New Belgian code of good practice for pavements with large precast concrete flags and slabs

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Abstract:
Over the past 10 years, large precast concrete flags and slabs have been increasingly used in public spaces in Belgium, including trafficked areas. This has been a response to new demands of contemporary urban design, looking for creative solutions and architectural effects. In addition to the functional requirements, aesthetic and even environmental considerations have to be taken into account for these applications. However, such applications require specially adapted design and construction methods, differing substantially from "normal" concrete block paving. Moreover, there are no existing technical guidelines in Belgium dealing explicitly with these large size concrete paving flags or precast concrete slabs, which are often used also in areas with considerable traffic loads (industrial pavements, car parks, market places, etc.). That is why the Belgian Road Research Centre decided to form a working group to prepare a set of recommendations for such applications – together with all the stakeholders in the field, such as manufacturers, contractors, architects and designers, public authorities etc. The output of this effort, a new code of good practice for pavements constructed with concrete flags, large size flags and precast slabs, is due for publication in 2019. The first part of this document will present the application areas, which are generally restricted to areas with no or limited heavy traffic, and the various types of product. Subsequent chapters will discuss the design of the pavement structure and aspects related to construction before zooming in on product properties and requirements, including also aesthetic considerations for paving elements. Finally, special applications – including water-permeable pavements – and the maintenance and repair of this type of pavement will be documented. This paper will present a general overview of the new Belgian code of good practice for the design and construction of pavements with normal and large concrete flags and concrete slabs, including some new applications in Belgium to illustrate their success in recent years.
Key Words: concrete paving flag; precast concrete slab; code of practice; design method; concrete products

1. Introduction

BRRC's working group on large size paving elements has been working over the past three years on guidelines for the design, construction and maintenance of pavements with large precast concrete flags and slabs. Below we will give a brief overview of the texts in their current state of preparation, based on a critical review of existing literature, model calculations and empirical methods, Belgian practice and experience, and intensive discussions in the working group.

A durable pavement with precast concrete paving flags and slabs can only be obtained when all the rules of good practice are followed, the entire road structure (not only the slabs or flags) is designed and installed correctly, and the proper materials are used.

2. Application areas and terminology

Large size paving elements are defined as precast concrete flags or slabs with a nominal length of more than 600 mm and length/thickness ratio greater than 4. Pavements with large precast concrete flags and slabs are designed for applications in areas where traffic speed is limited to 30 km/h, such as market places, allotments, industrial estates, car parks, pedestrian areas, etc.

2.1 Application areas

Five categories of traffic loading have been defined as shown in Table 1, where 1 is the category with the heaviest traffic and 5 the category with the lightest. Expected traffic loads are added by way of indication and a lifetime of 20 years is presumed. Depending on the category considered, limitations are set to the dimensions of the precast slabs and a specific choice has to be made for the design of the road structure (see Section 3.1).

Table 1. Categories of traffic loading and indicative application areas

Category	Application	Flags	Large flags	Precast slabs	Loading (max. wheel load)**
1 – Heavy traffic, till 100 heavy vehicles* per day 	Industrial estates		X	X	65 kN
2 – Limited heavy traffic 	Shopping streets and squares accessible to commercial heavy vehicles (deliveries); bus stops		X	X	40 kN - 65 kN occasionally
3 – Light traffic, occasional heavy traffic 	Residential areas; car parks for light vehicles; driveways	X	X	X	20 kN
4 – Light traffic 	Bicycle lanes; pedestrian areas; public spaces not accessible to traffic; private driveways	X	X	X	10 kN
5 – No vehicular traffic 	Terraces	X	X	X	

* = vehicle > 3.5 t.

** 10 kN = light lorries; 20 kN = lorries – fork lift trucks; 40 kN = heavy lorries, partially loaded – buses – fire engines; 65 kN = heavy lorries, fully loaded.



