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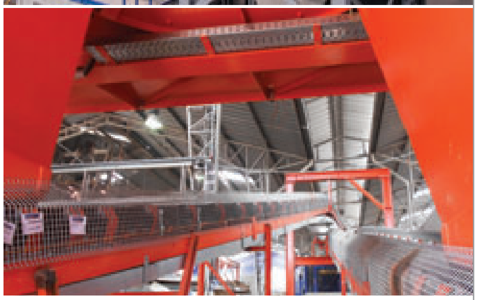


A first approach

Towards sustainable civil engineering works using precast concrete solutions

Most of the achieved advances related to define standardized methodologies to quantify the contribution to "sustainabilize" the construction are linked to buildings rather than infrastructures, and much more in particular to housing. Global impact on housing is the widest and highest one, gathering the three sustainable axis: environmental (greenhouse gas emissions derived from heating or cooling to reach indoor comfort conditions), social (home is a basic need for families) and economic (it usually represents the main expense over the life of people). Meanwhile civil engineering work has not evolved as long on this topic. Although we generally refer to greater constructions, sustainable impacts are more diffused and don´t have such a direct repercussion into the citizens and daily life. For this reasons, there are not as many assessment methods for civil engineering works as there are for buildings, or even any literature regarding this field. Therefore it may implies a technical and promotional handicap to promote a higher use of precast concrete elements in a sort of constructions governed by engineers that usually appreciate better their performance advantages. This article pretends to describe the strengths that precast concrete construction will have into the upcoming standards for civil engineering works, in order to enhance their possibilities to reach a greater market share. Sustainable indicators on current draft standards will be assessed.

■ Alejandro López-Vidal,
ANDECE – Asociación Nacional de la Industria del Prefabricado de Hormigón, Madrid, Spain
Víctor Yepes, Universitat Politècnica de València, Spain ■

The reason of the sustainability

Concepts of sustainability and sustainable development are mentioned in nearly every activity related to the use of resources, energy or the outdoor environment. But they are not new terms, having evolved significantly over the last few decades until having such an enormous importance in many decisions to be taken nowadays, especially on those countries or economies more developed where the concerns about consequences of climate change, lack of energy or demographic growth are crucial matters.

Construction has a tremendous influence from the economic, social (as employment generator, or as a way to solve some of basic needs of people, like housing or infrastructures) and environmental (use of natural resources, energy, or damages to the environment) points of view.

Governments are more conscious each time about the current construction model can (and must) improve quite much:

- Greenhouse gases: ↓ 30 – 40%
- Water consumption: ↓ 12 – 20%
- Primary energy consumption: ↓ 35 – 40%
- Raw material consumption: ↓ 30 – 40%
- Land occupation: ↓ 20%

It is clear that making constructions "greener" will have a significant impact on general goals of administrations and the whole society. However, most of the construction rules qualified as sustainable are not new at all being some used in the long past when a more responsible use of the available resources was surely made, there was either not another possibility or the absence of a culture to make some architectonic excesses that we have looked recently.

But sustainable approach may also run the risk to be misunderstood due by a certain excessive use. We are living times that many construction products are directly defined as sustainable so a more moderate use of this concept should be made. By this way, we must be very careful with the interpretation and the acceptation of everything provided as sustainable, putting it on the right context. For instance, timber is always presented as the most sustainable one against other construction materials, not taking into account any factor such as the climatic, social, economic and cultural context of the location where the material is used, causing sometimes skepticism about the concept itself.

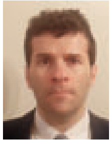
Sustainability measurement framework

Several procedures are already available to assess how sustainable is a building or an infrastructure. They may be divided into private methodologies and standardized models. Two principal private certification systems are BREEAM [1] which was the first building certification process developed in 1990 in the UK by the Building Research Institute; and LEED [2], developed in 1996 and operated by the U.S. Green Building Council. Both rating systems are expanded worldwide. SBTool (Canada), HQE (France) or DGNB (Germany) are other applicable certification systems. One common aspect to all of them is that they are addressed to buildings.

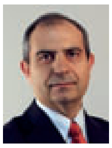
For the sustainable assessment of infrastructures, certification methodologies like CEEQUAL or SUNRA are remarked.

