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Advancing Construction with IoT and RFID Technology in Civil Engineering: A Technology Review

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ABSTRACT: Nowadays, the realm of civil engineering has expanded to encompass Internet of Things (IoT) technologies, which can contribute to making sustainable, high-performing, and durable buildings. These innovative techniques allow for monitoring concrete structures and developing inspection and maintenance plans to ensure their long-term integrity. By leveraging the power of IoT technologies in civil engineering, we can improve the efficiency and effectiveness of building maintenance, reduce costs, and optimize the use of resources, all while promoting sustainability and longevity in the built environment. In this article, a technical review will be made of RFID technology's significance in civil engineering. RFID technology is utilized in inspecting building materials, especially in reinforced concrete, monitoring cavities in riverbeds, monitoring stress in reinforced concrete structures, monitoring corrosion of reinforced concrete reinforcements, monitoring excavations at a construction site and many others. This article concluded that RFID technology has significant benefits in the field of civil engineering, and using the Internet of Things, it greatly impacts following up on building structures and conducting inspections and immediate maintenance of them.

Keywords: Industry 4.0, Civil Engineering, Internet of things, RFID technology, Artificial intelligence, Smart home.

1. INTRODUCTION

The rapid pace of technological advancement and application growth is leading to remarkable progress in various domains, and technology has the potential to revolutionize numerous aspects of our lives, including the domain of building technology [1][2]. Within this growth, the processes of controlling goods and machines appeared in different places using Internet information technologies and their application in the industry named Industry 4.0, and this process is named in the United States as Industrial Internet [3-6]. In contrast, the global term used for it is the Internet of Things (IoT) [7][8]. This term has achieved significant recognition in the online community, which comprises an extensive network that interconnects all devices through the Internet and enables a seamless exchange of information and data [9][10]. The data gathered by these devices can be utilized for diverse purposes, including monitoring, and controlling various processes and organizations. This technology is widely distributed and involved in many domains, such as smart homes, wearable devices, industrial automation, healthcare, transportation, agriculture, military, patient health monitoring, identification and recognition technologies, hardware, software, cloud platforms, communication technologies and networks, software, algorithms, location technologies, data processing and storage solutions, power, energy, security mechanisms and many more. These devices have the ability to communicate with other devices through the Internet, and companies and individuals can collect and analyze the required data and make appropriate decisions. The Internet of Things (IoT) has brought about a revolutionary change in several industries by enabling real-time data monitoring, enhancing efficiency, and reducing operational costs [11-15]. Nevertheless, the proliferation of

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IoT devices has also raised situations regarding the security of sensitive data and the potential for electronic attacks to compromise data privacy. Additionally, new threats that can manipulate data traffic within the electronic environment have amplified these situations. Figure 1 highlights the value of fourth industrial (Industry 4.0) technology, which relies heavily on the Internet of Things to drive digital transformation and unlock new business opportunities. Anyway, as the IoT continues to evolve, it is essential to prioritize measures that safeguard data privacy and security and mitigate the risks associated with cyber threats [16-23].

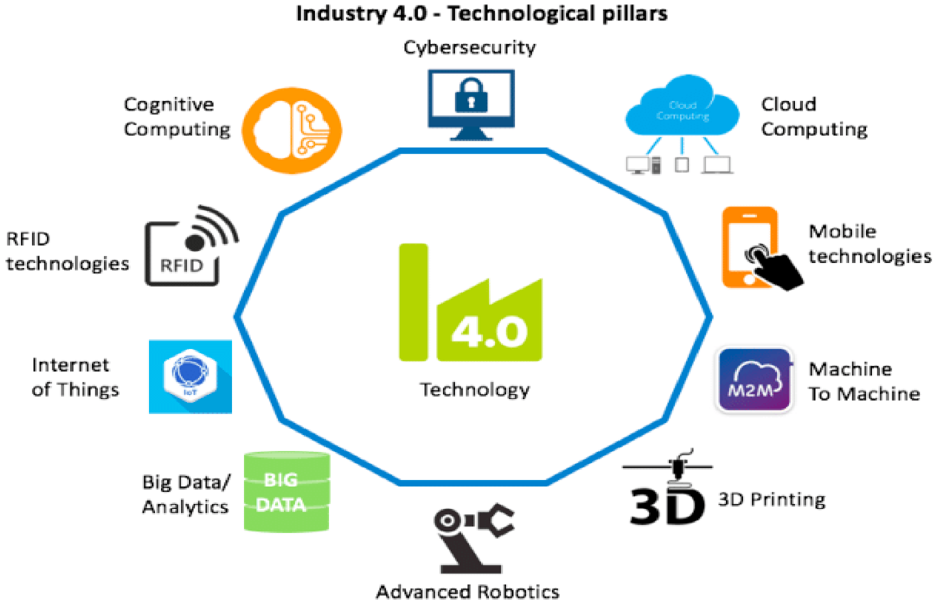

FIGURE 1. - The significance of Industry 4.0 [24].

