Digital Transformation of Ready-Mix Concrete

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Abstract- The use of digital tools by all parties involved in investment-construction activities becomes a necessary component of logistical and manufacturing processes as the technological evolution of the construction industry affects every stage of the cycle. The RMC factory consistently produces high-quality concrete. It offers a high level of harder concrete's overall durability and the structure's efficiency after it reaches maturity. Because RMC processes are highly automated and completely managed by electronic controls, the likelihood of mistakes in a variety of procedures is decreased. Additionally, it is environmentally benign and reduces pollution from dust during construction. RMC can help speed up this process. Around the world, RMC is being used extensively in civil construction. Ready-mix concrete, despite its lack of widespread recognition, is preferred for numerous construction projects due to its minimal batch variation, superior consistency, improved durability and strength, reduced air pollution and noise, and lower labor and monitoring expenses compared to traditional concrete production methods.

Keywords- Site mix concrete, modern technology, fresh concrete, innovation, productivity

I. Introduction

Ready-mix concrete (RMC) is a ready-to-use material made from a predetermined mixture of cement, sand, aggregates, and water. It is manufactured in a factory according to a set recipe or customer specifications at a centrally located batching plant. RMC is typically manufactured under computer-controlled operations and transported and placed at project sites using sophisticated equipment. It is delivered to worksites using truck mixers capable of mixing ingredients on route or just before delivery. The use of RMC is facilitated through a truck-mounted boom placer that can pump the product for ready use at multi-storied construction sites. In India, RMC accounts for less than 5% of cement consumption, with 82% of cement consumption in the form of site-mixed concrete. The share of RMC is expected to increase from 5% to 70% of total cement production in the future. Because of its superior quality, speed, environmental friendliness, lower cost, and removal of purchasing and storage problems, ready-mixed concrete—which is made at a central batching facility and transported to building sites using truck-mounted transit mixers—is a popular substitute for site-mixed concrete[1].

Conventional technologies used in the building sector cannot address the severe housing shortage brought to light by the affordability issue. For plans like Housing for All to be implemented effectively, new innovations will be essential[2]. The Indus Valley Civilization, dating back to 3000 BC, is one of the oldest documented examples of building in the world. It was found in Harrappa and Mohen-jo-daro, showcasing a highly structured urban culture with well-planned streets, thoroughfares, wide roadways, and sophisticated drainage systems. Starting to employ more cutting-edge building technology is crucial for construction companies, particularly in the modern period[3]. The construction sector in India has historically prioritized labor, leading to slow automation progress. Ready-mixed concrete is a

dynamic resource that requires regular reassessment based on the economy, country, local industry, and client. Market circumstances in developed economies are shifting from a product-cantered to a service-centred market, requiring regular market adjustments[4]. According to the 12th five-year plan, India's construction sector has the second-highest average GDP growth rate of 9.1%[5].

The ready-mixed concrete supply chain is influenced by factors like raw material availability, delivery, quality, production processes, loading time variability, and deliveries. With the fourth industrial revolution, digital transformation is crucial, and construction companies must collaborate with businesses with complementary digital skills to achieve this[7]. Nowadays, concrete is the most widely utilized and adaptable building material. Even though civil buildings have existed for as long as human civilization, it is hard to think of a modern construction that does not utilize or require concrete[8]. Information-communication technologies' effect on all aspects of socioeconomic interactions has grown steadily as they have developed and proliferated. Information and digital technologies were first viewed by the firms as tools for creating new products, increasing worker productivity, and streamlining some company procedures[9].

Roads play a crucial role in inland transportation, and their importance and contribution to the transportation industry are simply unmatched. Highway engineering, a subset of traffic and transportation engineering, includes roads[10]. The difficulties in integrating digital transformation in building projects are covered in this study. It would be easier to find the best solutions to get past the obstacles and ensure the success of the digital transformation if the difficulties facing the construction industry are recognized. Consequently, a successful digital transformation will profit from the newest technology in the construction industry's project execution[11]. Concrete is a crucial construction material due to its strength, durability, and superior building qualities. It allows for any shape, affordability, accessibility, and sustainability, making it a popular choice for commercial, residential, and infrastructure development projects[12].