The recent proliferation of these procedures makes it difficult to make meaningful comparisons between programs, or even between environmentally-conscious construction and traditional construction. As a reaction to such numerous methods for measuring the environmental (sustainable) performance of products, the main standardizations organizations worldwide, CEN (European Committee for Standardization) and ISO (International Organization for Standardization) are now developing their own standards. ISO deals with sustainability aspects on their committees TC207, ISO TC59 SC17 and ISO TC71SC8. While CEN through its TC 350 focuses on sustainability of construction works, having a group specifically devoted to civil engineering works issues (CEN/TC 350/WG6).

The assessment methods for environmental, social and economic performance of civil engineering works given in the standards take into account performance aspects and impacts that can be expressed with quantifiable indicators, which are measured without value judgements and which lead to a clear result for each indicator.



■ Alejandro López-Vidal (1978) graduated in Industrial Engineering at the Universidad de León. He has performed some charges in ANDECE (Spanish Precast Concrete Association) since 2008, being chosen as Technical Manager in 2013. He is member of several organizations related to precast concrete industry such as the Technical and Environmental Commissions of BIBM or being the Spanish Delegate within the CEN/TC 229. As interesting remarks, he holds the technical secretary of the Spanish mirror committee of CEN/TC 350 for building matters and he is working with the Task Group 6.15 of FIB which is developing a new document about "Sustainability of precast structures"



■ Víctor Yepes (1964) is Civil Engineer and Associate Professor at the Universitat Politècnica de València, where he received his PhD. He is currently involved in several research projects related to optimization and life-cycle assessment of concrete structures. He is currently teaching courses in construction methods, innovation and quality management. He is also the academic director of the MSc in Concrete Materials and Structures. He is senior researcher at the Concrete Science and Technology Institute (ICITECH) and leads the Research Project BRIDLIFE: "Decision-making in the life-cycle management of prestressed bridges in terms of social and environmental efficiency and under restrictive budgets."

ISO 21931-2 [3] and EN 15643-5 [4] are the standards, which set out the framework for methods of assessment of the sustainability performance of civil engineering works. Both standards are still under discussion so their approvals won´t happen until 1 or 2 years.

Moving to a product level, ISO 21930 [5] and EN 15804 [6] must be highlighted. Both standards present a similar format. They provide core product category rules (PCR) for Type III environmental declarations for any construction product and construction service, defining the parameters to be declared and the way in which they are collated and reported, the stages of a product's life cycle that are considered in the EPD, the rules for the development of scenarios. This standards set up the basis to estimate the values corresponding up to more than 20 environmental parameters, that can be gathered into three main groups: Environmental Impact Indicators (Global Warming Potential, Ozone Depletion Potential, Acidification potential, etc.); Resource Use Indicators (use of renewable primary energy, use of non renewable primary energy, use of net fresh water, etc.); and Waste Category Indicators (hazardous and non hazardous waste disposed, Radioactive waste disposed). The assessment of social and economic performances at product level is not yet covered by European standards, at least through European scale.

And in particular, the European Standardization Committee for precast concrete products CEN/TC 229 has just initiated the works to define a specific product category rules (PCR) guidance for the development of Type III environmental declarations for precast concrete products according to EN 15804.

It is also important to remark the following fact. Against the approach followed by most of construction materials which only declare their environmental parameters up to the end of production process, no taking into account the rest of impacts (which is called as cradle to gate option), precast concrete products environmental declarations will be based on the cradle to grave option, showing the users all the impacts obtained along the whole life cycle until even the deconstruction and possible reuse of the elements in another structure at some time in the future.

Role of the precast concrete solution to increase the sustainability of the civil engineering works

There is increasing demand for construction options that will contribute to achieving sustainable development so the precast industry