The Fourth Industrial Revolution happened and developed when computer technology became more significant and influential in communities, without which tasks could not be achieved [25][26]. The subsequent revolutions are expected to be around sensors that will be worn on humans. One of the most remarkable growths in technology is Tesla's brain chip initiative, which involves creating tiny chips that can be implanted in the human brain. The primary objective of this project is to help visually impaired individuals regain their sight, as well as restoring the ability to move and communicate. However, this is just one of the many instances of how technology is transforming people's lives. Artificial intelligence (AI) is rapidly growing [27-32], and innovations such as ChatGPT platform support people in writing, programming, and developing applications with greater ease and efficiency [33-40]. Self-driving cars, also known as autonomous vehicles, are another breakthrough that promises to revolutionize the way we travel and commute. These technologies profoundly impact society by providing human services and assistance to people in need. Across-the-board, these technological advancements demonstrate the vast potential of science and engineering to enhance the quality of life for people worldwide. Nevertheless, it is also essential to address any ethical concerns that may arise and ensure that these technologies are developed and deployed safely and responsibly.

In civil engineering applications, the Internet of Things is employed for various purposes, especially in building smart homes [41][42]. Today, all home appliances, such as opening and closing lights or curtains with sound or clapping, doors, windows, air conditioners, and heating/cooling systems that can be controlled by remote controls, are all controlled by IoT devices. So, the Internet of Things is required in civil engineering applications, and companies seek to develop their services significantly to keep pace with the latest methods in developing smart homes. RFID technology is the most common technology or IoT application in civil engineering [43-45]. This technology is an acronym for (Radio Frequency Identification) and it is a type of wireless technology that uses electromagnetic fields to transmit data. An RFID system consists of three fundamental components: a tag (also known as labels), a reader, and a computer system (see Figure 2). Tags can be attached to or embedded in various objects and contain a chip and antenna. The chip stores the data, and the antenna enables the tag to communicate with the reader via radio waves. The reader, connected to a computer system, sends and receives data to and from the tag. This technology is employed to identify and track all kinds of living and unconscious objects from certain distances without touching them. RFID technologies are becoming increasingly prevalent worldwide and are employed in many sectors, such as construction, automotive, fuel, logistics, retail, agriculture, health, medicine, textiles, finance, banking, energy, production and security. It significantly reduces the costs of work performed with RFID technology, speeds up workflow, and increases efficiency and quality. RFID technology also has applications in healthcare, where it can be utilized to track patient records and medical equipment. In retail, RFID technology can assist in managing inventory and reduce the risk of theft. However, there are also privacy and security concerns related to using RFID technology, as it can be operated to track individuals without their knowledge or consent. The main contribution of this article is a comprehensive technical review to catch the significance of RFID technology in civil engineering, what services it provides and explores how it can benefit the field [46-51].

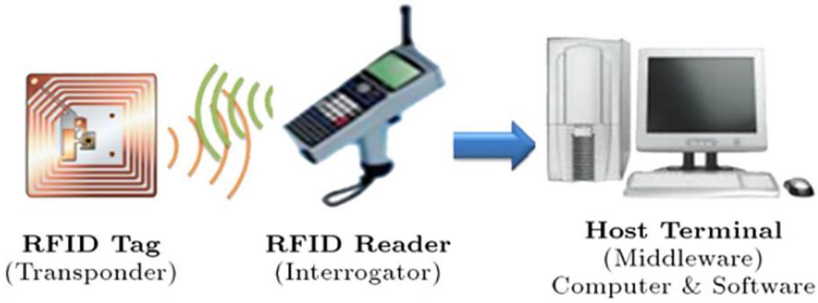

FIGURE 2. - RFID system components [52].

