A CAST OF 50

Celebrating 50 years of the Irish Concrete Society

Edited by
Professor Roger P. West & Dr. Rosemary Byrne

April 2023

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Preface

In 1972 the first meeting of the Irish Concrete Society Council was held, attended by 12 people, each with a keen interest in learning more about concrete as a material for construction. Fifty years later, the Irish Concrete Society has over 50 corporate members, with monthly technical events and its prestigious Annual Awards Dinner, which is itself celebrating its 40th year. The list of former and current Chairs, Secretaries and Treasurers who have served the Society with distinction over the decades is given overleaf. They represent a small subset of the many remarkable people from all sectors of the concrete supply chain, designers, suppliers, contractors and skilled concrete technologists, innovators all in their own way, who have left a legacy of concrete structures and knowledge on which this and future generations depend. The current members, who are custodians, users and creators of this knowledge, are recorded herein, with thanks, through the reproduction of their respective logos.

This publication, "***A Cast of 50***", has been produced to celebrate the 50th anniversary of the Irish Concrete Society, with 50 invited authors from all over this island, who have written the articles on 50 different concrete types. There are, of course, many more than 50 types of concrete but this collection represents not only commonly used types, but also some more esoteric types and some, perhaps, for the future. Irrespective of their use, they represent the enormous versatility of concrete as a material of choice in modern construction, concrete being the single most used man-made material in the world.

The authors were asked to write a general one-page article about their specific concrete type under certain headings: What is it? What is different about its constituents/ production and its properties? What is a good example of its use in practice and is there an interesting fact about it? Inevitably, my sincere thanks go to all the authors for their work and co-operation in bringing this book together – their names and affiliations are recorded herein.

Thanks also are due to the reviewers – all articles were peer-review under strict guidelines - namely, Prof Brian Broderick, Prof Ravindra Dhir OBE, Dr Breiffni Fitzgerald, Aidan Fogarty, Dr John Gallagher, Dr Ciaran McNally, Dr Sreejith Nanukuttan, John Newell, Dr Shane Newell, Dr Éanna Nolan, David O'Mahony, Dr Declan Phillips, John Reddy and Emeritus Professor Mark Richardson.

This book is designed to be a working book as well as one containing useful information - of use to students, academics, researchers, designers, suppliers and construction practitioners alike. It is probably not the sort of book which one would read at a single sitting, but one can dip in and out as needed. A notes page is provided with every article so that users can record extra information as it arises: mix recipes, suppliers and expert contact details, further references, etc. And a series of spaces has been provided at the end to allow for information on other concrete types to be recorded by the owner of the book in future.

Finally, sincere thanks to the Council of the Society whose support for this project has ensured that this book will reach as wide an audience as possible.

In conclusion, hopefully this publication will be a fitting way to mark the occasion of 50 years of the marvellous work of the Irish Concrete Society, recognising in it the gifts of "***A Cast of 50***" people dedicated to the ubiquitous material that is "**Concrete**".

Prof Roger P. West, Chair, Irish Concrete Society 2021-23

Chairs of the Irish Concrete Society 1972- 2023

Years	Name	Organisation
2021-2023	Prof Roger P. West	Trinity College Dublin
2018-2021	Mr Eamon Booth	John Paul Construction
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Honorary Secretaries of the Irish Concrete Society 1972- 2023

Years	Name	Organisation
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2007-2008	Paul Fuller	Irish Cement
2006-2007	Stéphane Guérineau	Irish Cement
2005-2006	Eddie Hanlon	National Building Agency
2003-2005	Marie O'Donovan	Irish Cement
2002-2003	Maxine Gallagher	Irish Cement
1998-2002	Brendan Lynch	Irish Cement
1995-1998	Mark Prendergast	Irish Cement
1993-1995	Dr Mark Richardson	UCD
1988-1993	Brendan Lynch	Irish Cement
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1974-1975	Michael O'Callaghan	Readymix
1972-1974	John McNerney	Readymix

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Years	Name	Organisation
2014-2023	Dr Ciaran McNally	University College Dublin
2006-2014	Michael Holst	Clifton Scannell Emerson Associates
2000-2006	Eddie Hanlon	National Building Agency
1985-2000	Peter Fagan	Clifton Scannell Emerson Associates
1972-1985	Paddy Sides	Collen Construction

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IRISH CONCRETE SOCIETY
Celebrating 50 Years

"Any concrete that is used in a farming setting"

Did you know

Agricultural concrete was the first usage of concrete to have an agreed certification process and third-party certification and auditing of concrete manufacturing plants.

Find out more at: S.100 Farm Concrete, published by the Irish Concrete Federation, 2018

1. Agricultural Concrete *by Dr Robert Leonard, Department of Agriculture, Food and the Marine*

Agricultural concrete is any concrete that is used in a farming setting. Concrete is widely used in agriculture for the construction of buildings (mostly walls and floors), uncovered yard areas, fodder stores, silage pits and structures for the holding of slurry, soiled water and effluents to prevent pollutants from entering both surface water and groundwater. Concrete in agricultural settings is expected to perform under a wide range of conditions including sulphate attack, retaining acidic forage (silage pits), experiencing freeze thaw episodes (in open yards) and being exposed to abrasion and heavy traffic, as well as being exposed to animal slurry.

Quality concrete delivered to site is the first step to ensuring durable structures that will prevent pollutants entering ground or surface waters. It has been a requirement since the early 1990s that concrete used in an agricultural setting, in particular for grant-aided structures, be produced in a plant audited by a third party. Since 2008 all concrete used in agricultural structures has been required to be produced in a plant certified to EN 206 by an EU Notifed body, such as the National Standards Authority of Ireland with agreed Concrete Manufacturers Specification and Factory Production Control certificates.

Agricultural concrete is normally designed with a design life of just 25 years compared to 50 years plus for most other uses. Even with this reduced design life the major focus on the concrete design is in relation to the durability of the concrete. Due to the aggressive nature of the environment in which it is used it is important that the concrete mixes used are durable.

The mix designs are set by the Department of Agriculture, Food and the Marine in specification S.100: Minimum Specification for Concrete Composition used in Agricultural Structures.

Agricultural concrete is used all over rural Ireland, with farmers using concrete structures to store slurry, effluents and silage and to provide housing for all types of farm animals, with some being sensitive in scenic areas of the country. Agricultural concrete can be both precast products or as cast insitu concrete for a wide variety of structures.

Notes

2. Air-entrained Concrete *by Dr Declan Phillips of University of Limerick*

Air entrained concrete (AEC) involves the intentional addition of air to a concrete mix to improve its resistance against freeze-thaw weather cycles.

The photograph shows entrained air consisting of spherical air bubbles between 0.05 and 1.25 mm in diameter uniformly distributed throughout the mix. Entrapped air can also be seen beneath the larger aggregates. These microscopic spherical bubbles act as temporary hosts for water in saturated hardened concrete as water volume increases by 9% upon freezing. The bubbles act as 'shock-absorbers that prevent the build-up of high expansive pressures that cause surface scaling in non-AEC, as shown in the image. Entrained air should not be confused with entrapped or unintentional air due to incomplete compaction that is randomly distributed in all concrete. Entrapped air typically occupies between 1 and 2% of the concrete volume and does not impart free-thaw resistance to concrete.

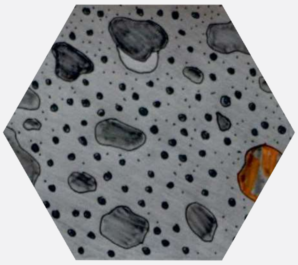
Air-entrainment of concrete can be achieved by typically adding a soap-like fluid admixture to the concrete during mixing. The chemical composition of the admixture imparts surface tension effects that ensure the air bubbles hold their shape and not coalesce to form bigger voids – essential for successful freeze-thaw resistance. The normal amount of entrained air in a concrete mix is between 4 and 8%. Amounts greater than 10% may cause the concrete to segregate.

The addition of air in concrete inevitably reduces its compressive strength by about 5% for each 1% of air added. However, the air entraining admixture improves the workability of concrete by causing the mix constituents to flow more freely; like ball bearings in a well-oiled joint. This makes placement of AEC easier and permits a reduction of mix water normally intended to aid concrete placement, thus offsetting some of the compressive strength loss. The total amount of air in fresh concrete can be measured using an air meter.

AEC is used for all exterior concrete such as in cold storage facilities and runways, roads and footpaths in countries that experience numerous freeze-thaw cycles.

Find out more at: Find out more at: Admixtures for concrete - What is an air entraining admixture?, Available at https://www.youtube.com/watch?v=CXg6kvZWeO0

"The intentional addition of air in a concrete mix to improve its resistance against freeze-thaw"

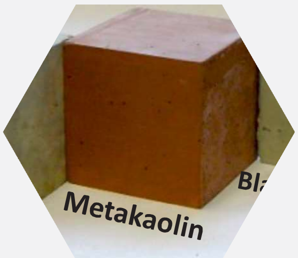


Did you know

Entrained air also reduces bleed water on the concrete surface. The air bubbles appear to prevent the aggregates from settling thus avoiding the upward migration of water to the surface. The reduction in bleed water potentially means permeability and laitance are also reduced leading to a more durable concrete.

Notes

"In alkali activated concrete, precursor and activator together form the binding material"



Did you know

The colour of the end product varies based on the ingredient minerals in the precursor, for example if an iron rich calcined clay (Metakaolin) is used, the end product will be a shade of red.

Find out more at: RILEM's State of the Art Report TC 224-AAM on Alkali Activated Materials, 2014

3. Alkali Activated Concrete *by Dr Sree Nanukuttan of Queen's University Belfast*

Alkali activated concrete is created from a similar range of materials as that of traditional concrete. In traditional Portland cement concrete, cement takes the role of the binding material, whereas in alkali activated concrete, precursor and activator together form the binding material. Reaction products containing calcium, sodium, aluminium and silicon, such as calcium alumino-silicate hydrate and sodium alumino-silicate hydrate, make up the bulk of the binding material.

Common precursors are any of the supplementary cementitious materials such as ground granulated blast furnace slag, fly ash, metakaolin or other calcined clays. The most common activator is a mixture of sodium silicate and sodium hydroxide, but potassium salts are also popular. Acidic media such as phosphoric acid can also be used for activating the precursor.

The quantity of activator varies based on the type of precursor used and properties required, ranging from 5-25% of the mass of precursor. Whilst the precursor has a low to ultra-low carbon footprint, the silicates and hydroxides used as activators are of higher embodied carbon. Precursors with higher calcium content require lower quantities of activators and gain strength more rapidly without the need for heat curing.

The notable difference in production is that alkaline activation, which is of high pH, needs to be prepared and homogenised beforehand, typically 24 hours in advance and stored until mixing. Rheological properties can be controlled by varying the composition of activator in combination with the precursors. Research into effective admixtures is critical.

The greatest advantage is the rapid strength gain associated with this material which makes it a very suitable product for the precast industry. If high calcium precursors are used, the material will develop strength rapidly (greater than 20 MPa in 24 hours) under normal curing. With higher activator dosing, metakaolin-based materials can also reach high strength rapidly under normal curing regimes.

Alkali activated concrete has been in the research domain since the 1930s and the first reported use in buildings was for a 20-storey residential building at Lipetsk, Russian Federation, built between 1987 and 1989.

Notes

4. Board Marked Concrete *by David O'Mahony of MOLA Architecture*

Board marked concrete is a decorative finish to a cast concrete surface achieved through allowing the grain of timber shuttering to be expressed in the exposed concrete elements of a building or structural element. The effect is achieved by carefully selecting the facing material of the mould or shutter, which becomes the imprinted pattern of the cast concrete surface, creating a decorative effect. This method of construction is becoming more frequently used due to concrete's suitability as an exposed finished material in modern design.

While it is important to use the correct concrete mixture with adequate fluidity to pick up the intricacies of the wood grain in the formwork and reduce the chance of honeycombing, the most important part of the production is in the preparation of the formwork itself. Great care should be taken when installing the planks in the mould, as it is the pattern created by the planks that will be displayed when the formwork is removed. It is a more artistic process than using standard smooth forms and as such it typically takes two to three times longer to prepare than conventional concrete formwork.

Board marked concrete distinguishes itself from other methods of concrete construction due to its aesthetic appearance. By imprinting the wood grain on the surface, it visually softens and warms concrete's somewhat cooler appearance while still allowing concrete to express the construction technique. It also grows old gracefully as ageing is disguised by the surface undulations.

Perhaps the most famous example of board marked concrete in Ireland can be found at the Berkeley Library in Trinity College Dublin, designed by ABK Architects and completed in 1967. Board marked concrete is the dominant material both internally and externally of this Brutalist concrete building. In the interior not only is it omnipresent in the structure and form but also in the fixed furniture elements which are moulded in concrete.

"A cast concrete surface is achieved through allowing the grain of timber shuttering to be expressed in the exposed concrete elements"

Did you know

The grain effect can be enhanced through light sandblasting of the planks.

Find out more at: Calder, B, Raw Concrete: The Beauty of Brutalism, Heinemann , London, 416 pp., 2016

Notes

"A supplementary cementitious material for concrete which is produced by heating and grinding a clay containing specific minerals"

Did you know

The geology of County Antrim is particularly suited for the provision of clays for use in this application. Outcrops of such a clay can be seen as red layers in the cliffs at the Giant's Causeway.

Find out more at:
Zunino, F, Dhandapani, Y, Ben Haha, M, "Hydration and mixture design of calcined clay blended cements: Review by the RILEM TC 282-CCL", Materials and Structures, 55, 234, 2022

5. Calcined Clay Concrete *by Dr Andrew McIntosh of Kilwaughter Minerals Ltd*

Calcined clay is a supplementary cementitious material for concrete which is produced by heating and grinding a clay containing specific minerals (for example, kaolin) to between 500 and 800°C. This drives off chemical water, giving a product (known as a pozzolan) that contributes to the strength of concrete on hydration. Although utilised in Roman concretes 2,000 years ago, co-product alternatives like fly ash and blast furnace slag have taken precedence over calcined clay. Plentiful reserves of suitable clays are abundant throughout the globe and as availability of these other options become more restricted, calcined clay offers long-term sustainability of supply.

