How concrete contributes to sustainable construction

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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 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 CO_2 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.

Concrete, an essential material for sustainable construction

There are two ways to assess the sustainability of a material: its environmental footprint (burden) and its value provided to the people and to the society (benefit). While the former can be quantified scientifically through a life cycle analysis, the latter is much more qualitative in nature.

Here, we will describe concrete's unique set of properties that makes it an excellent contributor to sustainable constructions:

1. **Strong, highly-resilient and durable**
   - **Compressive strength**
     - A wide range of concrete types exists, with compressive strength spanning 5MPa (or 50kg/cm^2) to 200MPa. Combined with steel reinforcement, countless structural and nonstructural applications are possible: foundations, façades, walls, slabs, tanks, pipes, roads, tiles, paving, landscaping, urban furniture, etc.

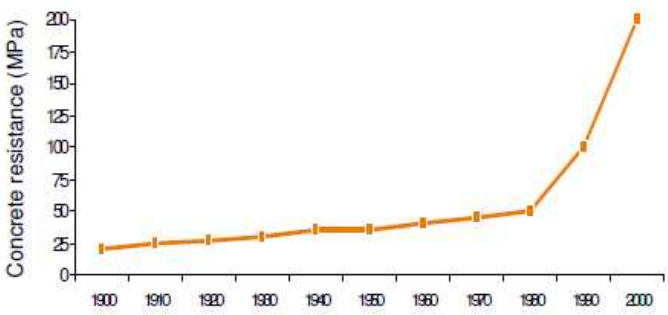

Figure 1: Progress of concrete's compressive strength potential over the years

     - Resilient to external aggressions, its compressive strength remains intact over the years.

- This property also guarantees a very high resistance to impacts, which is particularly important for safety issues.

- **Resilient to weathering, pollution, saline environment, erosion, heat, and fire**
  - **Durable -** Through scientific modelling, it is possible today to predict life expectancy of concrete. For example, with a sound design and high workmanship standard, concrete structures can last over 2000 years as illustrated by the concrete dome structure of the Pantheon in Rome (Italy) that was built between 118 and 128 A.D.

Figure 2: Concrete dome in the Pantheon in Rome

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 - aggregates, sand, limestone and clay - are available in large quantities everywhere on the planet.
   - **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. The main benefit of recycling concrete is to reduce the need for gravel mining and landfill space.
     - Recycling water should also be part of good manufacturing process. At Lafarge, most concrete plants have a water management system to recycle water or to use for cleaning.
   - **Represents a channel to recycle by-products from other industries**

     By-products from other industries, that cannot be used elsewhere, can be incorporated into the cement blend to replace up to 60% of clinker, or can be added into the concrete mix. Examples of admixtures are:
     - Fly ash: a by-product of coal-fired electric generating plants
     - Ground granulated blast furnace slag: a by-product of steel production
     - Silica fume: a by-product of silicon and ferrosilicon alloys production
     - High reactivity metakaolin: a by-product of porcelain manufacturing

     While silica fume is usually dark gray or black in colour, high reactivity metakaolin is usually bright white in colour, making it the preferred choice for architectural concrete where appearance is important.

3. **Low embodied energy, low carbon footprint**

- **Some prior knowledge**
  - Embodied energy is the sum of all the energy used to make a product. It is measured in mega joule per unit of volume or mass: [MJ/m3] or [MJ/kg]
  - Carbon footprint is the sum of all the greenhouse gas emissions generated to make a product. It is measured in carbon dioxide equivalent per unit of volume or mass: [kgCO_2eq./m^3] or [kgCO_2eq./ton]
  - Comparing materials based on these indicators makes little sense, since their life times and properties are generally not comparable
  - This data serves as input for a more complex, rigorous and multi-criteria environmental assessment method called Life Cycle Analysis
- **A local product**
  - Concrete embodied energy and carbon footprint is low per unit of volume. Typical values range from 150 to 400 [kgCo_2eq./m^3] or 60 to 160 grams of CO_2eq./kg of concrete
  - Concrete manufacturing requires very little energy, since the process simply involves mixing different components and does not require any heating
  - Concrete is produced locally and delivered within a 50km radius, thus limiting transport- related greenhouse gas emissions
- **Cement industry's levers for more CO_2 reductions**

Most of the embodied energy and carbon in concrete comes from cement. As a result, the cement industry works to reducing its CO_2 emissions by the following means:

- Improving energy efficiency of the manufacturing process and by modernizing factories
- Substituting fossil fuels with renewable and alternative energy sources
- Increasing volumes of by-product additions in cement

- **Lafarge: a pioneer**

Since 1990, Lafarge has been working on those three levers, achieving substantial CO_2 emissions reductions:

- 12.5% absolute CO_2 emissions reductions in industrialized countries in 2008, compared to 1990 levels. The original target was 10% reduction by 2010.
- 18.4% reductions of CO_2eq./ton of cement produced by the Group worldwide in 2008, from 1990 levels. The Group's commitment is to reach 20% reduction in 2010.
- Lafarge dedicates more than 50% of its R&D budget for issues related to sustainable construction. This results in new cement and concrete formulations that have a lower environmental footprint at product or building level.

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. Depending on the climate, savings can be as high as 15%.

- **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 two reasons: first, concrete constructions have very few joint/connections. Second, like most mineral-based materials, concrete keeps its dimensions over time. No noticeable deformation or twisting happens, even under the influence of humidity, temperature variations and aging. This stability ensures that gaps and leakages are less likely to materialize over time.

- **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.
  - Rising population, urbanization 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.

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.

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.
   - o Many different concrete types exist with variable compressive strength, colours, surface finish, setting time etc. Architects and engineers can even

request a customized concrete to serve their design intent, paving the way for more innovations
- o For buildings requiring few columns or walls, pre-stressed or post-tensioned concrete technology allows for very long spans of slabs and beams
- o For fast construction, concrete elements can be precast in a factory and transported to the site.

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
   - o Produced locally, concrete provides job opportunities to local communities

Lafarge's innovative concrete range contributes to sustainable construction

- Researchers at Lafarge have developed a profound scientific understanding of concrete and are working to develop new solutions, which enable constructions to be even more resource efficient.

For more information www.lafarge.com.