2. THE IMPORTANCE OF IOT IN CONSTRUCTION

The Internet of Things (IoT) technology is transforming the field of civil engineering in numerous ways. From the initial design phase to the ongoing operation and maintenance of structures, IoT is having a profound impact on all aspects of the field. This rapidly evolving technology is enabling civil engineers to collect and analyze data in real-time, optimize energy usage, monitor structural health, and enhance overall efficiency. As IoT continues to advance, it is poised to revolutionize the way civil engineers approach the built environment. The integration of IoT technology in civil engineering has brought about a multitude of critical applications that support both construction and operation activities. One such application is the development of smart buildings, which are designed to optimize energy efficiency, improve air quality, and reduce operating costs. By leveraging IoT sensors and data analytics, these buildings can monitor and adjust temperature, lighting, and ventilation in real-time, resulting in significant energy savings and a more comfortable indoor environment. As the domain of civil engineering continues to investigate the potential of IoT, smart buildings are just one example of the transformative impact this technology can have on the built environment. In addition to optimizing energy usage and reducing operating costs, smart buildings are being developed to offer a variety of services to occupants, such as enhanced security and remote monitoring and control of various systems within the building. These advancements in building design also have implications for the types of materials and construction techniques used in the building process. Figure 3 shows the components of smart cities.

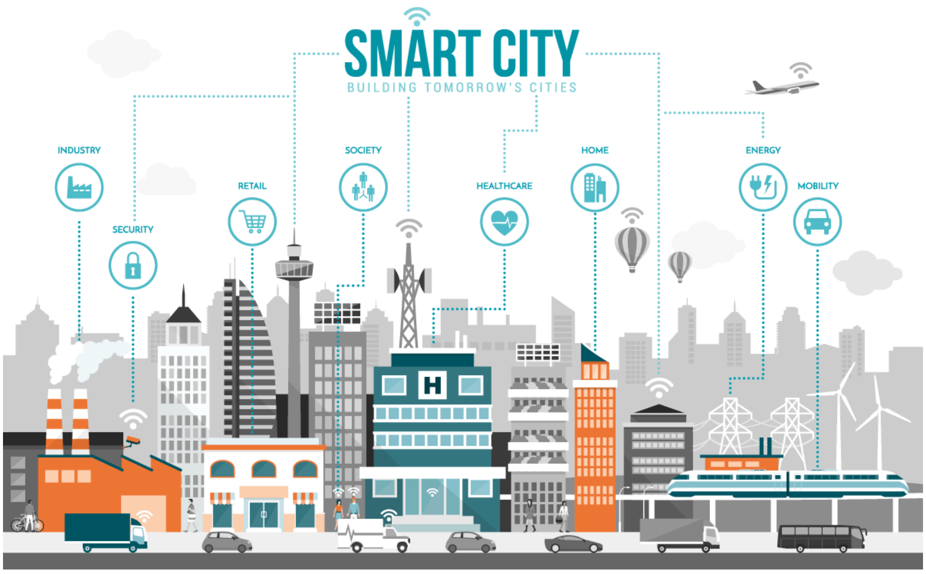

FIGURE 3. - Smart city components [53].

Smart buildings are just one aspect of the more significant trend towards creating smart cities, which leverage IoT technology to enhance the quality of life for residents while promoting sustainable development. From intelligent transportation systems to energy-efficient buildings, smart cities are poised to transform the way we live, work, and interact with our environment. In these smart buildings, various sensors are embedded in the structure of the building to monitor and control the operation of the building. These sensors include temperature sensors, humidity sensors, CO2 sensors, motion sensors, and sound sensors. These sensors collect and transmit data to the cloud to provide real-time monitoring of the building's various systems and the occupants. Currently under construction, the city of NEOM in the Kingdom of Saudi Arabia is garnering attention as one of the most famous cities being built. Dubbed the "city of robots," NEOM is entirely reliant on Internet of Things (IoT) technologies and artificial intelligence (AI) for its development. Here are some examples of how IoT can be used in civil engineering:

- Structural Health Monitoring (SHM): IoT sensors can be installed in buildings and bridges to monitor their condition in real-time. These sensors can detect vibrations, temperature changes, and other factors that may indicate a potential problem. SHM systems can help prevent catastrophic failures and reduce maintenance costs.
- Smart Building Systems: IoT technology can be used to automate building systems, such as lighting, heating, and cooling. Smart building systems can improve energy efficiency, reduce maintenance costs, and enhance occupant comfort.
- Traffic Management: IoT sensors can be used to monitor traffic flow and optimize traffic management systems. This can help reduce congestion, improve safety, and reduce emissions.
- Environmental Monitoring: IoT sensors can be used to monitor air and water quality, noise levels, and other environmental factors. This information can be used to develop better urban planning policies and improve public health.
- Construction Site Monitoring: IoT sensors can be used to monitor construction sites in real-time, providing insights into worker safety, equipment performance, and project progress. This can help reduce construction delays and improve project management.

