Design and construction of a roundabout in fibremix concrete

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Abstract

Road pavement constructed with fibremix concrete allows longer distances between joints compared to unreinforced concrete pavements. Fibremix concrete has been used in parking areas near motorways, city roundabouts, road crossings, bicycle paths and regional roads with uncracked lengths up to 80 m.

Without a dedicated design tool for fibremix concrete pavements, the maximum crack-free slab length was obtained by trial and error during several projects.

In 2015, with the experience from the past years, the Province of Noord-Brabant, a regional government in the Netherlands, has constructed a roundabout in fibremix concrete on a crossing between two regional roads.
This paper describes the design, special details and execution of this roundabout in fibremix concrete.

Some technical details of the roundabout:
T-crossing on the N625 near the city of Oss, the Netherlands
One single-lane roundabout: pavement width: 5.25 m
Diameter: 50 m
Thickness of concrete pavement: 25 cm
Fibremix concrete (2 types of steel fibres + 1 type of polypropylene fibre)
Only 6 doweled joints

Note: the roundabout was designed and constructed by the Den Ouden Group in the period May – June 2015.

Introduction

The Province of Noord-Brabant already has decades of experience in concrete pavement, and manages the largest area of concrete roads of all provinces in the Netherlands. Roundabouts on secondary roads are usually built in continuously reinforced concrete being the present standard for roundabouts. The Province also has its own standard details, to which reference is made in specifications. The Province of Noord-Brabant always has an interest in innovative concrete applications and is supporting new developments with concrete pavement, such fibrous concrete.

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Table 1: Previous experience with fibremix concrete.

Year	Application	Slab length	Experience
2003	N279 roadway	18 m	No cracking
2005	Cycle lane	250 m	Cracking every 50 m
2007	Foundations (in groundwater)	50 m	Cracking at narrowing
2010	N279 crossing (+ silent top layer)	55 to 84 m	No cracking
2014	Bus station	32 m	No cracking
2015	N625 roundabout	26 m	No cracking

N625 roundabout

The roundabout in the N625 is the first roundabout in the Province of Noord-Brabant built with fibremix concrete. With a huge experience of roundabouts in continuously reinforced concrete and experience of fibremix concrete in various road applications, as a logical consequence the Province has carried out a pilot project with fibremix concrete in a roundabout.

The location in the N625 – Beatrixweg T-intersection was considered as a pilot because of the accidents and the low risk of failure as the traffic intensity is rather moderate and the pavement can be easily repaired..

The existing T-crossing was unsafe with many accidents happening regularly as a result of high speed, limited visibility and unsafe bicycle crossings. Furthermore, the reconstruction of this intersection became necessary within the context of the 'Duurzaam Veilig' road (Sustainably Safe Roads) initiative which is a theme policy in the Netherlands

Location

Figure 1: Location and old situation

Figure 2: The old concrete pavement on the N625 dates from 1959!

