READY-MIXED CONCRETE:
AN ALL–IN-ONE SUSTAINABLE MATERIAL

Adrian IORDACHESCU

Abstract

Concrete is an essential material for the development of human societies and its success has made it the most widely used building material in the world. Indeed, concrete is an indispensable material for making buildings, roads, bridges, tunnels, water treatment facilities, drinkable water distribution networks, dams, ports, and infrastructure for public transport (metros, trains, airports and many other facilities). To respond to the demand for all those services to society, more than 10 billion m^3 of concrete are utilized each year across the world. This is equivalent to about $1.5m^3$ per person per year. Although concrete's embodied energy and carbon footprint is low per m^3, the volume consumed to meet construction needs over the world makes it a major contributor to global CO2 emissions. It is essential to keep on reducing this global footprint.
In the last decades, concrete has made considerable progress both technically and aesthetically.
Concrete is fully adapted to today's needs and the industry is improving to better respond to tomorrow's challenges. It is a modern, contemporary material in constant evolution and very well suited for building more sustainable.

Keywords

Concrete, energy saving, carbon footprint, CO2 emissions, sustainable buildings

Biographical notes

Adrian IORDACHESCU is a Ph.D. Civil Engineer, Professor at University of Architecture „Ion Mincu", Bucharest, Romania. After graduating from Technical University of Civil Engineering Bucharest, he started his career in 1987 as Chief of the work sites for the maintenance of Buzau River. After three years he became Assistant Professor at the Technical University of Civil Engineering Bucharest. From 2002, he is Professor at University of Architecture „Ion Mincu", Bucharest, Romania, teaching Structural engineering class. With his approximately 130 projects for new households, cultural, social, administrative and industrial buildings etc, and for restoration/maintenance, of which: the rehabilitation of the City Hall of Bucharest, the Victor SLAVESCU – Academy of Economical Studies building and the Triumph Arch in Bucharest – for all of them using the method of base isolation, Adrian IORDACHESCU is a representative of the new technologies promoter. In 2005 Mr. Adrian IORDACHESCU became Executive Director of Romanian Ready Mixed Concrete Association.

1. INTRODUCTION

Concrete is an essential material for the development of human societies and its success has made it the most widely used building material in the world. Indeed, concrete is an indispensable material for making buildings, roads, bridges, tunnels, water treatment facilities, drinkable water distribution networks, dams, ports, and infrastructure for public transport (metros, trains, airports and many other facilities). To respond to the demand for all those services to society, more than 10 billion m3 of concrete are utilized each year across the world. This is equivalent to about 1.5m3 per person per year. Although concrete's embodied energy and carbon footprint is low per m3, the volume consumed to meet construction needs over the world makes it a major contributor to global CO2 emissions. It is essential to keep on reducing this global footprint.

In the last decades, concrete has made considerable progress both technically and aesthetically.

Concrete is fully adapted to today's needs and the industry is improving to better respond to tomorrow's challenges. It is a modern, contemporary material in constant evolution and very well suited for building more sustainably. For example, new high-, and ultra-high strength concretes have been developed over the past few decades enabling new architectural expressions while remaining very resource efficient.

2. Concrete, a Liquid Stone for Sustainable Construction

2.1 Strong, highly-resilient and durable

- **Compressive strength**
  - A wide range of concrete types exists, with compressive strength spanning 5MPa (or 50kg/cm²) to 200Mpa (Figure 1). Combined with steel reinforcement, countless structural and nonstructural applications are possible: foundations, façades, walls, slabs, tanks, pipes, roads, tiles, paving, landscaping, urban furniture, etc.
  - Resilient to external aggressions, its compressive strength and integrity remains intact over the years.
  - This property also guarantees a very high resistance to impacts, which is particularly important for safety issues.