Produced at a lower temperature than Portland cement, in a process that does not involve the release of carbon dioxide from limestone, leads to a reduction in the embodied carbon of a concrete. The product can be blended with Portland cement at the cement factory or included as a raw material during the production of concrete at the batching plant.

Calcined clays react with a by-product of the hydration of Portland cement (that is, calcium hydroxide) to produce additional, pore-blocking, cementitious products that can result generally in a stronger, more durable and longer lasting concrete. For example, by reducing the rate at which chlorides migrate through concrete, steel reinforcement is protected for longer in exposed coastal locations. Concretes containing calcined clay have also been found to be more resistant to abrasion.

Calcined clay concrete is growing in popularity – particularly in Cuba, South America and India. In 2019, a concrete using calcined clay technology was used to form a pier in Belfast harbour for the transfer of scrap metal to ships. It was chosen for its abrasion resistance, resistance to chloride ingress and high strength properties. In 2018 calcined clay concrete was specified for the construction of a basement due to low water permeability properties.

Notes

6. Controlled Low Strength Concrete
by Aidan Fogarty of Ecocem

Controlled low strength concrete (CLSC) is a self-compacting, cementitious material used primarily, but not exclusively, as a replacement for conventionally compacted fill. Several terms are currently used to describe this material including flowable fill, controlled density fill, flowable mortar, plastic soil cement and soil cement slurry.

Conventional materials found at the concrete plant are used to produce CLSC. The majority of flowable fills are composed of fine aggregates and a high proportion of supplementary cementitious materials. These contribute to extended setting time and slower strength development. To aid in the rheological performance of the concrete both superplasticisers and air entrainers may be used, although segregation is a risk. Soil stabilisation and sediment valorisation involves on-site action for the treatment to be carried out, for which CLSC is particularly suited.

CLSC is a material that typically results in a compressive strength of less than 10 MPa, with cementitious contents usually ranging from 100-200 kg/m^3. CLSC can be designed with different strengths and densities depending on requirements. Lower strength material can allow for future excavation. Other properties of CLSC can be controlled to suit specific job requirements, such as the ability to retain pollutants may be the primary requirement in some projects.

In Howth Port extension, one objective was to valorise the Howth port dredged sediments. In addition to a high-moisture content (> 60% by weight) and fine grains (90% passing 80 μm), these sediments were contaminated with multiple heavy metals (zinc, copper, nickel) and Organotin compounds. The contractor used CLSC to treat sediments to improve their geotechnical properties and to ensure that all identified pollutants were effectively captured by the solidified matrix. Geotechnical performance was achieved within seven days, and pollutant leaching was reduced below the environmental assessment requirements, as demonstrated by further monitoring on-site for several months.

"A self-compacting, cementitious material used primarily but not exclusively as a replacement for conventionally compacted fill"

Did you know

The Howth project resulted in the construction of a port extension utilising only the treated sediments that were directly dredged in the port.

Find out more at:
Controlled Low Strength Materials, reported by ACI Committee 229 ACI 229R-94, 15pp, 2013

Notes

"Multiple layers of finely divided steel mesh encased in a cement-rich mortar"

Did you know

The Irish engineering consultants Delap and Waller developed a system of thin shell construction that used hessian as the mesh in a concrete mortar matrix.

Their system is a form of Ferrocement in which the bonded warehouse at the Kilbeggan Distillery in Co. Westmeath is a surviving example.

Find out more at: ACI 549R-18: Report on Ferrocement, by ACI Committee 549, 2018

7. Ferrocement *by Dr Dermot O'Dwyer of Trinity College Dublin*

Ferrocement comprises multiple layers of finely divided steel mesh encased in a cement-rich mortar. Ferrocement sections are usually very thin with the typical thicknesses varying from 10 to 40 mm. The steel mesh is frequently galvanised and may be augmented by standard reinforcing bars of small diameter, typically 6 to 10 mm. The term ferrocement is also used where the mesh is non-ferrous.

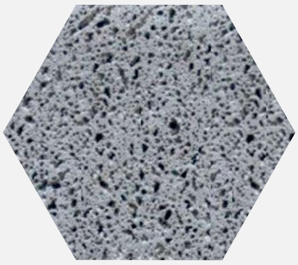
The constituents used in ferrocement are similar to those used in traditional reinforced concrete where steel bars are used. For finely divided mesh, the thin sections preclude the use of larger aggregate, so the concrete component typically comprises a sand-cement mortar with a ratio of 1:2, with a 0.4 water-cement ratio being typical. The challenge in producing ferrocement is to ensure that the mortar fully penetrates the mesh. Ferrocement can be produced in a factory setting or on site with construction professionals or in a self-build fashion with unskilled labour. Ferrocement is often used in lower income countries because of its economic use of materials, though the scale of the structure is often limited in height.

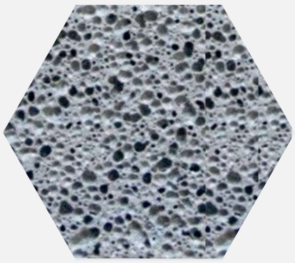
A ferrocement section behaves as a homogenous elastic material. It is well-suited for forming curved shapes especially shell structures. Where flat panels or shells of single curvature are produced, fins or stiffeners can be added to strengthen the section. The ability to form curved structures of ferrocement without the need for formwork has led to the use of ferrocement for food and water storage in the developing world.

Pier Luigi Nervi used ferrocement to great effect in a number of his shell and stiffened plate structures. He also used it to form permanent shuttering for complex-shaped reinforced concrete elements and used it to construct his yacht Nenelle: Ferrocement has been used widely for boatbuilding and canoes. A more recent use of ferrocement that demonstrates its potential is in the Gatehouse of the Yanbu Cement Company in Saudi Arabia, which was designed by Studio65.

Notes

"A lightweight, low-density porous concrete formed using foam"





Did you know

Within the range of available foamed concretes, the lightest ones generally offer the best insulating properties and can float in water. It is a good insulator and a low-strength construction material, if the combination of required strength and insulating value are achieved.

8. Foamed Concrete *by Dr Suhaib Salawdeh of Atlantic Technological University, Galway*

Foamed concrete is a lightweight, low-density porous concrete formed using foam. Density typically varies from 400 kg/m^3 to 1600 kg/m^3, with strength ranging from 0.5 MPa to 12 MPa. As it is very fluid and flowing, it does not require any levelling or compaction. It can easily be pumped long distances and will fill most cavities. The material is typically made by mixing cement, sand, water and foam. Foamed concrete is specified for many purposes, for example to reduce loadings, for insulating floors and roofs and void filling.

Foamed concrete is in the form of foamed grout or foamed mortar - coarse aggregates are not used as they would segregate out. This leads to lower densities and lower compressive strengths when compared to conventional concrete. Its density depends on how much foam is put in the mortar and a special machine is needed to generate the foam. The different components added to the mix will determine the strength and durability of the concrete, though it is seldom used to form reinforced concrete. It may be made using a pure Portland cement, but often limestone and/or pulverised fly ash are added.

Foamed concrete has good void filling capability because its low viscosity allows it to flow over large distances Thus, it may lower labour costs during construction. Its low density reduces dead or permanent loads on the structure and foundations. It also enhances concrete thermal resistance and so can contribute to energy conservation.

Foamed concrete is used for a wide range of purposes: for void filling, insulation, enlargement of bearing capacity or replacement of soil, soil stabilisation, roof slopes, blocks and wall panels, construction of sports fields and athletics tracks, backfilling of utility trenches and shock absorption.

Find out more at: Just Foamed Concrete - An Overview, in Specialist Techniques and Materials for Concrete Construction, Eds. EP Kearsley, RK Dhir, and NA Henderson, 2015

Notes

"Fibres are bound together in a polymer matrix to produce composite materials"

Did you know

FRP rods are non-metallic and thus have certain advantages over steel reinforcement - they do not corrode, so require lower levels of concrete cover. Moreover, they are non-magnetic so are suitable for use in specialised applications, such as high-tech laboratories which may be extremely sensitive to changes in magnetic fields.

Find out more at:
Analysis and Design of FRP Reinforced Concrete Structures, Singh, McGraw Hill, 2015

9. Fibre Reinforced Polymer Concrete *by Dr Paul Archbold of Technological University of the Shannon*

Fibre Reinforced Polymer (FRP) composite materials constitute a range of materials, whereby fibres are bound together in a polymer matrix to produce composite materials with advantageous mechanical properties. The range of fibres available is wide and growing, from metals to synthetics to organic fibres.

FRP reinforcement comes in many forms, the most common of which are presently used as rods or bars. These are normally extruded, with the structural fibres held together in a thermoset polymer resin such as polyester. FRP can also be bonded externally to strengthen existing structures, usually in the form of sheets/strips bonded to the surface of the structural element, particularly beams. They can also come in the form of a fabric which can wrap around columns to strengthen them.

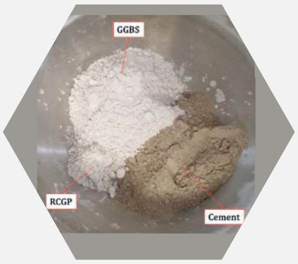
FRP properties vary depending on the material comprising the fibres and the resin matrix. Typical values for selected properties are shown below for steel, carbon, glass and basalt FRP. Notably, the tensile strengths of FRP rods are signficantly higher than that of steel.

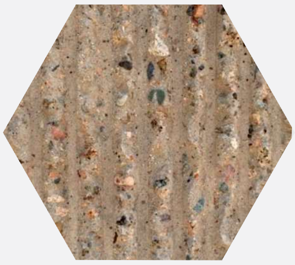
Property	**Material Type**			
	Steel	CFRP	GFRP	BFRP
Density (kg/m^3)	7,850	1500 – 2100	1250 – 2500	1900 – 2100
Tensile Strength (MPa)	500	600 – 3920	483 – 4580	600 - 1500
Young's Modulus (GPa)	200	37 – 784	35 – 86	50 - 65

An example of an FRP structure is Thompson's Bridge in Northern Ireland, where BFRP fibres were used as the reinforcement for the deck.

Notes

"A concrete that contains glass, replacing a fraction of the cement content or the aggregate"





Did you know

In Ireland, between 25,000 and 30,000 tonnes of glass are not recycled every year. Researchers have shown promising results using glass powder in dosages of up to 20%, enabling the reuse of glass waste to reduce the embodied carbon impact of concrete.

10. Glass Concrete *by Dr Oliver Kinnane of University College Dublin*

Glass concrete is broadly defined as a concrete that contains glass which replaces a fraction of the cement or aggregate content. It is commonly considered to be a more sustainable alternative to conventional concrete by enabling the recycling of a waste material and the offsetting of virgin materials. Partial cement replacement with glass powder will reduce the embodied carbon of concrete.

In glass concrete, the standard concrete constituents are altered to include a portion of processed waste glass, often referred to as glass cullet. This may be incorporated into concrete as a cement replacement in milled powder form, referred to as Recycled Container Glass Powder (RCGP). Alternatively, it can be incorporated in larger particle sizes as fine or large aggregate replacement.

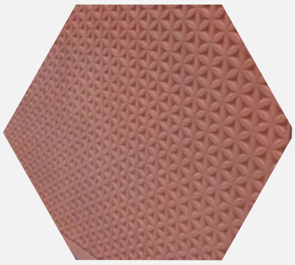
RCGP is pozzolanic and as such may be viewed as a supplementary cementitious material. RCGP can be combined with, for example, ground granulated blast furnace slag (GGBS) and cement. However, in contrast to GGBS and cement, RCGP is predominantly silica based - glass aggregates are often highly reactive due to both high alkali and silica content embedded in their microstructure. Thus, the general consensus in academic literature is that glass in powder form enhances Alkali-Silica Reaction (ASR) resistance, whereas in aggregate form, the risk of ASR is increased.

One of the most famous uses of glass concrete is in the famous Brutalist architecture building on Yale campus in New Haven, Connecticut, designed by the great American architect Paul Rudolph. Glass aggregate is visible in the bush hammered fluting of the building's concrete façade.

Find out more at: Sustainable Construction Materials - Glass Cullet. RK Dhir, J de Brito, GS Ghataora and CQ Lye, Eds.; Woodhead Publishing Series in Civil and Structural Engineering, 2018

Notes

"A cement-rich mixture with no coarse aggregate and a high volume of alkali-resistant glass fibres"



Did you know

GRC performs so favourably in flexure that, when used as cladding, it can be as thin as 12 mm in non-ribbed areas, an order of magnitude thinner than conventional concrete wall sections.

11. Glass Fibre Reinforced Concrete *by Dr Richard O Hegarty of University College Dublin*

Glass fibre reinforced concrete, better known by its acronym GRC (or GFRC), is unique in how it is made, what it is made of and how it performs. It is a concrete mix which does not require conventional steel reinforcement to perform adequately under flexural loading, which subsequently enables the design of lighter structural components. This fibre-rich concrete mixture is in the engineered cementitious composite family and performs similarly to ultra-high performance fibre reinforced concrete (UHPC), in that it boasts strain hardening behaviour, continuing to take greater and greater loads even after initial cracking.

It is also a cement-rich mixture with no coarse aggregate and a high volume of alkali-resistant glass fibres. Several admixtures are used, including superplasticisers, shrinkage reducers and pumping aids. It is typically sprayed on to a mould but can also be pre-mixed and poured, although the latter option is less common. The sprayed production methodology enables the inclusion of a greater percentage of glass fibres which enhances its hardened properties.

It differs from conventional concrete primarily in how it performs in bending. The composite behaviour realised between the matrix of glass fibres and mortar, when experiencing applied bending stresses, results in flexural strengths in the order of 20+ MPa, that is, about 5 times that of conventional concrete. It behaves like a ductile, rather than brittle, material, with high post-cracking toughness.