II. Literature review

The industry's move toward incorporating digital technology for efficiency and competitiveness is highlighted in the literature on digital transformation in construction firms. Nevertheless, a lot of businesses have trouble integrating completely and frequently use fragmented technology, which limits their potential advantages.

The literature review emphasizes efficient resource use while highlighting different definitions and ideas of productivity in the building industry. Important studies by Oglesby et al. (1989) and Prokopenko (1987) differentiate between productivity and performance with an emphasis on cost-effectiveness. Productivity is divided into partial and total components by Sumanth (1984). The survey emphasizes the value of benchmarking and performance metrics in raising construction productivity, especially when it comes to the concreting process, which is the subject of the study.

Ready Mix Concrete (RMC) has evolved since the first plant was established in India in 1987, with notable expansion in metropolitan areas, according to the literature review. RMC addresses environmental issues and building space limits by contributing 5% of the nation's total concrete consumption. Even if it is more expensive, its effectiveness and quality make it more and more popular, which calls for better building methods and industry knowledge.

Key determinants of ready-mix concrete (RMC) operations are identified by the literature review and categorized into managerial, operational, plant machinery-related, and human aspects. It emphasizes the significance of prompt concrete delivery, effective batching plant productivity, and the influence of traffic and weather. Reflecting the changing environment of RMC usage in India, the report also highlights the necessity of automation in the construction sector to increase productivity and meet project deadlines.

The literature on ready-mixed concrete (RMC) emphasizes how the necessity for speed and quality in building led to its birth in India following liberalization in 1989. Since its 1994 commercial introduction, RMC has progressively gained traction, and by 2001, it had replaced site-mixed concrete by 2% of the market.

Improved quality, lower labor costs, and less material waste are some of the main benefits. But there are still issues like the high initial cost and difficulty of shipment. It is anticipated that the participation of international companies and significant cement manufacturers would promote the industry's expansion, provided that regulations are supported and consumers are more aware of RMC's advantages.

Ready-mix concrete (RMC) has evolved since its invention in Germany in 1903, with commercial delivery starting in the United States in 1913, according to the literature on the subject. Time and money savings are just two of the many benefits that RMC provides in construction, particularly for large infrastructure projects and crowded sites. Research shows that RMC outperforms site-mixed concrete (SMC) in terms of assurance of quality and finish. However, there are still issues in Bangladesh's RMC market, such as disparities in pricing and inconsistent strength results. All things considered, RMC is becoming more and more acknowledged for its efficacy and efficiency in contemporary building methods.

The benefits of ready-mix concrete (RMC) in the construction sector, such as better quality control, lower labor costs, and increased efficiency, are highlighted in the literature. Research emphasizes the need for thorough material testing to guarantee adherence to Indian Standard Codes and guarantee the longevity and functionality of concrete. Concrete installation and transportation are made easier by the use of concrete pumps and transit mixers, which save waste and maximize resources. Furthermore, RMC's uses include a range of building projects, demonstrating its adaptability. All things considered, RMC is a contemporary method of producing concrete that promotes both economic expansion and high-quality advancements in building techniques.

Ready-mixed concrete's importance in contemporary building is emphasized in the literature because of its efficiency as well as quality control. The manufacturing process, which includes batching, mixing, and delivering concrete to guarantee uniformity and performance, is highlighted in studies. The environmental effects are also covered by research, which promotes sustainable methods of waste reduction and resource procurement. To increase productivity, technological innovations, including robotic mixing and shipping systems, are being investigated. Additionally, as several experts in the area have pointed out, the use of ready-mixed concrete in a variety of structures demonstrates its adaptability, making it a popular option for projects that are residential as well as commercial.

A. Development of RMC in INDIA

Since its introduction in India in the 1950s, ready-mix concrete (RMC) has been utilized in a number of building projects, such as the Bhakra Dam. In 1993, the first commercial RMC factory opened its doors in Pune. RMC is responsible for between 50 and 60 percent of concrete output in major cities like Bangalore, Delhi, and Mumbai. Over 800 commercial RMC facilities already exist, and India now has more than 2000 automated batching plants. The remaining plants are grown specifically for domestic use.

