VDB® INGENIERÍA CIRCULAR, TRANSFORMING CIVIL ENGINEERING FOR A GREENER WORLD WITH RENEWABLE INVESTMENTS

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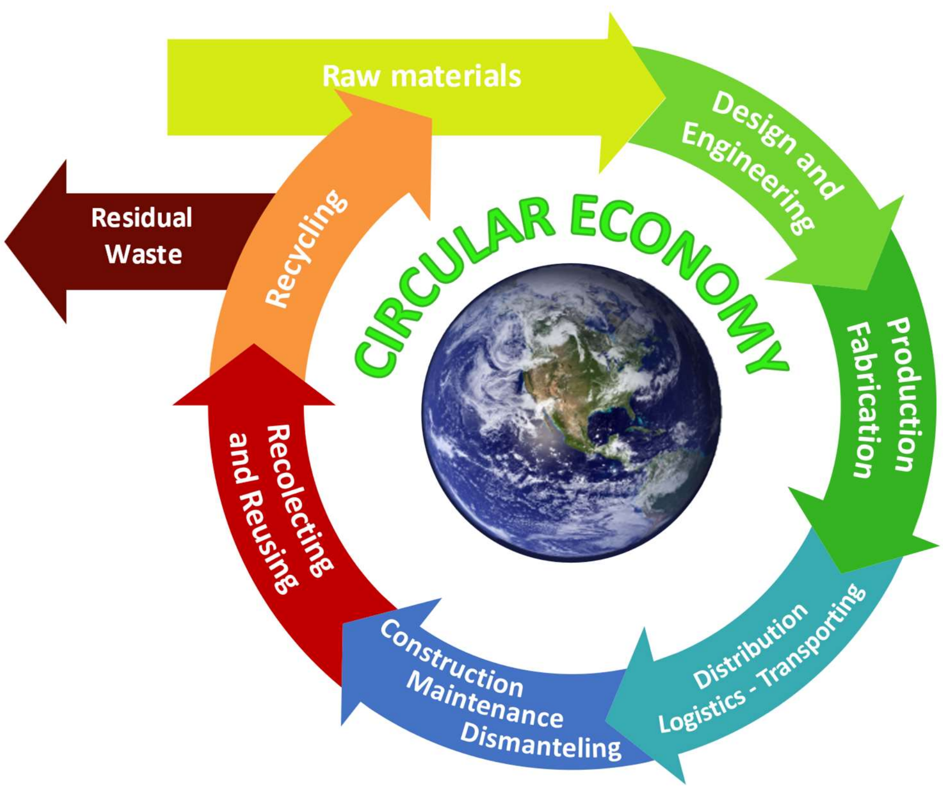
VDB®
INGENIERÍA CIRCULAR

Introducing an innovation

A new Civil Engineering process management system is what **VDB® Ingeniería Circular** (VDB Circular Engineering) has developed to meet the **3R´s** objectives for **R**eusing, **R**ecycling and **R**educing **W**aste of concrete in the construction industry at an Economic, Social and Environmental level. Using the innovative **PFP® Precast Full Potential** methodology, it is the tool by excellence to make visible and traceable the steps in the new engineering process. Professionals who use this new **PFP®** methodology in the development of their Civil Engineering projects can directly show their technical contributions in the creation of a better, greener world, with a real circularity of the structures in reinforced concrete.

A Greener, Circular World

The Circular Economy is showing us that with new knowledge and approaches we can realize what our conscience confirms to us day by day, that our environment and the whole world require more respect and care, so that as human beings we can consider ourselves as inhabitants who take care of their planet. Personal responsibility allows us to put this new knowledge to good use and motivates us to act responsibly in our profession and specialty to contribute to this purpose. In the design and construction of reinforced concrete works, which is our field of interest, we have identified a methodology to incorporate circularity and eliminate environmental liabilities, through modular structures design that reuse prefabricated elements and reduce waste and residues.



Adding three new objectives and requirements in the development of a specific project allows us to modify the traditional linear methodology (Engineering, Production, Transportation and Construction) to a closed circular one. These three objectives are related to **reuse, recycling, and waste management**. Sustainability in construction is considered when we change the life cycle of our concrete structures and projects into cycles of use. We have identified the content of the word **sustainable** in civil engineering as a word that allows us to reuse the products and elements several times, generating renewable investments.