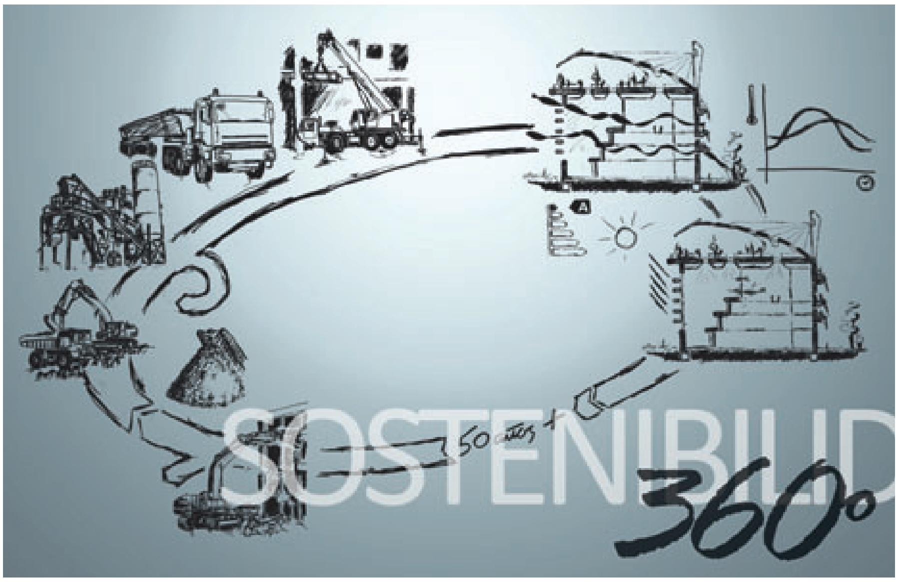


Figure 1: Life cycle that illustrates the whole process of the construction using precast concrete elements

Table 1: Precast concrete elements for civil engineering works, following the clause 5 of ISO 21931-2 [3] draft

Civil engineering works fields	Infrastructures	Precast concrete elements
Industrial processes infrastructures	Power generation plants	Walls or any other precast concrete structure
	Utilities for conveying electricity, gas, water, etc.	Pipes, manholes and inspection chambers, curb inlets and catch basins, box culverts
	Water and other treatment systems	Wastewater and septic tanks, grease interceptors
	Energy generation and supply	Masts for wind turbines, electrical lines, telecommunication lines, supports for lighting, etc.
Linear infrastructures	Bridges	Deck elements, girders, piers, abutments
	Footbridges	Any element is prefabricable
	Highways	Safety barriers, paving slabs, sound walls
	Railways	Sleepers, slab tracks
	Tunnels	Vaults, segmental linings
Dams and other fluvial works	Canals	Precast slabs and walls
	Flood defence	Retaining walls systems
Maritime works	Harbour	Slab berth, pavements
	Breakwater	Solid blocks for levees
Other civil engineering works	Public realm works	Pavements, urban furniture

is becoming more resource efficient and environmentally aware and how its products can contribute to achieving greener construction.

The concept of civil engineering works includes a wide range of projects, in which the precast concrete elements play each time a more relevant role:

The sustainable design of buildings is different as an infrastructure has. While in the first case some requirements like fire resistance, thermal or acoustic insulation are essential, civil engineering works are moving on different criteria. Actually, there is a different distribution of the importance of the life cycle stages. While the operational phase in buildings is the main one (responsible of around the 80% of the total carbon footprint), in infrastructures the construction usually implies greater impacts rather than the service period.

Some of the assumed sustainable aspects were already intrinsic part of the manufacturing process of precast concrete products carried out for the last few decades, like the correct use of the materials or an increased use of high strength concrete, but precast concrete elements have still a big potential of growth:

Practical cases

Two important international companies like FCC and ACCIONA must be underlined. FCC has its own sustainability assessment methodology for civil works, called SAMCEW, which has into account the experience learnt from its own system of sustainability management for the last years. It is based on a methodology of flexible analysis depending on the type of civil work, the location, the project characteristics or the evaluated phase, which will decide what parameters will have more impact than others. ACCIONA have carried out some interesting initiatives based on the quantification of the sustainability rate of works, becoming an international pioneer of the development of Environmental Product Declarations for infrastructures, as the railway bridge "Arroyo Valchano" [7] for the high-speed line between Madrid and Galicia which included an analysis of all materials used from cradle to gate, or the road span of the N-340 in Elche.

Description of the railway bridge "Arroyo Valchano"

The railway bridge is a double track railway and it is built only for transportation of

Figure 2: Sleepers and segmental linings play a essential role in the construction of railway lines and tunnels as it is currently happening in two of the biggest works at the new crossing of the Bosporus Strait in Istanbul and the new Crossrail line in London

passengers. The board consists of precast beams and a slab "in situ" with the following span distribution: 35 + 5x45 +35 = 295 m. The beams have 14 m wide slabs and over them, an "in situ" slab of variable thickness. The functional unit is one meter of bridge.

System boundaries and data quality

The EPD covers bridge "structure" only. LCA of the railway bridge mainly consists of the production of different materials used and on site construction of the bridge (including transport from production site to work area). Operation, maintenance and end of life have not been taken into account.

