# A Review:

# Special Types of Concrete Used in Structures

**Lect. Reem Hatem Ahmed[1][*]**
**and Prof. Dr. Mohammed Mosleh Salman[2]**

1- Ministry of Higher Education and Scientific Research,Reconstruction and Projects Directorate. Baghdad / Iraq
2- Al-Mustansiriya University, College of Engineering, Department of Civil Engineering, Baghdad / Iraq.
E-Mail: reem.algburi4@gmail.com ,mmsalman1956@gmail.com

# مقالة مرجعية:
# انواع الخرسانة الخاصة المستخدمة في المنشآت

**مدرس ريم حاتم احمد(*) و أستاذ دكتور محمد مصلح سلمان(**)**

* وزارة التعليم العالي والبحث العلمي - دائرة الاعمار والمشاريع, بغداد \ العراق
** الجامعة المستنصرية - كلية الهندسة, قسم الهندسة المدنية, بغداد \ العراق

## Abstract

The term “special” possesses inherent significance and is utilized in this context to denote the distinctive attributes characteristic of concrete. The term “special” connotes enhanced strength, durability, and solidity in concrete. The production of specialized concrete involves the incorporation of distinct components via specific procedures following specific criteria. Specialized concrete is required to construct unique structures such as power plants, offshore buildings, docks, and airports. Each of these unique structures is essential for survival in harsh conditions, including sulfate, chemical, acid, and chloride attacks, as well as other surface characteristics. Concrete is a versatile material that exhibits good compressive strength and can be tailored to meet specific requirements such as lightweight, high density, fire protection, and radiation shielding. However, the material exhibits several limitations, such as inadequate tensile strength, susceptibility to liquid permeation, reinforcement corrosion, vulnerability to chemical degradation, and suboptimal durability. Cement concrete has undergone various modifications over time to address its drawbacks. Advancements in material and construction technology have brought about notable changes, leading to enhanced functionality and increased affordability, thus expanding the scope of application. The current review delineated 12 different kinds of specialized concrete and comprehensively elucidated each type. The current review also addressed the practical implementation of these types in building and construction. Ultimately, it is advisable to employ specialized variants of concrete that have undergone modifications to address the limitations of traditional concrete. Implementing structures composed of specialized concrete material would yield superior outcomes in regions susceptible to seismic activity. Implementing specialized concrete can enhance the safety of residential facilities owing to its special characteristics.


**Keywords: Special concrete, Lightweight concrete, Glass fibre reinforced concrete,Green concret and High  strength.**

## المستخلص

مصطلح "خاص" له أهمية متأصلة ويستخدم في هذا السياق للدلالة على السمات المميزة للخرسانة. يشير مصطلح "خاص" إلى القوة والمتانة والصلابة المعززة في الخرسانة. يتضمن إنتاج الخرسانة المتخصصة دمج مكونات متميزة عبر إجراءات محددة تتبع معايير محددة. المطلوب هو خرسانة متخصصة لبناء هياكل فريدة مثل محطات الطاقة والمباني البحرية والأرصفة والمطارات. كل من هذه الهياكل الفريدة ضرورية للبقاء في الظروف القاسية ، بما في ذلك تأثيرات الكبريتات والمواد الكيميائية والحمضية والكلوريد ، بالإضافة إلى المؤثرات الاخرى. الخرسانة هي مادة متعددة الاستخدامات تُظهر قوة ضغط جيدة ويمكن تصميمها لتلبية متطلبات محددة مثل الوزن الخفيف والكثافة العالية والحماية من الحرائق والوقاية من الإشعاع. ومع ذلك ، فإن المادة تتعرض للعديد من القيود ، مثل قوة الشد غير الكافية ، وقابلية نفاذية السائل ، وتآكل حديد التسليح ، والتعرض للتدهور الكيميائي ، والمتانة دون المستوى الأمثل. خضعت الخرسانة الأسمنتية لتعديلات مختلفة بمرور الوقت لمعالجة عيوبها. أحدثت التطورات في تكنولوجيا المواد والبناء تغييرات ملحوظة ، مما أدى إلى تحسين الوظائف وزيادة القدرة على تحمل التكاليف ، وبالتالي توسيع نطاق التطبيق. تطرقت المقالة الحالية الى 12 نوعًا مختلفًا من الخرسانة الخاصة وشرحت بشكل شامل كل نوع. كما تناولت المقالة الحالية التطبيق العملي لهذه الأنواع في البناء والتشييد. في نهاية المطاف ، من المستحسن استخدام متغيرات متخصصة للخرسانة التي خضعت لتحسينات لمعالجة قيود الخرسانة التقليدية. إن تنفيذ الهياكل المكونة من مواد خرسانية متخصصة من شأنه أن يؤدي إلى نتائج أفضل في المناطق المعرضة للنشاط الزلزالي.و يمكن أن يؤدي تنفيذ الخرسانة الخاصة إلى تعزيز سلامة المنشآت السكنية نظرًا لخصائصها الخاصة.