B. Scope of Ready Mixed Concrete

By using ready-mix concrete (RMC), we might be able to save labor costs. RMC is used in a number of situations:

1. Major infrastructure projects, such as roads, bridges, tunnels, canals, dams, and bridges.
2. Congested spaces that make it difficult to store materials for laying concrete.
3. Locations where heavy foot traffic is creating logistical issues.
4. Situations when supervisors and workers are in short supply.
5. To speed up the building schedule.
6. Large-scale residential and commercial building projects

C. Types of RMC

Depending on how the different elements are mixed, ready mix concrete (RMC) comes in three different varieties, as listed below:

1. Transit mixed concrete
2. Shrink mixed concrete
3. Central mixed concrete

a. **Transit mixed concrete**: Because all necessary ingredients, including water, are charged directly into the truck mixer, it is also known as dry-batched concrete. After loading the ingredients, the mixer drum quickly rotates

at charging speed and then keeps at a constant agitating speed.

b. **Shrink mixed concrete**: After the concrete has been mixed in the plant mixer, the remaining mixing is done while traveling using a truck-mounted drum mixer. The quantity of mixing done in the transit mixer is determined by the amount of blending done in the central mixing plant. Experiments must be conducted to determine the necessary mixing in the drum mixer.

c. **Central-mixed concrete:**
A central batching facility is another name for it, where the concrete is carefully mixed before being put into the truck mixer. Sometimes, this kind of plant is referred to as a premix or wet-batch plant. During the transportation of concrete, the truck mixer just acts as an agitator. Non-agitating units or dump trucks can also be used when the distance is short or the workability requirements are low.

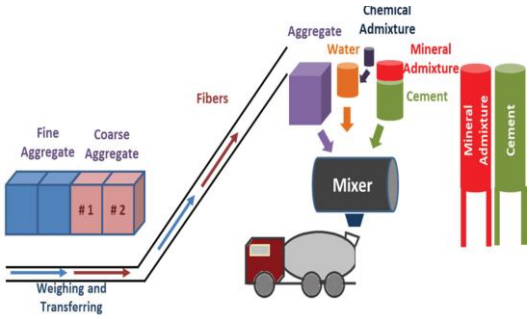


Figure 1 Production system of rmc

E. FEATURES OF READY MIX CONCRETE (RMC):

• Concrete of higher grade is created.
• Removal of fundamental supplies storage space from the site;
• Removal of equipment and plant used for hiring
• Basic material waste is prevented.
• The labor involved in making concrete is no longer used.
• A significant reduction in time is needed.
• There is less noise and dust pollution at the location.
• There is no waste on site.
• Ecologically friendly [14].

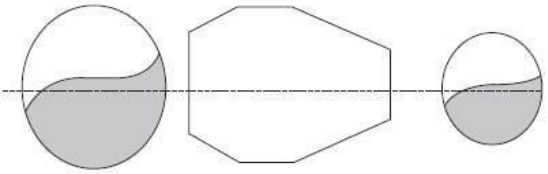
D. Producing and transporting

Batching and mixing procedures, which are described as measuring and adding components to a mixer and evenly mixing ingredients, respectively, are part of the production of RMC (Shetty, 2006). RMC factories use automated computers to combine the components and batch and mix ready-mixed concrete in state-of-the-art facilities. Materials used in RMC production that undergo laboratory testing are kept in stock at the RMC facility. In accordance with the mix design formula, the desired quantity of aggregate, cement, and water are all delivered to the mixer at the same time. After that, mixing is done in batch mixers to make sure the RMC is completely homogenous, consistent in colour, and uniform in consistency. Figure 2 depicts the RMC production system[13].

F. Materials Required for RMC

Figure 2 materials required for rmc

G. Equipment's Required in RMC



➢ Cement Silos: Used to store large quantities of cement.
• Aggregate Bins: Used to store crushed stone, gravel, and sand.
• Weigh Batching Systems: To precisely measure the necessary quantities of every item.
➢ Concrete mixers: Used to mix the ingredients for concrete properly.
Tanks for holding water used in mixing are known as water storage tanks.
Materials are moved from storage to the mixer via conveyors.