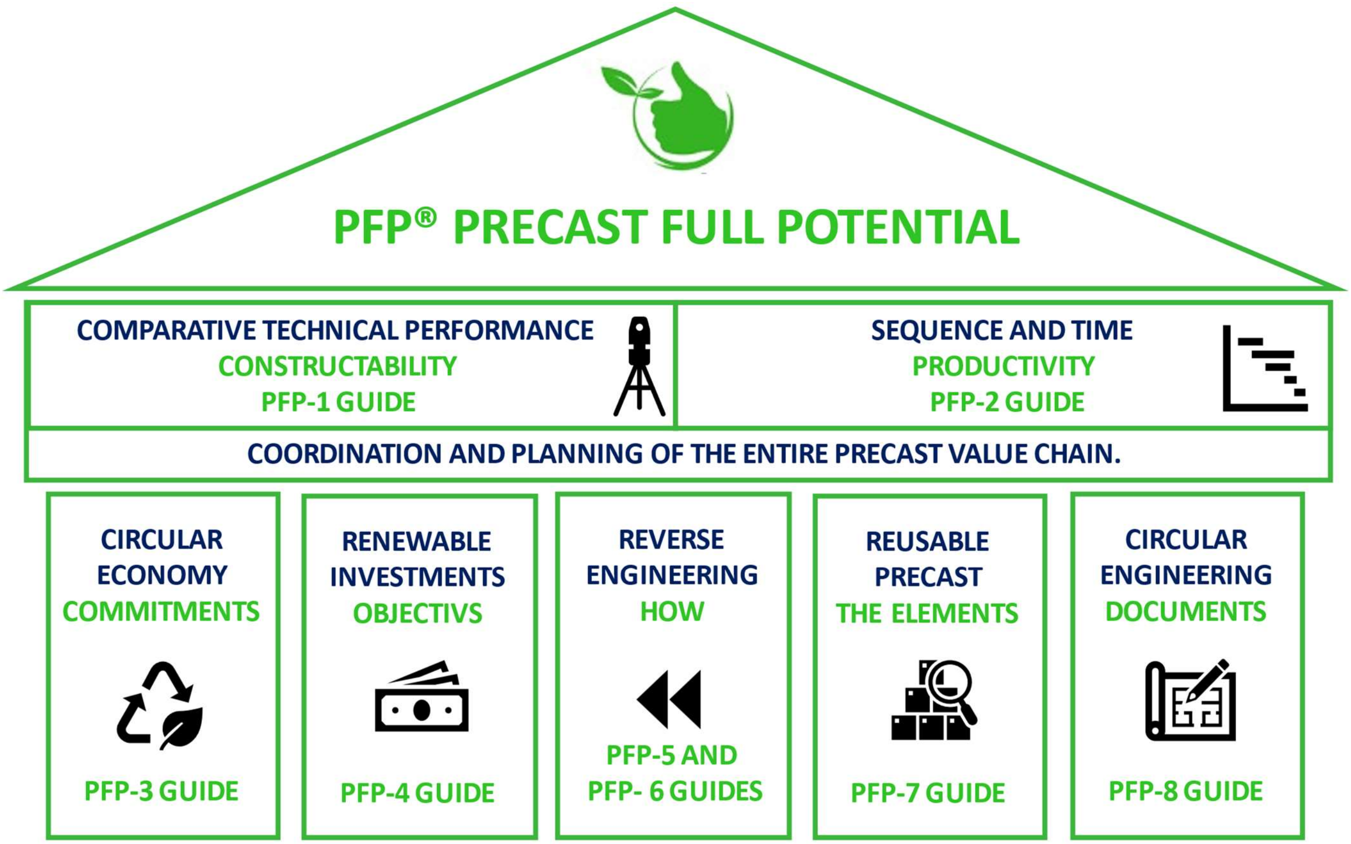
With this methodology, investors, owners, or clients will be able to define what percentage of the total project should be designed incorporating the aspects of Reuse, Recycling and Reduction of Waste and Environmental Liabilities. For example, if in a project it was originally foreseen that the reinforced concrete foundations, executed in situ, generate 100% environmental liabilities and are not recycled; now the clients have this new option that allows for the structures to be traceable and that they do not generate environmental impacts or avoidable waste, as an example:

- **35%** reuse of new sustainable structures using Renewable Precast Elements to reduce environmental liabilities.
- **55%** recycling of the planned new structures, being removable and transportable after their first use.
- **10%** of unavoidable waste that, for now, cannot be reused or recycled and cannot be removed from the site where they have been installed.