**الكلمات المفتاحية : الخرسانة الخاصة، الخرسانة خفيفة الوزن ، الخرسانة المسلحة بالالياف الزجاجية ، الخرسانة الخضراء و المقاومة العالية.**

## Introduction

Concrete is a composite material composed of cement, sand, and coarse aggregate combined with water to form a microcontent. The structural integrity is contingent upon the characteristics of the concrete employed. Typically, the concrete produced on-site or through ready-mix concrete (RMC) is deemed appropriate for general construction applications within standard localities and environmental circumstances.

When specialized facilities such as power plants, offshore structures, docks, or aerodromes are required, a unique type of concrete possessing a specific set of properties is necessary. Each of these special structures is essential for survival in hostile environments, including but not limited to sulfate, chemical, acid, chloride, and other surface-related attacks. Special concrete refers to a type of concrete that is specifically designed to withstand particular aggressive conditions or situations. This objective can be achieved by modifying the fundamental constituents, the production methodology, or a fusion of both. The mixture proportion will deviate from conventional concrete and incorporate distinct constituents to endure the harshness for which it is designed.

The present review endeavors to examine various categories of specialized concrete, encompassing:

- High-workability concretes,
- Lightweight concretes,
- Sprayed concretes,
- Ultra-high-strength concretes,
- Polymer impregnated concretes,

- Water-resistant concretes,
- Self-Healing bacterial concrete / bioconcrete,
- Colored concrete,
- Ferrocement concrete,
- Self-compacting concrete,
- Glass Fibre Reinforced Concrete, and
- Green concrete.

In addition, the current review looks at special concrete applications and the difference between ordinary and special concrete.

## Special types of concrete and Ingredients

In contemporary times, the evaluation criteria for construction materials have expanded beyond the conventional 28-day compressive strength, owing to the prevalence of concrete in the built environment. In addition to its physical strength and durability, concrete may possess other desirable properties relevant to a particular project. Below are the special types of concretes.

### 1- Light weight concrete

According to the BS EN 206-1 standard, lightweight concrete is characterized by a density range of 800 kg/m3 to 2000 kg/m3 when dense natural aggregates are substituted with lightweight aggregates, either partially or entirely. The utilization of pumice as an aggregate in construction dates back to the second century, when the Romans introduced this technique during the construction of the Pantheon (Samidi,1997). Pumice was the most prevalent type of aggregate employed during that specific year.

Subsequently, the utilization of lightweight concrete has been extensively disseminated in other nations, including the United States, Sweden, and the United Kingdom.

It is suggested that structural lightweight concrete is expected to demonstrate sufficient compressive strength and increased durability while retaining a low density (ACT,2004 and ACI,2009). The modulus of elasticity of lightweight concrete is relatively lower than that of conventional normal-weight concrete. The creep and shrinkage properties exhibited by lightweight concrete are slightly higher than those of ordinary concrete with equivalent grades. Therefore, it is imperative to consider this aspect while designing the structure (Topeu & Ugonoglu,2010).