General, IoT technology can greatly enhance the efficiency and sustainability of civil engineering projects. Engineers can make more informed decisions, reduce costs, and improve safety by employing IoT sensors and data analytics.

3. RFID TECHNOLOGY IN CIVIL ENGINEERING

RFID technology is an integral component of modern construction sites, facilitating material distribution and quality management. By using ultra-high frequency radio waves, RFID can accurately and efficiently identify people and materials within buildings. This helps ensure that materials are delivered to the correct location, enabling project managers to track inventory and monitor work progress. Besides, this technology provides an added layer of security by tracking the movement of personnel and materials, reducing the risk of theft or loss. General, this technology plays a crucial role in improving the efficiency and safety of construction projects. The adoption of middleware and RFID technologies has proven to be highly effective in the off-the-shelf industry across the USA. Figure 4 provides a visual representation of how RFID technology is being employed in this industry. By leveraging these technologies, businesses are able to streamline their operations, improve supply chain visibility, and enhance inventory management. RFID tags can be affixed to products, enabling real-time tracking of goods as they move through the supply chain. This facilitates faster and more accurate inventory management, reduces the risk of stockouts, and ultimately improves customer satisfaction. In addition, the integration of middleware and RFID technologies has become a game changer in the off-the-shelf industry, enabling companies to operate with greater efficiency and effectiveness. The performance of this technology offers several benefits for manufacturers and customers alike. For manufacturers, it can reduce costs and streamline operations by providing real-time data on the production process, inventory levels, and the quality of materials being used. This enables authorized personnel to remotely monitor production and inventory records, improving operational efficiency and facilitating better decision-making. Additionally, the technology can ensure the authenticity and quality of products, safeguarding the manufacturer's reputation in the market. Furthermore, this technology offers a powerful tool for improving efficiency and quality in the manufacturing and construction industries. In addition, providing real-time access to data and remote monitoring of production and inventory records can assist businesses in optimizing their processes and maintaining their competitive edge in the marketplace.

FIGURE 4. - RFID technology is being employed in the concrete structures [downloaded from Google].

Concrete structures can deteriorate over time due to the increasing pressure they face. Traditionally, wire strain gauges or rebar strain transformers were operated to measure stress by connecting them to data loggers. However, this method has several drawbacks and is no longer preferred. It can be unreliable and inaccurate, and it may need to provide more data to understand the problem's extent fully. As a result, newer, more advanced techniques are being developed to improve the accuracy and efficiency of stress measurement in concrete structures. Long-term stress measurement in concrete structures can be challenging due to the deterioration of cables that extend beyond the building frame. These cables not only affect the structure's aesthetics but also make it challenging to monitor stress levels over time. Fortunately, the RFID stress sensing system offers a solution. By embedding data communication equipment and sensors directly into the structure, it becomes possible to monitor its condition without the need for external cables continuously. This approach provides several advantages, including improved accuracy and reliability, as well as a more aesthetically pleasing appearance for the structure. In addition, RFID technology utilizes electromagnetic waves that are transmitted from the surface of the chassis to the RFID tags. These tags, in turn, direct sensors to measure voltage and other important parameters. This approach has been displayed to be effective in tracking deformations in reinforced concrete, as illustrated in Figure 5. By using RFID technology for stress measurement, it becomes possible to collect data in a non-invasive manner and with a high degree of accuracy. This can assist engineers and researchers in better understanding concrete structures' behaviour over time and develop strategies for mitigating stress-related issues. The RFID technology makes it possible for anyone with a computer and a particular reader to perform stress measurement without any required effort efficiently. This technology enables the monitoring of the corrosion of reinforcing bars placed inside reinforced concrete structures, which helps to counteract tensile stresses. By embedding sensors and data communication equipment directly into the structure, RFID technology allows for continuous monitoring of the structure's condition over time. This can support to identify of potential issues early on and execute measures to prevent further damage. With its ease of use and high level of accuracy, RFID technology is becoming an increasingly popular choice for stress measurement in concrete structures. Advanced applications make it possible to get remote measurements at high frequencies and monitor the corrosion condition by closely tracking the diameters of the reinforcement with low frequencies. By operating these techniques, it becomes possible to gather accurate data on the condition of concrete structures in real-time, allowing for proactive maintenance and repair measures to be carried out before significant damage happens. This approach can extend the lifespan of concrete structures and improve their safety and reliability. One of the benefits of RFID technology is its ability to monitor asphalt pavements. By placing RFID chip elements on the asphalt surface after paving the roads, characteristics such as temperature, moisture content, and pavement cracking can be wirelessly transmitted. This is particularly useful for controlling the speed of passing cars and ensuring the safety of drivers. However, it should be noted that the ability to read RFID cards decreases with the vehicle's acceleration, which may limit the effectiveness of this approach for high-speed roads. However, the use of RFID technology in asphalt pavements offers a promising way to monitor the condition of roads in real-time, enabling authorities to identify potential issues early on and take suitable measures to maintain and repair the infrastructure.