• Transit mixers and flows: Used to move the mixed concrete to the building site.
• Control System: To oversee and automate the manufacturing process

H. Manufacturing Process

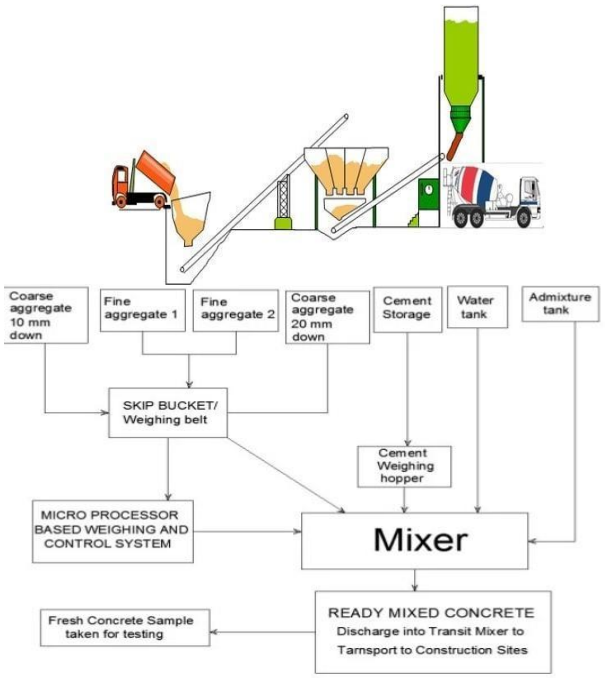


Figure 3 Process of manufacturing of ready-mix concrete

I. Types of Ready-Mix Concrete Plants: -

1. Dry batch concrete plant
2. Wet batch concrete plant
3. Half-wet batch concrete plant
4. Combination batch concrete plant

Figure 4 Ready Mix Concrete Batching Plant

1) Dry Batch Ready Mix Concrete Plants:-

A truck mixer in a ready-mix concrete factory creates a consistent mix through two mechanisms: the intricate flow of plastic concrete in the drum and internal friction between the concrete and the drum.

Figure 5 Cross Section of Track Mix Action

The height that concrete can ascend until gravity overcomes it and causes it to fall depends on two elements. First, the linear velocity of the drum surface, which is determined by the drum's internal diameter and angular velocity. As linear velocity increases, so does the concrete's dropping point. Second, when concrete workability decreases, the concrete falling point increases.

There is no longer any concrete dropping when the concrete spins in full contact with the drum surface at a speed of 22–27 rpm (typical speed is 10–14 rpm). Avoiding the concrete's falling point will result in significantly less effective local mixing, which might cause issues.

2) Wet Batch Ready Mix Concrete Plants:-

Wet batch systems come in a variety of forms, and the plant-based mixer is one of them. This indicates that various concrete mixture ingredients, including cement, aggregate, and water, are combined in the system. Wet batch concrete plants are often regarded

Figure 6 Dry Batch Ready Mix Concrete Plant

as large plants since their production is higher than that of dry batch concrete plants. Furthermore, if mortar manufacturing is needed, a wet batch concrete facility is required.

The biggest mixer drum can sufficiently mix around 6 m^2 of plastic concrete in about 45 seconds, and there are many mixer sizes that range from 0.8 m^2 to 6 m^2. Additionally, the selection of a particular mixer is based on a number of parameters, such as the output required, the primary types of mixes delivered, plant layout, available space, and startup and total life expenditures.

- **Types of Wet Batch Mixer and its Mixing Action**

The many kinds of wet batch mixers that are available and their mixing functions are listed below.

a. Rotating Drum Mixer

• Free-falling mixing steps, tilting, and spinning drum;

• Free-falling mixing steps, tilting, and spinning drum.

b. Fixed Trough Mixers

• A stationary blending trough with ascend blades rotating on lateral shafts.