The implementation of the **PFP® Precast Full Potential** methodology in the development of reinforced concrete projects makes it possible to create visibility of the compliance with the traceability of the materials used and the circularity of the design with solid results. Additionally, it generates the Social, Economic, Environmental and Safety improvements required. Some of these specific results and benefits are:

- Coordination and planning of the entire value chain of participating suppliers.
- Reduction of civil works execution time and compliance with the deadlines.
- Reduction of the carbon footprint and direct benefits in environmental issues, such as the reduction of waste during the construction stage.
- Improved safety for construction personnel in the field.
- Reduction of the CAPEX in investments in concrete civil works.
- Reduction of the number of people in the execution of the work itself, with a slight increase in the number of assembly and teams.
- Elimination of maintenance costs.

PFP® Precast Full Potential incorporates knowledge on how to achieve changes in the definitions of the engineering project objectives and what to do at each stage to achieve circularity in the use of reinforced concrete. The goal is to empower and massify a migration process from monolithic reinforced concrete structures executed on site to modular segmented solutions with reusable Precast concrete Elements.



The application of the **PFP® Precast Full Potential** methodology rests on five pillars, which allow to generate traceability and visualization of each action and the results of its use, the definition of how to add new steps to the Engineering, which materials to use, what to design and calculate in each specific document. This results in a new procedure that allows the design and execution of a sustainable structure using reinforced concrete. The detail that each pillar covers is:

Pillar 1: Circular Economy - Delivers the values and sequences over time of the use of structures, guiding the construction market to greener and more circular solutions. Clients, owners, and investors in concrete infrastructure can fulfill the commitments that concrete **circularity** can be delivered, committing the engineering industry and the precast supply chain to its full realization.

Pillar 2: Renewable Investments - Because an investment in concrete cannot simply be depreciated or forgotten over time, the steps of reuse, recycling and generation of new raw materials must be part of the economic evaluation of investments in each stage, from preparation to the existing of projects. Extended supplier responsibility applies not only to suppliers of products such as plastic packaging, but also to suppliers of financing. Having green and circular targets for financiers can now go hand in hand with requiring designers to make compliance percentages transparent on a project-by-project basis.