There are three methods for the production of lightweight concrete. These techniques are:

a- Utilizing lightweight stones ( pumice, porcelanite, limestone).

b- Replacing fine aggregate with gravel of 20 mm maximum size.

c- Applying gas to the concrete to create “gas concrete.”

## 2- High workability concrete

High-workability Concrete is utilized in scenarios with constraints on the amount of vibration that can be applied, especially when a void filling is required. By utilizing an appropriate mix design, it is possible to attain concrete with high workability without causing any substantial effects on its mechanical characteristics, such as compressive strengths and shrinkage. The adequacy of the workability of newly mixed concrete is crucial for its intended use, as it directly affects the effectiveness of handling, placing, and compaction processes.

The European and UK standards for concrete, namely BS EN 206 and BS 8500, provide directives on the appropriate level of workability for various applications. Using cement replacement materials like fly ash can significantly enhance concrete mixes’ handling and placement characteristics. In addition, the utilization of admixtures, specifically water reducers, and superplasticizers, has beneficial impacts on the workability of concrete while maintaining the integrity of its other properties (https://www.concretecentre.org). Several techniques can achieve concrete with enhanced workability, such as elevating the water-to-cement ratio, incorporating larger aggregate, and utilizing well-rounded and smooth aggregate instead of irregularly shaped aggregate, elevating the duration and temperature of the mixing process.

## 3- Ultra high strength concretes (UHSCs)

UHSCs are high-strength concrete (HSC) that have garnered attention as a potentially transformative material in the concrete industry. Implementing specialized production methods makes it feasible to produce concrete with a compressive strength exceeding 1000 kg/cm3. Portland cement, fine sand or quartz, silica fume, a water-reducing additive, and steel fibers are all listed as ingredients in this kind of concrete (Allena & Newtson, 2011) . The widespread accessibility of additives and admixtures like silica fume and water-reducing admixture makes establishing concrete factories across the globe a viable option for increasing the economic viability of ultra-high-strength concrete (UHSC) (Du, *et al.*, 2020 & Mousari, *et al.*,2019). Establishing an Ultimate Heat Sink System (UHSC) is a crucial safety measure for nuclear reactors. The production of ultra-high-strength concrete can be achieved by regulating concrete ingredients. To produce ultra-high-strength concrete by controlling the ingredients of concrete With an increase in cement content, reduce W/C by using a superplasticizer, and add the additive material such as silica fume to reach the high strength.

## 4- Sprayed concrete

Applying sprayed concrete involves using a nozzle to pump the concrete, which is then consolidated by the effect of subsequent sprayed particles. The process of wet-sprayed concrete consists of transferring pre-mixed concrete from a hopper to a nozzle, where it is combined with compressed air and an accelerator. Upon contact with the substrate, the wet mixture is sprayed and undergoes flash-setting. This diverges from the traditional method of applying concrete, wherein it is manually or mechanically pumped through a pipe and subsequently consolidated under the influence of gravity, often augmented by vibration or other compaction modes. According to Jolin, *et al.*,(2014), the placement technique facilitates the application of sprayed concrete in vertical or overhead areas, possesses irregular geometries, and requires minimal or no formwork.

The process of sprayed concrete involves the conveyance of a blend of aggregate and Portland cement through compressed air to the nozzle of a spray gun, where water is added. Subsequently, the wet mixture spreads on the designated surface and can be promptly carved or troweled with a trowel. The optimal ratio of cement to aggregate is contingent upon the specific construction methodology employed. The recommended weight ratio for cement to sand and stone in dry spraying is between 1:4 and 1:4.5. For wet spraying. Maintaining a weight ratio of 1:3.5 or 1:4.0 between cement, sand, and stone is recommended.