• A stationary combines trough with twin shafts on each side that spin paddles.

c. Pan Mixers

- A stationary horizontal pan with mixing paddles that circle an annular channel.
- A fixed horizontal pan where mixing paddles rotate on their own axis and move around an annular channel.
- A fixed horizontal pan with a planetary motion for the mixing blades as they move around the pan bottom.
- Two sets of mixing paddles move in opposing directions around an annular channel in a fixed horizontal pan.
- Horizontal pan spinning with non-coincident axes of rotation beneath a stationary motor unit with paddles installed.

d. Reversing Drum Mixers

• A collection of shovels and cutters inside a rotating, tilt-free drum that provides both a required merging action and a collapse.

e. Continuous Mixers

• A secured trough mixer that creates an ongoing mixing motion by utilizing twin spinning shafts with paddles tilted at around 20°.

3) Half-Wet Batch Ready Mix Concrete Plants:-

In a half-wet method, sand, cement, and water are mixed to create a slurry, which is then loaded onto a truck along with aggregate. The half-wet technique significantly reduces batching time in addition to reducing wear and strain on central mixer machines.

4) Combination Batch Ready Mix Concrete Plants:-

This kind of batching plant combines both dry batch and wet batch systems. The majority of the concrete is composed in dry leg; however, tiny mixers weighing between 0.8 and 2 m^3 are used to distribute the concrete to the client.

J. Advantages of Ready mix Concrete over Site mix Concrete: -

- Consistent Quality: RMC facilities generate concrete with consistent qualities, guaranteeing dependability and consistency in building endeavours.
- Time Efficiency: The amount of time required for on-site mixing is greatly decreased when pre-mixed concrete is supplied to the location ready to use.
- Lower manpower expenses: Since less manpower is needed for mixing when concrete is produced off-site, labor expenses are decreased.
- Less Waste: Concrete is manufactured in precise amounts in accordance with project specifications, reducing material waste.
- Environmental Benefits: At building sites, centralized mixing lowers noise and dust pollution. Furthermore, RMC facilities frequently include water and other material recycling procedures.
- Flexibility and Customization: Concrete may be altered to satisfy certain building requirements, such as altering its colors, strengths, or other characteristics..
- Better Workability: When it comes to workability, RMC is typically easier to install and finish than site-mixed concrete.
- Quality Control: To guarantee that high standards are upheld, RMC factories are outfitted with quality control labs to evaluate the raw ingredients and final product.

K. Disadvantages of RMC:-

- The time it takes to travel from the factory to the site is crucial for longer distances since the components are batched at a central facility, where the mixing process starts. Some websites are simply too far away; however, this is typically more of a business than a technological problem.
- Site access and access roads must be strong enough to support the truck's weight and load.

  About 2.5 tons per cubic meter is concrete.
- Ready-mix should be deposited at the plant within two hours of batching due to the short

time span for concrete between mixing and going off. After this, concrete can still be used, although it might not meet all the requirements.

Figure 7 Ready Mix Concrete Batching Plant

L. Scope Of ready-Mix Concrete

Concrete has grown more significant than other building materials in the twenty-first century, which has increased its use. Before beginning building, contractors and builders frequently gather raw materials, but this is impossible in crowded locations. Ready-mix concrete (RMC), which saves labor costs and time, can be utilized to get around these problems. RMC is applicable in a variety of settings, including factories, warehouses, and building sites.

1. large-scale coordinated projects, such as highways, bridges, tunnels, canals, dams, etc.
2. for concrete in crowded places where it is impossible to store materials.
3. locations where traffic volume causes issues.
4. when there are fewer labourers and supervisors.
5. To cut down on the amount of time needed for building, etc.
6. Large-scale residential and industrial developments[15].

M. Main Trends Influencing the Future of Construction, Hence the Ready-Mix Concrete Business

Construction efficiency, urbanization, improving home comfort, digitization, and sustainability are the main issues facing the global construction industry now and will likely shape its future. Most nations must address issues related to accelerating urbanization, decreasing resources and scarcity, and persistently unsustainable methods of consumption and production. These issues are fueled by a need for the protection of the current market, the growing middle and upper classes' aspirations for a better and more comfortable life, and recent environmental and industrial policies. The primary difficulty facing the construction sector is productivity. Construction is still lagging behind industries that have reinvented themselves, including manufacturing and transport.

