EUROPEAN CONCRETE PAVING ASSOCIATION

Safe, robust and sustainable road restraint systems – the case for concrete safety barriers

The European Commission's goal is to achieve zero road deaths by 2050, which is referred to as 'Vision Zero'. Safe infrastructure is one of the pillars of this approach and road restraint systems play an important role in this, both in the central reservation and on the verge of the road.

At the same time, the European Green Deal is obliging our society to strive for climate neutrality by 2050 and this involves material producers and equipment manufacturers.

And then there is the Circular Economy Action Plan, introducing legislative and non-legislative measures to ensure the EU transitions towards a circular economy, reducing the pressure on natural resources.

Finally, let us not forget the broader picture of 'sustainability', the umbrella term for all the economic, environmental and social aspects.

This paper describes how the industry for concrete safety barriers (CSBs), both precast and in-situ cast, is tackling these challenges.

Concrete Safety Barriers, both in-situ cast and precast, fit into the wider concept of sustainability.

Concrete safety barriers have a long history: the New Jersey barrier was first used in the US in the 1950s and in Europe since the early 1970s. Already at the time, the combination of safety, durability and low maintenance was decisive for the worldwide adoption of this solution. A considerable number of these in-situ cast concrete safety barriers built around 40 to 50 years ago are still in place and contribute to safety on our roads. Longevity is an intrinsic feature of many concrete structures, the importance of which we will demonstrate further in several areas.

What are the arguments for the CSB industry to ensure its products are sustainable? Let us first consider **the social aspects**, which are mainly covered by the core function of vehicle restraint systems: their **safety performance**. Then, we'll look at the **economic aspects** and finally the **environmental pillar**, with a separate focus on **carbon neutrality and circular construction**. It will also become clear that "robustness" of a road restraint system - the extent to which performance is guaranteed regardless of conditions such as the substructure or even a collision - is an important characteristic in all these fields.

Social aspects

The goal of road restraint systems is to make our roads safer. But there are many different types of roads, types and volumes of traffic, and situations, e.g. obstacles on the verge of the road or in the median reserve. This also means that the right product must be installed in the right place. CSBs, just like steel guardrails, have been adapted, improved and sometimes reinvented to ensure better performance in terms of safety and durability. Safety performance of CSB and steel guardrails is mainly characterised by the containment level, working width, vehicle intrusion and impact severity, which are all described and regulated in standards EN 1317-1, -2 and -5. Today, a wide range of CSBs are available, both precast and cast in-situ, covering almost all classes of the mentioned characteristics. For in-situ CSBs, the combination of high/very high containment with the lowest classes of normalised working width is an important benefit. In addition, their performance, when installed on a concrete or asphalt base, is not dependent on subgrade conditions, such as wet saturated or hard frozen soil. On the contrary, CSBs' excellent performance is very constant and hardly changes, with slight variations in material properties or substructure. That is essential for a robust system and typical for CSB.