## 5- Water resistant concrete

Concrete materials that exhibit water-resistant properties can prevent water penetration and other liquids, regardless of whether they are situated above or below the surface. These concretes with high density include cement replacements consisting of fine particles. Formerly, waterproof concrete had an external coating, integral mixing, and an external membrane. Additive materials are used in concrete to reduce the water absorption rate (Okene, *et al.*,2017).The composition under consideration is primarily comprised of four elements, namely Portland cement or Kaolin in the range of 30 to 40%, marble dust or silica sand in the range of 20 to 30%, lime in the range of 25 to 35%, and ground salt, alum stone, or calcium chloride in the range of 3 to 12%. The intended purpose of this composition is to provide waterproofing and sealing properties. The powder, which has a texture similar to talcum, is combined with water and utilized as a form of paint.

## 6- Self healing bacterial concrete / Bioconcrete

Bio-concrete can generate calcium carbonate (CaCO3) crystals that effectively seal cracks that appear on the surface. As cracks emerge in the concrete edifice, moisture infiltrates into the cracks. Upon exposure to water and oxygen, the dormant bacteria undergo activation. The present study investigates the utilization of diverse bacterial strains in the production of bio-concrete in comparison to conventional concrete. According to the experiment's findings, water infiltration into concrete after developing cracks triggers the reactivation of previously dormant bacteria through metabolically mediated calcium carbonate precipitation. This process ultimately enhances the strength of bio-concrete in comparison to conventional concrete, as documented in reference (Bashir, *et al.*, 2016).

Bioconcrete is generated through the combination of concrete mixture with microorganisms. Due to the highly alkaline nature of concrete, the selection of bacteria to be added must adhere to specific criteria. The introduced microorganisms must possess the ability to endure the severe ecological circumstances inherent to concrete. Concrete can be fortified with diverse strains of aerobic bacteria, including Bacillus sphaericus, Bacillus pasteurii, Bacillus subtilis, and Escherichia coli.

## 7- Colored concrete

Concrete can be colored through two primary methods. The initial method involves the application of a dry pigment that is spread over the surface of the concrete after its placement. The second method consists of incorporating liquid or dry pigment into the concrete mixture before it is poured. The hardened properties of colored concrete are comparable to those of conventional concrete. From the 1970s onwards, color regained significance in the constructed environment using paints and other coating materials, resulting in the concealment of gray concrete surfaces (Tietz, 2008) .

Nonetheless, sealing provides tangible advantages by protecting against water damage and stains. Although not essential, applying a sealant to colored concrete can enhance its longevity and mitigate surface dusting.

Colored concrete is made by adding colored pigment to the concrete mixture. The main type of pigment used in coloring concrete is synthetic iron oxide. These chemical compounds are commonly used to add natural, earthy colors to concrete. New processes have allowed for more consistent synthetic oxides to serve as pigments, but the effect is similar.

## 8- Ferrocement concrete

A hydraulic cement mortar-reinforced matrix with numerous layers of closely spaced, continuous, and comparatively thin wire mesh is characteristic of the reinforced concrete called ferro cement. According to ACI (2006), the mesh may be made from metal or other materials (ACI,2006).

Ferrocement is a construction methodology that involves the application of reinforced mortar or plaster (comprising cement or lime, water, and sand) over an "armature" consisting of woven, metal mesh, metal fibers, or expanded metal, and closely spaced thin steel rods like rebar.

## 9- Glass fibre reinforced concrete

GFRC is a variety of concrete that is reinforced with glass fibers. The item above is commonly referred to as "glass fiber reinforced concrete," or GRC, in British English to as "glass fiber reinforced concrete," or GRC, in British English. Glass fiber reinforced concrete (GFRC) finds its primary application in the construction of exterior building facade panels and as architectural precast concrete. Glass fibers (GF) were used as reinforcement for mortar and concrete in 1931(Gorski, *et al.*, 2018). The process of creating them involves the extraction of molten glass through spherical holes, followed by the formation of approximately 200–240 individual fibers through stranding, and ultimately culminating in the segmentation of these fibers into smaller portions (Zych, 2010) . Glass fiber, a byproduct of the glass manufacturing industry, is disposed of in substantial amounts. The utilization of said fibers has the potential to enhance the mechanical performance of concrete as well as streamline the management of industrial waste, as evidenced by previous research (Kumor & Baskar, 2014).

