of technical points. The best examples of these technical points are the removal of shutter prop jacks, changing the center of gravity of the concrete slab during installation, and the asymmetric long slab concrete, as seen in Figure 5 (b).

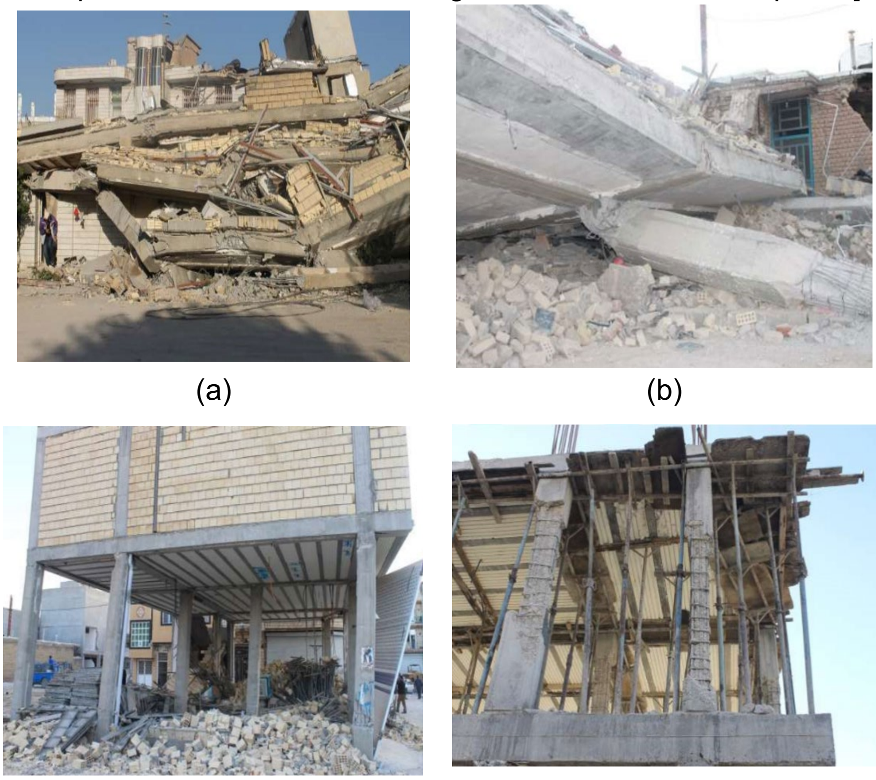
(a)

(b)

Fig. 5 - Construction operation issues at the construction site: (a) columns and beams reinforcements weakness; (b) reinforcement concrete slab failure

The high risk of an earthquake in Tehran is the main factor in the long-term impact of the concrete installation problem. Figure 1 emphasizes the high risk of an earthquake in Tehran, which, in this condition, the importance of safety building against earthquakes significantly multiplies this hazard risk. Kamranzad et al. [23] proved that the risk of seismic hazard increases considerably in the future in Tehran. The reported historical and instrumental seismological results prove that Tehran is at risk of a large earthquake in the future due to the south of the Alborz fault [24]. Another compelling case for improving the seismic resistance of building design codes was the Kermanshah earthquake in 2017 [25]. Due to the damage caused by the Kermanshah earthquake, it has been decided to pay more attention to earthquake-resistant structures. The International Institute of Earthquake Engineering and Seismology of Iran published a report about the Kermanshah earthquake, in 2017. According to this report, mistakes in the construction of buildings had a significant contribution to the collapse of the structure during the Kermanshah earthquake in 2017. The sixth chapter of this report was dedicated to the performance of reinforced concrete structures, which illustrates that most structural collapses were due to not making the technical points.

Meanwhile, the weakness of transverse reinforcement had contributed significantly. For example, Figures 6 (a) and (b) show a collapsed structure due to the weak performance of transverse reinforcement in beams and columns. Creating soft stories and concrete quality are other important safety building factors during an earthquake. For example, Figures 6 (c) and (d) illustrate the formation of a soft story and bad qualification of concrete during the Kermanshah earthquake [26].



(a) (b)

(c) (d)

Fig. 6- Construction collapses in the Kermanshah earthquake: (a) stirrup weakness in the structure; (b) stirrup weakness in the structure; (c) soft story problem; (d) weakness concrete quality (Earthquake report on November 7, 207, Sar-Pol-Zahab, Kermanshah Province (Third Ed), 2017)

The resistance of structures against earthquakes is one of the essential issues that should be considered in Tehran as the capital of Iran. Tehran, with a population of more than 15 million, is the largest city in Iran, where many nearby faults have always threatened it. Therefore, paying attention to the re-resistance of structures against earthquakes is a fundamental point in constructing new buildings.