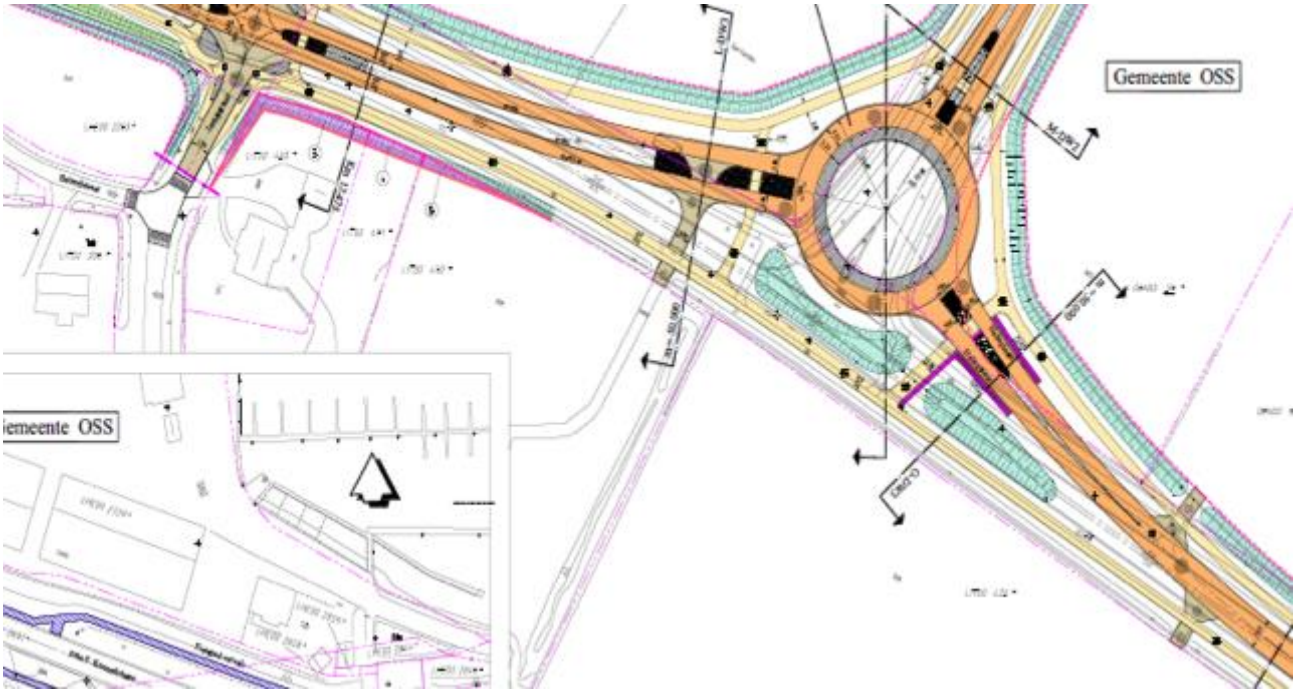

Figure 3 Drawing of new situation

Contract

As distinct from customary contracts in the form of specifications on the basis of RAW (specification system for civil and hydraulic engineering works) Standard 2015, the pilot project was put on the market as an Engineer & Construct contract. The contractor has to take responsibility for the design and construction of this roundabout along with additional activities.

The principal included the following requirements in the contract, among other things:

- construction in fibremix concrete (Fibricon fibremix)
- as few joints as possible

- maintenance-free for 10 years
- pavement design life of 40 years
- settlement of a maximum of 0.10 m in 30 years
- customary requirements concerning skid resistance, evenness
- standard details to the extent possible in line with the Details 2011 of the Province of Noord-Brabant

The requirement for as few joints as possible is the challenge for the contractor, who must supply guarantees and, for a lower risk, would like to use more joints.
From a technical/physical perspective, a smooth subsurface is required for unimpeded shrinkage during hardening and a rough (or rougher) subsurface to combat expansion and shrinkage as a result of temperature fluctuations.

The Province of Noord-Brabant awarded the construction of the roundabout to Den Ouden Aannemingsbedrijf BV in Schijndel. Den Ouden contracted VIA Aperta Verhardingsadviseurs BV for the arithmetic design of the roundabout in fibremix concrete.

Design
The province drew up tender specifications for the design and engineering. In addition to the already specified contractual requirements, with respect to the layer thickness design for the approaching roads and the roundabout account was taken of:
- the road construction must be able to sustain all loads during the set working life;
- the road/roundabout must be accessible for all vehicles allowed on the public roads;
- the road construction must be of a uniform structure across the whole width;
- the residual settlement of the new road construction must remain limited to a maximum of 0.10 m after 27 years (10,000 days);
- leaching materials (e.g.furnace slag) may not be used in the pavement or foundations;
- the part between the roundabout up to and including the cycle crossings must be constructed in fibremix concrete pavement with as few joints as possible;
- the roads approaching the cycle crossings must be constructed in asphalt pavement;
- the transition or connection between the pavement in asphalt and fibremix concrete must be such that for 30 years after acceptance it is guaranteed that the transition from concrete pavement to the asphalt pavement (and vice versa) remains smooth;
- the roundabout must have a diameter of 50 m up to the outer edge of the pavement.

Structure construction
A cement concrete pavement construction in the Netherlands usually consists of the concrete driving surface on top of granulate foundations and a sand bed.
With continuously reinforced concrete roads in conformity with the standard details of the Province of Noord-Brabant, an unbonded stone foundation of 0.20 m mixed aggregate 0/31.5 with on top an intermediate layer of asphalt (5 cm AC 16 base 40/60) is customary.

Foundations
The contract for the roundabout left the choice of the foundations open. The contractor is offered the option of constructing granulate foundations, a bituminous intermediate layer or another choice. An important aspect here is the shrinkage behaviour of the newly hardened fibremix concrete. With unimpeded shrinkage, the hardening concrete shrinks without the likelihood of wild cracking being too great. The application of the concrete on a plastic foil is favourable in this sense. However, the slip layer has the disadvantage that seasonal temperature variations can cause large movements in the joints. A joint seal will not be able to

accommodate these relatively large joint width movements and will detach. As a result, with the selection of the foundations the mobilising friction of the subsurface in relation to the hardening concrete was looked at, as well as the mobilising friction force as a function of the surface (length) of the 'jointless' slab parts.

For the calculation of the impeded deformation of the elastic supporting slab the friction with the subsurface is calculated. For the cohesion and coefficient of friction between concrete slab and subsurface one can (indicatively) assume the values in table 2.