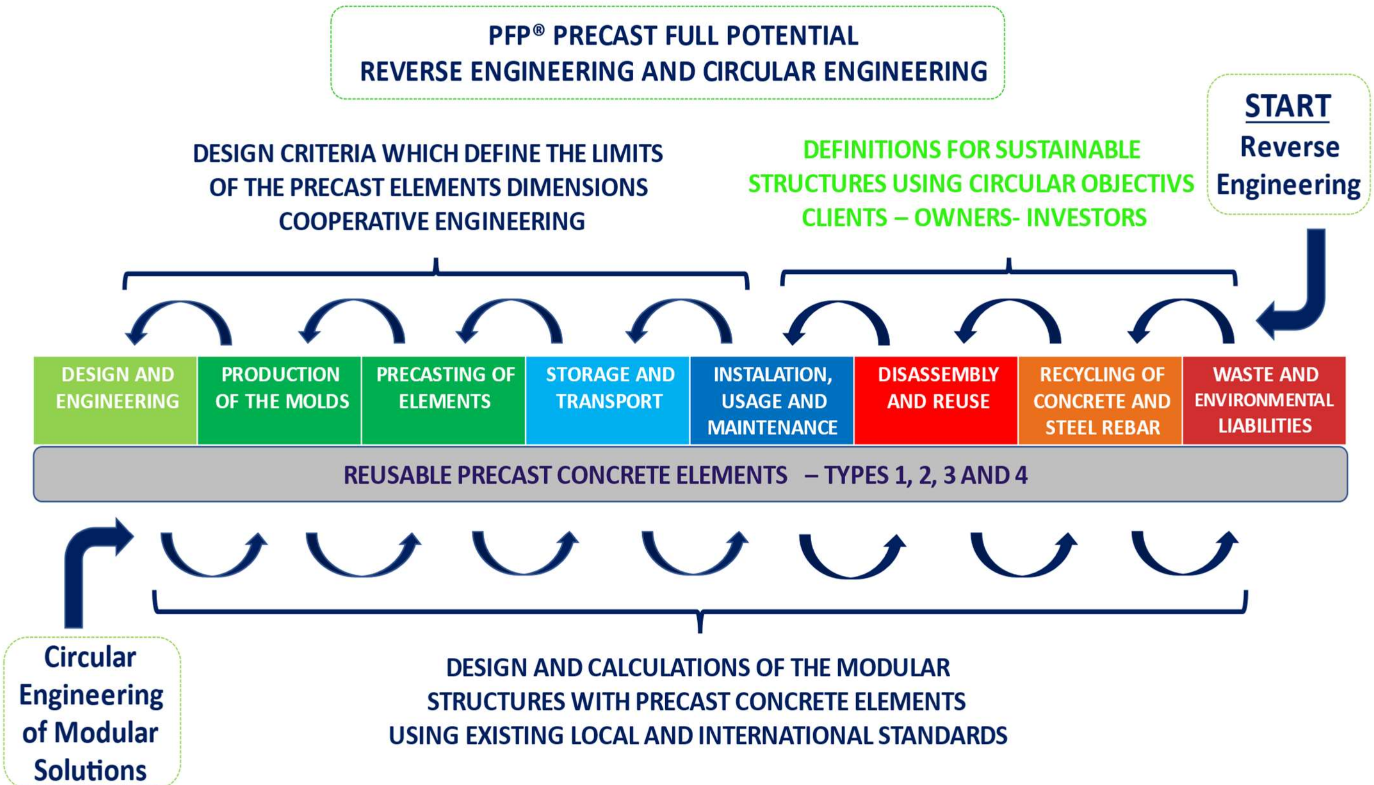
Pillar 3: Reverse Engineering - How to migrate structures traditionally designed in cast in-situ concrete to modular solutions with Prefabricated Elements. Starting at the waste creation and environmental liabilities stage, at the end of the first use of the structure, each of the 8 sequential parts of the circular economy is passed through to incorporate the criteria corresponding to Precast at the beginning of the modular engineering stage. The definition of sustainable structures requires from clients, owners, and investors the definition of circular criteria related to waste management, recycling, and reuse. Together with cooperative engineering, the design criteria for the precast element dimensions are defined.

Pillar 4: Renewable Precast - The two components in reinforced concrete are steel rebar and concrete, both of which are recyclable when taken to a recycling center to be separated. The rebar can be shipped to the steel manufacturers and the crushed concrete becomes a type of gravel that can be used in new concrete products. The concept of renewable precast is to ensure that the reinforced concrete elements used can be both assembled and disassembled; this is achieved by incorporating permanent lifting systems, which allow for proper handling, and specific joints between all the elements. Renewable products can be reused or recycled and do not generate abandoned structures after their first use, thus eliminating environmental liabilities.

Pillar 5: Circular Engineering - Contemplates the realization from early stages of defining a project, that design criteria incorporate modular solutions with Prefabricated Elements, generating the complete documentation for a Circular Engineering. Reinforced concrete structures with prefabricated elements allow their joints to be assembled and disassembled, thus conceiving elements with multiple uses and more than one life cycle.

Key Concepts in Reverse Engineering

In **Reverse Engineering**, the aim is to gather the starting data and the criteria to define the modular solutions in an early stage of the project, which allows migrating directly to modular structures with precast reinforced concrete. In this way, a step-by-step work guide is obtained, which allows having visible and traceable information that is registered in digital files, that will contain all the knowledge that was required for the definition of the designs. Cooperation between clients, consultants and the specialized companies for services and products, that make up the entire chain of precast concrete suppliers is essential. A new system of early contracting of experts for each project also has to be incorporated, in order to take greater advantage of the benefits in the use of Renewable Prefabricated element solutions.