3.2 Construction Supervise View

Building supervision or structure monitoring is an important factor in achieving a safe structure during the construction of the building at the construction site in a short time and a safe building against natural disasters as a long-term performance of the structure. A supervising engineer must monitor a building considering design, construction operations, and construction supervision codes to ensure that this building is constructed safely and correctly. Therefore, the efficiency of the supervising engineer is the most important factor in achieving the high performance of the structure with a low risk of any accident in the building.

There are many examples of unacceptable construction supervision in Tehran. The weakness of construction supervision significantly increases the risk of building collapse from natural disasters such as floods, earthquakes, etc., in the sense that construction supervision is a preventive activity that increases building health and safety. Moreover, true building monitoring can reduce the percentage of construction operation accidents at the construction site and in the long term.

Many problems of the structure can predict and prevent the occurrence of accidents. For example, the destruction and incorrect construction monitoring of the main components of structure construction are the main problems that the supervisor engineers should pay attention to. As an example, Figure 7 (a) focuses on beam destruction due to finding a way to use construction equipment that can cause the malfunctioning beam at critical times. Moreover, Figure 7 (b) shows an unconnected beam and column that can collapse the cantilever slab during an earthquake or introduce dynamic or unexpected loads to the structure. Supervising engineers should pay attention to the depth of cantilever slabs and beams. For example, Figure 7 (c) shows a three-story building with an incorrect depth of cantilever slabs. The 9th building Iranian design code mentions that the depth of cantilever slabs can reach 1.5 meters in maximum conditions. In comparison, the depth of the cantilever slabs is more than 1.5 meters in Figure 7 (c). Furthermore, Figure 7 (d) mentions another weakness of the supervising engineer, that the columns are not able to transfer the load of the building to the foundation due to the wrong arrangement and incorrect connection of the columns. In this case, the structure can collapse due to the load not being restrained.

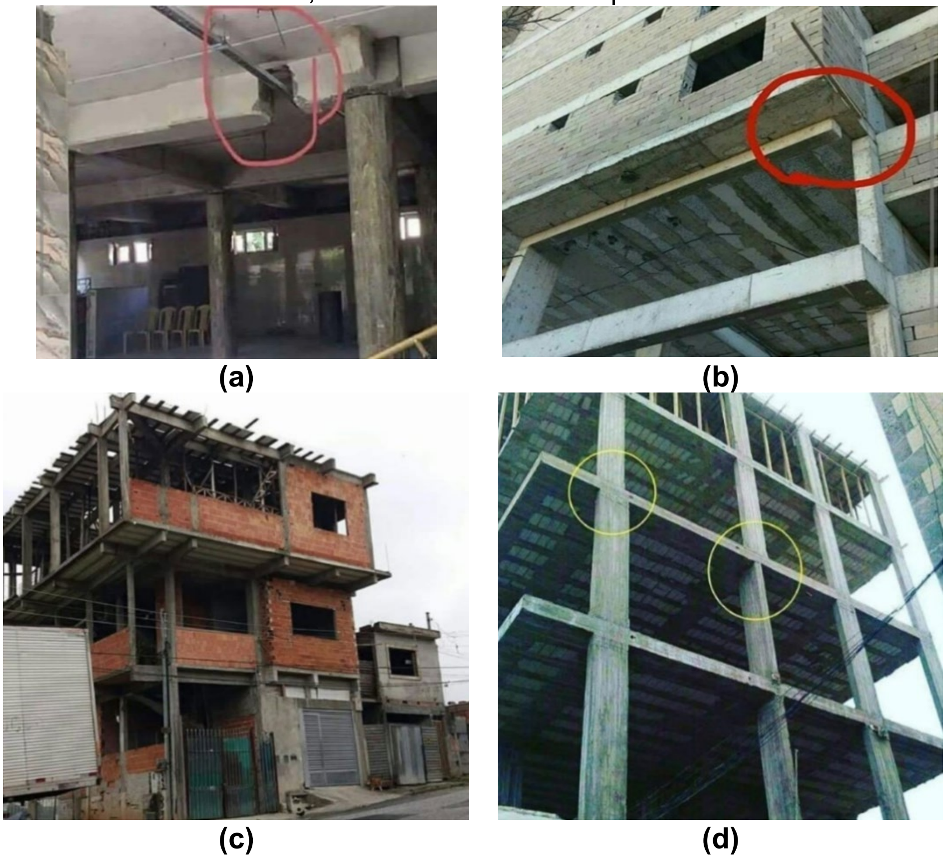


Fig. 7- Construction problem and mistakes: (a) destroy the beams due to equipment installation; (b) connection problems between columns and beam; (c) illegal cantilever slabs; (d) incorrect connections between columns

The importance of the supervising engineer for structural monitoring is not limited to the impact of supervision during construction. In contrast, many structural incidents in the future are related to supervisory issues. Therefore, supervisor engineers should pay attention to monitoring the building for a long time after the structure is constructed.

