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A Review of Modern Civil Engineering Materials and Construction Systems: Concrete Modification, Predictive Modelling, and Pre-Engineered Steel Buildings.

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Abstract: The construction industry is facing changes as new building materials are made new data-based prediction tools are used and factory-made building systems are developing. Concrete remains a material but Concrete's performance, how easy it is to work with and how long it lasts all depend on the mix ratios curing conditions and the addition of fibres or other substances. Meanwhile machine learning and classic math models can predict cement and mortar traits cut down on repeated lab tests and help pick the materials. Pre-engineered building systems give another option to steel construction by using standard designs building parts in factories and using structural pieces more efficiently. This review looks at these three fields by selecting published work on cement and mortar prediction, polypropylene fibre-reinforced concrete, Fevicol-modified concrete and comparing steel buildings with pre-engineered ones. Extra studies help explore the technical picture. The review points out the gains, limits and future research needs, for each method. It focuses on model checking, long-term Concrete durability, how well additives work together structural safety, building cost and how fast projects finish. The review ends by saying that new materials, solid prediction tools and efficient building systems can make construction better when backed by lab tests engineering rules and case-by-case checks.

Keywords: engineering; concrete modification; cement mortar; machine learning; polypropylene fibre-reinforced concrete; concrete additives; pre-engineered buildings; steel structures; sustainability.

1. INTRODUCTION

Modern civil engineering needs materials and systems that meet demands for strength, lasting quality, safety, money-saving and building faster. Old ways of building are still important. Better materials, computer tools and making parts beforehand are helping to make things better.

Concrete is used in places like buildings, bridges, roads and other structures. How well it works depends on the mix of cement the amount of water the type of rocks and stones used how it is kept wet after pouring. If there are other things added. Testing in labs is still the way to find out about concrete but trying many different mixtures can take a long time and cost a lot. Predictive models can help by guessing how materials will behave based on lab results.

Kudoli and Bala (2025) looked at new ways of predicting the qualities of cement and cement mortar. Their study shows more people are interested in using computer tools to get guesses about materials. Also Kudoli, Patil and Yeole (2025) looked at ways of improving concrete with fibers made from a plastic called polypropylene. Their work focuses on how strong and long-lasting this kind of concrete can be. These studies deal with parts of concrete tech: guessing how materials will act and changing how materials behave. Other research also shows that using data to make predictions is useful. Picking the right model having enough data and checking it is important (Yeh, 1998; Ben Chaabene et al. 2020; Terlumun et al., 2024).

Adding things to concrete is another thing being studied. Kudoli and Bobade (2017) looked at using a glue called Fevicol in concrete. Checked some of its features when it was fresh and after it had dried. These kinds of studies can help find out what happens when new things are added. More proof is needed about if the mix works well can be made the same way each time lasts long and is safe. Research on concrete that uses plastics shows that how well it works depends on the type of plastic how much is used how it is kept wet after pouring and how it mixes with parts. So results can't be used for all types (et al. 2018).

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In building structures there are ways to make buildings using steel. Pre-engineered steel buildings use parts made before and standard designs to make building easier. Londhe et al. (2024) Compared steel building methods with new ones using a real example. Their study gives a way to look at which building system's better depending on cost how the building is shaped and how fast it can be built. Looking at how long a building lasts is also important because costs for fixing and using it can change which system is best (Polder et al., 2014).

Even though these topics are, about making building better they look at different parts of the work. One study looks at how the material works another looks at using computers to guess and improve. A third looks at how to design buildings and get them built. This review connects these topics in one area of engineering while keeping their separate details.

1.1 Objectives

The goals of this review are:

1. To look at ways and computer-based learning techniques for predicting the qualities of cement and concrete.
2. To study the strength and lasting features of concrete that has polypropylene fibers added to it.
3. To check the studies and problems related to special materials used in concrete.
4. To look at the things engineers think about when dealing with regular steel buildings and buildings that are made in a special way before they are built.
5. To find out what areas need study and what the future might hold when it comes to how materials work, how to predict their behavior how structures are built and how to make things better, for the environment.

2. REVIEW METHODOLOGY

This paper adopts a narrative literature review approach. Four supplied publications form the reference base: two reviews published in 2025 on cementitious-material prediction and polypropylene fibre-reinforced concrete one experimental study on Fevicol-modified concrete published in 2017 and one 2024 case study comparing conventional steel and pre-engineered building systems. The additional sources were selected for relevance to the manuscript's three themes; this expansion does not convert the work into a review and the search strategy should be documented more fully if the target journal requires a systematic method.