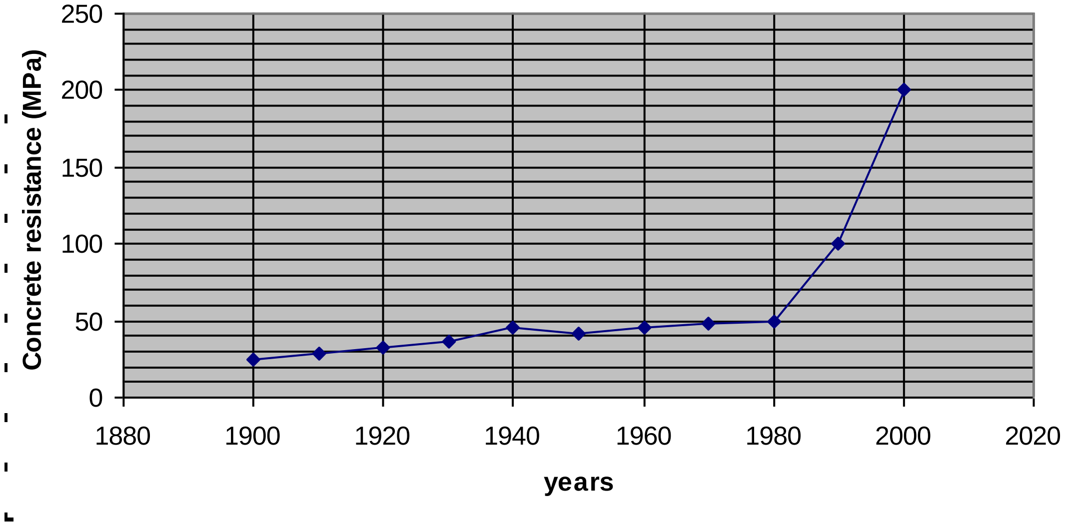

Figure 1 Progress of Concrete's Compressive Strength Potential Over the Years

- **Resilient to weathering, pollution, saline environment, erosion, heat, and fire**
    - The nature of concrete, like a stone, makes it highly weather-resistant and resilient to aggressive environments (pollutions, salt etc). It is therefore a material of choice for bridge piles and infrastructure elements in contact with water (Figure 2).
    - Exposed to heat or fire, concrete doesn't release toxic gases or fumes, and doesn't melt or burn. This is because concrete is a mineral material and has low thermal conductivity. As a result, insurance companies do not require a sprinkler system for concrete load- bearing structures. This in turn can represent significant cost savings.
    - Concrete-based elements are also a solution for climate change mitigation/ protection against severe environment actions (e.g. floods, storms, extreme temperatures).
    - . Because of its strength and durability, it is particularly suited for dams, wave breakers and other protective infrastructure.
- **Durable**
    - Through scientific modelling, it is possible today to predict life expectancy of concrete.
    - Based on the vast experience, design of concrete mixes and technology for concrete placing in construction works highly contribute to an improved durability and consequently to a longer service life.

Figure 2 Apolodor from Damascus Bridge over Danube River 101 o.e.

2.2 Respectful of natural resources

- **Using abundant resources**

Concrete's major components by mass are natural aggregates and sand. Depending on the type of concrete, 5 to 18% of cement is added to glue the aggregates together. Water and admixtures are also added to make the cement react and to ease workability. Cement itself is mainly made from limestone and some clay. All concrete's components and raw materials – aggregates, sand, limestone and clay - are available in large quantities everywhere on the planet.

Even so, cement and concrete industry make continuous effort to use alternative by-porducts in order to save natural resources.

- **Fully recyclable**

Concrete recycling is increasingly common due to improved environmental awareness, governmental laws, and economic benefits. Reinforced concrete is collected from demolition sites, steel reinforcement bars are removed with magnets and recycled elsewhere while the concrete is put through a crushing machine. The crushed concrete is then sorted by size and re-used either as gravel, sub-base for roads, or sometimes as dry aggregate for brand new concrete (in a specific percentage in correlation with exposure classes). The main benefit of recycling concrete is to reduce the need for gravel mining and landfill space (Fig. 3).

Recycling water should also be part of good manufacturing process of concrete.

Figure 3 Concrete Crushing Machine

- **Represents a channel to recycle by-products from other industries**

Cement industry currently use significant quantities of blast furnace slag and fly ash. The clear trend is to increase utilization of by-products in a wider range of products which can bring real advantages to durability of concrete structures.

Also, under specific conditions these by-products are used in concrete, with real benefits.