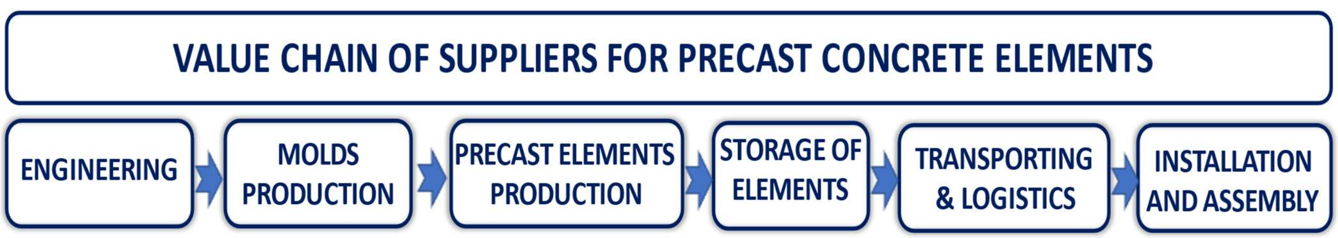
For the digital traceability of data considered in the **PFP® Precast Full Potential** methodology, **PFP** guides have been developed for each of the **five pillars** on which it is based, which allow recording and storing data in the Prefeasibility Engineering, Feasibility Engineering and Detail Engineering stages. For Pillar N°3 there are two different guides that must be used together, detailing the topics of interest while doing **Reverse Engineering**; the details of these guides are as follows:

PFP® Precast Full Potential **Criteria definition for Prefabricated Concrete Elements designs**			
Reverse Engineering **PFP-5 Guide** **Definition of Precast Elements**		**Reverse Engineering** **PFP-6 Guide** **Key Principles and Considerations**	
5.1	Waste control – Environmental Liabilities	**6.1**	Client´s requirements
5.2	Recycling	**6.2**	Security and Safety
5.3	Reuse	**6.3**	Everything that is not designed will not be executed and not be paid to anyone.
5.4	Assembly, Use and Maintenance	**6.4**	Traceability
5.5	Transportation	**6.5**	Modularization starts early in the design process
5.6	Storage areas y logistical facilities	**6.6**	Constructability
5.7	Precast Elements Production	**6.7**	Standardization
5.8	Production of Molds	**6.8**	Joint Science
		6.9	Lifting Science

In the **PFP® Precast Full Potential** methodology, it is Pillar 3 of **Reverse Engineering** that generates the capacity to translate the needs of the **Circular Economy** and **Renewable Investments** into data and criteria that allow the development of designs, with sustainable and technical criteria, that are achieved with the use of **Reusable Prefabricated Elements** in **Circular Engineering**, resulting in modular civil works with more than a single use.

Key concepts in Circular Engineering

It consists of elaborating, from the early stages of the project, the records of documents that incorporate the solutions and knowledge of the use of Modular Solutions using Precast Elements. The migration from cast in place concrete to precast requires between 2 and 4 times more design and engineering work to create the detailed digital records, with all the required information for all suppliers of the precast value chain. The use by the client and suppliers of tools such as Building Information Modeling (BIM) allows to record, preserve, and update the contributions in designs, costs, and time (among others) of each of the specific links in the chain during the realization of the investment and construction of a project.