Figure 1. Typical application areas of precast concrete flag or slab pavements

2.2 Product groups

The precast concrete products are classified into different groups according to their dimensions and their length-to-thickness ratio *L/D*:

- traditional concrete paving blocks (NBN EN 1338 [1]): $L/D \leq 4$ and $L \leq 320$ mm;
- large concrete paving blocks: $L/D \leq 4$ and $320 < L \leq 800$ mm [2];
- traditional concrete paving flags (NBN EN 1339 [3]): $L/D > 4$ and $L \leq 600$ mm;
- large concrete flags: $L/D > 4$ and $600 < L \leq 1{,}500$ mm;
- precast concrete slabs: $L/D > 4$ and $L > 1{,}500$ mm.

The new Belgian code of good practice focuses mainly on these last two paving elements.

3. Road design

When opting for a pavement with concrete paving flags, large flags or precast slabs, it is crucial that the dimensions and thickness of the paving elements be adjusted to the expected traffic loading (see Table 1). In addition, the entire road structure including the laying course, base layer, and subbase if present (Figure 2) will influence the thickness design required to withstand occasional or frequent traffic.

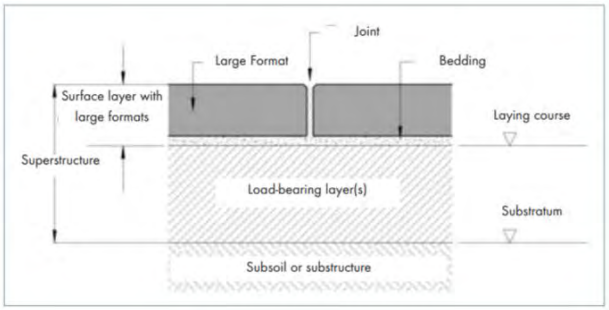

Figure 2. Example of road structure with concrete paving flags, large flags or precast concrete slabs [4]

3.1 Thickness design

The minimum thicknesses recommended in the code of good practice according to traffic loading and the maximum length-to-width ratio (*L/W*) of the paving elements are shown in Figure 3. The values presented are based, on the one hand, on calculations of flexural stresses for square sizes, where the entire road structure (pavement + load-bearing layers) is taken into account such that the maximum permissible stress in the concrete is not exceeded. On the other hand, it has been verified, through the influence of the *L/W* ratio on the breaking load, from which *L/W* value on an increase in minimum thickness is needed, and the thicknesses obtained have been checked against practical experience both at home and abroad. It is important to note here that these are recommended values and that with higher *L/W* ratios than those shown in Figure 3 a specific calculation is needed for the situation at hand.

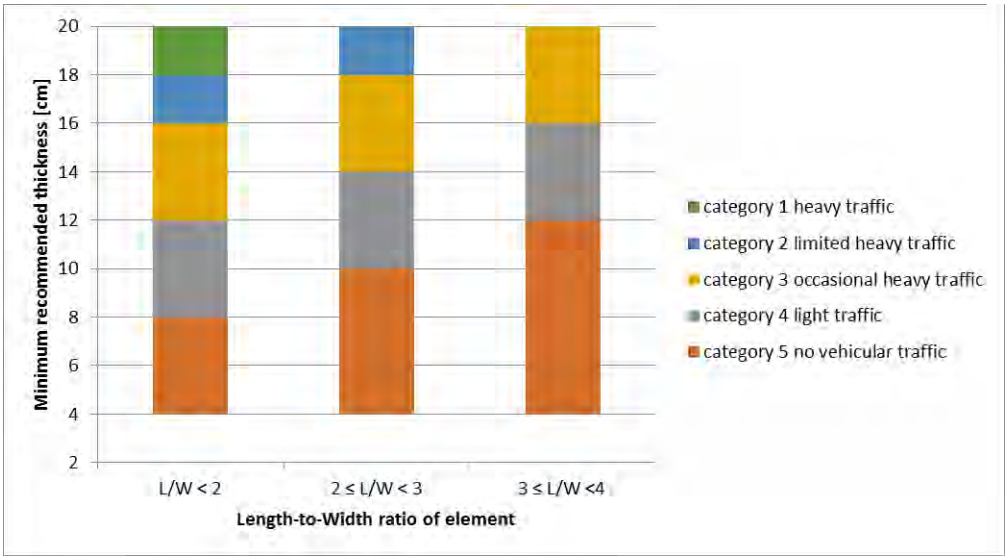

Figure 3. Minimum recommended thicknesses depending on traffic loading (Table 1) and the length-to-width ratio (*L/W*) of the paving elements

3.2 Road structure

In addition to the thickness design described above, other recommendations are made for the entire road structure including subgrade, subbase and base layers, water drainage, laying course, and joint filling material. Table 2 for instance presents some requirements for the laying course material, depending on traffic loading.