3.3 International Similar Construction Problem

Construction issues are common in different countries due to the operation and supervision views. The fast development of urbanization and increasing demand in expanding areas are important factors in construction issues. Urban development and settlements often occur on large flat structures that are sometimes interrupted by ditches and natural or artificial terrain features. These situations create additional problems for engineers who need to monitor buildings during and after construction. This approach is very important both for the protection of human lives and for protective construction [27–31]. For example, in Iraq, it is shown that operation and maintenance are the last important steps among the different categories of disaster reconstruction plans. It is mentioned that the operation and supervision of the construction are the weak points of developing countries [30]. This situation is repeated in Iran as well; the operation and supervision of construction are the biggest weaknesses of buildings after collapse or before the accident and during construction. Another study shows that the most important construction issue affected by security measures is changing government regulations and bureaucracy in Iraq [32]. While in Iran, most of the construction problems are caused by bureaucracy or problems of engineers. Also, contractors in both countries had more reserves in this problem. The neglect of supervision and monitoring at construction sites has been repeated in Pakistan. Shaikh [33] investigated the reason for the delay at construction sites in Pakistan. He found that most of the problems with construction delays are related to poor building monitoring and the financial problems of contractors. It seems that the neighboring countries of Iran had the same issues but with different impact factors. This problem is also investigated in Iran, and the neglect of the supervisor was one of the most important problems in building construction in Iran [34].

The shortage of skilled labor and workers was another problem observed in Tehran, which was the cause of the study. Most of the labor force which is working in Iran are Afghan workers who are working without accuracy and skills. Most Iranian contractors desire to employ Afghan workers for tax evasion, lower labor costs, and other financial benefits [35]. The shortage of skilled workers is illustrated in South Africa as well. The experience of the labor force was the main issue in the South Africa project at the construction site [36]. Poor labor force productivity was another example of the construction problem in Indonesia. Kaming et al. [37] studied the factors that influence high-rise buildings in Indonesia. They found that the contractor's lack of experience and the problem of labor productivity were two major issues at the construction site during construction. In this term, the lack of experience of the contractor and the skill and productivity of the workforce is an important factor in the problem with the construction site.

The operation construction problems are often revealed after the construction of buildings. These problems, which occur for various reasons, are common among countries and have happened after natural and artificial disasters such as earthquakes, floods, etc. As an example, the "Four Seasons Kaiyuan Hotel" in Wujiang District, Suzhou, China, collapsed due to illegal renovation of the building. The main reason for the collapse of the building is an overloading caused by over-live loads on the roof. The roof was not able to bear live loads which was applied on the rooftop [38].

Another interesting report mentions that the heaviest collapsed after a seismic hazard involving masonry buildings such as brick and stone construction materials near Siuris County in Elazig City in eastern Turkey in 2019 [39]. The most collapses of reinforced concrete and steel frame buildings were related to the Kermanshah earthquake in the west of Iran. Both areas were close to each other, and although concrete and steel are more expensive than masonry, casualties and heavy collapse in Kermanshah were significantly more due to lack of supervision of the building, weakness of material, neglect of engineering knowledge among the contractors, etc. were the main reasons for the destruction of buildings [40].

According to the investigations, when the stone structure was built in Turkey without engineering supervision it cracked and broke after the earthquake. Roofs, corners of structures, wall damage due to cutting, sliding cutting, bending loads, inappropriate length and span of unconnected walls, etc., are among the most important challenges in masonry buildings and reinforced concrete buildings [40].

Unfortunately, most of Iran's neighboring construction have a similar situation, which involves operations and supervision. The easier solution is to improve the codes of the countries, emphasize and act on civil engineering codes, and take monitoring and operation engineering seriously.

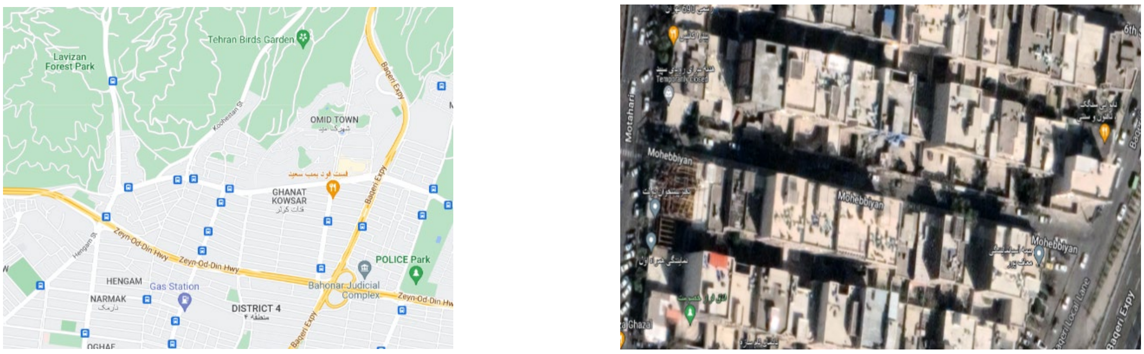
4 Results and Discussion

4.1 Example Research Studies

Two buildings in Tehran were selected to analyze real situations. Two buildings have been selected among hundreds of construction sites in Tehran with specific conditions:

- Two buildings are in the same province in Tehran.
- Two buildings are chosen among reinforced concrete structures.
- Two buildings are constructed by the individual construction contractors.
- The situations of individual construction contractors are considered.

The locations of the two buildings are as close as possible so that the study conditions are similar to each other. In this regard, two buildings have been selected from reinforced concrete structures in one province of Tehran and in one street. Ghanat Kowsar, in the fourth district of Tehran, was chosen as the study location because of its proximity to the study site and the author's familiarity with the site. This place is in the northeast of Tehran and close to the Lavizan Forest Park. Ghanat Kowsar is located between Baqeri Expressway from the east, Zeyn-Od-Din Highway from the south, Omid Town from the north, and Seraj Street from the west (Figure 8). Research observations indicate that Ghanat Kowsar province is a suitable place for the construction of new apartments by individual contractors due to the favorable economic, environmental, cultural, and social conditions of this place.



(a) **(b)**

Fig. 8 - The location cause of study (satellite picture): (a) Ghanat Kowsar province; (b) Construction site street (Mohebbiyan)

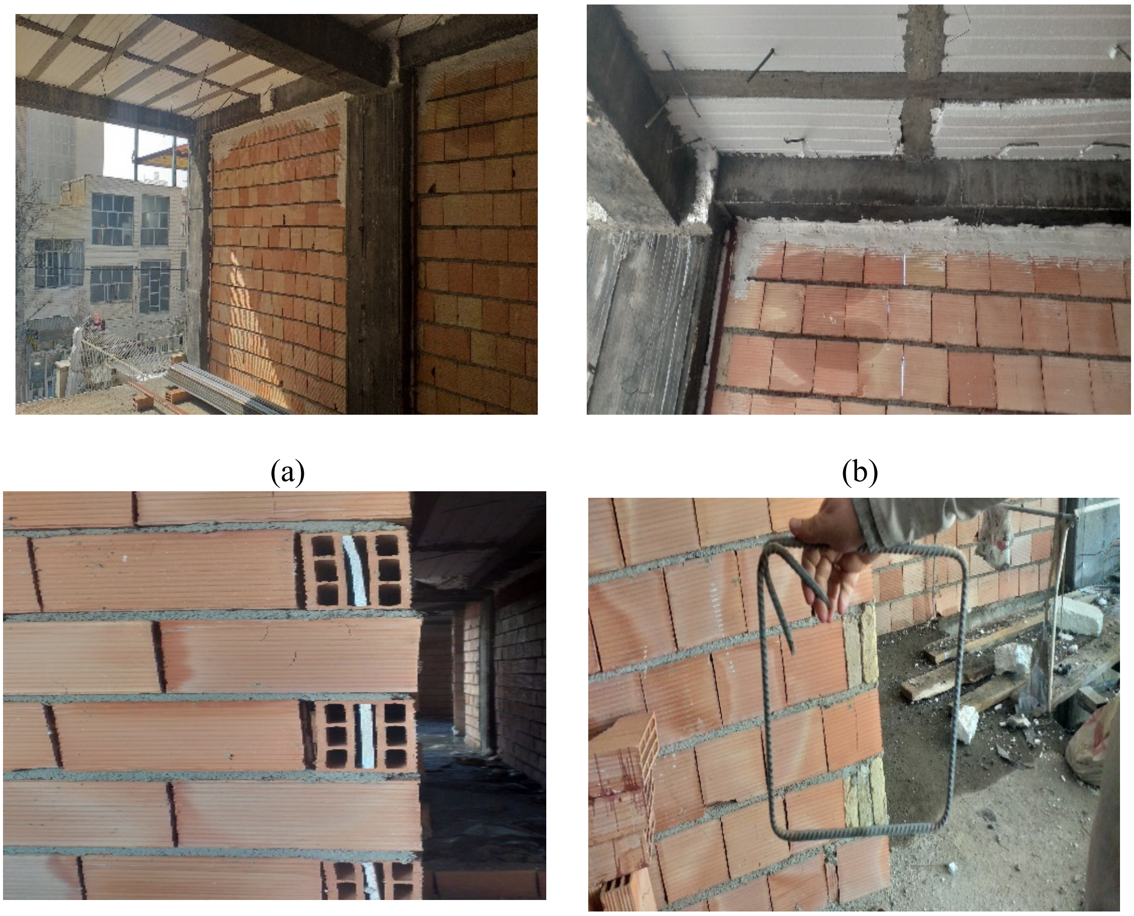
Two buildings were built by two separate construction contractors. The first building (1B) is in the west of Mohebbiayn Street, and the second building (2B) is in the east of Mohebbiayn Street (Figure 8 (b)). The conditions of the contractor are different in terms of education level, age, culture, etc.