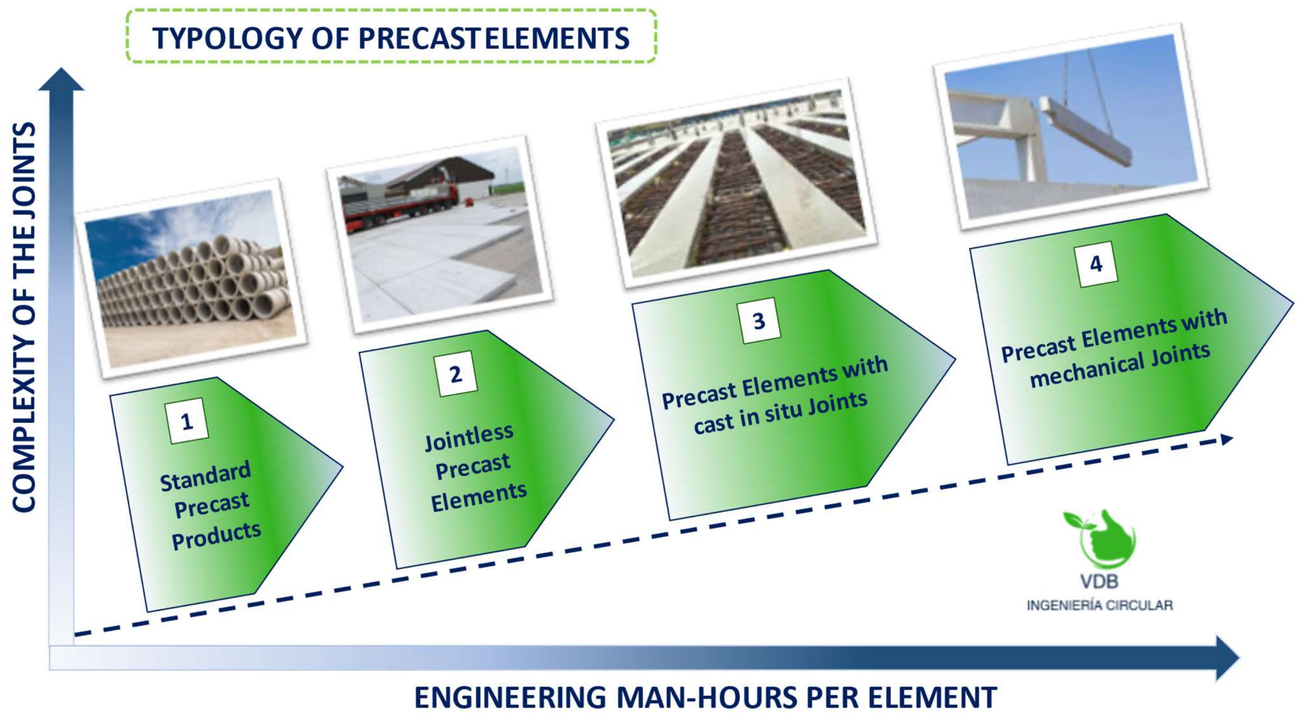
The early definition of the incorporation of the use of Prefabricated Elements allows to generate the technical documents for the visualization of the new execution method based on installation and assembly, which allows to achieve the required financial, safety and time benefits. Digitally visualizing the execution sequence, with the positions of the storage areas for the precast elements and the positions of the right type of assembly cranes, allows modifying the layout of the civil works for each structure to allow the new execution method to become a reality. Functional spaces for the positioning of equipment not only allows for assembly and disassembly, but also favors the expansion and maintenance of modular structures made of precast elements.

In reinforced concrete civil works, the incorporation of Renewable Prefabricated Products and Elements allows strengthening the contributions of segmented and modular designs for the realization of a wide variety of Sustainable Solutions. Works that from the first moment incorporate Constructability, Reusability and Recycling are possible with **Circular Engineering**. The incorporation of **Circular Engineering** in the Prefeasibility Engineering stage is the key to optimize the use of Renewable Prefabricated Elements in the structures. The generation of waste at the end of the Cycle of Use of Sustainable Structures is reduced by 80% with the design executed through **Circular Engineering**.

In the Guide **PFP-7** there are the percentage records of 7 different uses of concrete in civil works designs. It is a way to generate traceability on the migration from in-situ concrete to modular solutions with precast registering 3 types of in situ uses of concrete and 4 types of prefabricated elements.

En total son 7 diferentes usos de hormigón los que están registrados. Tres partes sobre hormigón in situ y cuatro partes sobre las diferentes tipologías de Elementos Prefabricados Renovables. El prefabricado tiene muchas variantes, desde Productos Estándares de hormigón armado de 15kg hechos a máquina, hasta Elementos Prefabricados de hormigón armado de más de 25.000 kg de peso hechos a la medida.

En la planificación y coordinación de la producción y suministros, la división en 4 Tipos de Prefabricados facilita la trazabilidad y el cumplimiento de los objetivos de la obra.



An example of elements Type 2 that are not connected, has been developed by **VDB® Ingeniería Circular** to manufacture concrete foundations for parking lots for buses, pick-up trucks, vans, and other vehicles (Figure 1). These are industrially produced slabs that incorporate the parking curb wheel stopper, which also can function as an integrated pavement slab to generate the boardwalk on the side of the roads. This eliminates the installation and replacement of bolted rubber or plastic beams and changes them into concrete, generating a monolithic concrete slab with beam without any joints. It is a sustainable design for the various Cycles of Use of pavements in ports, parking lots for mining sites, fuel stations, energy Substations to name a few. It is all part of an Engineering aimed at satisfying the needs of the present without compromising the needs of future generations at a sustainable level.