Table 2. Recommended laying course materials and corresponding properties

Category	***Laying course material***[1,2]			***Fines content (< 63 µm)***	***Aggregate properties [5]***
	Concrete paving flags	*Large flags*	*Precast concrete slabs*[3]		
1 – Heavy traffic		*Coarse sand 0/4-0/6.3 or crushed aggregates 2/6.3-2/8*	*Coarse sand 0/4-0/6.3 or crushed aggregates 2/6.3-2/8*	*≤ 3 %*	LA_{25}; M_{DE} *20*
2 – Limited heavy traffic				*≤ 5 %*	LA_{25}; M_{DE} *20*
3 – Light traffic, occasional heavy traffic	*Coarse sand, crushed aggregates, river sand (e.g. 0/4)*	*Coarse sand, crushed aggregates, river sand (e.g. 0/4)*	*Coarse sand, crushed aggregates, river sand (e.g. 0/4), sea sand*	*≤ 5 %*	LA_{35}
4 – Light traffic				*≤ 5 %*	LA_{35}
5 – No vehicular traffic	*Coarse sand, crushed aggregates, river sand (e.g. 0/4)*			*≤ 7%*	-

[1] In the current version of NBN EN 13242 [5] "sand" is defined as fine aggregate with $D_{max} \leq 6.3$ mm.

[2] Coarse sand 0/4 or 0/6.3 is generally composed of a homogeneous mixture of 40 % natural rounded sand or natural crushed sand with $D_{max} \leq 2$ mm, and 60 % crushed aggregate 2/4 or 2/6.3.
[3] For precast concrete slabs, a mixture of *crusher sand* from recycled concrete aggregates and natural sand may be used if the requirements of Table 2 are met.

4. Installation

Some rules of good practice are described for the installation and execution of a pavement with large precast flags or slabs – including, but not limited to:

- quality control of the delivered materials;
- attention to the unloading and stacking of the large size elements on site;
- proper compaction of the subgrade and sufficient edge locking if needed;
- proper execution of the base layers and installation of the laying course;
- laying of the large paving elements preferably with vacuum devices;
- eliminating unevenness, and joint filling with proper sealing materials;
- careful finishing around embedded elements and at the edges of the pavement.