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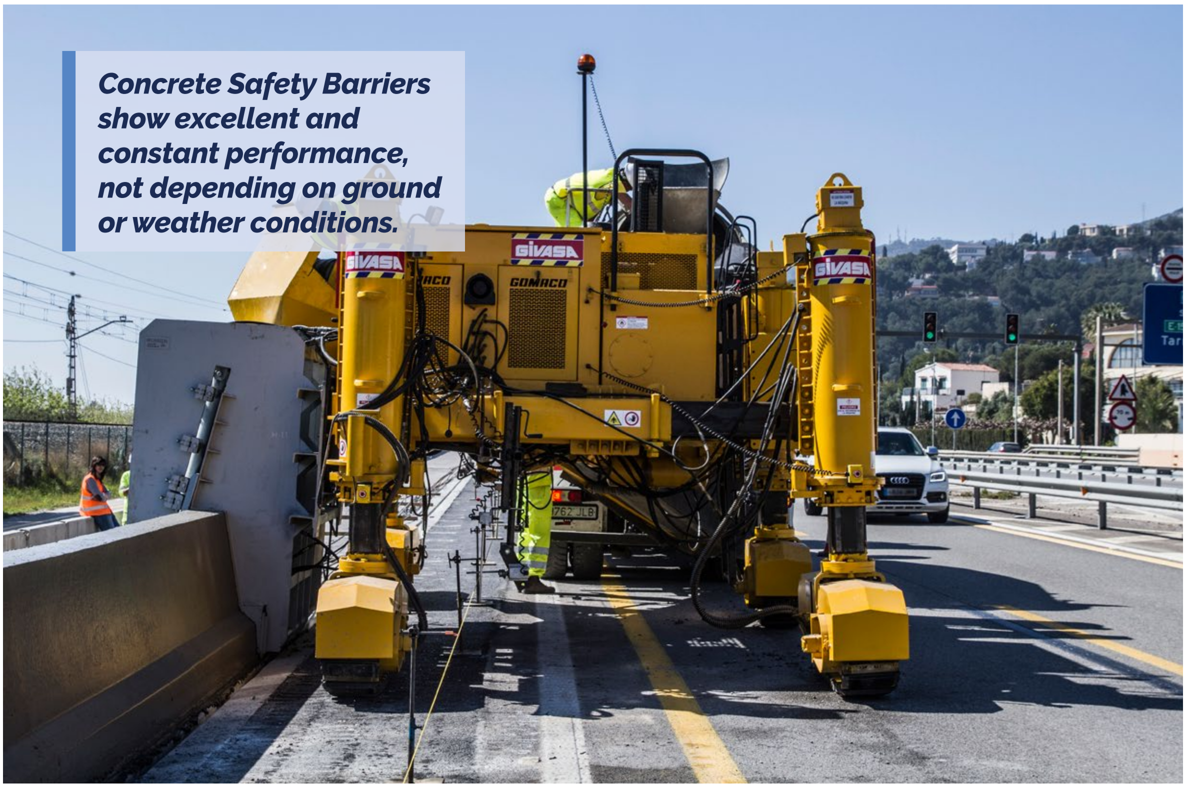

Concrete Safety Barriers show excellent and constant performance, not depending on ground or weather conditions.

Illustration of the robustness of an in-situ cast concrete safety barrier. These photos show a system which underwent in total three impact tests: TB11, TB32, TB51 (N2, H2, L2. No dynamic deflection was measured, no damage, which would have required repairs, was observed. The left picture shows the concrete barrier after the last impact – the TB51. All three impacts were driven into the same impact location.

What is also important to road users is the availability of the road. A sustainable road is a road that is open to traffic with minimal hindrance. Two aspects are important here: CSBs hardly require any maintenance and they almost never need repairs or replacement. The low level of maintenance is due to the very high durability of the system, thanks to the quality of the concrete mix and the corrosion protection of the steel reinforcement and other steel parts (in regions where the climate necessitates this). Therefore, the joints do not even need to be sealed. The fact that there are hardly any repairs is a consequence of the robustness of most concrete systems, mainly cast in-situ solutions. In other words, most systems have a high integrated reserve, allowing them to continue to perform after most accidents where a barrier gets hit. This has also been demonstrated in crash tests where a barrier has been hit twice by a heavy vehicle at the same impact point, with success. Altogether, this results in higher availability of the road restraint system and consequently of the road, making CSBs an ideal solution for the central reserve.

Economic aspects

The abovementioned benefit of low maintenance and few repairs also entails fewer costs in the operational phase. Together with the products' long life, it is clear that CSBs' total life-cycle cost is low. The minimal repair work results in less traffic disruption and thus offers significant ecological and economic benefits. Thanks to this robustness, CSB have in most cases a lower life-cycle cost in comparison with equivalent steel systems. Availability becomes an economic benefit in the case of PPP projects, where unavailability leads to penalties.