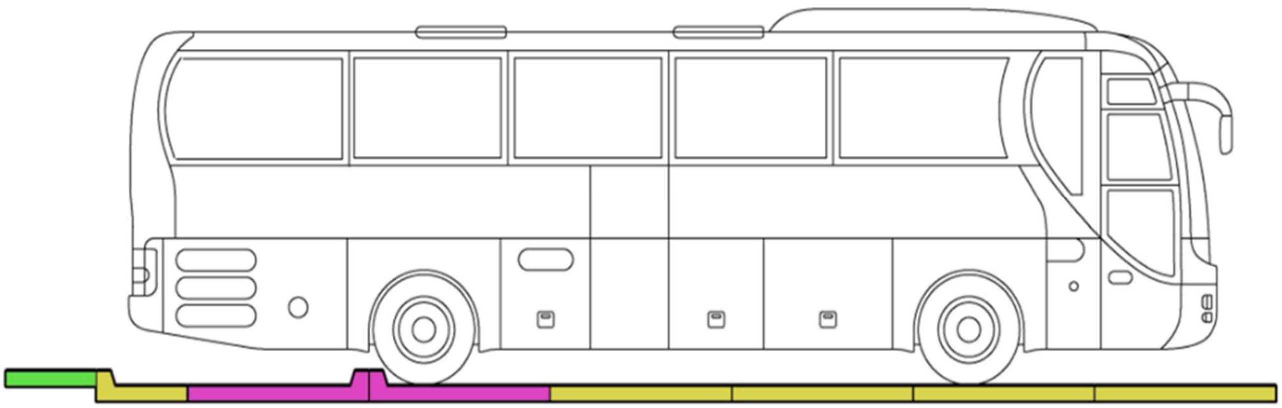


Figure 1: Prefabricated pavement slabs with built-in Curb Wheel Stopper.

When a structure is segmented and, therefore, contains more than one Precast Element, the design process must include the way to join them together to generate the most efficient and safe way to materialize the assembly and disassembly of the structure. For example, a one-span frame for a shed consists of two columns, a top beam and other secondary structural elements that serve for cladding. The three Main Structural Elements are the ones that support loads, such as the self-weight of the complete structure (beam, roof, etc.), the weight of snow, wind pressure, seismic stress, among others, while the secondary elements only transmit specific loads to the main elements. In this way, it is possible to recognize Primary Structural Prefabricated Elements, as well as Secondary Non-Structural Prefabricated Elements.

With Type 3 Precast Elements that use "cast in place" concrete connections, an overlap is generated between the steel bars of the column reinforcement and the beam; in addition, bars are added to complete the confinement of the concrete in a cage type structure. This area of the joints is then covered by molds to confine the area and fill the space with concrete. The use of fresh concrete to complete the joint generates a monolithic connection between the Precast Elements. These types of joints are made on site and at the end of their first use the concrete of the joint must be demolished and removed to be able to disassemble the structures.