Environmental performance

Selected generic data for raw material production and fuel production and combustion were taken from PE databases within GaBi 6 software. The results are given over a calculation period of 60 years.
At a research level, it should be underlined the work "Cost and CO_2 emission optimization of precast–prestressed concrete U-beam road bridges by a hybrid glowworm swarm algorithm" [8]. This research describes a methodology to optimize cost and CO_2 emissions when designing precast–prestressed concrete road bridges with a double U-shape cross-section. To this end, a hybrid glow-

Table 2: Several advantages of precast concrete elements for civil engineering works, analysed from triple dimension of sustainability

Precast concrete characteristics	Environmental	Social	Economic
Durability (increased useful life)	Good long-term solution means the preservation of natural resources, reduction of impacts, energy savings and increased potential for extracting natural resources	Longer life of infrastructures means less disruptions for citizens	Initial costs are amortized along a longer period Less maintenance (fewer costs)
Industrialization	Lean construction: nearly no waste Dry construction: precast concrete arrives on site ready for installation	Increased safety: fewer labour accidents	Sooner refund of loans
Resource efficiency	Reduction of the consumption of natural resources by using waste materials in products (ex. recycled aggregates from concrete wastes)	Partial elimination of a global problem	Increased use of better materials(high-resistance/performance concrete, prestressed steel) means an optimized ratio materials/cost
Increased use of self-compacting concrete (SCC)	Reduces its electricity consumption	No vibrations makes the factory much quieter and safer	
Raw materials origin	Local supply network means travel distances are shorter and so the carbon footprint is reduced All the materials come from natural and recycled sources, mainly inorganic	Materials are available locally, enhancing regional economies and employment	
Carbonation	Reabsorption of CO_2 from the atmosphere	Partial elimination of a global problem	
Photocatalysis	Diminish the air polluting effect by exhaust gasses (NOx, etc.)	Reduction of respiratory diseases	

worm swarm optimization algorithm (SAGSO) is used to combine the synergy effect of the local search with simulated annealing (SA) and the global search with glowworm swarm optimization (GSO). The solution is defined by 40 variables, including the geometry, materials and reinforcement of the beam and the slab. Regarding the material, high strength concrete is used as well as self-compacting concrete in beams. Results provide engineers with useful guidelines to design PC precast bridges. The analysis also revealed that reducing costs by 1 Euro can save up to 1.75 kg in CO_2 emissions. Finally, the parametric study indicates that optimal solutions in terms of monetary costs have quite a satisfactory environmental outcome and differ only slightly from the best possible environmental solution obtained.

Upcoming challenges of the precast concrete industry

The precast concrete industry acknowledges that has not only a responsibility to improve its performance on sustainability demands but this global approach should serve as a way to increase its competitiveness, being an ideal basis to enhance all its potential in terms of the characteristics described above, which are really appreciated by designers, owners, builders, insurers and even final users.

One of the apparent weaknesses of the concrete products is the cement, and in particular the clinker which is responsible of such a high amount of CO_2 emissions. By this way, the precast industry works hard to improve the efficiency of cement use by maximising hydration and by optimising cement content to reduce embodied CO_2. The use of other cementitious materials such as ground granulated blastfurnace slag and pulverised fuel ash is also growing. Both these additions have much lower embodied CO_2 than Portland cement. [9] Sustainability in precast factories is about improving resource efficiency, reducing waste and ensuring that standards such as ISO 14001 and EMAS are maintained.