These two buildings have been analysed and compared in terms of contractors, structures, operational errors, etc., and the results show that the conditions of the contractor affect the quality of construction performance.

4.1.1 First Building Analysis Results

The first building (1B) is located on the west of Mohebbiayn Street in the Ghanat Kowsar Province (Figure 8). The contractor works as an individual without affiliation to a government (or corporate) manufacturing contractor. The contractor is a 35-year-old civil engineer who also works as an operation engineer at a construction site. The quality of the structure was his biggest concern, and the contractor wanted to complete it with the best quality. The contractor of the first building is known as a civil engineer with developed construction technology. Still, he was motivated to use new materials due to doubts about the quality and condition of new materials. For example, the contractor preferred to use brick masonry blocks because some issues are resolved after the wall is built. The contractor claimed that the brick masonry blocks of the groves prevented cracking on the plaster, and the colour of the wall was created later. According to the details in this section, he has a good status in the field of general knowledge of civil engineering. The contractor could also use structural design software on the computer and his English language level was also good.

The first building's build-up area is more than 1440, and it includes two parking areas and five residential stories. According to the concrete laboratory experiments, the compressive cube test was 50 MPa, considering the compressive strength design. The building uses composite steel concrete precast beams with polystyrene foam blocks as the concrete slab Figure 9 (a). Moreover, the strip foundation is used to connect the foundations together. According to the observation, the concrete corrosion is not illustrated in the reinforcement concrete columns and beams, as well as the slab was without any shrinkages because of the attention of the contractor as an operation engineer to casting and installing concrete Figure 9 (b). Polystyrene foam is used to provide sound and thermal insulation between bricks and masonry blocks to improve the insulation effect of walls (Figure 9 (c). The stirrups are operated correctly according to 9th Iranian building design codes with 45-degree bending Figure 9 (d). The wall post is properly executed on all walls to support the lateral masonry walls during an earthquake (Figure 9 (a)).



(a) (b)

(c) (d)

Fig. 9 - First building information: (a) bricks masonry blocks; (b) composite steel concrete precast beam with polystyrene foam blocks; (c) Polystyrene foam isolation; (d) rebar correct bending degree

Despite paying attention to the design code, it would be more interesting if it was implemented to points such as optimization of using new material such as AAC blocks, using new methods of slab designing (because of saving the space occupied on the floors), and other new methods to achieve maximum performance of the structure.

4.1.2 Second Building Analysis Results

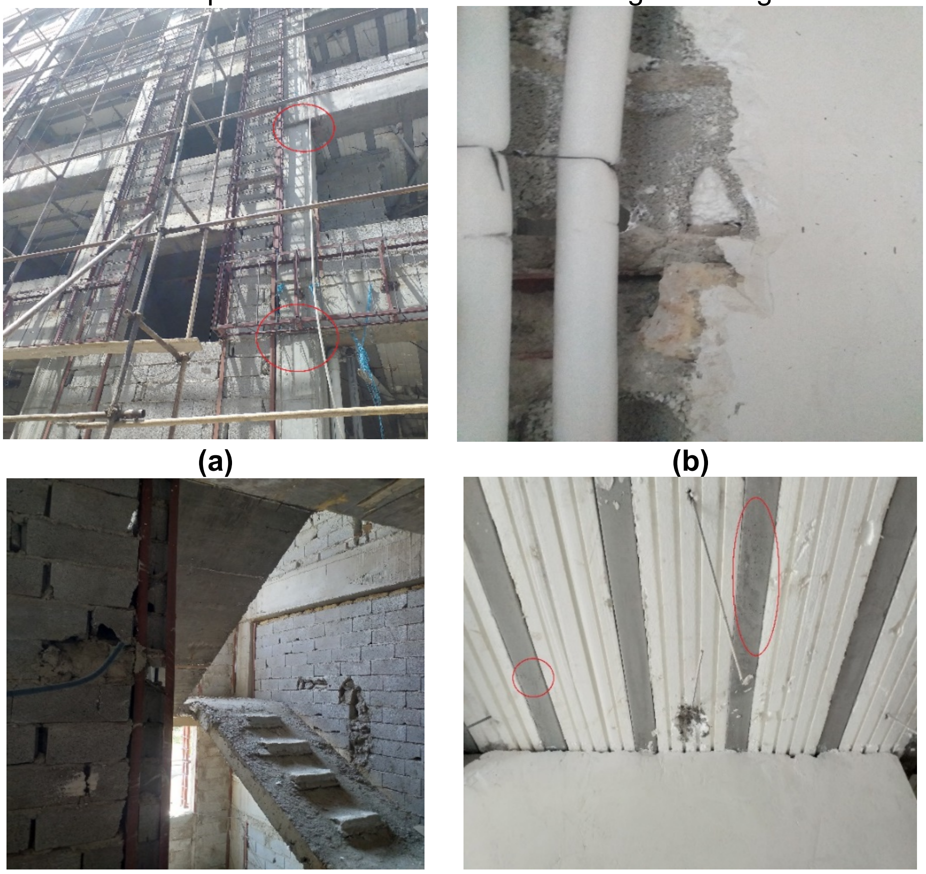
The second building was also built by an individual contractor. He is a 65-year-old investor with disaffected experience. In addition, he did not have an adequate level of education. Thus, most of the work was in the operations and supervisor engineers.