GRC/GFRC is typically used in non-load bearing applications such as cladding. The images shown here are examples manufactured by Techrete, an architectural precast concrete manufacturer with Irish origins, who specialises in concrete cladding solutions.

Find out more at: Glass Fibre Reinforced Concrete: Principles, Production, Properties and Applications, Peter J. M. Bartos, Whittles Publishing, 2017

Notes

"A white cementitious binder that brings architectural, engineering and environmental benefits to concrete"

Did you know

GGBS is a latent hydraulic material and will slowly set and develop strength on its own in the presence of water. However using a Portland cement with GGBS accelerates the concrete's early age properties.

Find out more at: ICE Handbook of Concrete Durability – A practical guide to the design of resilient concrete structures (Second Edition), M Soutsos, 2010

12. Ground Granulated Blast Furnace Slag Concrete *by John Reddy, Ecocem*

Ground granulated blast furnace slag (GGBS) is a white cementitious binder that brings architectural, engineering and environmental benefits to concrete. It may replace up to 70% of cement in Ireland on a 1:1 replacement basis in ready mixed and precast concrete.

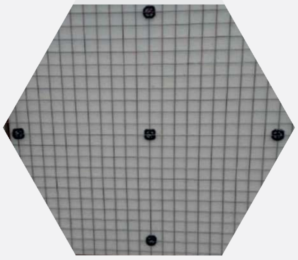
GGBS is a by-product of the iron making industry. It has the same chemical constituents as CEM I (normal Portland) cement but in different proportions. Molten slag is rapidly quenched with water as it exits the blast furnace to form granulated blast furnace slag (GBS). GBS is a glassy sand-like material that is transported in bulk to manufacturing sites. Then large industrial drying mills are used to manufacture GGBS from GBS which is delivered in bulk tankers and stored in a dedicated silo at a concrete plant. It can then be mixed at the concrete mixer to make GGBS concrete with the required percentage use, usually in the range 30-60%.

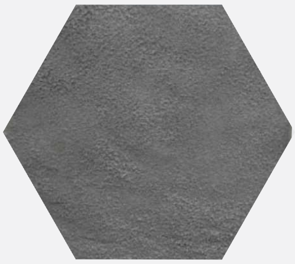
GGBS concrete is brighter in colour than CEM I concrete, enhancing its whiteness and reflectivity. Long term concrete strength and most durability aspects are enhanced, which increases the service life of concrete. Porosity is reduced and concrete is better protected against chloride and sulphate attack. Carbonation rates are faster and consideration to providing additional cover may be required. The low heat characteristics of GGBS concrete make it suited for large concrete pours, reducing the risk of thermal cracking occuring. GGBS is a 100% recycled industrial by-product that reduces the greenhouse gas emissions in the manufacture of concrete by over 50%, scoring highly on environmental rating systems such as LEED and BREAAM.

The first use of GGBS concrete in Ireland was on the Jack Lynch Tunnel, Cork, in the late 1990s. This was followed shortly after by the Mary McAleese bridge at the Boyne Valley. At the National Convention Centre, Dublin, 10,500 tonnes/carbon dioxide (190,000 dairy cows equivalent) was saved with the use of 70% GGBS concrete, which lowered the carbon footprint, reduced the risk of cold joints during the pour and thermal cracking post pour, thereby enhancing the sustainability of the concrete.

Notes

"A cementitious mix that is pneumatically projected at high velocity from a nozzle onto a surface... a dry-mix sprayed concrete"





Did you know

Gunite was first invented in 1895 by Dr Carlton Akeley, curator of the Field Museum of Natural Science in Chicago, to accurately form animal body shapes around skeletal frames. As it is sprayed, the impacting jet of material compacts the material already in place. Therefore, it can support itself without sagging on vertical or sloping surfaces as it hardens, forming perfect animal shapes.

13. Gunite *by Dr Tomás O'Flaherty of Atlantic Technological University*

Sprayed concrete, often referred to as Gunite, constitutes a cementitious mix that is pneumatically projected at high velocity from a nozzle onto a surface to give a dense concrete mass. This versatile and flexible process makes it suitable for situations where formwork and traditional concrete casting methods are impractical or undesirable. Sprayed concrete can be applied using either dry or wet mix processes. The term Gunite refers to the original sand and cement dry-mix patented in 1911 and is still used today to refer to dry-mix sprayed concrete where water is added at the nozzle. Alternatively, the term Shotcrete (see topic 40) evolved in the US and refers to the wet-mix process in which water is added at the mixer.

The constituents used in Gunite are largely the same as those used in conventionally cast concrete. Steel and synthetic fibres may be included to improve performance, as can silica fume, pulverised fly ash and ground granulated blast furnace slag. The gradation of the aggregates means that Gunite contains significantly less coarse aggregates than conventional concrete to avoid excessive rebound of coarse aggregates when sprayed. All aggregate should be less than 8 to 10 mm. The predetermined ratio of cement and aggregate is batched and mixed without added water. The mixture is then pressurised, introduced into a high-velocity air stream, and conveyed to the spray nozzle through flexible hoses. At this nozzle, a fine spray of clean water is added to the stream of materials to hydrate the cement and provide the right mix consistency. The uninterrupted stream of materials is then projected onto the surface.

Its ease of application, start and stop capability and the thin-layer application provide distinct advantages. Rebound properties are important due to the high velocity of the impacting jet and although some rebounding material is inevitable, the use of fibres help to minimise this. The rebounded material should be discarded as it is of unknown grading but consists of the larger aggregate particles.

Sprayed concrete is widely used in mines, stabilisation of slopes and rehabilitating structures such as bridges, tunnels, dams, tanks and swimming pools.

Find out more at: ISEN 14487 on Sprayed Concrete, 2020

Notes

"When gypsum is blended as an ingredient in concrete"

Did you know

Quarries in Montmartre produced calcined gypsum or dehydrated gypsum which, when combined with water, hardens very rapidly. This material is known as Plaster of Paris.

14. Gypsum Concrete *by Dr Daniel McPolin of Queen's University Belfast*

Gypsum is a sulphate-based mineral with the chemical formula $CaSO_4.2H_2O$ and is quite soft. When gypsum is blended as an ingredient in concrete containing Portland cement (PC) and aggregate it is often referred to as gypsum concrete or gypcrete.

Unlike regular concrete, gypsum concrete usually only contains sand as the aggregate and this, combined with the addition of lightweight gypsum, results in a concrete which has a much lower self-weight.

Lightweight Gypsum concrete typically has a density of 500-1,800 kg/m^3 as opposed to regular PC-based concrete with a typical density of 2,400 kg/m^3. Gypsum concrete also has excellent fire-resistant properties due to its two water molecules being chemically bound to the gypsum, which must first be broken down as the temperature rises. As a material it also has good sound insulation properties. Unlike PC concretes it does not shrink much as it cures and consequently tends to crack less. Gypsum concrete however is not very water resistant and will eventually dissolve in the presence of water. In terms of strength, it is generally weaker and more brittle than regular PC concretes.

Gypsum concrete is most commonly used as a subflooring material, often in timber framed buildings. The lightweight nature of the material makes it easier to place and, with only fine aggregate, it requires less levelling. When used in timber frame buildings, the excellent fire resistance means that less thickness is required to achieve the required fire resistance. This further reduces the weight of the gypsum concrete subfloor compared to a PC concrete, which can be of significant benefit.

Find out more at: https://www.funktionalhome.com/gypcrete-vs-concrete/

Notes

“Concretes and mortar made with hemp and a lime-based binder”

Find out more at:
Walker, R, Pavía, S and Mitchell, R, “Mechanical properties and durability of hemp-lime concretes”, Construction and Building Materials, 61, 340-348, 2014

15. Hemp-Lime Concrete *by Dr Sara Pavia of Trinity College Dublin*

Hemp-lime concretes and mortars are made with hemp and a lime-based binder. They are deformable and non-loadbearing materials with excellent thermal properties and high water vapour permeability. They are used in both new construction and thermal upgrades of existing buildings.

As they are made from a renewable plant (hemp) they are a carbon sink, hence hemp materials are lower-carbon and more sustainable. They have futher environmental credentials as they are natural, non-toxic and biodegradable.

These concretes are lightweight materials with good insulation characteristics due to their high thermal resistance arising from a low thermal conductivity that results in low U-values. Lime-hemp buildings are inherently air-tight, and the wide monolithic walls negate the risk of thermal bridges which further enhances the thermal performance of the material. The high vapour permeability of hemp concrete buffers internal humidity, avoiding condensation and improving indoor air quality.

Lime hemp materials have been used in numerous projects in Ireland in the last decade. An interesting example is the Passiv house in County Longford, built by self-builder J. Byrne. In some projects, factory-made construction systems and hempcrete blocks are used instead of formwork and cast as monolithic walls on site.

Did you know

Even though they are low-density materials, hemp-lime concretes behave like dense, high-thermal-mass materials in reducing the range of temperature variation in a space they enclose. This is due to their low diffusivity and phase change properties. They are highly effective in storing heat at warmer times and releasing it at cooler times, delaying and reducing temperature variations.

Notes

"Concrete having a density of greater 2,600 kg/m³ in an oven dried condition"

Did you know

While Baryte was mined in Sligo until the late 1970s, most heavy-weight concretes produced in Ireland today use a Magnetite heavy-weight aggregate sourced from Kiruna, located 145 km inside the Artic Circle in northern Sweden.

16. Heavy-weight Concrete *by Colin Heffernan of Roadstone*

Concrete density is defined into three different categories: lightweight, normal-weight and heavy-weight. The typical density of normal-weight concrete produced in Ireland is 2,400 kg/m^3. Heavy-weight concrete is defined as having a density of greater than 2,600 kg/m^3 in an oven dried condition, with densities of greater than 3,800 kg/m^3 commonly used in practice.

Aggregates typically comprise 80% of a concrete's mix constituents. Therefore, it stands to reason that to produce a heavy-weight concrete mix, a high-density aggregate is required. There are numerous high-density aggregate types which can be used, with baryte and magnetite being the most frequently commercially available. Limestone is the most commonly used aggregate type in concrete production in Ireland and has a typical particle density of 2.7 t/m^3. By contrast, commercially available magnetite has a particle density of almost twice that at 4.8 t/m^3.

Heavy-weight concrete has similar constituents to normal-weight concrete. It is produced, placed and compacted in a similar manner to normal-weight concrete, however some additional considerations have to be taken into account. Producers have to reduce their load size, while formwork designers have to consider increased hydrostatic pressures. For contractors, higher frequency poker vibrators employed at closer centres are necessary when compacting the mix as a greater amount of energy is required to transmit vibration through the denser material.

The increased density of heavy-weight concrete makes it suitable for application types such as radiation shielding in nuclear or hospital facilities. Where thinner elements can be constructed and used as counterbalance due its extra weight, it is used in structures such as bridges. For example, heavy-weight concrete was used for counterbalancing purposes in the Samuel Beckett Bridge in Dublin and in the LINAC bunkers of the radiotherapy unit in Bon Secours Hospital in Cork. Heavy-weight concrete has also been used in the condensed spaces below London's West End theatres to limit sound and vibration being transmitted from the Underground system beneath.

Find out more at: ACI 304.3R-20, American Concrete Institute report, Heavyweight concrete: Measuring, mixing, transporting, and placing, 2020

Notes

17. Lean Concrete *by Keith Goodwin of Kilsaran*

This type of concrete is referred to as lean because it contains a lower amount of cement than conventional concrete. It is typically used for applications where strength is not a key factor and the concrete element is considered non-structural.

Normal concrete is designed to have a cement content of about 15-20% of the mix constituents by weight. This is adequate to achieve structural performance, as well as providing a suitable volume of cement paste, allowing the concrete mix to have adequate workability, which in turn is easier to finish. With lean concrete, however, the cement content will be typically less than 10% of the mix, resulting in a higher aggregate to cement ratio.

As the concrete will have a lower cement content, the strength and durability of lean concrete is reduced. In addition, the higher than usual aggregate to cement ratio will result in a stiffer concrete which also does not lend itself to achieving a good finish, although for typical usage applications this is not usually considered important.

Lean concrete is used widely on many construction projects, typically to provide a layer of “blinding” concrete where the ground is not even, to provide a level surface where raft foundations or concrete slabs can be poured on top afterwards using conventional structural concrete. In the same application it can be used to protect the structural concrete element to be placed above it from moisture and chemicals that may be contained in some soils. Other common uses of lean concrete are to provide concrete haunching as back up to kerbs prior to the construction of roads and car parks, and for bedding and haunching pipes and cable ducts.

“Concrete with low cement content”

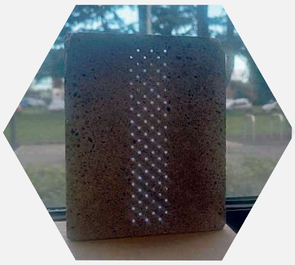
Did you know

Lean concrete is often confused with “semi-dry” concrete. While lean concrete is typically a low slump semi-dry concrete, a cement rich conventional “semi-dry” structural concrete can also be supplied at low workability and so the two terms are often confused but are not interchangeable.

Find out more at: Khot, S, Shagoti, A and Palankar, N, “Studies on Dry Lean Concrete using new mix design approach”, Sustainability Trends and Challenges in Civil Engineering, Singapore, Springer, 2021

Notes

"A form of concrete that allows light to pass through it"



Did you know

In 2004, the original concrete developed by LiTraCon was listed by Time Magazine as one of the most important inventions of the year.

Find out more at: https://www.litracon.hu or https://www.lucem.com

18. Light Transmitting Concrete *by Dr Ciaran McNally of University College Dublin*

Light transmitting concrete (LTC) is a form of concrete that allows light to pass through it. The use of LTC is primarily architectural and it can transmit both natural and artificial light. LTC was originally developed by Hungarian architect Áron Losonczi in the early 2000s. He later went on to form the company LiTraCon to produce the material commercially. Since then, several other companies have produced their own versions of LTC.