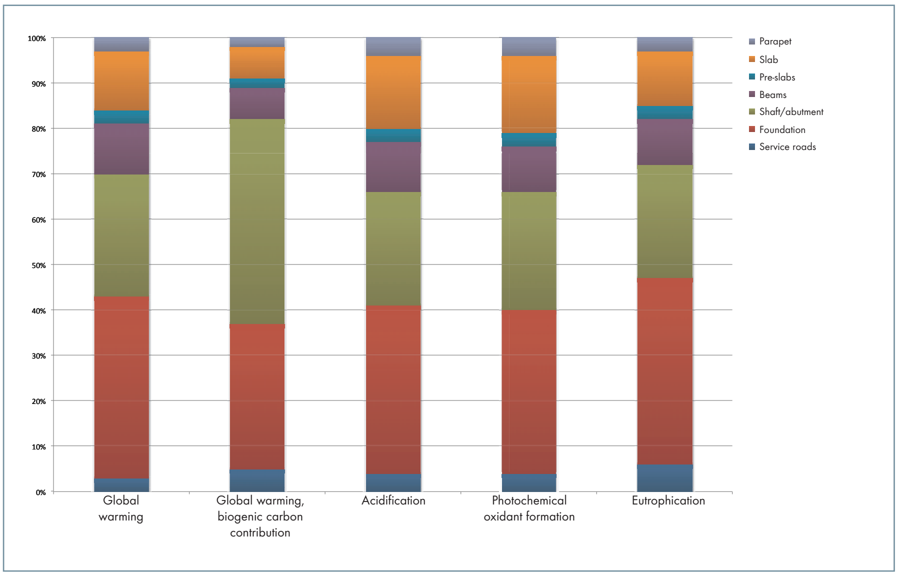


Figure 3: Impact categories for construction of 1 m of "Arroyo Valchano" railway bridge

New factories incorporate major recycling systems to re-use the water or any other material waste. None of this would be possible without the sector's highly skilled and dedicated workforce who are critical to its success and, in many cases, are the driving force behind advances in energy saving techniques, recycling initiatives and local community liaison programmes.

The "Precast Sustainability Strategy and Charter" from the British Precast Concrete Association must be underlined [10]. It was first introduced in 2007 with only 17 companies signing. Today, and as part of the "Raising the Bar" initiative, all full member companies of British Precast are now committed to the Precast Sustainability Charter. It is to encourage member companies of the Association to go beyond legislation and take voluntary actions to make their products and operations more sustainable. In order to meet this aim, a set of sustainability principles has been developed based on the key sustainability issues facing the precast industry. First period of analysis was from 2008 to 2012 and 12 of 14 affixed goals were achieved. In 2013, the British Precast Council approved a new set of targets by 2020 based on 2012 as the baseline year:

- Reducing overall kWh/ tonne of energy used in production by 10%
- Reducing CO_2 emissions for production by 20%
- Reducing overall factory waste by 10%

Figure 4: Construction of a maritime bridge using precast concrete box girders

- Reducing factory waste to landfill to < 0.5 kg/ tonne
- Increasing the proportion of alternative cement additions (as a % of total cement) to 25%
- Increasing the proportion of recycled/ secondary aggregates (as a % of total aggregates) to 25%
- Reducing mains water consumption by 20%
- Reduction in accident frequency of 50% between 2015 and 2020
- Increasing the tonnage, as well as production sites, covered by an EMS (e.g. ISO 14001) to 95%
- Increasing the tonnage, as well as production sites, covered by a quality system (e.g. ISO 9001) to 95%
- Increasing the tonnage, as well as production sites, covered by a Responsible Sourcing standard (e.g. BES 6001) to 95%
- Reducing the convictions for air and water emissions to zero
- Improving the capture of transport data up to 2015 (A target will be set for 2016)
- Increasing the % of employees covered by a certified management system (e.g. ISO 9001/ ISO 14001/ OHSAS 18001) to 100%
- Increasing the % of employees covered by MPA Safer by Competence training and qualifications to 100%
- Maintaining the % of relevant production sites that have community liaison activities at 100%

Other important issue to be dealt with will be the compliance of the precasters with the new essential requirement "Sustainable use of natural resources" according to the Construction Products Regulation [11]. The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and in particular ensure the following:

- Reuse or recyclability of the construction works, their materials and parts after demolition
- Durability of the construction works
- Use of environmentally compatible raw and secondary materials in the construction works

The industry is assessing how best to present clear Life Cycle Analysis (LCA) data, potentially in the form of verified Environmental Product Declarations (EPDs) which comply with new European Standards that will ultimately feed into Building Information Modelling (BIM) systems. This will allow designers to achieve measurably low impact buildings and infrastructures based on reliable whole life data. This will also serve the manufacturers to optimize their production processes throughout a higher resource efficiency (materials, water and energy), the minimization of waste and even the innovation to use alternative sources of energy or materials.

This environmental (sustainable) concern shall become a progressive stimulus to all the enterprises. This approach is been introducing by means of the decisions taken derived from public procurement procedures as it happens in Sweden or Norway, or more recently in the region of Basque Country (Spain) which stands for the use of precast products as a way to no producing wastes.

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FURTHER INFORMATION

ANDECE – Asociación Nacional de la Industria del Prefabricado de Hormigón
Paseo de la Castellana 226, Entrep. A
28046, Madrid, Spain
T +34 91 323 8275
F +34 91 315 8302
tubos@andece.org
www.andece.org
www.atha.es