It is clear from the construction site that the problem of using the structure is related to the contractor's experience. In this regard, the installation of concrete in the second building had many problems. For example, concrete columns do not overlap each other (Figure 10 (a)). This problem is related to the lack of supervision of engineers on the building. In another example, beams and structures are destroyed to use equipment on the structure (Figure 10 (b)), which is attributed to the negligence of the supervising engineers.

The general lack of knowledge about civil engineering was evident. For example, he was not up to date in the field of new materials and new construction technologies, and he did not know advanced materials technologies. However, he used LECA blocks (clay concrete blocks) instead of brick masonry blocks. In addition, the walls are separated by polystyrene foams to prevent sound and temperature transmission (Figure 10 (c)). The wall post is not observed in the second structure, which shows that the issue of earthquake resistance was not important for the contractor.

The size of the building is more than 1000 units, and there are two parking lots and five floors in this structure. Based on observations, concrete corrosion was visible in some columns and beams (Figure 10 (d)), which can reduce the performance of the structure in critical situations such as earthquakes.

In general, the lack of general information and attention to the budget instead of safety has been the reason for the construction qualification in the second building not being satisfied.



(a) (b)

(c) (d)

Fig.10 - Second building information: (a) connection problems between columns and beams; (b); remove the structure (c) using LECA blocks; (d) corrosion concrete problem

4.2 Comparison between US and Iranian RC Codes

In Iran, there are three distinct building regulations that specify how reinforced concrete construction should be designed. The European and American codes that served as the model for Iranian codes are incompatible with Iran's climate and building style. Iranian "ABA" is the code for concrete design, which was based on by American "ACI318-14". The 9th National Building Code of Iran is the code for general design, and Iranian "Building 2800" is the code for seismic design. American "ASCE 7-10". The primary cause of miscommunication and confusion among engineers when selecting the appropriate codes is the fundamental difficulty with Iranian design regulations. As a result, some Iranian engineers frequently make references to and apply American and European codes.

The following are some examples of how ABA codes and ACI 318-14 differ and are remarkably comparable: ACI 318-14 has 27 chapters, while ABA, the primary code for designing reinforced concrete buildings in Iran, has 25 chapters. Both codes are divided into two sections, one is about codes, and another is about comments and definitions. First, attention is drawn to the mechanical qualities of concrete. While "Mechanical Properties of Concrete" is the title of the third chapter of the ABA, "Concrete: Design and Durability Requirements" is the definition of concrete qualities in the nineteenth chapter of ACI 318-14. There are fifteen varieties of concrete specified in the Iranian code design, and two types of concrete, referred to as "Normal Weight and Light Weight" concretes, are described in ACI 318-14. ABA is described as C10, C12, C16, C20, C25, C30, C35, C40, C45, C50, C55, C60, C65 and C70 concrete types. In this expression, the number after "C" is known as "compressive strength of concrete" in MPa. While ACI 318-14 explained that the compressive strength is in two classes "normal weight (maximum without any range) and light weight (minimum 20 MPa) ». The Modulus of Rupture and Modulus of Elasticity are similar for both code designs, it seems that the ABA is inspired by the ACI 318-14. The Modification Factor is defined for ACI 318-14 as an equation (Equation (1)), while the ABA neglected this equation. Equation (1) is defined as follow:

$$\lambda = \frac{f_{ct}}{0.56\sqrt{f_{cm}}} \le 1.0 \quad (1)$$

Where: λ known as Modification Factor, f_{ct} known as Splitting Tensile Strength, and f_{cm} known as Measured Average Compressive Strength.