Table 2: Indication cohesion and friction subsurface and max. slab length at UGT≤ 1.0

Material	Cohesion (kN/m^2)	Friction	Maximum friction force (kNm)	Maximum slab length (m)
Bituminous intermediate layer	10	0.30	344.4	50.0
Mixed aggregate + foil	8	0.60	388.8	50.0
Mixed aggregate	15	1.20	451.7	30.0

Table 2 includes a number of possible foundations and the properties for friction and cohesion. By comparing the maximum tensile force with the mobilising tensile force with a slab thickness of 0.250 m, a unity check can be carried out on the limit state design (LSD). With non-reinforced and steel fibre concrete, the maximum occurring bending tensile stresses and tensile stresses in the limit state design (LSD) are checked against the bending tensile strength and the tensile strength (unity check). (Theory of Petterson and Alemo)

Concrete strength

- Strength class concrete C35/45, Fibricon;
- According to NEN-EN 206-1, the environment class for reinforced concrete on the top side is XC4 - XD3 – XF4 and on the bottom side XC3;
- As regards durability, the application of Portland fly ash cement (CEM II/B-V 32.5 R) is preferred;
- For reasons of durability, coarse aggregate must be used in the concrete mix.

Layer thickness concrete pavement

The CROW design program Vencon 2.0 is used to determine the concrete thickness. The slab thickness is determined on the basis of the strength criterion (as being an unreinforced slab; joint edge loading case, temperature gradient and axle load spectrum in wheel track).
The Vencon 2.0 program can carry out design and control calculations for elastic supporting road pavement with given subsurface parameters, loads, properties of concrete/steel.
In the Vencon 2.0 program it is not, however, possible to calculate directly with the material steel fibre concrete. A workaround is needed to be able to calculate with fibremix concrete. By using an imaginary higher strength class than C35/45, the actual properties (higher tensile strength and modulus of elasticity) of Fibricon are calculated.
To use this workaround, based on the calculation value of the tensile strength of Fibricon 145-55W fibremix-reinforced concrete C35/45, there is a recalculation to an imaginary characteristic strength class associated with normal concrete.
With the assumed traffic intensity and loads in the year 2020 and the compression strength workaround, a specification thickness (incl. nominal variations) of 236 mm was calculated. Including tolerances for paving, a concrete thickness of 0,25 m which equals the standard

thickness for CRCP- roundabouts was constructed. As the pavement thickness of the fibrous roundabout is equivalent to that of a CRCP roundabout, advantages such as cost reduction and reduction of construction time are feasible. The structure of the concrete pavement comprises of:

- Fibremix concrete 145/55W, strength class C35/45, layer thickness 0.25 m;
- 0,05 m asphalt (AC 16 40/60)
- 0.250 m mixed aggregate;
- 0.500 m sand for sand bed;
- Natural sand subsurface.

Road pavement

The thickness of the pavement is to 250 mm just like the carriageway. The adjacent pavement is normally constructed in non-reinforced printed concrete and the joints of the practically square slabs are sealed with bitumen.

To accentuate the road pavement, a pigment can be added to the concrete mixture and a printed pattern can be applied. The printed pattern is made by pushing stamps into the fresh concrete. For example, this can be a printed pattern similar to basalt cobbles. This printing takes place by pressing a template with a pattern in the fresh concrete.

Details

Fibremix concrete has a number of specific design and construction aspects. The principle solutions and the detailing depend on the construction methods and the selected solutions for aspects including the concrete curbs, the roundabout curb and the driveable strip. The solutions are contractually in conformity with the Construction Practice of the Provincial Authorities of Noord-Brabant, version 2011.

Based on the preconditions and the resulting coordinated design, the following parts are of importance:

- The application of 2.0 m wide sleeper slabs at the connection of approaches to and exits from the roundabout;
- Slipform paved heavy roundabout curb (dimensions: 320/400x500 mm)
- Application of RWS (lip curb profile) and concrete curbs, application of non-reinforced printed concrete (cut in every 2.5 m);
- Manual application of reducing slabs for approaches and exits. These are made with dowels with a both sides a plastic cap allowing 2cm compression as construction joint.

During construction, the following measures are required:

- All vertical and horizontal joints between pavement and curbs are provided with 6 mm ethafoam so no cracking is caused due to adhesion of adhering surfaces;
- After concrete paving and curing, the concrete is covered/insulated so less temperature shrinkage occurs;
- On hot and sunny days, pouring concrete at night;

Basic principles for design with fibremix concrete

Fibremix concrete shrinks just like conventional concrete. Because pouring takes place in larger slab sizes, measures are required with design and construction. The risks concerning cracking with the application of fibremix concrete are higher than with normal concrete. Extra care is also required to reduce the risks of wild cracking.