## 10- Polymer impregnated concrete

PIC (Polymer-impregnated concrete) refers to a type of precast and cured hydrated cement concrete subjected to impregnation with a low-viscosity monomer.. This composite material has undergone significant development and is known for its superior structural and durability properties, making it the most advanced. Notably, the essential enhancements to these properties have been achieved through PIC.

The study involved the production of concrete-polymer composites through the impregnation of sand-cement mortar with various polymers such as polystyrene, polyacrylonitrile and, polymethylmethacrylate, as well as copolymers, including styrene-methylmethacrylate, styrene-acrylonitrile, styrene-butyl methacrylate, styrene-butyl acrylate, methyl methacrylate-butyl acrylate, methyl methacrylate-ethyl acrylate, polystyrene crosslinked with divinyl benzene, and styrene-acrylonitrile crosslinked with divinyl benzene (Maiti & Kirtania,1986).

## 11- Self compacting concrete

Self-compacting concrete (SCC) is a novel type that eliminates the need for vibration during placement and compaction. The material can self-flow under its gravitational force, occupying the entire formwork and attaining complete compaction, even in densely packed reinforcement. The inception of SCC was initially introduced by Okamura in 1986, followed by the prototype's development by Ozawa at the University of Tokyo in 1988 ( Nagamoto & Ozawa,1997).

Self-compacting concrete is produced by mixing cement with aggregates of size (1–20) mm, well-graded cubical or rounded aggregates, sand, and water, and adding chemical admixtures such as superplasticizer and mineral admixtures such as silica fume and fly ash.

### 12- Green concrete

Green concrete refers to concrete that has been recycled from environmentally safe sources. Green concrete is made using as many recycled resources as possible. The benefits of green concrete over traditional concrete were examined by Agarwal (Agerwal & Gerg, 2018). Using recycled aggregates and materials lessens the load on landfills and reduces aggregate waste. The net CO2 emission is therefore decreased. Recycling materials also significantly boosts the economy. Since it is environmentally benign, green concrete may be a crucial component of sustainable development. In green construction methods, green concrete is often employed.

The production of green concrete involves the utilization of waste materials to partially or entirely substitute cement, fine aggregate, or coarse aggregate. The utilized waste materials include recycled concrete aggregate, recycled demolition waste aggregate, glass aggregate, manufactured sand, blast furnace slag, and fly ash.

## Application of special types of concrete

The utilization of special concrete in construction enhances the durability of the structure in comparison to regular concrete, owing to the observance of specific conditions during the preparation process. Specialized concrete formulations are well-suited for severe weather conditions and can endure challenging environmental conditions. Special concretes exhibit low-heat properties. The following is a list of the applications of different special concrete types.

## 1- Light weight concrete

- Screeds and walls that need nailing to secure timber,
- Thickening and screeds for common use, particularly when they add weight to roofs, floors, and other structural members,
- Roof insulation for heat.
- Casting structural steel as a building covering or as a fire and corrosion-resistant material.
- External structures of small homes and surfaces rendered,
- Building partition and panel walls in frame structures,
- Water pipe insulation,
- General wall insulation
- Fixing bricks to accept joinery nails, primarily in residential or domestic-style buildings,
- Furthermore, it is currently employed in constructing reinforced concrete structures( https://theconstructor.org).

## 2- High workability concrete

- Inaccessible locations,
- Underwater applications,
- Over distances concrete pumping,
- Large flat areas (ACI,2008).

## 3- Ultra-high-strength concrete

Ultra-high-strength concrete has been widely utilized in civil engineering owing to its exceptional characteristics, including remarkable strength and excellent durability. High-performance concrete has been utilized in the construction of various infrastructure projects such as bridges, hydropower structures, and pavements.