Literature on machine-learning methods, for concrete-property prediction and polypropylene fibre-reinforced concrete durability is included to provide broader context.

The studies are grouped into three areas:

- Material engineering: concrete modification, fibre reinforcement and durability.
- Predictive engineering: mathematical models and machine-learning approaches.
- Structural-system engineering: steel construction and pre-engineered buildings.

The review compares the purpose reported contributions, engineering implications and limitations of these research areas. It is not presented as a review because a reproducible database search, formal screening process and structured study-quality assessment have not been completed.

3. CONCRETE MODIFICATION AND MATERIAL PERFORMANCE

3.1 General considerations in concrete modification

Concrete performance is controlled by how the materials in it interact. This includes the types of materials used how much of each's in the mix how the mix reacts when it gets wet the structure of the tiny spaces inside and how it is kept wet while it hardens. Changing the mix can help one property. It might hurt another. For example a mix made to increase strength might become harder to work with. An additive that changes when the mix starts to harden might also change how strong it gets on.

Because of this material changes should be tested using a mix of tests on concrete tests on the hardened concrete and checks for how well it lasts. Compressive strength is important. It alone does not show how well the concrete will last or if it is good for building structures.

Important properties to check include how the mix flows how long it takes to start hardening, how strong it is when pushed how strong it is when pulled apart how strong it is when bent how water it takes in how easy it is for water to go through how much it shrinks and how well it stands up, to weather. The tests chosen should match what the concrete is going to be used for and follow the engineering rules.

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3.2 Polypropylene fibre-reinforced concrete

Kudoli, Patil and Yeole (2025) looked at progress in polypropylene fibre-reinforced concrete. They focused on how it behaves how long it lasts and how it's used in structures. Polypropylene fibres are mixed into the concrete to help manage cracking, deformation. What happens after cracks form.

Liu et al. (2021) Studied how polypropylene fibres affect durability factors. These include drying shrinkage, how water the concrete absorbs, its permeability, chloride-ion penetration, resistance to sulfate freeze-thaw cycles, carbonation and fire resistance. They also pointed out problems like uneven fibre spreading and weak bonding between the fibres and the cement matrix.

How polypropylene fibres work depends on things: their length, thickness, amount used shape, how they're mixed in and what the concrete is made of. The fibres can help stop cracks from forming and make the concrete tougher.. How much better it gets depends on the mix and the test setup. Adding fibres doesn't always mean stronger concrete under compression. Many fibres or ones that aren't spread well can make the mix hard to work with and uneven. These kinds of trade-offs come up often in studies, about how the material fails and how long it lasts (Ahmed et al., 2021; Abdulkareem et al. 2022; Blazy & Blazy 2021; Song et al., 2022).

The literature therefore supports evaluating PPFRC as a multi-property material rather than judging it using a single strength value. Future experimental programmes should compare mixtures under consistent conditions and report fibre dosage, mixture proportions, curing regimes, specimen dimensions, and testing methods.

3.3 Fevicol as an unconventional concrete additive

Kudoli and Bobade (2017) looked at adding Fevicol to concrete. They tested Fevicol additions of 3 percent, 6 percent and 9 percent. They looked at compressive strength, workability and setting behaviour. They found that compressive strength rose when Fevicol was added at 3 percent. It fell when the Fevicol dosage went beyond the lower range. They also saw that slump dropped as the Fevicol dosage grew. These findings show why it is important to optimise the dosage when testing additives. A material can change the hydration environment, the fresh-concrete consistency or the hardened properties and the resulting changes may not match the amount of material added. However the study should be read within its limits. Fevicol is a product category, not a standardised concrete admixture with one universal chemical composition. Results for one Fevicol formulation cannot automatically apply to adhesive products or concrete mixtures. Further research should identify the Fevicol formulation decide if dosage is based on the mass of cement or the total mixture include a control mixture and use replicated specimens. Testing should also look at tensile and flexural behaviour, water absorption, permeability, shrinkage and long-term durability. The compatibility of the Fevicol additive with cement hydration and relevant construction standards must be checked before any structural recommendations are made. Thus the study should be seen as a look at additive-modified concrete not as definitive proof that commercial adhesives are fit, for general structural applications.

