# CIRCULAR CONSTRUCTION.

## RETHINKING CONSTRUCTION PROCESSES AND ENERGY CONSUMPTION IN CONSTRUCTION AND BUILDABILITY TRANSFORMATION

## CRITERIA FOR THE CONSTRUCTION SECTOR:

This document presents a series of fundamental technical criteria for the necessary transition between current construction systems and energy consumption in buildings, towards their evolution as efficient and low-carbon circular construction systems. These criteria are being implemented in the city of Medellin and will be included in a Public Policy on Sustainable Circular Construction. This article includes the fundamental criteria and principles of circular construction, the 7R Circular Building Strategy, the circularity chains involved in Sustainable Construction, the criteria for circular construction designs, the criteria for circular construction materials and examples of innovative construction technologies. Issues like the degree of circularity of a construction material and the critical components in the materials production are contemplated.

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## BASIC CRITERIA TO BE CONSIDERER IN CIRCULAR CONSTRUCTION

-**To Implement new construction processes**: Reduction of earth excavations and land cuts, use of lower volumes in structural elements, use of modular and prefabricated elements, promotion of the inclusion of renewable components in construction and therefore the consumption of less energy, their optimization and efficiency in the construction and operation of buildings.

**- To optimize the construction processes**. Design and conversion of buildings. From the design, plan the future adaptations of the buildings to avoid their demolition as much as possible and promote their reconversion for other uses and dispositions, according to the demands of their use, occupation and activities that are going to be carried out in them.

- **To Avoid as much as possible, the total and partial demolition of buildings**, tending to their preservation and reconversion. This is due to the fact that they must be used, given the existing embedded or incorporated carbon in the construction materials to be demolished and that were generated with their initial elaboration.

- **To Introduce new materials for the construction sector and the use of circular materials with low embedded carbon content**, materials used in other industrial sectors, such as nanotechnologies, new products generated in the chemical industry, new electrical materials, recovered, reconverted or recycled materials, among others.

- **To prevent over-design and over-sizing of buildings or construction structures**.

## BASIC PRINCIPLES OF CIRCULAR CONSTRUCTION

Build efficiently with the use of fewer natural resources, without destroying nature and its ecosystems. Avoid as much as possible the use of new raw materials and the generation of debris or disposable construction by-products.

To carry out all types of constructions so that they are multi-functional, durable, sustainable and with a low carbon footprint, promoting the use of local materials and technologies.

Extend the useful life of existing buildings through their transformation and rehabilitation of buildings and their areas or spaces.

From the design, plan energy efficiency and efficiency in water consumption, with clean energy technologies, use and reuse of rainwater and grey water. This type of forecast leads to a decrease in operating carbon during the operation of buildings and construction works.

In relation to construction materials, it is to achieve the circulation of products and materials to a high degree. This means keeping materials in use, either as a product or, when they can no longer be used, as components or raw materials to be reused. In this way, nothing becomes waste, its intrinsic value is preserved, and no additional embedded carbon is generated in its production or use; avoiding new costs for extraction, transport and those of the entire production and construction chains

## 7Rs CIRCULAR CONSTRUCTION STRATEGY: R1. REDESIGN, R2. REDUCE, R3. REUSE, R4. REPAIR, R5. RENEW, R6. RETRIEVE AND R7. RECYCLE R1.

**R1. TO REDESIGN**. Based on future reconversion processes of buildings. Consider Redesign options. Changes in the destination or use of real estate or buildings.

**R2. TO REDUCE**. Processes to reduce the consumption of sand, stone and metallic materials and with flammability or toxicity contents.

**R3. TO REUSE**. Reuse of materials, built parts, building elements: doors, windows, prefabricated elements, sanitary appliances and others

**R4. TO REPAIR**. Repair and preventive maintenance of construction components. Repowering of buildings.

**R5. TO RENEW.** Renovation of old buildings and recent buildings, processes of adaptation or preadaptation of constructions to new conditions required. **Retrofit (8R)** process to install new or modified parts or equipment in previously manufactured or constructed buildings.

**R6. TO RETRIEVE**. Recovery processes of metallic elements, critical circular materials and with higher embedded carbon content.

**R7.TO RECYCLE**. Recycling and transformation processes of stone materials, sands, clays and construction waste or debris.

## INVOLVED CHAINS IN CIRCULAR CONSTRUCTION PROCESSES

**SUPPLY CHAIN**: It is the set of procedures that allow construction activities and builders to have the raw materials, construction inputs and the different elements necessary for the development of a product or construction process with low carbon load. Its main objective, is to consolidate a market that satisfies the demands of the requirements and construction elements to ensure circular materials and circular buildings.

**VALUE CHAIN:** Includes the processes and activities that are required for a design, activity, material, product or construction service to meet standards of maximum efficiency, durability, resistance and versatility; through its different stages of production, from its conception to its delivery to consumers and reuse or reintegration into other processes after its initially intended end use.