FIGURE 5. - Monitoring deformations in concrete structures using RFID technology [55].

Data gathered by RFID sensors is transferred in real-time using Internet of Things (IoT) technologies and sent to central monitoring centers via the Internet. This approach allows for the early detection of potential issues and helps to prevent construction accidents and crises. RFID technology is particularly well-suited for this application as it can be used to connect to a network wirelessly, enabling the continuous monitoring of critical infrastructure. By leveraging the power of IoT and RFID technologies, it becomes possible to collect, process, and analyze data in real-time, enabling authorities to take swift action in response to changing conditions. RFID systems have been developed to efficiently scan and analyze unforeseen work accidents in construction site environments, identifying the tools and equipment involved in the incident. In order to reduce accidents and improve safety in high-risk areas, warning systems have been created that can communicate with objects through a wireless network. This approach enables real-time tracking of workers and equipment, allowing for the detection of potential hazards and the implementation of appropriate safety measures. By utilizing RFID technology in this way, it becomes possible to significantly reduce the number of accidents and ensure a safer working environment for all. In addition, the use of RFID systems can enhance the efficiency of operations, enabling better management of resources and reducing the likelihood of costly downtime caused by accidents or equipment failure. Another benefit of this technology is excavation monitoring, reporting and monitoring of the amount of excavations in construction by taking advantage of the identification and security benefits of RFID and the opportunities offered by the real-time online web system. Moreover, this technology is used to monitor earthquakes and detect abnormal movement in buildings and other structures by placing RFID sensors in key locations and programming them to detect movement during an earthquake. These sensors monitor the structures and trigger an alarm or warning system to alert the workers or residents of the building. Another possible application of RFID technology in earthquake monitoring is tracking the movement of people and animals during an earthquake. RFID tags can be attached to people or animals, and sensors can be placed in buildings or other structures to detect movement. This could be valuable for emergency responders who need to quickly locate and rescue people or animals that are trapped or injured during an earthquake. Eventually, RFID technology can be used to monitor earthquake-related changes in the environment, such as ground movement, changes in water levels, or temperature changes. In addition, sensors can be positioned at critical sites to collect data, and the data can be used to provide early warning of potential earthquakes or to help scientists better understand the mechanisms of earthquakes.

4. CONCLUSIONS AND FUTURE WORK

Applications and technology based on artificial intelligence and the Internet of Things mainly support humans in achieving various life duties. One of the most influential of these technologies is RFID technology, as it has become of great importance and influence in the domain of civil engineering through the significant benefits it provides to engineers. This technology has the potential to study and track hydraulic structures to prevent the collapse of critical structural elements such as bridges due to waterbed situations. Moreover, it monitors the rate of deformation of reinforced concrete structures under both static and external dynamic loads and internal reinforcement corrosion employing wireless network technology. This technology is widely utilized by companies and effectively in construction sites and has a significant impact on the success of the process of tracking construction and deformations within structures. Depending on the Internet of Things technologies, data can be gathered and analyzed in real-time, and the required measures can be taken to treat distortions in building structures. In the future, a series of studies will be conducted on the most important technologies and applications that are used in the domain of civil engineering.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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