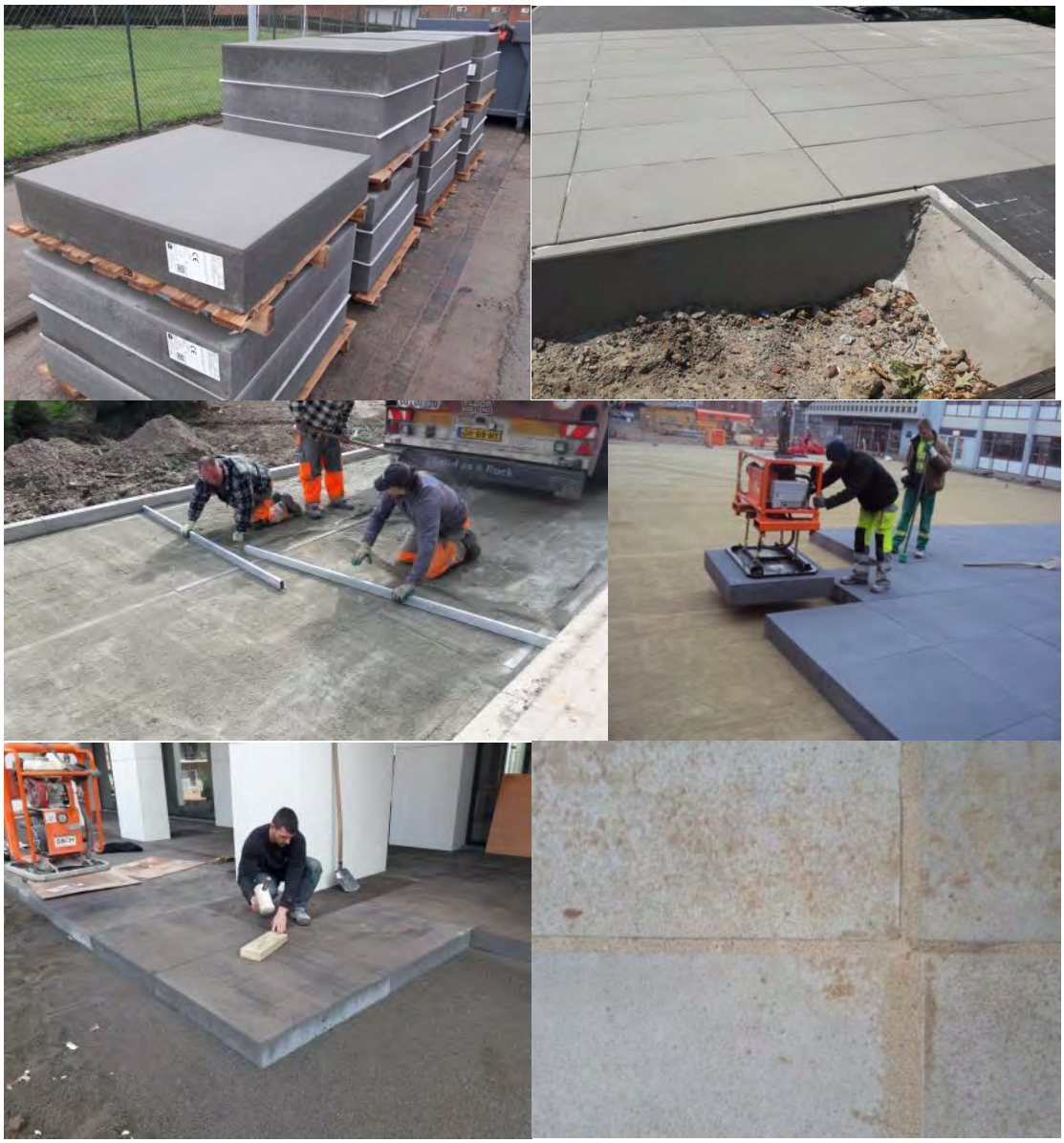

Figure 4. Good practices for the installation of pavements with large precast flags or slabs

5. Production and surface finishing

The choice of the type and finishing of large precast concrete flags or slabs depends on functional as well as aesthetic requirements. Different production processes (by *pressing* or by *casting and compacting*) and a wide variety of surface finishing techniques are available to create a wealth of different and decorative concrete structures meeting all kinds of demands.