**POST-PRODUCTION CHAIN AND ITS RELATIONSHIP WITH THE SUPPLY AND VALUE CHAINS.** The Post-Production Chain refers to the state of products or construction materials once they have been produced and used for the purpose for which they were designed or created. This includes materials that have already been used or are deteriorate or damaged. The post-production chain is located between the Value Chain – Valuation of construction elements in their significance in circular construction – and the Supply Chain.

## CIRCULAR CONSTRUCTION PROCESSES: CONTEXT OF CIRCULARITY IN THE DIFFERENT COMPONENTS IN BUILDING CONSTRUCTION ACTIONS.

### RATIONALITY IN DESIGNS:

**Architectural Design (Light and Sustainable).** Rationality in design: consider the functionality of the design of the spaces or areas to be built and how they can be used more effectively/optimized (avoiding underutilizations) and how they can be changed/adapted if the building changes use.

**Structural Design.** Earthquake Resistance**.** The structural design has been characterized by the high energy level required for the production of metal and structural reinforcement materials – Steel, Iron, Aluminum and others**-** The rethinking for these designs is to generate or design slender structures of non-high weight, in the concretes and other required construction supplies. In many cases, it is necessary to consider avoiding high-rise constructions, since it is proven that tall buildings have high energy consumption, due to the complexity of the ventilation systems, lighting of common areas and the elevators required, that consume greater additional energy, compared to medium or low rise buildings.

**Electrical and Information Technology Design**: These designs are key to energy efficiency in the operational or operational stage of buildings or constructions. Energy efficiency and low operational carbon generation will largely depend on the designs of these systems and the technologies and devices used in them.

**Design of ventilation and heating systems**. Air conditioning: Similarly and associated with the designs of electrical systems, ventilation and heating systems must include aspects of maximum efficiency and versatility, given their requirements in buildings and other industrial processes or in hospital or service buildings where cold air and heat supplies are required due to high demands and consumption.

**Hydro-sanitary design**. Like electrical design, its quality, versatility and sufficiency will determine the efficiency of water or the use or consumption of water in buildings.

## RATIONALITY IN THE DEVELOPMENT OF CONSTRUCTION WORKS

**Construction efficiency.** In general, construction works are evaluated for their functionality and profitability, sometimes without measuring the impacts or relational effects that they have during their construction and during their operation in their environment. An important aspect to take into account from the conception and design of construction works is the carbon footprint of the construction techniques and elements to

be used and the materials or components to be used. It's about applying the principles of **"Doing More with Less"**

## PRODUCTION OF CIRCULAR MATERIALS AND OTHER CONSTRUCTION INPUTS. NEW CONCEPTION AND DESIGN OF MATERIALS

**CIRCULAR MATERIAL CONCEPT**. A circular material is one that from its conception is designed to have a long useful life or durability, high resistance and efficient dynamics and interaction with the construction process. It includes raw materials or reprocessing of other materials with low carbon load. Design is the key to the success of circular materials, this is achieved through the use of recycled, natural or locally sourced materials. In addition, efficient models are used in its production that generate less waste and less energy use during its manufacture and in which both its useful life and its recycling, transformation and subsequent reuse are taken into account.

**Biotecture and the Inclusion of wood Materials in Circular Construction**: Wood and its by-products are an option that, if well managed, would achieve the supply of circular organic materials. These include: - Slats, joists, boards, veneers and plywood. OSB. Agglomerates or Conglomerates. MDF or MDF. Triplex, wood ceilings and floors. The use of vegetation in shading and acoustic barrier effects is another important factor to consider: palm fronds, bamboo, green walls and green roofs.

**(See the work of the Forest & Climate Leaders' Partnership (FCLP) and particularly its statement endorsed by the Initiative for Greening Construction with Sustainable Wood on 6 December 2023 during the 28th UN Climate Change Conference.)**

**Degree of Circularity of a Material. (Life Cycle Assessment – Environmental Declaration of the Product or Material)** It is defined by the life cycle of Carbon in relation to the Materials and the energy used in the construction processes. Define impacts throughout the life cycle from the extraction of materials through reuse, reconversion or recycling.

**Critical components in the production of a circular material.** The critical component of a circular material occurs in two ways: Positive sense: locally abundant material with lower embedded carbon content, great durability and resistance, additionally its best price-quality ratio is included. Negative sense, which would classify it as a non-circular material: Material with a high carbon footprint, high price, low durability and resistance, need to be transported from long distances.

**Attenuation or substitution of a critical material**. Looking for constructive alternatives in the use of critical materials, from the designs, is a fundamental action in circular construction. Most materials that include non-renewable natural resources, such as minerals or metals, are considered critical materials.