4. PREDICTIVE MODELLING OF CEMENT AND CONCRETE PROPERTIES

4.1 Traditional predictive approaches

Traditional methods for estimating cement and concrete properties include equations, regression models, statistical relationships and mathematical descriptions of hydration and material behaviour. These methods are easy to interpret and useful when applied within the conditions for which they were developed.

However concrete properties are affected by interactions among mixture proportions, curing, constituent materials and environmental conditions. A simple empirical model may not adequately represent these interactions when applied to a concrete type or unfamiliar mixture.

Traditional models remain valuable as baseline approaches against which complex prediction methods can be compared. Their continued use is especially important when data availability is limited or when an engineer requires a relationship between inputs and predicted properties.

4.2 Machine-learning approaches

Kudoli and Bala (2025) reviewed machine-learning and traditional models for predicting the mechanical properties of cement and cement mortar. Their work highlights the limitations of experimental testing and the potential for predictive methods to improve consistency and efficiency.

Moein et al. (2023) Also reviewed machine-learning and deep-learning approaches for concrete-property prediction. The methods discussed in this research area include neural networks, support-vector machines, decision trees, ensemble algorithms and other computational approaches.

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These methods can learn relationships between mixture proportions and material performance. Potential input variables include cement content, water-to-cement ratio, aggregate proportions, admixture dosage curing age and environmental conditions. The predicted outputs may include strength, tensile strength or other experimentally measured properties.
Recent reviews also stress the importance of model evaluation, transparent reporting and testing beyond the training data (Ben Chaabene et al. 2020; Terlumun et al. 2024; Algur et al. 2026; Kassa et al., 2026).
Nevertheless the quality of a prediction depends strongly on the quality and representativeness of the training data. A model trained on concrete cannot automatically predict PPFRC or Fevicol-modified concrete accurately. The model must include examples or undergo suitable independent validation.
A robust modelling study should separate training, validation and test datasets; avoid data leakage; report performance measures; and test the model on mixtures not used during model development. Useful metrics include the coefficient of determination mean error and root mean square error. Prediction uncertainty and the models range of applicability should also be reported.

4.3 Integrating testing and prediction

Machine learning should complement rather than replace laboratory testing. An effective workflow begins with a controlled programme, followed by data preparation, model development, validation and interpretation. Neural-network work established the feasibility of strength prediction while contemporary explainable models extend this work with interpretability and uncertainty assessment (Yeh, 1998; Kassa et al., 2026).
For concrete a dataset may include conventional mixture proportions, fibre dosage, additive dosage curing conditions and measured performance. Models can then be compared to determine whether they provide predictions, for the specific mixture types represented in the data.
Explainable machine-learning techniques can help identify variables and explore trade-offs among properties. However variable importance alone does not establish causation. Experimental testing remains necessary to confirm whether a predicted improvement is reproducible and technically meaningful.
An integrated framework could eventually support optimisation seeking mixtures that balance strength, workability, durability, cost and environmental impact. Such optimisation should remain constrained by material compatibility, applicable standards and verified engineering requirements.

5. CONVENTIONAL STEEL BUILDINGS AND PRE-ENGINEERED BUILDING SYSTEMS

Conventional steel building systems
Conventional steel buildings are usually created with designs that're specific to each project. These designs might require checking each beam, column bracing system, connection and foundation to meet the needed load combinations and serviceability limits.

This method can handle shapes, special loading and unique architectural needs. However the amount of project- planning and building might lead to more coordination, more material waste and longer time to build depending on the project and how it is bought.

These results aren't always the same. A conventional steel building that uses parts and good building methods can be just as good as a PEB system. Comparisons must use the building functions, spans, loads and performance needs.

Pre-engineered steel buildings
Pre-engineered buildings usually use a design and building method that is connected. The parts are designed, made and ready for the site to be put together. These systems are often used for factories, warehouses, workshops and other buildings that have shapes and large open areas.

Making parts in advance can cut down on the work done on site and help the building go up faster. The parts can be made to fit the load patterns but the actual savings in material depend on the shape the loads, the design choices and the type of system used.

PEBs also need to think about transport, lifting, how parts fit together how the foundation connects, how to stop rust how to handle fire and changes that might be needed later. Systems that are standard may not work well for buildings with very unusual shapes or projects that need a lot of design changes.

The benefits of PEBs should be looked at based on what the project needs not because of the type of building.

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Comparative study of steel and PEB systems

Londhe et al. (2024) In A Comparative Analysis of Conventional Steel Building and Pre-Engineered Building Systems: A Case Study Approach, looked at the two ways of building using a case study method. The study gives a base for comparing which system to use when building.