The ABA defines the Poisson ratio, coefficient of thermal expansion of concrete, creep of concrete, and other mechanical properties of concrete. The ABA has just defined the mechanical properties of concrete, While the ACI 318-14 not only studied concrete mechanical properties but also focused on the concrete durability requirements.

Chapter 7 of ABA is about loading as "Load Factor, Load Combination and Strength-Reduction Factor". Also, ACI 318-14 loading is defined in chapter 5 as "Loads". The ABA is defined a little more about loading conditions. For example, besides load combination, the ABA includes the liquid pressure loading and strength-reduction factor.

4.3 The study's outcome

This research work examines and analyses Reinforced Concrete RC structures according to construction methods and challenges. This research examines the methods and challenges of construction in the city of Tehran, and two buildings have been selected as the reasons for studying in this article.

In the first part, the results of the study of RC structures are examined in relation to the influence of operation engineers and supervising engineers. The analysis of RC structure from the point of view of operation engineering emphasizes the point that the most damage and structural accidents occur in construction workshops. Meanwhile, the highest percentage of RC structure accidents is related to excavation construction accidents [1]. Other incidents that are investigated for the cause of operation and monitoring occur in both short-term periods at construction sites and long-term ones that occur after construction when a disaster such as an earthquake occurs. In this regard, the effects of the Kermanshah earthquake have been analyzed to apply new design codes for RC structures throughout Iran. The results obtained from observations and statistical reports show that the RC structure of Tehran was built in a similar way to Kermanshah, which did not pay attention to the quality of construction and design regulations. This attention emphasizes that the quality of structures is related to the design and risk management methods, which are not considered in most areas of Tehran, Iran. The current trend of construction in Tehran, Iran mentions that RC construction operations and supervision are mostly neglected, but proper supervision can reduce the risk of disaster in the long term. The first hypothesis is that the neglect of engineers and contractors to implement buildings correctly is the main construction problem in Tehran, Iran.

In the second part, the results obtained from two buildings are compared. The trend of the results was towards emphasizing the factors that were studied and mentioned that affect the construction. The factors indicate the social, scientific, and economic level of the contractors, which reflects their personality on the importance, health, and safety of the structure. These causes are emphasized in other studies as well [1]. For example, the rate of civil engineering knowledge is long-term affected by the structure since the first building uses bricks masonry blocks, and the second building uses LECA blocks. The first building wall paints have existed for a long time. This action was undertaken by the first building contractor, who had suitable knowledge of new and advanced construction equipment. According to the results and consequences, the second theory is that the personality factors of contractors directly affect the quality of construction in the short-term and, in this regard, the amount of risk of the structure in the long-term.

In this regard, two dimensions of important structural analysis is achieved in this article:

1. Effect of attention of both engineers and contractors in the quality of structures.
2. Effect of the personality factors of individual construction contractors to structure quality.

Considering the impact of this industry on socio-economic development, the Malaysian government is trying to fill technology with neighbouring countries in the construction industry [7]. According to the studies, most of the government policies of Malaysia are focused on construction safety and waste management in construction. However, some studies in Malaysia have focused on the use of mechanization of construction tools [41], [42]. It is possible that the effect of builders' personality factors is investigated by data mining, and a comprehensive management algorithm to predict structure quality through new programming methods such as neural network, machine learning, data mining, etc. is found as this algorithm. It has been done in risk management as well as company management.

4.4 Recommendation to Improve the Construction Method

According to the present study, the construction method of Tehran is similar to other capitals and neighbouring cities of Iran. Although the construction situation of Tehran is better than some cities and similar or weaker than other cities of West Asia. In this condition, there are some recommendation to improve the construction method in Tehran.

An important issue uses new and advanced technique of construction in Tehran. The methods of constructing prefabricated buildings are felt in Tehran [43]. With using prefabricated structure, time, energy and resources are saving. It should be attend, the prefabricated structure can be constructed by concrete or steel-concrete composite [44]–[46]. Prefab construction technology has been used for more than 100 years, many countries such as Australia, Singapore, England and China have already developed this technology [47]–[51]. For example, Research shows that in China's 13th Five-Year Plan (FYP), the country has achieved 30% of prefabricated structures within a decade [52]. Different types of prefabricated construction concrete structure have been designed. For example prefabricated concrete T-beams have been used widely in construction [53]–[57]. For example, another good example is panels and precast concrete sandwich panels (PCSP) for external wall. Studies show that PCSP has high structural, thermal and fire performances [58]. Other studies try to build prefabricated segmental concrete, beams due to high potential of the impact resistance [59]–[61]. In additionally, another method is UHPC-shell strengthened prefabricated structures [62].