The key difference compared to traditional concrete is the aggregate type and size, and the use of optical fibres. These fibres are used at a concentration of up to 5% (by volume) and can be plastic or glass. Glass fibres have better optical properties but are also significantly more expensive. LTC also uses only fine aggregates as the presence of larger aggregate particles can damage the optical fibres.

There is increased interest in LTC as an energy efficient form of concrete; its ability to transmit natural light may lead to reduced lighting requirements and energy savings. From a mechanical perspective, the use of optical fibres leads to a reduction in strength. The bond between the optical fibre and the concrete can be a weak point and the distance between fibres can be sufficient to allow microcracks to progress.

The use of LTC is primarily architectural and it is often used in bespoke, decorative concrete elements. It can be used with pigments to give different colours and can also be polished to obtain different finishes.

Notes

"Concrete made with natural or manufactured lightweight aggregates"

Did you know

Lightweight concrete was used in Roman times to build structures such as the dome of the Pantheon in Rome (AD 127), with crushed pumice as a natural lightweight aggregate and which is still in use. LAC elements of density lower than 1,000 kg/m^3 will float in water.

Find out more at: Guide for Structural Lightweight Aggregate Concrete, American Concrete Institute, ACI 213R-14, 2014

19. Lightweight Aggregate Concrete *by Brendan Lynch, Consultant*

Lightweight aggregate concrete (LAC) is one particular category of lightweight concrete made using natural or artificial lightweight aggregates. There are a number of other types of lightweight concrete produced by different methods, such as foamed concrete (see concrete type 8). Concrete made using lightweight aggregate is lower in density and strength than conventional concrete.

Lightweight aggregates are natural or manufactured aggregates which are more porous / less dense than normal concrete containing rock aggregates. Pumice is an example of a natural lightweight aggregate resulting from volcanic action. Manufactured lightweight aggregates are produced, for example, by heat treatment of pulverised fly ash, expanded clay/shale or from foamed slag from a blast furnace. Some trade names of different type products are: Lytag, Leca, Liapor and Pellite. Lightweight aggregate is defined as having an oven-dry loose bulk density of less than 1,200 kg/m^3. Both fine and coarse lightweight aggregate sizes can be produced as constituents for LAC. Cement contents are usually higher in LAC due to the need to recover some of the strength loss incurred by virtue of the LAC's inclusion.

LAC offers benefits in lower deadweight (self-load) for structural uses and in better thermal insulation than conventional concrete. To be considered lightweight, the oven-dry density of the LAC concrete is required to be below 2,000 kg/m^3 and can be as low as 800 kg/m^3, in comparison to concrete made with crushed rock aggregates which is typically around 2,400 kg/m^3. Lightweight concretes can be specified by density and/or strength classes. Due to its increased porosity, lightweight aggregate has higher water absorption which can pose difficulties during mixing, transportation and placing of fresh concrete. It is difficult to maintain mix cohesiveness / stability which can be overcome by wetting the aggregates before use, suitable mix design and admixtures.

There have been limited examples of use of LAC in Ireland because all the aggregates must be imported, thus making the concrete more expensive. Some uses here include use in new floors in the refurbishment of existing structures and new screeds to improve falls. In the UK, examples include use in multi-storey buildings, bridges and gravity bases for oil platforms. Lightweight aggregate is commonly used in Ireland in the manufacture of lightweight concrete blocks, principally for better thermal insulation.

Notes

“Limestone fines can act as a filler in the concrete, improving the surface finish, improving the particle packing and its durability”

Did you know

Cement and concrete research and development is continuing into the use of limestone and limestone fines to further increase the sustainability of concrete.

Find out more at:
Portland-Limestone Cement: State-of-the-Art Report and Gap Analysis, for CSA A 3000, 2007

20. Limestone Fines Concrete *by Dr David Collery of Atlantic Technological University, Sligo*

The chemical name for limestone is calcium carbonate ($CaCO_3$) and it is a type of sedimentary rock composed mostly of the mineral’s calcite and aragonite, which are different crystal forms of $CaCO_3$. Limestone formation is a very slow process, in which layers and layers of limey deposits built up on the ocean floor and were compacted by the weight of the water over millions of years. Eventually the layers of sediments were consolidated into beds of hard limestone rock. On the island of Ireland, 65% of the rock is composed of limestone. Limestone, once quarried, can be used in many products especially aggregates for the construction industry, but it is also the key ingredient in the production of cement clinker, agricultural lime for farming and many more products.

Traditional Portland cements (CEM I) are 95% based on clinker produced by burning limestone and silica materials at high temperatures in a kiln. This production process results in carbon dioxide emissions arising from the de-carbonation of limestone and the combustion of fuels. To reduce the carbon footprint of the cement, cement manufacturers have replaced traditional CEM I cement with new CEM II lower carbon cement types in recent years. For example, in the new CEM II A-L product between 10 and 15% of the clinker is being substituted by ground un-burnt limestone powder in the final cement product. This reduces both “process” carbon dioxide emissions arising from the de-carbonation of limestone in cement manufacture and “fuel” emissions arising from the burning of the limestone in the cement kiln, thereby substantially reducing carbon emissions per tonne of cement.

CEM II cements produced in accordance with the European standard EN197-1 provide similar performance as their CEM I predecessors, whilst simultaneously increasing the sustainability of the cement product. Additionally, the use of limestone fines as an addition to concrete, in accordance with BS 7979, is increasingly popular in concrete as a mixer addition. It can act as a filler in the concrete, improving the surface finish and improving the particle packing which in turn lowers the diffusion rates of deleterious materials into concrete, thereby improving its durability. Limestone fillers are also commonly used in the production of concrete precast units.

Notes

“Concrete that has a lower carbon dioxide footprint compared to traditional concrete”

Did you know

The production of concrete is a significant contributor to greenhouse gas emissions, primarily due to the production of cement, which is responsible for circa 7% of global CO2 emissions. According to the Irish government’s Climate Action Plan 2022, public bodies, leading by example, shall specify low carbon cement materials as far as practicable from 2023. Furthermore, an embodied carbon building rating calculation methodology, scheme and software shall be developed by 2025.

21. Low-Carbon Concrete *by Prof Jamie Goggins of University of Galway*

Low carbon concrete is a type of concrete that has a lower carbon dioxide footprint compared to traditional concrete.

A range of approaches has been explored to reduce the carbon footprint of concrete. These frequently include the use of supplementary cementitious materials such as fly ash, ground granulated blast furnace slag, silica fume and calcined clay to partially replace Portland cement, the most commonly used cementitious material in concrete. The incorporation of recycled materials, such as recycled aggregates and recycled water into the concrete mix, can reduce the demand for virgin materials and lower the carbon dioxide (CO_2) emissions associated with their production. Optimisation of the concrete mix design by carefully selecting the type and amount of aggregates, use of admixtures and optimising the water-cement and aggregate-cement ratios in the mix can also help to reduce the carbon footprint of the concrete, as can, perhaps in combination, increasing efficiencies in material processing, using low-carbon fuels such as hydrogen and biomass for material processing and transportation; using electricity from renewable energy sources for material processing and transportation; adopting carbon capture and storage technologies, which capture and store the CO_2 emissions produced during cement production; and injecting captured CO_2 into freshly mixed concrete, where it converts to a solid mineral, calcium carbonate.

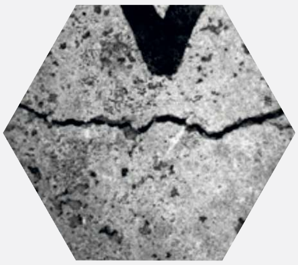
Overall, the properties of low carbon concrete will depend on the specific mix design and materials used, but they are typically similar to traditional concrete in terms of strength, durability, and workability. However, in some cases concrete setting is slower and carbonation of concrete with a high substitution rate of SCM needs consideration.

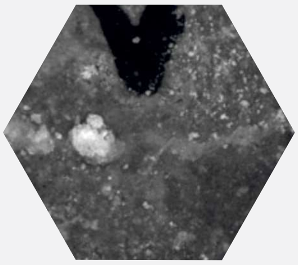
Buildings that have been constructed using low carbon concrete in Ireland typically use GGBS up to rates of 70% substitution (for example, ESB Headquarters, Dublin). As awareness of the environmental impacts grows, design with focus on reducing embodied carbon will become more prevalent.

Find out more at: CEMBUREAU ‘Building carbon neutrality in Europe’ (https://circulareconomy.europa.eu/platform/sites/default/files/cembureau_-_building_carbon_neutrality_in_europe.pdf)

Notes

"An innovative concrete that can heal and seal itself when damaged"





Did you know

Concrete is too alkaline for most bacteria to survive in. However, certain extremophile bacteria found in alkaline soda lakes thrive in such alkaline conditions making them highly suited for bacteria-based self-healing concrete applications.

22. Bacteria-Based Self-Healing Concrete *by Dr Damian Palin of Trinity College Dublin*

Bacteria-based self-healing concrete is an innovative material that can heal and seal itself when damaged. This autonomous healing ability is made possible by incorporating a bacteria-based healing agent within the concrete. When the concrete is damaged and water enters through cracks, the agent is activated and mineral healing takes place, which blocks and waterproofs the cracks. This smart, biologically enabled cementitious material promises structures with longer service lives and associated economic benefits.

The healing agent of bacteria-based self-healing concrete generally consists of bacterial spores (of non-pathogenic bacteria) and nutrients. These spores can withstand the harsh alkaline environment of cementitious materials, while the nutrients trigger spore germination and act as a precursor for mineral ($CaCO_3$) precipitation and the healing process. The agent can be loaded into carrier materials, including clay particles or hydrogels, before incorporation into the concrete. Alternatively, the bacterial spores can be combined with the nutrient source itself.

Compared to ordinary concretes, bacteria-based self-healing concrete has an enhanced healing and sealing capacity. As a result, water-tight structures made from this material can use less steel reinforcement to limit crack width formation, reducing the cost and environmental impact of these structures.
Bacteria-based self-healing concretes have been used for several large-scale infrastructural projects globally, including the construction of a water basin in the port of Rotterdam in 2017, where water tightness was a strict requirement. While it is too early to draw definitive conclusions, this project demonstrates promising functional performance and durability, highlighting the considerable potential of this technology for the construction of specific infrastructure.

Find out more at: RILEM's State-of-the-Art report, Self-healing concrete, TC 221-SHC, 2013

Notes

"Concrete that incorporates nanomaterials, typically with a size of less than 100 nm"

Did you know

Although the development of nanotechnology began in the 1980s, early uses of nanomaterials can be found in the Lycurgus cup, housed in the British Museum, which was likely made in the 4th century. The glass of the cup appears translucent green or translucent ruby red depending on the location of the light source.

Find out more at: ACI Report, The application of nanotechnology and nanomaterials in concrete, by A Peyvandi, ACI 241R – 17, 2017

23. Nanoconcrete *by Prof. Ravindra K Dhir OBE of Trinity College Dublin*

Nanoconcrete refers to cement-based mixes, such as pastes, mortars and concrete, that incorporate nanomaterials. These materials can take various forms and shapes, typically with a size of less than 100 nm, which is much finer than the familiar silica fume that typically has a mean diameter of less than 1 μm. Studies have shown that nanomaterials can replace Portland cement, with an optimum content usually less than 5% by mass of cement, but with as little as 1%, resulting in cement-based materials with significantly enhanced properties.

The main roles of nanomaterials are as (i) fillers for filling voids; (ii) cementitious materials for cement/pozzolanic reaction; (iii) activators/accelerators for pozzolanic reaction; and (iv) nucleation seeds for precipitation of hydration products. These lead to refinements in the inter-transition zone, which is often the weakest link within a concrete-like material, with reduction in porosity and development of a denser microstructure. However, as nanomaterials tend to agglomerate easily during mixing, the use of a superplasticiser, normally polycarboxylate ether based, is necessary to ensure uniform dispersion. Other dispersing methods, such as ultrasonication and surface functionalisation, have been attempted and shown positive outcomes in laboratory-scale tests.

The use of nanomaterials could lead to improvements in both the engineering properties and durability of cementitious mixtures. Additionally, some specific beneficial effects can be introduced into nanoconcrete, as follows:

Nanomaterial	Special Function
Carbon nano tubes	Provide strain-sensing capabilities and resistance against UV rays
Graphene oxide	Controls nano-sized cracks in hardened paste
Nano Al_2O_3	Enhances residual properties of mortars at temperatures up to 400 °C
Nano SiO_2	Improves abrasion resistance
Nano TiO_2	Provides a self-cleaning effect to prevent biological growth on surface

As the development of nanoconcrete is still in its infancy, much of the relevant work has not moved beyond the laboratory. Furthermore, the health and environmental hazards associated with the use of nanoconcrete in practice require careful evaluation due to the minute particle size of nanomaterials.

Notes

"Natural fibres from animal, mineral or vegetable sources are added to improve mechanical properties and reduce cracking"

Did you know

The incorporation of natural fibres has the potential to significantly contribute to carbon neutral products and structures. Plant-based fibres absorb carbon during their growth phase and are carbon neutral in their unprocessed form. This carbon can be locked into concrete infrastructure in natural fibre concretes.

24. Natural Fibre Concrete *by Dr Aimee Byrne of TU Dublin*

Natural fibres have started to replace the use of synthetic fibres in concrete due to environmental concerns. Natural fibres from animal, mineral or vegetable sources are added to improve mechanical properties and reduce cracking. Plant fibres are the most common form used in concrete, for example, hemp, bamboo, flax, coconut, and wood fibre.

Natural fibres have various advantages compared to artificial fibres: easy to source, relatively cheap, less production energy, smaller carbon footprint and biodegradability. Many natural materials are actually carbon sinks. However, due to their hydrophilic nature and surface properties, adhesion difficulties can arise. This is mitigated against in design using chemical, physical and biological pre-treatments.