Over the past 20 years, the global labor-productivity increase in construction has averaged just 1% annually, whereas the growth in manufacturing and the overall economy has been 3.6% and 2.8%, respectively. In the majority of nations, where urbanization and population growth necessitate more housing and better transit systems, closing this gap becomes more difficult.

Additionally, the problem of living space quality is being brought up by the aging building stock, mostly in Europeans but not exclusively. Europe stands to gain much from the rehabilitation of the current housing market and the transportation infrastructure.[16].

N. Site mix concrete and Ready-mix concrete

Table 1 site mix concrete vs Ready mix concrete [15].

Site Mixed Concrete	Ready mix concrete
The quality of concrete varies since it is prepared by hand.	Construction may be finished in half the time thanks to the production of consistently high-quality concrete in sophisticated batching plants with automated environments.
The job will require longer to finish since manual mixing takes longer.	Concrete in large amounts can be ordered. This helps the organization to grow and handle projects of any size.

Let it run a bit longer. Repeated mixing is necessary for large volumes since the mixer will grow too small to meet the requirements.	On-site, no raw materials were wasted. Everything is prepared in advance and customized to meet the demands of the customer.
A substantial quantity of the beginning ingredient is wasted as a result of hand mixing.	After a careful examination, raw materials are selected.
Raw material quality is tested manually or not at all.	Construction may be finished in half the time thanks to the production of consistently high-quality concrete in sophisticated batching plants with automated environments.

O. COMMON QUALITY PROBLEMS:

The following is a list of quality issues of different kinds that might be reported:

- Concrete that takes more than 24 hours to set
- fissures that appear when the concrete is still new.
- formation of fractures in concrete that has hardened.
- The strength of the concrete cubes, which were cast on site, did not meet the requirements after seven days.
- Concrete cube density (cast on site) did not meet 28-day standards.
- The concrete that was delivered to the site either contains more slump than was called for or has hardened, making pumping challenging[8].

P. THE PRODUCTIVITY OF CONSTRUCTION SECTOR

In an engineering system, which is complicated because of workers, supplies, machinery, tools, capital, and design, output is the ratio of inputs to outputs. Technology, governmental legislation, weather conditions, financial situations, management, and elements of the internal environment all have an impact on the conversion process. A straightforward ratio of productivity index for only one input (workers' hours) and product (item as size in m2) may be used to determine productivity in a system that is closed.

One or more external or internal variables, such as an unidentified disturbance, may be the cause of the productivity shift. Furthermore, several production indices for various purposes may exist, and these indices are tied to location and time.[17].

Q. Business history in India

Due to an absence of resources and historical and economic neglect, study on Indian business history is still in its infancy. Corporates have permitted the destruction of documents after books have been written on them, and several industrialists, such as Naval H. Tata, issued wills directing that their papers be destroyed upon their passing. It wasn't until the 1960s that historians were permitted to study business history, and other obstacles, including the scarcity of surviving archives and commercial documents, make research more difficult.[18].

R. Cost factor compared to Site mix concrete:-

Because concrete must be transported to different locations, ready-mix concrete has become somewhat more expensive than site-mix concrete. However, the cost aspect is insignificant when taking into account the benefits of ready-mix concrete. RMC Concrete is still the superior option when more concrete strength and a larger volume of concrete are needed.

III. Conclusion

The sector is being revolutionized by the digital evolution of precast concrete production, which improves sustainability, quality, and efficiency. Concrete factories may streamline production processes, save waste, and guarantee consistent quality by combining technology, real-time data data analysis, and the Internet of Things. Smart logistics and predictive maintenance increase delivery accuracy and operational dependability.

Furthermore, by reducing resource use and environmental effect, these digital innovations promote eco-friendly behaviours. All things considered, digitalization opens the door for creative and durable building solutions by allowing the concrete sector to fulfil expanding needs with increased agility, cost-effectiveness, and performance.

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