2.3 Low Embodied Energy, Low Carbon Footprint

- A local product
- Some prior knowledge
- Cement industry's levers for more CO_2 reductions (Figure 4)

Energy consumption in the cement industry has declined significantly over the past 50 years.

This is mainly attributable to improvements in plants and process technologies. Being committed to use alternative fuels have real benefits in preserving waste and contribute to lower overall CO_2 emissions.

Of significance for sustainability is the ability of cement-based materials (typically concrete) to re-absorb/uptake CO2 throughout their life. Exposed to air, these materials will absorb CO2 over time in a process termed recarbonation.

Recarbonation is likely to occur during the service life of concrete, but more importantly will occur rapidly with demolition and reprocessing.

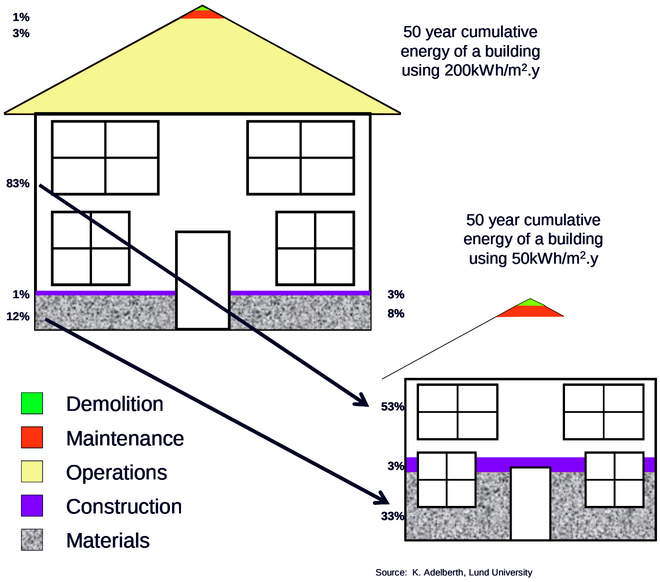

Figure 4 50 Year Cumulative Energy of a Building

2.4 Energy efficient buildings thanks to concrete

- **Thermal mass to increase thermal comfort and save energy**

Thermal mass is effective in improving indoor comfort because it levels out the indoor temperature when external temperature undergoes signification variations, typically between day and night time. A material with high thermal mass capacity such as concrete will absorb heat and release it with a time lag of a few hours, usually at night. This phenomenon results in energy savings because less heating or cooling is needed.

It's well known the Portia Winery building in Burgos, Spain, designed by Sir Norman FOSTER for Faustino Winery Group, with photovoltaic cells incorporated into the roof, and the recycled concrete structure which uses thermal inertia to help control the indoor temperature, reducing energy demand (www.arup.com - Figure 5).

Figure 5 Portia Winery

- **Ensures air tightness over time to save energy**

Air leakages through the building envelope are substantial sources of energy losses (heating or cooling). They usually appear between joints and connections. Concrete-based construction systems perform better over time than - for example - timber frame constructions because of the following reason: concrete constructions have very few joint/connections.

- **The most efficient building shape is best made with concrete**

A cube-like shaped building contains a large volume compared to its total façade area. Because most energy is lost through its façade, a compact (cube-like) building shape is the most energy-, and resource-efficient design. To allow for natural light to reach the deep indoor areas of a building, optimum building height should be around 5 to 10 storeys. Up to 30% energy savings are achievable simply by choosing a compact building shape. Due to concrete's set of properties combining strength, fire-resistance and cost-efficiency, these buildings are best made in concrete.

The extraordinary structure of Vodaphone Portugal new headquarters designed by architects Jose Antonio Barbosa and Pedro Guimaraes "is a shell of concrete irregular shapes, forming a kind of mosaic that plays with the acute forms of the glass, becoming a unique and formidable piece of art". (http://portugalconfidential.com - Figure 6).

"The formalization of this concept is based on the concrete, which through its plasticity, allows the ability to create irregular and free-form shapes, working both as a structural solution and exterior appearance, creating a unique shape, a monolithic building, bringing cohesion and unity to the set. The technical complexity of the building leads to a periphery structural solution, a shell of concrete, like an egg, reducing internal support to the two stairwells and three central pillars, allowing great versatility in its interior space use." – Barbosa & Guimaraes.