Each plant type possesses different compositions and proportions of cellulose, hemicellulose and lignin, therefore, their behaviour inside a cement matrix also differs. Natural fibres tend to have favourable properties of low density, good modulus-to-weight ratio, high acoustic damping, high thermal resistance and are hygroscopic, meaning that they can naturally regulate humidity and temperature in a building.

Several proprietary blocks and panels are readily available. The Hemp House by Steffen Welsch Architects is made of natural materials, including hempcrete.

Find out more at: The Proceedings of 1st to 4th International Conference, Bio-Based Building Materials, 2015 – 2022

Notes

"A concrete whose associated greenhouse gas emissions are equal to the amount of greenhouse gas removed from the atmosphere during its whole lifecycle"

Did you know

Carbon capture technology has been used since the 1920s in the oil and gas industries, with the current approach of capturing CO_2 and preventing it from being released into the atmosphere first suggested in 1977.

Find out more at:
ConcreteZero: https://www.theclimategroup.org/concretezero, 2022

25. Net Zero Carbon Concrete *by Dr Patrick McGetrick of University of Galway*

Net zero carbon concrete is a concrete whose associated greenhouse gas emissions, primarily carbon dioxide (CO_2), are equal to the amount of greenhouse gas removed from the atmosphere during its whole lifecycle via its production and construction processes, operational use and end of life processes. Research to achieve net zero carbon concrete is still at a relatively early stage, primarily focused on the supply side, investigating alternative cementitious materials to ordinary Portland cement (CEM I) that have lower emissions but can also be scaled up and made readily available. Alternative aggregates, carbon offsets, lower-carbon fuel utilisation in production processes and novel technologies such as carbon capture, use and storage have also been proposed to achieve the net zero emissions balance.

A large proportion (up to 60%) of the embodied carbon of a typical concrete mix is difficult to avoid and is associated with the production of CEM I. It has been common to replace this with supplementary cementitious materials such as ground granulated blast furnace slag and pulverised fly ash. However, these cannot be wholly relied on due to reducing supplies and increasing demand. Greater use of alkali-activated cementitious materials and calcined clays as cement replacements is expected as a result of this. However, to achieve net zero carbon concrete, the concrete and cement industries are reliant on the carbon dioxide emitted during cement production to be captured and stored (or used) before it reaches the atmosphere. Based on current research, it will be extremely difficult to achieve net zero carbon concrete for typical applications by 2050 without this technology. Other solutions include concrete with no cement, concrete incorporating ashes from natural sources (for example, bamboo, banana peel, corn, straw), hemp-lime concrete, geopolymer concrete and waste-based concretes containing rubber, plastics, glass and tile.

The properties of net zero carbon concrete can vary quite significantly due to the range of alternatives that have been proposed. Due to limited studies on strength, durability, placing, curing and hardening, further investigation is required to validate the practical applications of these solutions, but many properties exhibit reduced performance.

Net zero carbon concrete remains a huge challenge and is not yet used in practice. However, efficiencies in concrete design, use of precast elements, specification of lower carbon concrete and reuse can help to achieve net zero carbon buildings, such as the Edinburgh One redevelopment project in Scotland.

Notes

"An open textured cellular concrete arising from the absence of fine aggregate"

Find out more at:
Sommerville J, Craig, N and Charles, A, No-fines concrete in the UK social housing stock, Glasgow Caledonian University, Glasgow, 2011.

26. No Fines Concrete *by John Newell of Ecocem*

No fines concrete (NFC) is an open textured cellular concrete arising from the absence of fine aggregate. NFC became prominent in residential construction in the UK during 1950s when an acute shortage in skilled labour and building materials resulted in a severe social housing crisis. Basic designs, high productivity, formwork reuse and low cost were to be the key drivers to achieving economies of scale. The entire outer structure of such houses were poured in one operation accelerating the construction programme. The estimated total number of NFC units completed in the UK was 300,000 between the 1950s and 1980s.

A typical specification for an NFC mix would be for a 10 mm aggregate with no fine aggregate, an aggregate ratio of between 6:1 and 10:1, yielding a density of between 1,600 and 1,700 kg/m^3. The voids contained in NFC act as insulation and offer better thermal performance. A low water demand in a stiff mix allowed the use of low cement contents with w/c ratio varying between 0.38 and 0.52, being careful to avoid poor binder dispersion and segregation. Compaction of NFC was often specified as "light rodding".

In the 1980s, the UK Parliament commissioned a report into the design of the houses. In the absence of any other insulation, mould growth and dampness were the main defects associated with NFC. The investigation identified poor workmanship and compaction as an issue. Some cored samples showed 66% voids compared to laboratory cast cubes of 37%, where voids sizes between 2 and 6.5 mm were reported. However, the report concluded that whereas the buildings were structurally sound, the mould issues were due to poor windows and heating, although the insulating properties of the no-fines walls were adjudged reasonable compared to single skin buildings of the same period.

Did you know

There is now a case for the revival of NFC in residential construction. Since the 1950s, knowledge has developed significantly with the introduction of admixtures, supplementary cementitious materials, impermeable renders and construction techniques. NCF, supplemented by internal or external insulation, is in a position to provide a self-compacting cellular, low carbon concrete solution in the housing market. The main applications of NFC are the construction of loadbearing walls for low rise housing, provision of drainage layers in civil engineering works and free draining layers in parking areas.

Notes

"Concrete specifically designed for use in highway and airfield pavements"

Did you know

PQC can be placed at rates in excess of 200 m^3/hour.

Find out more at:
Ministry of Defence, Pavement quality concrete for airfields, Defence Infrastructure Organisation, Sutton Coalfield, UK, 72 pp., 2017

27. Pavement Quality Concrete *by Thomas Burke, Roadstone*

Pavement Quality Concrete (PQC) is a concrete specifically designed for use in highway and airfield pavements. While the use of PQC in concrete road pavements is common across Europe, in Ireland it is mainly used in airport runways, taxiways, and aprons. It is placed, compacted and finished using a slipform paving machine, over a dry lean concrete subbase and is designed to take heavy compressive and flexural loads without steel reinforcement.

The coarse aggregate requirement is a crushed limestone which can incorporate particle sizes of up to 40 mm, unlike conventional concrete which typically has a maximum aggregate particle size of 20 mm. The percentage of the fine aggregate is fixed in a range of between 30 and 40% of the total aggregate mass, depending on the application method. An air-entraining admixture is added to the concrete during production to achieve the specified durability requirements, particularly frost resistance. PQC can be produced in traditional wet batch concrete plants and is commonly supplied as a low workability concrete in tipper trucks as opposed to traditional concrete mixing trucks.

PQC is specified by flexural strength to provide a rigid pavement design which can distribute the heavy impact loads from aircraft wheels to subbase layers. The workability of PQC is of a consistence suitable for full compaction without undue flow. Workability of PQC is specified by compaction class and assessed by determining the degree of compactability of the fresh concrete rather than the slump or flow test of more commonly used concrete mixes.

PQC concrete has been used in highway construction and airport runways globally for decades. The most recent large-scale use of such a concrete in Ireland was the construction of the new north runway at Dublin Airport completed in 2022. The total area paved measured a mammoth 306,000 m^2, comprising of the 3,110 m of runway and seven taxiways.

Notes

"Concrete that has the unique ability to allow water to flow through it easily"

Find out more at: ACI 522R-10, Report on Pervious Concrete, American Concrete Institute 44pp., 2011

28. Pervious Concrete *by Pawel Pyszka of Kilsaran*

Pervious concrete is an innovative concrete that has the unique ability to allow water to flow through it easily. It is also known as porous, no-fines, enhanced porosity, or permeable concrete. This drainage ability is achieved by producing a sponge-like voided material that contains 15%-35% voids which allows water to percolate through freely. Freshly mixed pervious concrete does not behave as a viscous fluid like a conventional concrete mix, but as a conglomerate of mortar-coated coarse aggregates.

Pervious concrete typically contains most of the same raw material as conventional concrete, such as standard cements, uniform-sized coarse aggregates and water, but with the fine aggregate proportion being totally or partially removed. Either single-sized or graded aggregates between 20 and 10 mm are used. Capable of being produced at most concrete plants, tight control on batching of all ingredients is essential to provide the desired results.

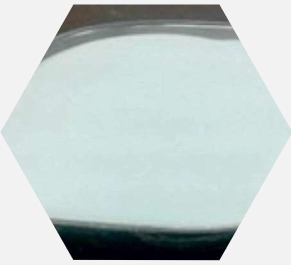
As pervious concrete has increased porosity and such high permeability, this material can be used in various applications where full drainage of water is required, such as driveways, civil infrastructure, landscaping, parks and gardens. Increased porosity also enhances insulation properties and reduces the weight of the structure. The typical compressive strength is low, ranging typically from 3 to 28 MPa. While drainage rates of pervious concrete vary and are measurable, typically flow through the subgrade is the limiting factor. Pervious concretes have been used for several large-scale projects across Ireland, such as in a large commercial project in Baldonnell (in 2022) to construct a subbase layer for permeable asphalt used in all parking areas around a large data centre (size 2,600 m^3). Pervious concrete was also used in a housing project in Howth to construct a permeable concrete layer behind a retaining wall (1,000 m^3).

Did you know

A high percentage of the urban surface area is covered by impermeable pavements, which inhibit groundwater recharge, contribute to erosion and flooding, increase the risk of pollution to local waters, and raise the cost of stormwater treatment. Pervious concrete supports recharging groundwater and reducing stormwater runoff and thus is an effective means to address these environmental issues and support green, sustainable infrastructural growth.

Notes

"A material that absorbs or releases high amounts of thermal energy while changing phase"



Did you know

The energy consumption by buildings is projected to increase by almost 50% from 2012 to 2040. The use of PCMs in buildings has shown potential to reduce annual cooling and heating loads by up to 50%.

29. Phase Change Material Concrete *by Dervilla Niall of Technological University Dublin*

A Phase Change Material (PCM) is a material that absorbs or releases high amounts of thermal energy while changing phase, that is during melting and solidifying. Using the concrete mass of a building as a thermal energy storage (TES) system by providing a high latent heat capacity, PCM concrete can reduce the building's heating and cooling demands. A TES system absorbs and stores both solar energy and excess heat which is then released to the internal environment when temperatures fall at night.

The melt temperature range of PCMs must be suitable for the intended application - in a temperate climate, a range of 20-24°C is deemed suitable for buildings. Paraffin is the most common choice of PCM as it is inactive in an alkaline medium. The paraffin is micro-encapsulated in polymer shells which are added to concrete during the mixing process.

Research has shown that the optimum quantity of PCM to be added to concrete is about 5% by mass, as higher quantities yield impractically low concrete strengths. The addition of microcapsules to concrete also reduces the workability significantly which can be counteracted by the use of a superplasticiser.

To effectively cool a building, it is critical that the internal environmental temperature of the PCM concrete itself varies above and below the melting range of the PCM within a 24-hour period. This is in order to discharge heat at night which facilitates heat absorption the following day. Full scale huts have been constructed in Ireland using walls containing PCM concrete. Thermal data was recorded over an 18-month period to enable an assessment of its thermal mass behaviour under real conditions in all seasons. The results showed that the PCM concrete composite can reduce peak internal air temperatures by up to 5°C.

Find out more at: Drissi, S, Ling, T, Mo, K and Eddhahak, A, "A review of microencapsulated and composite phase change materials: Alteration of strength and thermal properties of cement-based materials", Renewable and Sustainable Energy Reviews, 110, 467-484, 2019

Notes

30. Polished Concrete *by Vivian Hand of Techrete*

Polished concrete is one of the methods used to achieve a specific visual aesthetic on architectural concrete. Other similar methods used are acid etching, exposed aggregate or grit blasting. When concrete is cast, the finer mix constituents are the only particles that are visible on the flat finished face of the concrete and this results in a uniform colour. A more aesthetic architectural finish is achieved by removing the cement laitance from the surface of the concrete to expose the underlying aggregates.

The finish on polished concrete is achieved by grinding off the surface laitance and finer aggregates to depths ranging from 3 to 6 mm, exposing the underlying aggregates. At this depth, the coarse aggregate is also partly ground to expose its internal structure. This is achieved with a large polishing machine, using progressively finer grinding blocks with up to seven passes to expose and polish the coarse aggregates.

Polished concrete is predominantly used for interior flooring but in recent years it can also be found in architectural building cladding as a curtain wall system. As it is a high strength structural concrete, it can be cast into any shape and its size is only limited by transport constraints. It is frequently used to cast wall panels which have the windows and building insulation pre-fitted at the factory. The finished panels can be erected onto the building resulting in a fully finished façade without the need for external access. Once the panel joints have been sealed, a water and airtight finished façade is achieved.

The aggregates used in polished concrete must be granite or basalt aggregates as only these will accept a high polish and not be etched by acid rain. They will maintain their polished appearance and the finish achieved is similar to polished granite. As the surface is smooth, flat and highly polished, it sheds water quickly and is less prone to staining.

"Grinding off the surface laitance and finer aggregates to depths ranging from 3 to 6 mm, exposing the underlying aggregates"

Did you know

Different colours of cement and the addition of pigments can be used to achieve the desired colour of the concrete. Almost any granite aggregate of varying sizes to varying depths of polish can be utilised to create the desired aesthetic.

Find out more at: Doran, S, "Local Blackfriars, Manchester", Concrete, October 2019

Notes

31. Polymer Concrete *by Dr Caitríona de Paor of Technological University Dublin*

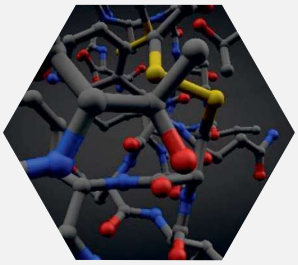
The term Polymer Concrete is used to describe concrete where the cement binder has been fully or partially replaced by an organic polymer material. Concrete which has polymer added to Portland cement is known as a Polymer Modified Concrete, while concrete where a polymer is used as a Portland cement replacement is known as Polymer Cement Concrete.