In addition, the concrete supply chain is a local market and that is important. First, that has financial importance; it provides income for citizens and for the government through taxes. But the importance is much broader; local economy also has social and environmental importance. When local production and use are closer together, there is less need for transport with its attendant drawbacks. It also allows a circular economy more easily; just think of recycled concrete aggregates that can be reused in new concrete. And competition is well assured thanks to a wide geographic availability of concrete plants and manufacturing units.

Environment

The focus will here be on climate neutrality and circularity.

The impact of cement production on CO_2 emissions is well-known, resulting from the inevitable $CaCO_3$ to CaO chemical conversion process, and from fuel combustion. But this is just a small part of the whole story. A building product's environmental impact of must be assessed according to the standards ISO 14040, which is the basis for an LCA (Life Cycle Assessment), and EN 15804, providing core product category rules (PCR) for environmental declarations for any construction products or construction services. This approach shows the importance of a holistic approach, taking all life stages into consideration, including the use phase in a cradle-to-grave concept. Among the many possible environmental indicators, the GWP (Greenhouse Warming Potential), expressed in kg of CO_2-equivalent, relates to climate change. What are the positive characteristics of CSBs that counteract the GWP and what action can be taken to improve the results?

- Choice of cement type: concrete mixes for road construction, including CSBs, can accommodate low-carbon cement types using secondary materials (fly ash and slag) recycled from other industries, resulting in equal performance. The whole cement industry worldwide is working actively on the further research and development of new cement types and alternative binders.

- Short transport distances: concrete is made from local materials and in many European countries, a lot of precast concrete factories and ready mixed concrete batching plants are available.

- Barrier design: double-sided CSBs can be used in the central reserve, working for both carriageways and minimising the amount of material needed.

- The long service life – 50 years – is again of crucial importance since that is the period of GWP assessment. No reconstruction is needed in that period.

- Cement (re)carbonation (or "carbon uptake": this refers to the process whereby CO_2 is reabsorbed by the hardened concrete. For CSBs, this is a very slow process during their service life because of the high quality of that concrete. At the end of their life, the CSBs are demolished and the concrete is then crushed. Its exposed surface area increases and this in turn increases the carbonation rate.

Today, there are already CSBs on the market which have a carbon footprint that is barely 50% of conventional solutions thanks to a reduced-carbon concrete composition, a lightweight design with minimal concrete and steel, and minimal transport distances, and this comes with unaltered safety performance. The carbon footprint is 4 to 5 times lower than for equivalent steel systems!

Availability of the roadway is important for both road users and road authorities.

Key facts for Concrete Safety Barriers

- Consistent performance and durability up to 50 years
- Not dependent on ground conditions
- Several solutions with no dynamic deflection, with or without backfilling
- Hardly needing repair after impacts of vehicles
- Offering the highest availability of the roadway

Let us now take a look at the transition to a circular economy. Circularity is about much more than just recycling materials. In a simplified way, the circular construction ladder defines a number of levels in descending priority: prevention – reuse – repair – recycle – waste disposal. What role do concrete safety barriers play in these different stages?

- Prevention: this is an aspect where the long service life of concrete products and structures especially comes into its own. Indeed, the most resource-efficient road equipment is equipment that is rebuilt once every 50 years, rather than every 25 years.

- Reuse: this is typically what is done with precast CSBs, particularly when they are used in work zone areas, but also when roads are redesigned or rebuilt. The concrete elements can be removed, stored and be put back in service after quality control and small repairs if necessary. Reuse may not seem possible for in-situ cast CSBs, just like most of the other types of road restraint systems. However, an innovative "overlay" process enables you to create a new barrier profile by pouring a lining of new concrete over an existing, old CSB. A brand-new safety barrier can be achieved with a minimum amount of new material.

- Repair: depending on the type and degree of damage, both precast and in-situ cast CSBs can be repaired. Obviously, heavily damaged precast concrete elements or sections of cast in-situ CSBs simply need to be replaced. However, minor cracks or chipped pieces of concrete can be treated or repaired.