## 4- Sprayed concrete

Sprayed concrete has numerous applications and uses, such as constructing curved structures like domes, shell roofs, tunnel linings, and free-formed facilities like climbing walls and swimming pools. It is also utilized in underground construction, retaining walls, and piled wall facings. Additionally, sprayed concrete is frequently employed for the fire protection of steelwork and to strengthen and repair existing structures (ACI,2008).

## 5- Water resistant concrete

Waterproof concrete is highly suitable for underground applications that require impermeability and numerous expansive above-ground edifices that could profit from its ability to endure water. For instance:

- Underground parking,
- Flood-prone building areas/those with high rain levels,
- High water table areas,
- High-rise buildings,
- Basements(https;//totalconcrete.co.uk).

## 6- Self-healing bacterial concrete / Bioconcrete

Bio-concrete exhibits versatility in various contexts. The adaptable nature of Bacillus microorganisms renders them suitable for employment in various forms of infrastructure, such as buildings, tunnels, and bridges.

The increased utilization of this substance has the potential to unveil numerous novel prospects in engineering, microbiology, and construction. In addition to cost savings, potential benefits of implementing the approach above include the ability to experiment with novel designs, enhanced structural durability, and long-term cost reduction (https://buildoft.com.au).

## 7- Colored concrete

For finishing exterior surfaces, flooring, window sill slabs, stair treads, and similar applications are used regarding decorative art and using stones in casting processes (https;//www.civilgiant.com).

## 8- Ferrocement concrete

- Implementation of planks as a substitute for expensive wooden planks in housing projects.,
- Construction of watercraft,
- Boxes of electrical and water meters Used in
- Rural areas for low-cost housing,
- Construction sewage utility hole covers,
- Some industrial and residential buildings (https://happho.com).

## 9- Glass fibre reinforced concrete

- Drainage and waterworks,
- Building renovation works,
- Tunnel lining panels and bridge,
- Architectural cladding
- Construction permanent formwork,
- Screens and acoustic barriers ( https://the constructor.org).

## 10- Polymer impregnated concretes

- Irrigation structures applications,
- Bridge decks surface impregnation,
- Underwater and marine applications,
- Structural members,
- Nuclear power plants
- Wastewater disposal works
- Ferro cement products impregnation
- Waterproofing of structures
- Industrial Use (https://www.engineeringenotes.com).

## 11- Self compacting concrete

- Repairing and retrofitting constructions
- Raft and pile foundations construction
- Drilled shafts
- Complex reinforcement distributions Structures
- Earth retaining systems construction
- Columns (Natsoulis,2019).

## 12- Green concrete

- construction of  bridges
- widely used in the construction industry.
- building construction.
- It can be used in the construction of roads (Waghmere, *et al.*,2021).

**Table 1: Comparision of special and ordinary concretes**

| **Special Concrete** | **Ordinary Concrete** |
|---|---|
| **Costly** | **Cost-effective** |
| **High strength and durability under aggressive conditions** | **Low durability and strength** |
| **High technique** | **The formal method to produce the special concretes** |
| **Made from special admixtures and other materials** | **Made from natural resources** |
| **Used in constructing power plants, nuclear plants, and radiation protection structures.** | **Used in typical construction works.** |
| **Used less** water/cement ratio **and superplasticizer.** | **Used 0.4 to 0.55 water/cement ratio** |

## Conclusions

The construction industry is increasingly recognizing the potential of special concretes due to their distinct characteristics. Nevertheless, due to the high cost of the mechanism, extensive research is required to facilitate its broader implementation. Specialized concrete materials are extensively utilized in developed countries, where cost is not a primary consideration. In the context of underdeveloped and developing countries, this factor holds significant importance. In the context of large industries, the primary concern for utilizing these products is their durability rather than their cost-effectiveness. In addition, it is prudent to utilize specialized variants of concrete that possess altered characteristics capable of mitigating the limitations inherent in conventional concrete. These types of structures would be advantageous in regions susceptible to earthquakes. Implementing specialized concrete could increase the safety of residential facilities due to its improved characteristics.

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