Polymers are added to the concrete mixes either in the form of an aqueous emulsion or in a dispersed form during the mixing stage. Acrylic, unsaturated polyester resin, polyvinyl acetate, styrene-butadiene resin, methanol and epoxy resins may be used, with unsaturated polyester resin being the most popular due to its low cost, easy availability and good mechanical properties. The polymer material fills in voids in the mix, thus reducing concrete permeability and increasing durability due to slower diffusion rates. It also gives polymer concrete increased resistance to weathering conditions such as freeze-thaw cycles. The mechanical properties of the concrete, such as tensile, flexural and compressive strengths, are also increased as well as being lightweight and having increased adhesion.

Polymer concrete may be used in a variety of applications, particularly where higher durability and resistance to corrosion may be required. It is commonly used for concrete repairs due to its good adhesion properties and in environments where waterproofing may be a requirement, such as swimming pools, marine and coastal environments, bridge decks, pipes, sewage works or water treatment plants.

Find out more at: Chapter 12 on Polymer Concrete in Developments in the Formulation and Reinforcement of Concrete, Ed. S Mindess, Woodhead Publishing series, 2008

"Concrete where the cement binder has been fully or partially replaced by an organic polymer material"



Did you know

Polymers may also be added to a concrete mix in the form of fibres to help reduce the potential for plastic shrinkage to occur.

Notes

"To enhance concrete's tensile and flexural load resistance due to the fibre's ability to absorb energy and control cracks during loading"

Did you know

In the 1960s, interest in the use of manmade fibres for use in concrete was initiated by the need to replace asbestos in many fibre reinforced cementitious products. Since the 1980s, the development of polypropylene fibres by the petrochemical industry has resulted in significant use in cementitious composites.

32. Polypropylene Fibre Reinforced Concrete *by Barry Gilroy of MATTEST*

It is well known that although concrete can be strong in compression, it has a low tensile strength. Polypropylene fibres are added to concrete to enhance its tensile and flexural load resistance due to their ability to absorb energy and control cracks during loading. Common applications of polypropylene fibre reinforced concrete include sprayed concrete, precast concrete, ground bearing slabs and in composite floors with profiled metal sheeting.

Polypropylene micro fibres (< 0.3 mm diameter) are used to modify the properties of the fresh concrete. These fibres can effectively control plastic shrinkage cracking, which is caused by the shrinkage of fresh concrete due to the absence of proper curing and/or excessive evaporation of bleed water. Polypropylene macro fibres (> 0.3 mm in diameter) act as a crack arrester and, with a sufficient dosage of fibres, alter the intrinsically brittle concrete matrix into a resilient material with better post-cracking toughness. Macro synthetic fibres are commonly used as an alternative to traditional steel reinforcement in a number of concrete applications.

Polypropylene fibres have very high resistance to acidic and alkaline environments so that they do not require concrete cover as protection against corrosion.

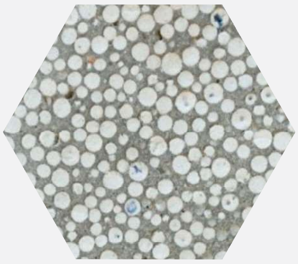
In 2015, the CACHI Hydro Power Plant in San Jose, Costa Rica, used polypropylene fibre reinforced shotcrete to line a 6 km tunnel from the reservoir to the hydro power plant. This type of concrete offered the benefit of a long service life due to its corrosion resistance and offered the benefit of a reduction in working time as no steel mesh installation was required.

In 2012, Molloy Construction designed and constructed water tanks for a new wastewater treatment system in Ireland which had a capacity of 15,000 L and were subjected to repetitive loadings, being filled and emptied every 15 minutes. Reinforcing the tanks with macro synthetic fibre eliminates any risk of corrosion and increased production speeds.

Find out more at: The Concrete Society Technical Report No. 65, Guidance on the use of macro-synthetic-fibre-reinforced concrete, 2007

Notes

“Concrete in which the coarse aggregate is replaced by polystyrene beads”



Did you know

With at least 60% polystyrene by volume in the mix, the density will be less than 1,000 kg/m^3 and the concrete will float.

33. Polystyrene Concrete *by Prof Roger P. West of Trinity College Dublin*

Concrete in which the coarse aggregate is replaced by polystyrene beads in known as polystyrene concrete. It is a lightweight, low-strength, energy absorbing concrete.

The polystyrene beads, usually made of expanded polystyrene, are a stable solid though voided material composed of about 95% air. The mortar which acts as the binder may or may not include sand, but has to be sufficiently viscous to prevent bead segregation through floating on compaction.

As stated, it is lightweight which imparts good insulating properies. It is also of low compresive strength capacity and crushes on impact, allowing it to absorb considerable energy without transmitting the impact force to a structure underneath. In other words, it acts well as a sacrifical fender layer to protect an underlying structure.

Examples of its use are as elements in floating marine structures, lightweight tilt-up panels or as a protective layer for undersea storage tanks. For example, in the photograph shown, a solid steel billet with a circular head was dropped onto a polystyrene concrete slab and the concrete crushed in the impact area, leaving its footprint in the concrete, but with no damage incurred on the underside of the slab. The sample slab was cut in half to show the footprint in the photograph, in which the disruption to the concrete matrix under the imprint may be observed.

Find out more at: Perry, SH, Bishoff, P and Yamura, K, “Mix details and material behaviour of polystyrene aggregate concrete”, Magazine of Concrete Research, 43, 154, 71-76, 1991

Notes

34. Power Floated Concrete *by Carl Egan of Keating and Doyle*

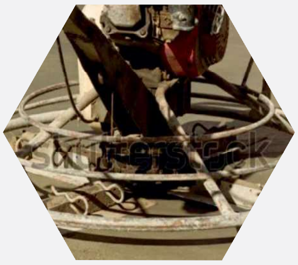
Power floated concrete is concrete in which a motorised trowelling machine with rotating flat blades is used to produce a floor slab with superior surface regularity (flatness and levelness). Developments and improvements of placing and finishing equipment (for example, laser screeds and ride-on trowels) have enabled placement of larger floors, greatly assisted by the power floating process.

Concrete mixes for floor slabs which have smaller aggregates require extra sand and extra water giving rise to greater shrinkage, so larger aggregates and superplasticers combined with low water contents are highly advised. Many ground supported floors in the last 3 years use a 40 mm aggregate mix design with remarkable reductions in shrinkage. An unintended consequence of this has been the near elimination of surface crazing and a significant increase in surface regularity, best achieved through power floating.

The dichotomy between design specification and the actuality of construction practices requires a strong collegiate approach from specifiers, design engineers, concrete suppliers, main contractors and concrete subcontractors to achieve a ‘fit for purpose’ well-finished durable slab within suitable surface regularity tolerances. Both saw cut and formed construction joints have always needed special attention in floors. Great care must be taken on ground preparation particularly isolation details around columns, re-entrant corners, joint location etc. to eliminate restraint and reduce potential cracking. The advent of jointless floors with steel fibre reinforcement has enabled the casting of 1,000-1,200 m^2 floors with no saw cut contraction joints and only peripheral edge armoured construction joints.

Find out more at: TR34 Concrete Society, Concrete industrial ground floors – a guide to design and construction, 4th edition, 2016

“Concrete in which a motorised trowelling machine with rotating flat blades is used to produce a floor slab with superior surface regularity”

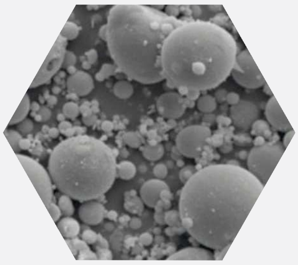


Did you know

Modern slabs can have a tendency to have too high a water content, be “over finished” and poorly cured. Contraction joints can be cut too shallow, too late and at oversized spacings, which can lead to cracking, delamination and poor surface regularity. However, awareness of and reaction to these potential problems in advance can eliminate their occurrence.

Notes

"A by-product of coal combustion that is often used in concrete as a supplementary cementitious material"



Did you know

Approximately 70% of fly ash is used as a cement replacement and filler in concrete with other applications including structural fills, road-base construction, waste stabilisation, mining, soil modification and masonry materials.

Find out more at: TR74, Cementitious materials: The use of GGBS, fly ash, silica fume and limestone fines on the properties of concrete, UK Concrete Society, 2011

35. Pulverised Fly Ash Concrete *by Dr Niall Holmes of TU Dublin*

Pulverised fly ash (PFA) is a by-product of coal combustion that is often used in concrete as a supplementary cementitious material. PFA concrete can reduce the overall carbon dioxide emissions associated with concrete as it can partially replace Portland cement with no further clinkering processes required. PFA concrete can improve the durability of concrete in harsh environments by filling the pore structure and lowering the porosity and permeability, providing longer lasting structures.

PFA has a spherical shape (see image) with a wide particle size distribution. It is mainly composed of SiO_2 with lessor amounts of $Al2O_3$. Depending on the amount of CaO, it is classified as a Class C (low calcium) or Class F (high calcium), with the latter being more common. The hydration of PFA blended concretes will lead to reduced Portlandite content (due to its pozzolanic reactivity) with associated higher amounts of the calcium silicate hydrate gel which binds the aggregates. Siliceous PFA is included in EN1971 as CEM II/A-V and CEM II/B-V with cement replacement levels of 6-20% and 21-35% by weight respectively. The use of PFA can improve the workability of the concrete due to its spherical shape. While it can be slower to gain strength with lower heat of hydration, it thus requires enhanced curing, but its long-term strength is often higher than non-blended concretes.

As mentioned, PFA concrete is used in environments where durability is expected to be an issue (with the exception of carbonation exposure, where ingress rates are higher). Many international projects including tower blocks, bridges, dams, power-stations and offshore structures have used PFA blended concrete due to the harsh environment. As well as improving the performance of the concrete in these environments, it also helps to control the heat of hydration and workability with minimum additional admixtures required, notably reducing the risk of thermal cracking in thick concrete structures.

Notes

"A concrete mix with special properties which make it possible to transport under pressure, by means of a pump, through a pipeline directly to a specific location on a site"

Did you know

While 400 m would normally be considered a long distance for pumping concrete, a world record was set in 2014 on the Sainj Hydroelectric Power Project in Himachal Pradesh, India when Schwing Stetter pumped concrete over a horizontal length of 2,432 m.

36. Pumped Concrete *by Dr Rosemary Byrne of the Irish Concrete Society*

Pumped concrete is a type of concrete mix with special properties which make it possible to transport under pressure, by means of a pump, through a pipeline directly to a specific location on a site. This method may be used for most placing applications but is most often employed where time is at a premium, or where access to the desired location is limited or difficult to reach by other placement methods.

As with all concrete, the design of pumped concrete mixes must meet the specification requirements. Generally, concrete may be pumped where a continuous combined grading curve and an adequate cement content to fill the voids within the aggregate can be achieved. Stiff concrete mixes are not suitable for pumping and where higher consistence classes are required, modification to the mix may be required to control the cohesion, segregation and bleeding.

A lubricating grout layer is needed to line the pipes and to ensure that this layer can be continuously replaced, so pumped concrete mixes will normally have a higher sand content, in the region of 4-5% more.

The pumping process affects the air content, rheological (deformation or flow in response to applied forces or stresses) and mechanical properties of fresh concrete. Studies have found this effect to vary according to the mix constituents and the amount of friction developed within the pipeline.

Pumped concrete has been widely used in Ireland for more than 50 years. Projects range from housing and farm buildings to industrial floors and multi-storey carparks. Examples include the placing of concrete for the 40m high Sillogue water storage facility in Dublin. Pumping is used in many large-scale single pours, such as the 1,650 m^3 basement of Project Fitzwilliam in Dublin and in Ireland's largest pour to date, that of the 4,200 m^3 base of the Titanic Signature Project in Belfast.

Find out more at: Choi, M, Kim, Y and Kim, J, "Prediction of Concrete Pumping Using Various Rheological Models", International Journal of Concrete Structures and Materials, 8(4), 269-278, 2014

Notes

"A type of concrete used to provide a smooth level finish to floors"

Did you know

Anhydrite screeds are not compatible with some glues, such as tile adhesives, where additional preparation before installing tiles is a requirement.

Find out more at:
The Mineral Products Association Data Sheet No 22 on Screeds, Issue 2, September 2021

37. Screed Concrete *by Dr Mark Russell of Queen's University Belfast*

Screed concrete is a type of concrete used to provide a smooth level finish to floors and is often added to an existing rough finished structural floor in order to provide a proper surface for tiles or some other form of floor covering. There are three screed types, as follows:

	Typical Placement	Design Thickness
Bonded	Laid on and bonded to a set and hardened base	Up to 40mm
Unbounded	Laid on DPM or separating later	No less than 50mm
Floating	Laid on insulation boards	No less than 75mm

Similar to conventional concrete, screed concrete is produced by adding water to a cement and aggregate mix. However, unlike conventional concrete, the aggregates are typically sand sized.

Screeds can be applied in a semi-dry form to better control shrinkage and eliminate curling.

New commercial screeds, such as polymer modified screeds, or those based on anhydrite, are increasingly being used to replace conventional Portland cement screeds. Polymer modified screeds and anhydrite screeds have properties that are different to conventional Portland cement screeds in that these screeds, which are often self-levelling and/or self-compacting, are manufactured to achieve a range of beneficial characteristics such as flowable, rapid drying, rapid hardening and shrinkage compensation screeds. Rapid drying is a crucial characteristic that eliminates long downtimes awaiting adequate drying during construction work.

In recent years, work was carried out to provide a screed floor for a new ticket hall at King's Cross St Pancras Underground Station in London in which time was a key factor. Using a conventional Portland cement screed would have meant a one-month construction delay to allow the screed to dry. However, the contractors used a rapid drying and rapid hardening screed which allowed further work to continue after just 24 hours, significantly reducing downtime.