National regulations mostly define the maximum allowable length and width of the cracks and the dimensions or weight of the detached parts that can be repaired. Cracks can either be treated like a joint, by creating a joint groove and sealing it, or they can be injected with a polyurethane liquid for example. An innovative way of treating shallow cracks is the use of a self-healing liquid repair, a spin-off from the research into self-healing concrete. The mechanism is based on limestone-producing micro-organisms (bacteria). If the bacteria come into contact with oxygen and water, they will convert nutrients into calcium carbonate (limestone).
Also, for a complete repair of an in-situ cast CSB consisting of a full replacement over a certain length, guidelines are available, mostly provided by the licence holder. The main principle is to ensure the continuity

Repair of an in-situ cast CSB by exposing the existing reinforcement and adding new tie-bars. Rapid-hardening concrete enables a fast and durable repair.

of the longitudinal reinforcement bars or strands. Best practice consists of exposing the reinforcement of the remaining existing CSBs and coupling it to the new reinforcement in the replaced section. Obviously, the concrete quality needs to be at least (strength, durability) equal to that of the initial concrete. Repair times can be significantly reduced by the use of rapid-hardening concrete mixes.

- **Recycle:** concrete is 100% recyclable. Having reached the end of its life, it can be crushed to provide aggregates – sand and stones – for use in new concrete or other cement-bound or unbound applications such as road bases. In all cases, natural resources are saved. In the case of CSBs, the recycled concrete aggregate (RCA) can be considered of high quality, enabling its reuse in concrete for new pavements, other infrastructure or buildings. Thanks to research and technical developments, the number of applications is growing, both for pavements and for kerbs, gutters and safety barriers. This means that the old CSBs can become new ones! Finally, new techniques of "smart crushing" allow for a better separation of aggregates and hardened cement paste in crushed concrete. This results in a better stone quality and enables reuse of the recycled cement, either in the cement manufacturing process or directly in the concrete mix.

- **Waste disposal:** this is not applicable to CSBs.

It is clear that at all stages of circular construction, **prevention-reuse-repair-recycling-waste,** CSB has key strengths to be the best student in the class.

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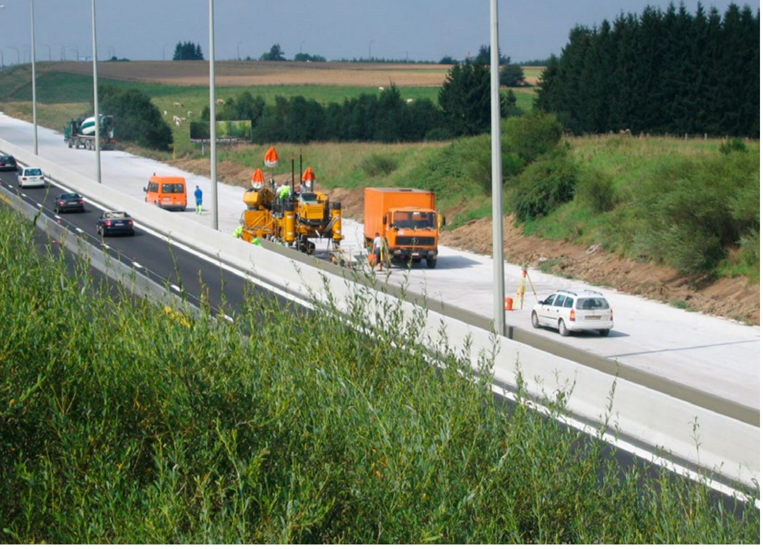
Combination of a precast concrete safety barrier and a noise reducing barrier, offering safety and comfort.

CSBs, both cast in-situ and precast, have been used as vehicle restraint systems for more than 50 years.

Their design and construction have been modified and improved in order to comply with European standards EN1317 in terms of safety and durability, and meet the requirements for savings (competitive design) and the environment (reduced carbon footprint, circularity, land use, etc.) at the same time.

Concrete safety barriers are robust and ready for the future!



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