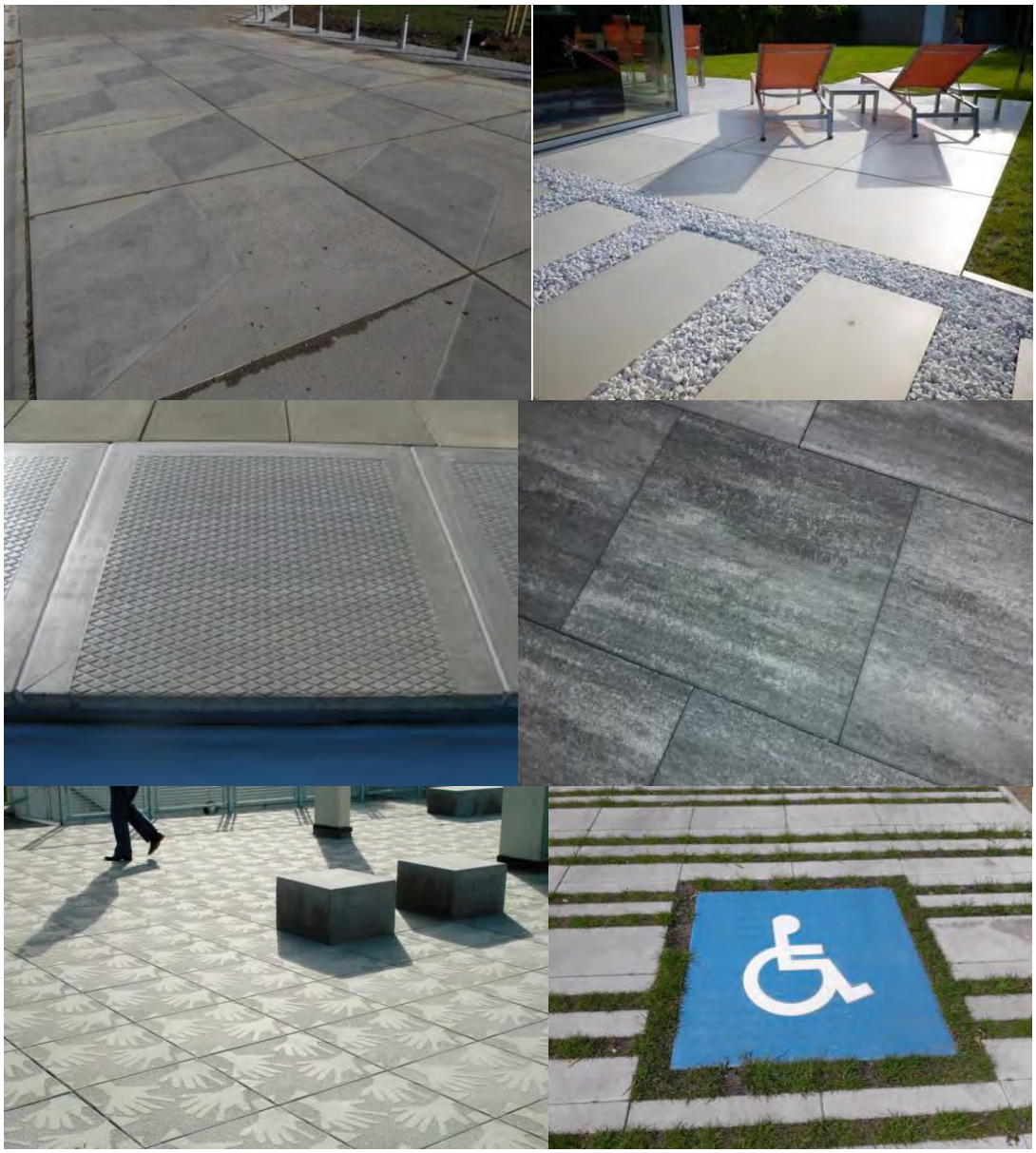

Figure 5. Different production processes and surface finishing techniques exist to produce a wide variety of decorative concrete structures meeting all aesthetic as well as functional requirements

6. Product requirements and quality control

Concrete paving flags with a total length smaller than 1 m and an *L/D* ratio greater than 4 fall within the scope of the European standard NBN EN 1339. These products must be marked with a CE sign to be traded within the EU. Their length may be extended to 1.5 m in the future revision of the EN standard, but for the moment precast flags and slabs with larger dimensions are not covered by any standards.

CE-marked products only have to meet minimum requirements for a limited number of properties (the so-called “harmonized” characteristics) and do not always offer the level of quality a customer desires. That is why the BENOR mark (also conforming to the national standard NBN B 21-211 [6]) has been created in Belgium to have complete compliance with all requirements in the relevant standards certified by a third party, in response to the quality aspirations of the Belgian construction industry.

The performance requirements for concrete paving flags (with length up to 1,000 mm) are determined by classes to which a certain marking (**CE**) applies according to NBN EN 1339:2003 [1]. The Belgian standard NBN B 21-211 [6], however, is somewhat stricter and only allows certain classes (**CE+BENOR**). One example is given in Table 3 for *permissible* deviations from specified dimensions of paving elements; for large flags and precast elements (with an overall length exceeding 1,000 mm) these are only *recommendations*, because of the lack of valid standards.