Notes

“A flowing concrete that compacts by means of its own self-weight”

Did you know

When superplasticisers are used as high water-range reducers, the reduction in water content can be more than 30%. This can give increases in 1-day strength of over 100% and 28-day strengths can be increased by as much as 50%.

Find out more at: The European Guidelines for Self-Compacting Concrete: Specification, Production and Use, EFCA, 2005

38. Self-Compacting Concrete *by Dr Alan Duggan of Atlantic Technological University, Galway City*

Self-compacting concrete is a flowing concrete that compacts by means of its own self-weight and does not require mechanical vibration to achieve full compaction. The design of a more flowable concrete is achieved by the addition of a high-range water-reducing admixture (called a superplasticiser) and a stabiliser (such as a viscosity modifier).

By virtue of the presence of the superplasticiser, the water content can be reduced to a much greater extent than can be achieved by using a normal water-reducing admixture. The use of superplasticisers is costly and the high workability is limited to 30-60 minutes. The resulting concrete is much more durable with attendant high early strength development. There is a substantial reduction in porosity compared to normal concretes, resulting in enhanced durability due to reduced permeability, reduced chloride diffusion and reduced carbonation.

Despite the stabiliser making the concrete cohesive enough to prevent the risk of segregation, the viscosity is low enough to allow any entrapped air to escape and thus the concrete can be deemed to be self-compacting, that is, mechanical compaction is not needed. The mix also requires the use of higher-than-normal amounts of powder (< 0.125 mm material), which increases cohesion and segregation resistance.

Typically, the consistency of self-compacting concrete ranges from 180 mm to a collapsed slump, which means the customary slump test cannot be used to measure the consistency of self-compacting concrete. Instead, standardised tests such as the slump flow, j-ring, V notch or L-box tests can be performed, measuring the concrete stability and passing and filling ability.

As high early strength development results in faster turnaround of formwork, self-compacting concrete is frequently used in the production of precast concrete units. It is best used where steel reinforcement is congested or where the concrete is required to flow horizontally. The superplasticisers greatly increase consistency which in turn decreases placing and finishing labour costs and facilitates pumping, particularly where long distances or large heights are involved. On site, the concrete offers the ability to concrete into difficult locations where vibration would not be possible, though larger formwork pressures may arise. It also has the potential to produce complex shapes to facilitate innovative construction.

Notes

"A type of flowable, highly fluid concrete that can be used to create a smooth, flat surface without the need for trowelling or other finishing techniques"

Find out more at: Vieira, M, Ferrara, L, Sonebi. M and Shi,, C "Mechanical properties of self-compacting concrete", RILEM State-of-the-Art Report, 2014

39. Self-Levelling Concrete *by Padraic McGrath of McGraths Limestone Cong*

Self-levelling concrete is a type of flowable, highly fluid concrete that can be used to create a smooth, flat surface without the need for trowelling or other finishing techniques. It is typically used to level uneven or damaged concrete floors, or to create a high quality smooth surface finish on a new concrete slab, dependant on the project specification.

Self-levelling concrete has a higher powder content than traditional concrete. Typically, 400–600 kg/m^3 of powder materials, such as cement, ground granulated blast furnace slag, pulverised fly ash and limestone filler, are commonly used to produce a highly flowable concrete without segregation occurring. However, the additional cementitious materials may increase the propensity for thermal cracking in thick sections. A high range water reducer/ superplasticiser is also added to the concrete to increase its workability resulting in a concrete with self-levelling properties.

Some common applications for self-levelling concrete include; levelling and smoothing out uneven or damaged concrete floors in commercial or industrial buildings; creating a smooth, level surface on a new concrete slab in a residential or commercial building; and preparing a concrete floor for the installation of flooring materials.

Did you know

Traditional concrete finishing techniques, such as trowelling and power floating, can be labour-intensive, require a lot of skill and is time-consuming. Studies have shown that, in contrast, self-levelling concrete can be poured directly onto the surface and only requires light tamping to create a flat level surface. Therefore, using self-levelling concrete in place of traditional concrete can reduce slab construction time by up to 75% and can reduce the number of operatives required for placement of the concrete.

Notes

40. Shotcrete *by Dr Éanna Nolan of Irish Cement Ltd*

"Concrete or mortar which is premixed and then placed by pump through high velocity pneumatical projection"

Shotcrete (a wet mix sprayed concrete) is concrete or mortar which is premixed and then placed by high velocity pneumatical projection. Shotcrete is pumped through a hose and directed into place by an operator (a nozzle person) to form a dense homogeneous concrete layer. A Shotcrete mix is typically relatively dry and full compaction is achieved by using forceful application.

Specific aggregate gradings are recommended and coarse aggregates are normally no larger than 10 mm. Cementitious contents tend to be high. Considerable skill and experience are required by the operator to achieve consistent high quality Shotcrete.

Ideally the properties of Shotcrete should be comparable with a conventionally cast concrete. The ability to place Shotcrete on complex, inclined, vertical or overhead surfaces is what makes it preferred in particular applications. Fresh properties are critical as the concrete needs to immediately support itself without rebound off the applied surface, slumping or sloughing. Curing of concrete tends to be particularly critical on Shotcrete as the large surface area/volume ratio can lead to rapid drying.

Shotcrete is well established in a few specific applications: tunnelling and mining, repair, skate parks, swimming pools and slope stabilisation. The Irish Concrete Society Overall 39th Award winning project, La Fanu skate park, used a ready-mixed concrete supply which was Shotcreted to achieve parts of the complex finished shape. Dublin Zoo has recently used shotcrete to form tree-like structures in the Orangutan enclosure.

Did you know

Shotcrete is often mixed up with gunite: This involves a similar process except where the water is added to dry constituents at the application nozzle. In the Shotcrete process all constituents, including water, are premixed.

Find out more at:
European Federation of National Associations representing for Concrete (EFNARC), Guidelines on European Specification for Sprayed Concrete, 1996

Notes

41. Stamped Concrete *by Prof Emeritus Mark Richardson of University College Dublin*

"The top surface of fresh concrete is coloured and patterned through imprinting with cast aluminium moulds or plastic mats "

Stamped concrete is a technique whereby the top surface of fresh concrete is first coloured and then patterned through application of an operative's self-weight onto an imprinting cast aluminium mould through a fine plastic film stretched across the surface. The pattern choices are many, such as rectangular, hexagonal, circular, fan shape or crazy paving to match a style of brick, cobble (the most popular), slate, stone or timber decking. Colour choice includes black, biscuit, buff, charcoal, grey, mahogany and tan. A finishing sealer gives a high-gloss, water-repellent, wet-look effect. The pace of construction effort is demanding, requiring completion of casting, colouring and imprinting while the concrete remains workable, perhaps over large areas.

Brought to the international market in the 1980s through a franchise arrangement from New Zealand, 'Creteprint' was introduced into practice in Ireland by John Lombard, through Cobblestone Paving Ireland Ltd where the technique is still practiced by many paving contractors. Some imitators of the original 'Creteprint' technique use talc-like release agent, rather than the film and use small plastic mats rather than moulds.

Traffic loading dictates slab depth and reinforcement as in traditional surface slabs, where the minimum slab thickness is 100 mm. Drainage paths dictate surface slope. Saw cuts to induce controlled cracking may be necessary. Earlier use of reinforcing mesh has generally been replaced by use of fibres and strengths of 35 MPa are now typical. The maximum aggregate size is 10 mm and the sand content is higher than a typical mix. Colour is achieved through a powder-based pigment. Outdoor surfaces are finished with acrylic-based sealers or polyester-polyurethane-based sealants enriched with acrylic polymers. Indoor surfaces are sealed with polyurethane or epoxy. Erosion of the sealant and loss of colour is common so that maintenance can involve reapplication of the sealant every 4 or 5 years.

Stamped concrete is popular in the residential sector for driveways and patios but has not displaced concrete cobblestone pavers in established commercial markets, such as fuel filling station forecourts. A commercial sector example of its use is along Dublin's Luas Green Line light rail network.

Did you know

One of the smallest stamped concrete projects in Ireland is also the most photographed – the concrete base of the Patrick Kavanagh statue on the Grand Canal in Dublin.

Find out more at:
Majumdar, S, Stamped Concrete, Research Gate, 2011

Notes

"Steel fibres inhibiting the rapid and unlimited propagation of cracks associated with failure in plain mortar or concrete"

Did you know

Ultra-high-performance fibre-reinforced concrete has a compressive strength in excess of 150 MPa and contains steel fibres (2% by volume) to achieve post-cracking toughness behaviour in flexure and/or direct tension.

42. Steel Fibre Reinforced Concrete *by Prof Marios Soutsos of Queen's University Belfast*

The idea of reinforcing relatively brittle building materials with fibres has been known and practised since ancient times. Mud huts constructed from baked clay reinforced with straw and masonry mortar reinforced with animal hair are typical examples dating well back into history. Fibres are extremely effective in inhibiting the rapid and unlimited propagation of cracks associated with failure in plain mortar or concrete. This article is specifically about one type of fibre – steel fibres – though many types are used.

Steel fibres are classified into five groups according to the method of manufacture: (1) cold-drawn wire; (2) cut sheet; (3) melt extract; (4) shaved cold drawn wire; and (5) milled from blocks. Efficiently utilising fibres involves maximising fibre pull-out resistance without causing fibre "balling" during mixing which results when high dosage or high aspect ratio fibres are used. Types of steel fibre therefore aim to improve the pull-out resistance through their shape, such as indented, etched, with roughened surface, round with end paddles, round with end buttons, round with hooked ends, crimped (round, flat or any section) and polygonal twisted.

The fibres cause crack propagation to develop slowly and progressively with increase in displacement. They therefore enable stress to be transferred across a cracked section, allowing the affected part of the composite to retain some post-crack strength and to withstand deformations much larger than could be sustained by the unreinforced matrix alone.

Fibres are often used to replace the nominal conventional steel fabric in ground-bearing slabs. Savings in the cost of supplying and fixing the conventional welded fabric reinforcement that is replaced can offset the extra cost of adding fibres to the concrete. Other major applications for steel fibre reinforced concrete include external paved areas, sprayed concrete, composite slabs on steel decking and high strength precast elements.

Find out more at: Concrete Society's Technical Report No 63, Guidance for the Design of Steel-Fibre-Reinforced Concrete, 2007

Notes

"A concrete that has been modified by the addition of a superplasticiser or high range water reducing admixture"

Did you know

2021 marked the 40th anniversary since polycarboxylate superplasticizers were invented by the Nippon Shokubai company in Japan.

Find out more at: Admixture suppliers such as Sika, Master Builders Solutions, CHRYSO, MC-Building Chemicals, GPC

43. Superplasticised Concrete *by Thomas Holden of Roadstone*

Superplasticised concrete is a concrete that has been modified by the addition of a Superplasticiser (SP) or a High Range Water Reducing (HRWR) admixture. SPs are admixtures that have been modified by extending the polymer chain, the most widely used being polycarboxylate ether SPs. The backbone of the polymer is typically based on polymerisation of acrylic acid but this can be substituted or replaced with other monomer groups along the polymer backbone. The polyether is responsible for dispersion of the cement particles with the substituted chains tailored for specific applications such as improving its plasticity, decreasing its viscosity, decreasing friction during placing and reducing the total water by up to 30%. They produce a wide variety of concretes when used as a single admixture or blended with other admixtures, such as standard water reducing admixtures, stabilisers or shrinkage reducing admixtures. They are used to produce precast, high-strength, pump mixes/flowing, self-consolidating, low permeability, low water absorption, low shrinkage and other specialised concretes.

The production of superplasticised concrete requires the mix design to be reviewed to check its compatibility with the chosen SP in the following areas: cement type, water cement ratio, percentage fines (0-4 mm) and setting time. Once the cement and SP are compatible, adjustments to the water and fines content are generally all that is required. The blending of the SP with a standard water-reducing admixture to retain the setting time and stabilise the mix is also possible. The concrete and admixture supplier will confirm the performance of the mix by carrying out laboratory trial mixes and plant trials prior to suppling a project.

As listed above, SP can be used to produce a wide range of concrete types; for example, when used on S2 slump concrete as a HRWR admixture, there is no visible difference to the concrete and when vibration is applied the concrete will move freely, however, over vibration may cause the concrete to segregate. When used to produce high slump or flowing concrete (for example with an S4 or S5 slump value), the designed water cement ratio should be adhered to, as any additional water will cause the mix to segregate. Superplasticised concrete should not be over vibrated. Additionally, cement and cement blends should be checked for compatibility with the SP.

Precast concrete is predominantly produced with SP admixtures, modified to give easy placement around tight reinforcing, high early strength and a good finish. Ready-mix SP concretes are generally type specific, such as pump or self-compacting mixes.

Notes

"Aggregate resulting from the processing of inorganic material previously used in construction"

Did you know

The Irish Concrete Federation estimates that recycled concrete from demolition activities could account for one to two million tonnes of all construction and demolition waste produced nationally each year (depending on the level of construction activity). This makes recycled concrete from demolition activities one of the largest single waste streams after soil and stone.

44. Recycled Aggregate Concrete *by Dermot McCarthy of Roadstone*

Recycled concrete aggregate (RCA) is defined as aggregate resulting from the processing of inorganic material previously used in construction. RCA is typically produced from waste concrete sources such as construction and demolition waste and waste concrete which includes concrete structural elements, concrete products and concrete pavements. RCA concrete is any concrete mix whose aggregate content contains a proportion of recycled concrete aggregates.

RCA for use in concrete is typically sourced from a suitable recycling and processing facility. From there the RCA is produced through a standard process of crushing and screening, which is similar to that used in a quarry. RCA is then used to replace virgin aggregates in a concrete mix. The quantity of RCA used in such a mix will vary depending on a number of parameters such as the quality of the RCA and the limitations of the relevant product standards.