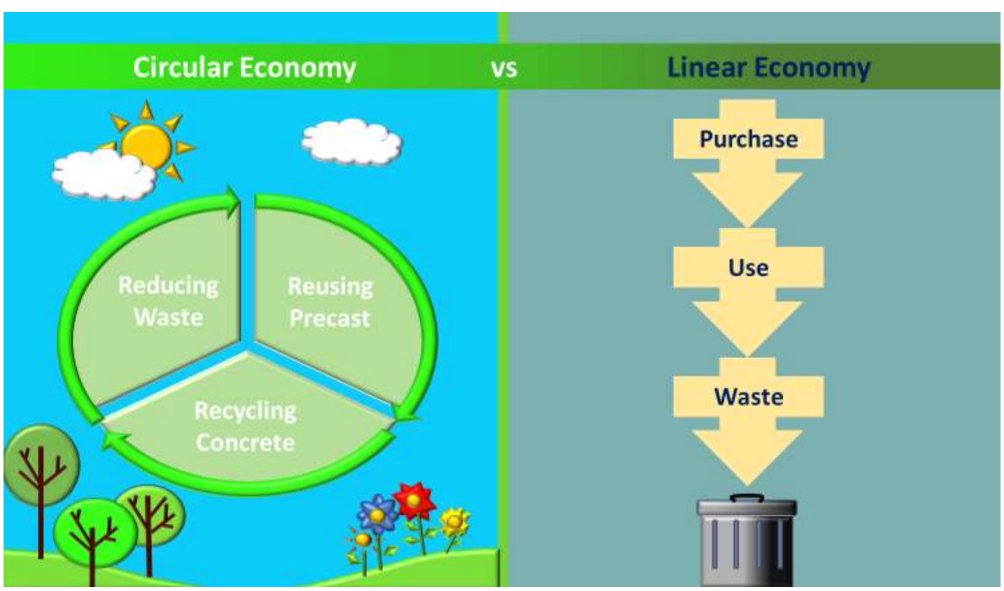
Precast Elements of Type 4 are assembled using mechanical connections, do not require or use cast-in-place concrete, but use metal connections, such as steel plates with bolts. The part of the structures that make up the joints always require the adding of Material, never subtracting material compared to a traditional completely cast on site structure. A monolithic reinforced cast-in-place concrete frame has less steel and concrete weight in the connection zone than when segmenting into two columns and a beam with wet connections. When generating a load transfer with mechanical joints between the precast elements, a technically appropriate behavior of the total modular solution must be achieved. To achieve the goal of an equivalent bond between precast elements, the addition of materials with specific characteristics is required to function properly. The benefits of using prefabricated elements are based on applying a new execution method that allows assembly and disassembly, reducing execution times and generating a safer construction, with less personnel on site only for the on-site assembly. This is achieved if the technical knowledge is correctly incorporated in the design and fabrication of the joints between the Prefabricated Elements.

Generating more field assembly and less traditional concrete construction work on site, using the **PFP® Precast Full Potential** method, allows for positive contributions in the social, economic, and environmental fields. Some examples of these positive contributions are the production of Prefabricated Elements in the vicinity of the projects, training and using local personnel; less transportation of people to distant sites or high altitude, generating lower costs for the client; and the possibility of dismantling the structures in for example large-scale mining after their first use, eliminating a large part of the concrete as an environmental liability, thus complying with new environmental laws. The Precast value chain shown on page 8 makes the project data visible in the Engineering stage and adds value at each step with the cooperation of the professionals of each supplier company, achieving the delivery of civil works in precast reinforced concrete with the quality and in the time required by the client for its projects.

To make the transformation of Civil Engineering to a greener and more sustainable designs and structures in concrete can be achieved incorporating the new knowledge of the **PFP® Precast Full Potential** methodology.

The new knowledge and ways of doing engineering indicated in the five fundamental pillars, allow the reduction of the environmental liabilities related to concrete and allow for traceable flows of materials due to recycling or reinforced concrete and prefabricated elements that can be reused time and again.

Incorporating the values and objectives of the **Circular Economy** in the Civil Engineering of concrete structures and at the same time generating **Renewable Investments** to ensure higher profitability, is possible with the designs using the methodology **PFP® Precast Full Potential** creating Prefabricated Modular Structures with several cycles of use.



Glossary

Renewable Investments - Generate investments in reinforced concrete civil works that over time continue to generate value for investors and owners. This is possible when the investment conditions stipulate the need for the presence of reuse, recycling, and generation of new raw materials in **a new way to manage Civil Engineering designs and engineering.** From early stages in the projects, it is necessary to generate the visualization of the economic values that concrete structures maintain after their first use.

Environmental Liability - The concept of Environmental Liability can be defined as that environmental situation that were generated by man in the past or in the present and future, that can generate a progressive deterioration of this situation over time, representing a risk to the environment and the quality of life of people at present and/or in the future. For example, a reinforced concrete structure left abandoned on a site that can remain there for centuries and/or collapse over time.

Residual Waste - The word residue (from the Latin residuum) describes a material that loses its usefulness after having fulfilled its mission or having served to perform a certain job. Residual wastes are products and materials that cannot be reused or recycled at this time.

Sustainability - In ecology, sustainability describes how biological systems remain productive over time. It refers to the balance of a species with the resources of its environment. In construction, the noble material of reinforced concrete does not need to generate waste because it can be kept in the environment and be reused or recycled repeatedly. Crushed concrete generates new aggregates and steel bars become scrap to enter a new cycle to produce steel.