**New Materials and High Strength Materials**. Elaborative processes of synthetic materials: These are materials that have resulted from research processes. New mixtures of more versatile, functional and resistant concretes have been found, which include paints, accumulation or reflection and refraction of light and heat. In the structural reinforcement part, the use of synthetic fibers is being implemented, highly resistant and usable in slabs, but still not usable in all cases of compression - columns. Composite materials, such as polymer concretes, now replace iron, steel, and conventional concrete. On the electrical side, high-strength and superconductivity conductors have appeared, replacing conventional electrical materials. Some examples are:

**Translucent Cement**. It is a polymeric concrete that includes cement, aggregates and additives in its composition, allows light to pass through and has mechanical characteristics superior to those of traditional cement.

**Self-healing concrete**. It consists of the introduction of capsules containing bacteria and calcium lactate into the concrete: if a crack appears, the next rain breaks these capsules, generating a chemical reaction that repairs them.

**Heat-insulating and heat-sealing paints**, putties, aerogels and stuccoes produced with Nanotechnologies.

## INNOVATIVE CONSTRUCTION TECHNOLOGIES:

**BIM**. It is a big tool of modernization and improvement of the construction sector. Building Information Modelling (BIM) is a collaborative work methodology that centralizes, in a digital and accessible database, updated in real time, all the information related to construction and infrastructure management.

**Augmented Reality (AR)**. This technological innovation makes it possible to compare virtual architectural projects with the reality of the land where they are built, reducing errors, saving time and resources and increasing their accuracy and efficiency.

**Iot.** Internet of Things. It makes it possible to optimize all types of processes and, in the field of digital innovation, construction is one of the sectors with the greatest potential when it comes to applying its solutions. It can be applied in the different stages of the construction process and offers great advantages both in the first phase of planning, design and calculation, as well as in the subsequent work on site.

**Prefabrication**. The prefabricated parts save 70% of energy and 50% of water consumption, improving the efficiency of the construction process, according to Shaanxi Construction Engineering Corporation. Prefabricated parts also reduce pollution and noise, generating very little waste.

**Versatile Tools and Technologies:**

**3D printing.** The benefits of this development have been seen in all sectors, from which construction and urban planning are already benefiting. There are currently no devices that can print entire buildings by 2025, a quarter of every building that is constructed will have to be made by 3D printing.

**Construction Robots.** Australian Mark Pivac created the Hadrian X robot, capable of placing 1,000 bricks per hour. For a few months now, this amazing mason robot has been working on real projects and building his first houses. In fact, he doesn't limit himself to laying bricks: he cuts blocks with millimeter precision and puts adhesive, among others.

**Drones.** Under construction, it is used for land prospecting and for the creation of visual content for inspections and safety guarantees. This technological innovation reduces time to action, risks and operational costs.

**Pocket-sized LIDAR**. LIDAR is the most accurate and efficient tool to check that what has been built corresponds to the digital BIM model. The most common scanning equipment until now was bulky and somewhat cumbersome. Now, thanks to two of the tech giants: Apple and Google, a mobile app has been developed that makes it more convenient.

**Heat Pumps**: The heat pump is a thermal mechanism that takes heat from a cold space and transfers it to a warmer one thanks to mechanical work provided from the outside. Nowadays, reversible machines appear, which are often referred to as reversible heat pumps, which are devices with four-way valves for winter-summer reversal, or heat-cold, depending on the thermal condition.

## OTHER ISSUES FOR FURTHER CONSIDERATION

**TO INCLUDE THE COSTS OF ECONOMIC EFFECTS OF ENERGY EFFICIENCY IN CIRCULAR CONSTRUCTION**:
Energy efficiency programs include, among others, the identification and correction of losses, the reduction of energy consumption at peak hours, and the reduction of the energy rebound effect and the general decrease in consumption in buildings. ECO-

**TO STABLISH ENVIRONMENTAL LABELING, CERTIFICATIONS and BASELINE FOR CIRCULAR CONSTRUCTIONS AND MATERIALS (Regulations)**

https://www.circuit-project.eu/about-circular-construction

Some examples of city actions:

https://www.c40knowledgehub.org/s/article/Making-the-Case-for-Clean-Construction-City-Profiles

## CIRCULAR BUILDING AND ENERGY EFFICIENCY INDICATOR SYSTEMS IN BUILDING CONSTRUCTION

**Indicators** – They have to be established to assess and measure the impact of the circular construction strategy and its energy efficiency. Its implementation must be developed based on primary information, with measurements on the real consumption conditions of each of the construction developments, but not by ranges or estimates and in accordance with **SDG 7**. Affordable and Clean Energy. **SDG 9**. Industry, Innovation and Infrastructure. **SDG 11.** Sustainable cities and communities and **SDG 12**. Responsible production and consumption.

**As an Illustration**: Triangle of virtues of the circular economy in "merit order", at the top those with the most virtues and reduction of environmental impacts. Source. Lang…