Another method of improving construction quality is using 3D printing concrete technology. For the first time, Khoshnevis developed Contour Crafting (CC) as a large scale printing concrete method [63], [64]. According to the previous studies, construction cost of 3D printing concrete structure had lower cost than traditional ways. Another reason of using 3D printing building is decreased the waste construction dust during the construction time [65], [66]. Some studies are even trying to 3D print reinforced concrete structures to improve mechanical properties [67]. Weng et al. Illustrated 3D printing concrete decreased more than 25.4% cost of 85.9% emission $CO_{2\ \text{and}}$ 87.1% energy consumption. They found that using 3D printing concrete has many advantages than traditional conditional construction method [68]. There are different types of 3D printing methods. For example, concrete robotic arm-based 3D printer, compound arm 3D printer (Massachusetts Institute of Technology), mobile truck-based printer, delta style 3D printer (WASP Company) and gantry 3D printer (Chinese Green Print Company) are Construction 3D printing methods [69]–[72]. Some studies attempt to use 3D printing technology to improve the formworks concrete of buildings [73]. Another type of using 3D printing technology is reinforced concrete via Fused deposition modeling method with different materials such as Polylactic acid (PLA) [74]. For example, Hematibahar et al. reinforced concrete with hyperboloid shell structure with PLA materials. They found that reinforced concrete with 3D printing hyperboloid shell structure can increase ductility of concrete. Another research study the effect of reinforced concrete beam with 3D printing trusses. The results show that reinforced concrete beam with some types of 3D printing trusses can improve the flexural strength. Reinforced concrete with 3D printing technology is a new way to improve mechanical properties which is depend on the infill, geometry, materials and other parameters of 3D printing. For example Farina et al. [75] reinforced cement with 3D printing patterned and simple rebar. They found that reinforcing cement with 3D printing patterned rebar improved the flexural strength and changed the strain behavior of cementitious beam to strain hardening.

Another important issue is improving construction materials or using eco-friendly materials in construction. For example, replace geo polymer concrete with cement base concrete due to eco-friendly effect is an important issue in Tehran [76], [77]. Another example, different types of fibers such as adding basalt, steel, bamboo and etc. to improve mechanical properties [78]–[81]. Moreover, using some advanced technologies such as cement and concrete self-healing materials can improve the quality of reinforced concrete structure [82]. Another method to improve the quality of construction materials is using machine learning and artificial intelligence to predict the mechanical properties. For example some studies can predict mechanical properties of concrete, percentage of mixture design, accuracy of designing results and etc., which can change construction method and improve the quality of concrete for construction [83], [84]. In this way many studies show that machine learning and artificial intelligence methods are very suitable to improve code design and designing methods and help to future designing methods [34], [85]–[87].

Overall, there are many types of methods which can improve the construction quality in Tehran as soon as possible. Considering the domestic capacity, achieving these goals is not far from reach, and if a special program is implemented in the next few decades in Tehran, it will raise the quality level of construction higher than in West of Asia.

5 Conclusions

The results show that the quality of RC buildings is associated with contractors and engineers as well as the personality factors of contractors. Analysing construction in Tehran as a cause of study reveals that many construction projects in Tehran are full of challenges and mistakes. The increment rate of construction accidents in Tehran and observation defined the contractors' personality factors as the first reasons for incorrect buildings construction. In this regard, the following are the findings of this investigation:

1. Two buildings have been analysed as a case study and compared in terms of contractors, structures, operational errors, etc., and the results show that the conditions of the contractor affect the quality of construction performance.
2. The current trend of construction in Tehran mentioned that the impact of operation and supervising engineers in the construction of reinforced concrete structures is mostly neglected. Still, proper supervision can reduce the risk of disaster in the long-term. As a result, neglecting engineers' and contractors' duties for the correct implementation of buildings is the main construction problem in Tehran, Iran.
3. In addition, paying attention to the design code is not the key solution but it would be more productive by considering the optimization of using new materials such as AAC blocks, new methods of slab designing (because of saving the space occupied on the floors), and other new methods to achieve maximum performance of a structure.
4. In general, the lack of general information and attention to the budget instead of safety has been the additional reason for not satisfying the construction qualification, so the personality factors of the contractors directly affect the quality of construction.
5. Localization of construction technologies can improve the quality of construction. Some advanced construction technologies such as 3D printed concrete, 3D reinforced concrete, prefabricated buildings have a direct impact on the construction method and other technologies such as machine learning, artificial intelligence and material science have an indirect impact on the construction method.
6. With a specific program, the quality of Tehran's construction can be improved in several decades. In this program, relying on domestic capacity to localize new construction technologies instead of focusing on increasing the level of traditional engineering should be considered.

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