Following production, tests performed on the RCA are similar to conventional aggregates, to assess chemical and physical properties including an assessment of grading, water absorption, specific gravity, flakiness index, total sulphur content, Los Angeles abrasion value and methylene blue value. Most studies on the use of RCA in concrete mixes have indicated that the increased water absorption and lower strengths of RCA can contribute to a reduction in concrete strength as RCA additions were increased. Nevertheless, research has also demonstrated that coarse RCA additions of up to 20% in place of virgin aggregates can be achieved without a significant impact on concrete strength and workability.

The use of RCA in concrete offers the opportunity to reduce the use of virgin aggregates while also diverting concrete demolition waste from landfills to the built environment, thus creating a circular economy. Despite this, the production of recycled aggregate concrete in Ireland has been limited to date. Opportunities to develop and promote the use of RCA should be explored by the concrete industry supported by continued research.

Find out more at: Dhir, RK, de Brito, J, Silva, RV and Lye, CQ, Sustainable Construction Materials; Recycled aggregates, Woodhead Publishing, pp. 652, 2019

Notes

45. Roller Compacted Concrete *by JJ O'Neill of Breedon Ireland*

Roller compacted concrete (RCC) is a paving material which is similar to conventional concrete insofar as it uses cement, water, sand and gravel, but in slightly different proportions. RCC is predominately transported in dumper or tipper trucks rather than ready-mix trucks, and it is distinguishable from conventional concrete in that it is compacted by passes of a heavy vibrating roller.

RCC can have a significantly lower cement content and a higher percentage of fine aggregate. This allows the consistency of the fresh material to remain stiff enough to stay stable under vibration rollers and just wet enough to allow even distribution of the paste throughout the mixing. The laying processes avoid segregation and facilitates tight compaction of the material by the vibrating rollers.

RCC typically does not develop high compressive strengths despite its low water cement ratios. The main factors for strength development with RCC is the compactability of the concrete. The more compactable the higher the compressive strength will likely be, therefore selecting the proportions of material in the mix design process is important in achieving optimum strength. While compressive strength in conventional concrete is very important, for RCC the tensile and shear strengths established through testing are more significant.

Over the last number of years there has been a re-introduction of roller compacted concrete across Europe, particularly in the UK for large industrial facilities with heavy industrial traffic. Many roads across Europe are now constructed using RCC, mainly due to the advantages it offers, in particular the wide variety of asphalt paving equipment available in the market and its longer lifespan. RCC is also used as a base layer with an asphalt wearing coarse on roads across Europe.

Find out more at: EUROPAVE, Roller compacted concrete: making concrete pavements available to the whole pavement industry, European Concrete Paving Association, www.eupav.eu, 2022

"It is compacted by passes of a heavy vibrating roller"

Did you know

In the 1970s, the use of RCC was researched by the US Army Corps of Engineers for use in dam construction. The first RCC dam was built by 1983 and was constructed in layers, with one layer able to support the next. Since then, through new developments and experience, its uses have expanded to include roads in particular.

Notes

"The coarse and/or fine aggregates are replaced, either fully or in part, with waste rubber, usually sourced from recycled car tyres"

Did you know

More than12,000 tonnes of car tyres were recycled into crumb rubber in Ireland in 2019.

Find out more at:
Recycling and re-use of used tyres, International Symposium, Dundee, Thomas Telford, Eds RK Dhir, MC Limbachiya and K Payne, pp 324, 2001

46. Rubber-Based Concretes *by Michael Grimes of Trinity College Dublin*

The disposal of car tyres is a significant environmental issue. Each year approximately 500 million tyres are dumped in landfills worldwide, whereupon they will decompose slowly over a period of about 80 years. As vehicle numbers continue to increase, so too does the need to find more sustainable end-of-life solutions for the disposal of these rubber waste products, such as by recycling the rubber for use as a substitute for aggregates in Rubber-Based Concrete.

In Rubber-Based Concrete, the coarse and/or fine aggregates are replaced, either fully or in part, with waste rubber using either weight or volume batching. The car tyres are mechanically processed (often cryogenically) and sieved to produce fragments of the desired dimensions. Chipped, shredded or crumbed rubber may be used in lieu of larger coarse aggregates (10-20 mm). Finer rubber may be used instead of sand as a fine aggregate.

The substitution of standard aggregates with rubber results in a concrete that exhibits numerous physical and chemical differences. The workability of fresh Rubber-Based Concrete is reduced significantly, not least because its density decreases. Once hardened, the compressive strength of Rubber-Based Concrete is markedly lower due to the flexibility of the rubber. This strength loss can be reduced somewhat, however, by treating the rubber with sodium hydroxide prior to mixing. In terms of advantages, the presence of rubber results in a more ductile material that exhibits improved elastic behaviour and enhanced sound insulation. Furthermore, Rubber-Based Concrete is more resistant to cracking caused by shrinkage and freeze-thaw.

Whilst Rubber-Based Concrete has been researched extensively in recent years, its use is still in its infancy. Researchers at the University of South Australia have produced numerous residential floor slabs and continuously monitored their performance over time. They report that the contractors who constructed the slabs found the novel mix to be less labour-intensive to produce. Initial observations also suggest improvements in acoustic insulation, thermal insulation, toughness and impact resistance for the finished structures compared to standard concrete.

Notes

"Concrete with smart admixtures, self-responsiveness and nano-additions"

Did you know

In 2004, the Shawnessy light rail station in Calgary comprised one of the first high durability performance concrete in its thin-shell canopies designed to resist the extreme freeze-thaw exposure conditions.

Find out more at: https://uhdc.eu/documentation/concept-of-ultra-high-durability-concrete-for-improved-durability-in-chemical-environments-preliminary-results/

47. Ultra-High Durability Concrete *by Peter Deegan of Banagher Precast Concrete*

Ultra-High Durability Concrete (UHDC) is a type of concrete with smart admixtures, self-responsiveness and nano-additions. It is the culmination of the technologies inherent in many other concretes in that it has high strength performance (that is, with strength greater than 90 MPa), is fibre reinforced, self-healing and self-compacting.

It usually comprises of Portland cement, ground granulated blast furnace slag, with nano to micro-scale constituents to promote matrix and interface densification (including Nanocellulose, Nanofibres and crystalline admixtures) with very low water/cement ratios. In all cases the bacteria-based additives are used to promote self-healing once cracked. All these materials are easily available in the present-day marketplace.

Such concretes, with considerably enhanced strength and resistance to chemical attack, allow for lower concrete cover to steel and, therefore, thinner, lighter sections.

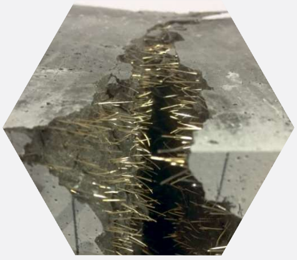
The formulation of UHDC is suitable for new builds but also retrofitting applications and is especially suited to aggressive marine or coastal exposure, but it has its place in any corrosive environment, such as road parapets where exposure to de-icing salts prevail.

Structural performance is paramount due to the key requirement of having exceptional durability, usually in extreme aggressive environments, even with its reduced material volumes and structural dimensions. This is due to the superior mechanical performance and increased structural efficiency of the material and its constituents.

To validate these concepts, six pilots in six different exposure conditions have been developed across Europe. The pilot of most interest in Ireland sits in Galway Bay with extreme exposure to Atlantic conditions. This living laboratory consists of three floating pontoons both reinforced and non-reinforced with data loggers and sensors measuring chloride and salt migration. The pilot will remain in place for several years to collect clean and detailed data and establish trends in performance of the truly novel material that is UHDC.

Notes

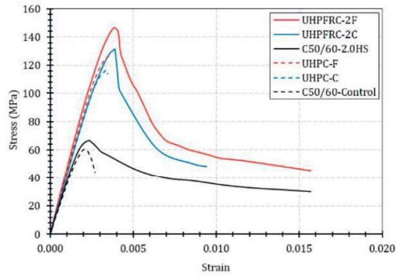
"Concrete that has a minimum specified compressive strength of 120 MPa"



48. Ultra-High Performance Concrete *by Dr William Wilson of Roadstone Ltd*

Ultra-High Performance Concrete (UHPC) is a cementitious, concrete material that has a minimum specified compressive strength of 120 MPa but can exceed 200 MPa. When fibres are included in the mixture, flexural strengths of more than 50 MPa can be achieved. UHPC construction is simplified by eliminating the need for reinforcing steel in some applications and the material's high flow characteristics can make it self-compacting. The enhanced strength of UHPC results in thinner sections, reducing the self-weight of structures and the volume of concrete and natural raw aggregates used in their construction.

As the compressive strength of a HPC mix exceeds the compressive strength of traditional coarse aggregate, the coarse aggregate becomes the weakest constituent in the mix. To further increase the compressive strength the coarse aggregate must be removed. This philosophy has been employed in UHPC where the coarse aggregate is replaced by stronger ultra-fine particles such as reactive powders, limestone fillers, quartz flour or fine sand. These ultra-fine particles also facilitate superior packing of the constituents, which in turn reduces the number of voids within the concrete. A water cement ratio in the region of 0.18 to 0.22 is achieved through the use of high-range water reducers or superplasticers.



UHPC has considerably enhanced post-cracking toughness and tensile strength capacity in comparsion to conventional or even high performance concretes. With the inclusion of fibres, such as high carbon steel, UHPC has the capacity to deform and support flexural and tensile loads after initial cracking has occurred, a first for concrete.

The use of UHPC has increased in the past two decades with the main application being in prestressed concrete bridges. The world's first engineering structure designed with UHPC was the Sherbrooke footbridge in Canada. Other applications to date include thin shelled canopies, blast protection and a wide range of architectural applications including furniture and cantilevered stairs.

Did you know

When UHPC is exposed to early age steam curing, compressive strengths in excess of 180 MPa can be achieved within 72 hours.

Find out more at: Federal Highway Administration, Ultra-High Performance Concrete: A state-of-the-art report for the bridge community, Publication No. FHWA-HRT-13-060, pp. 176, 2012

Notes

"Underwater concrete should be stable, yet fluid enough to spread readily into place without compaction"

Did you know

Underwater concrete should be self-compacting, highly resistant to water dilution (that is, good resistance to washout), segregation, and bleeding.

Find out more at: Japan Society of Civil Engineers, Recommendations for design and construction of anti-washout underwater concrete, Concrete Library of JSCE, No. 67, pp. 89, 1991

49. Underwater Concrete *by Prof Mohammed Sonebi of Queen's University Belfast*

Concrete used for underwater placement and repair should be stable, yet fluid enough to spread readily into place without compaction. Underwater concrete (UWC) can be proportioned to ensure a highly flowable consistency and good resistance to washout and segregation. UWC often incorporates a combination of a superplasticiser and an anti-washout admixture (AWA) to enhance flow properties. Concrete intended for underwater use should be tailored to achieve a good balance between the rheological properties and the mechanical performance. The resistance of concrete to water dilution and segregation is dictated by its composition and rheological properties.

Commonly used AWAs include cellulose derivatives and polysaccharides from microbial sources. Concrete made with an AWA can be proportioned to secure a given level of stability while maintaining greater fluidity than that of a non-AWA mixture. The enhanced cohesiveness can ensure better suspension of solid particles in fresh concrete and better retention of mixing water to reduce the risk of water dilution, segregation and blockage of flow through a restricted space. Highly flowable, yet stable, self-compacting concrete can therefore secure adequate in-place properties. The incorporation of AWA can be complemented with supplementary cementitious materials which further enhance in-place characteristics of underwater-cast concrete.

Underwater concrete should spread readily into place without mechanical compaction or physical movement, often placed with a tremie pipe whose discharge lies below the fresh concrete's surface. Its stability is critical in UWC and repair operations, such as those of marine and hydraulic structures, to secure proper durability and service life.

The Confederation Bridge connects Prince Edward Island to the mainland over the Northumberland Strait in the southern part of the Gulf of Saint Lawrence. At 12.9 km it is longest bridge in the world over ice-covered waters. UWC was used for the foundation using an anti-washout admixture supplemented with silica fume and fly ash.

Notes

"Concrete produced through precision placement of its intended target"

Did you know

Complex and intricate concrete structures can be created using these novel mixtures that otherwise would not be possible using traditional concrete.

50. 3-D Printed Concrete *by Patrick O' Donnell of Future Cast*

3-D printed concrete is concrete produced through precision placement to its intended target using a large 3-D printer. These concrete mixtures form part of new modern methods of construction which demand more from concrete throughout the mixing and placement phases, including enforcing rapid setting at the point of placement. It requires amending existing conventional concrete pump mixtures so that four key parameters are focussed on: Pumpability, extrudability, buildability and structural integrity. Admixtures assist in the control of these parameters, generally to alter plasticity and/or setting time. The concrete mixture is also dependant on the complexity of the design, the finish required, placement parameters and curing strength requirements. The use of suitable local aggregates helps with the sustainability aspect of the mixture, while still retaining the characteristics required.

It differs from traditional concrete insofar as the mixture is prepared for continuous pumping, but also placement needs to be controlled by the highly accurate 3-D printing apparatus. Specifically, admixtures are used in this instance to ensure control for pumping and setting phases. Although critical key concrete ingredients remain constant, the mixture needs to be in such a state that it can hold a certain shape when "printed" as required by the complex design. The consistency of the mixture of the concrete is of paramount importance to ensure interlayer bonding strength. Early compressive and flexural strength are critical and affect the speed of the construction.

Concrete mixtures that are suited for pumpability, extrusion and higher early age strength are used in 3-D concrete printing. These new technologies are now becoming more viable and the understanding of the material mixture is crucial to their development. Applications include building structures and complex design structures. The finish can be left natural creating a layered appearance or patterns are attainable for aesthetically desirable effects.

Find out more at: Khan, M, Sanchez, F and Zhou, H, "3-D printing of concrete: Beyond horizons", Cement and Concrete Research, 133, pp. 14, 2020

Notes

Other Concrete Types

Other Concrete Types

Other Concrete Types

Other Concrete Types

Other Concrete Types

Other Concrete Types

Other Concrete Types