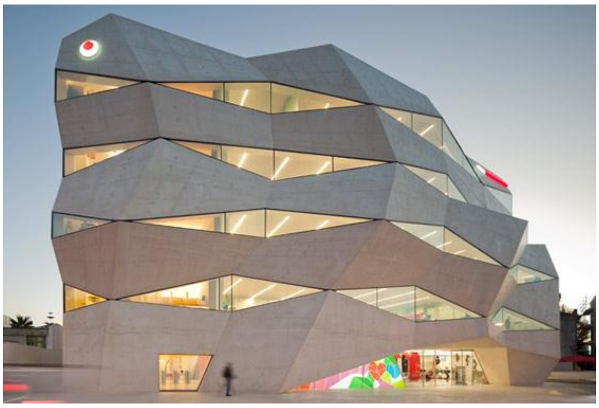

Figure 6 Vodaphone Portugal New Headquarters

Rising population, urbanisation trend and land scarcity call for cities with higher population density. 90% savings in transport-generated CO_2 emissions can be achieved in dense cities that have a developed public transport system. Concrete's properties, affordability and availability, makes it a material of choice.

2.5 Concrete contributes to acoustic comfort and healthy buildings

- **Acoustic comfort**

Concrete is very good against air-borne noise. An air-borne noise hitting concrete doesn't induce a movement in the material because of its weight. The wave is reflected instead of being transmitted through the material. This property of concrete is widely used for apartment blocks or for acoustic walls near motorways.

- **Inert, concrete creates healthy indoor environment**

Concrete is a re-created stone. As such, it is inert and doesn't release volatile organic compounds or dust. It is a low risk material for construction workers. As a mineral material, moulds and other hygiene-related issues (common in organic materials) are unlikely. It helps therefore to create healthy indoor environments.

Aesthetics of buildings created from the concrete material as the exterior façade looks very strong and extraordinary as A-Cero designed for a residence located on the outskirts of Madrid (http://www.worldarchitectnews.com/aesthetics-of-buildings-concrete-facade Figure 7).

Architecture design is developed on 3 levels so as to create a dramatic residential of the surrounding environment with game shape and volume from concrete building materials.

Figure 7 Aesthetics of Buildings Concrete Facade by A-Cero

2.6 Unrivalled versatility and aesthetics

Concrete is a very versatile material that can be poured on site to the form envisioned by the architect. As a liquid that solidifies within a few hours, many shapes are possible, opening ways for architectural creativity. Also it can offer the advantage of adaptability throughout its service life (a "flexible structure" form architectural point of view, can be altered, extended, subdivided).

2.7 Affordable, available and local

The reasons for concrete's worldwide success beyond its unique combination of material properties include its affordability, availability, and extremely versatility.

Produced locally, concrete provides job opportunities to local communities.

REFERENCES

Kibert, Ch. (2007). "Sustainable Construction: Green Building Design and Delivery".
Reeder, L. (2010). "Guide to Green Building Rating Systems".
ACI Committees 130, 233. (2010). "The Sustainable Material Choice". ACI SP-269.
Iordachescu, A. (2001). "Constructii inteligente". Editura Reg. Arcadia.
Park, R.; Tanaka, H.: "Flexural Strength and Ductility of High-Strength Concrete Columns". ACI SP-176.
Iordachescu, A. (2008). BETOANE EUROPENE DURABILE 2008 "Industria betoanelor in Romania – provocari si perspective". Bucuresti, Romania.
Iordachescu, A. (2009). "Impactul Noilor Relementari asupra Industriei Producerii Betoanelor in Romania" – Universitatea Tehnica de Constructii Bucuresti.
Nahoi, G. (2010). "How Concrete Contributes to Sustainable Construction", Lafarge Romania.
Adelberth, K., (2011). "Sustainable Constructions", Lund University
http://www.worldarchitectnews.com/aesthetics-of-buildings-concrete-facade
http://portugalconfidential.com
www.arup.com