Table 3. Example of performance requirements: classes of **recommended** maximum size deviations for large precast concrete flags and slabs with a length > 1,000 mm

Deviation in mm	*Large flags (1000 mm < L ≤ 1500 mm)*			*Precast slabs (L > 1500 mm)*		
	Class 1	Class 2	Class 3	Class 1	Class 2	Class 3
Length	+/-5	+/-3	+/-2	+/-3	+/-2	+/-1
Width	+/-5	+/-3	+/-2	+/-3	+/-2	+/-1
Thickness	+/-3	+/-3	+/-2	-1/+4	-1/+3	-1/+2

7. Special applications

A few more special applications of large size paving elements are documented in a subsequent chapter, while drawing attention to a number of specific points for their design and construction:

- water-permeable pavements;
- roof constructions, including applications with pedestals;
- special shaped elements;
- watertight industrial pavements.

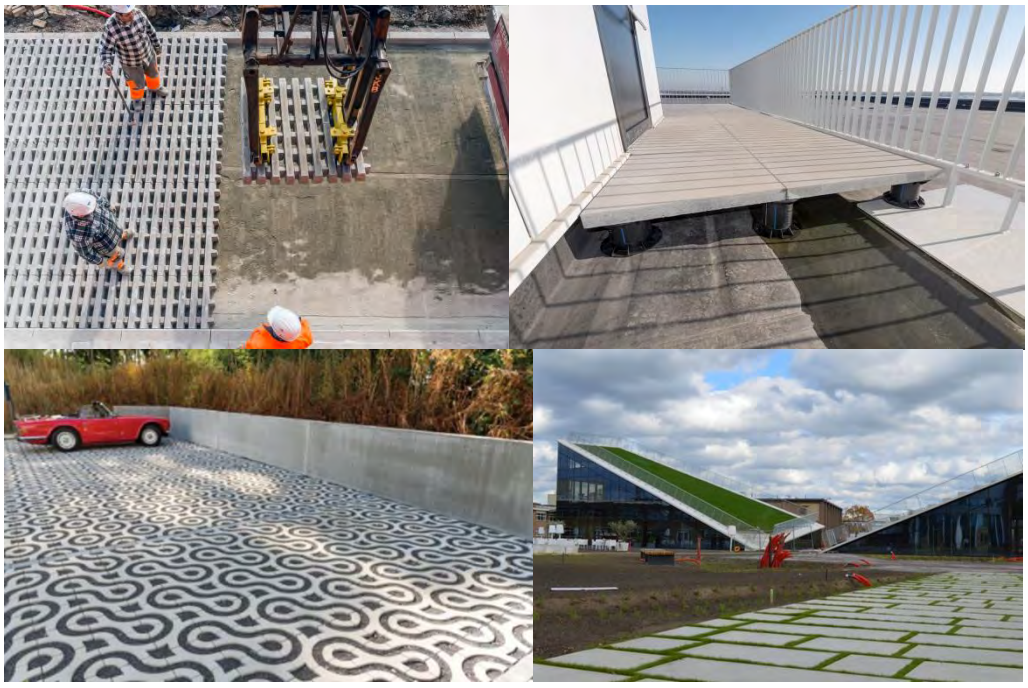

Figure 6. Special applications of large precast concrete flags and slabs

8. Maintenance and repair

Pavements with large precast concrete flags and slabs have a long service life when planned and implemented professionally following the rules of good practice established above, and when high-quality construction materials are used. This longevity is governed in particular by the stability of the various structural layers, by adequate permeability to water, and by the quality of the laying course and joint filling material. It is necessary to monitor surface condition regularly as well – just like any other road structure. Particular attention should be paid to the state of the joints and joint filling, and preventive and/or curative weed control should also be considered [7].

Premature damage is frequently related to improper dimensions and/or thickness of the paving elements with respect to traffic loading. In addition, careless finishing at the edges of the pavement and/or around obstacles may also lead to early failure. Unfortunately, in most cases replacement of the damaged paving elements, possibly with re-profiling and/or replacement of the laying course as well, is the only way to repair.



Figure 7. Premature damage is mainly related to improper design with respect to traffic loading and/or careless finishing at the edges of the pavement or around obstacles

Acknowledgements

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