A real comparison must look at the following things:

- Cost of materials and building parts.
- Needs for design and planning.
- Time it takes to build and put up.
- Weight of the structure. How well the materials are used.
- Needs for moving parts and lifting them.
- What the foundation needs.
- How to take care of the building stop rust and handle fire.
- How easy it is to change the building expand it or make changes later.
- Whether it follows the rules for building and construction.

What happens in a comparison depends on the shape of the building the space, the height of the walls the roof slope, the wind and earthquake forces what the building is used for the ground conditions and how the parts are made in the area. A fair case study should have these things the same for both options. Generally looking at the whole life of the building should include how long it lasts, how to take care of it and how it affects the environment not just the first cost (Polder et al. 2014; Scrivener et al. 2018).

A cost comparison should also tell the difference between the cost of the frame and the whole project. The foundation, outside walls, roof, insulation, pipes, transport, building tools and taking care of the building can change the cost a lot. Also a time comparison should say if it is looking at design, building preparing the site putting it up or the whole project plan.

Because of that PEBs might be better for buildings that're the same, like industrial or commercial ones but they should not be seen as always better, than regular steel building.

6. RESEARCH GAPS AND FUTURE DIRECTIONS

6.1 Standardised and reproducible experiments**

When researchers work with fibre-reinforced and additive-modified concrete they should share every detail of the mix – the exact proportions the dosage definitions, the material characteristics, the curing conditions the number of replicates and the test procedures. By doing these studies will be easier to compare and they will build trustworthy data sets that help create reliable predictive models.

6.2 Prediction models for modified materials**

It would be valuable for researchers to explore whether machine-learning models that learn from ordinary concrete can also predict the behaviour of fibre-reinforced and additive-modified mixtures. To prove this the models must be put to a test on fibre-reinforced and additive-modified mixtures estimate the uncertainty and report everything openly.

6.3 Long-term durability and additive compatibility**

The Fevicol study sparks curiosity about additives but the next step is to confirm that these additives work chemically repeat the tests look at environmental performance and check long-term durability. Only after these checks are satisfied should we consider using additives in structural work.

6.4 Multi-objective concrete mixture optimisation**

Future research should take a look at performance measures at once. If we focus on crushing strength the resulting mix might feel sticky fall apart quickly or cost too much. Multi-objective methods can find a mix that balances strength, workability, durability and cost.

6.5 Project-specific comparison of steel building systems**

When we compare steel and PEB systems it is essential to use the same shape, the same loading, the same design rules, the same material specs and the same cost scope. Later studies should also test how building span, site location, travel distance, factory capacity and construction timing affect which system is best.

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6.6 Life-cycle cost and environmental performance**
The price we pay when building is only one part of the story. We must also think about maintenance, replacement parts, operation how long the building will last and how it will be taken apart at the end. Environmental checks need limits and the same unit of measure so we do not claim a material is greener just because it is lighter or faster to build. This approach matches life-cycle cost studies for concrete and the broader work on low-carbon cement materials (Polder et al., 2014; Scrivener et al. 2018).

6.7 Digital integration across construction stages**
A promising idea is to link the lab data on materials the models that predict their behaviour the design tools for structures and the cost data, for projects. If we manage this link information will travel smoothly from choosing a material to designing a building and planning construction. Building this system will need data standards, strong quality checks and independent tests of the engineering results.

7. CONCLUSION

Today civil engineering is shaped more and more by materials, computer predictions and factory-made construction systems. The books we looked at show why these changes matter but they also show that each must be checked carefully in the technical setting.
Machine-learning models can help us guess the properties of materials and make mixes better. However these models are only as good as the data we give them and the tests we run on them.

Concrete with polypropylene fibres can reduce cracks make the mix tougher and improve some durability aspects. Still how the fibres spread how they stick together and how the mix is designed are still questions.
Studies on concrete show a first look at using an additive but we need more tests before we can say if it is safe for big structures.

Steel buildings that are made in a factory can be. Put together quickly for the right kinds of buildings.. When we compare them to ordinary steel buildings we must look at the load needs the full cost the building schedule, how long they last and how easily they can change later.

The main point is that better construction work needs the mix of proven material choices tested prediction tools and a look, at the specific structure of each project.
In the future we should focus on experiments that can be repeated on predictions that we can understand, on checking how long things last on balancing goals and on looking at the whole life of a project. These ideas can help civil engineering become safer, cheaper and greener.

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