The following are measures taken with the design:

- If possible pour with a uniform width; with diameter narrowing apply a dowelled transverse or coupled longitudinal joint;

- Allow concrete to freely settle longitudinally if possible. Experience teaches that at least 4 transverse joints are required. With a circumference of approx 160 m this means a length of 40 m. However, the joints must more or less coincide with the approaches and exits. On the basis of symmetry, 6 joints are applied in the carriageway. The slab length is somewhat variable; (see figure 4)

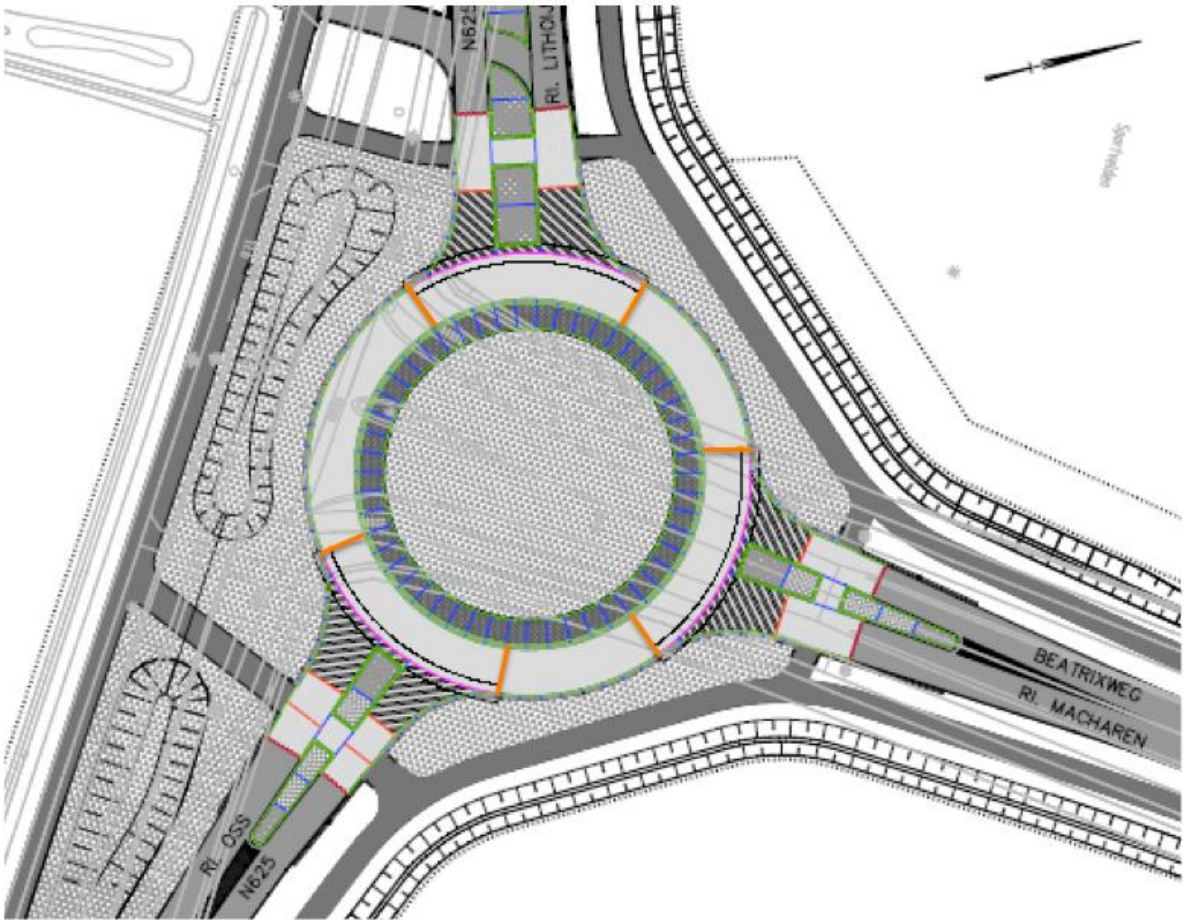

Figure 4 : Joints in fibremix concrete roundabout

- The connection of the roundabout to the approaches and exits is made with sleeper slabs. The thickness of sleeper slabs amounts to 0.25 m; the width amounts to 2.0 m;
- Provide transverse joints with dowels Ø25-25, 0.50 m long, with caps at 1/3rd h and 50% cut in;
- Joint opening: joint depth 30 mm, width 20 mm, bevelled edges 3 mm; seal joints with 2C polysulfide mastic (with backing material);
- Additional reinforcement is also required with Fibricon fibremix concrete with irregularly formed slabs, at corners, near drains, etc to prevent cracking.

Connection to asphalt pavement

For the concrete to asphalt connection, a variant with flexible joint transition is developed from the standard detail.

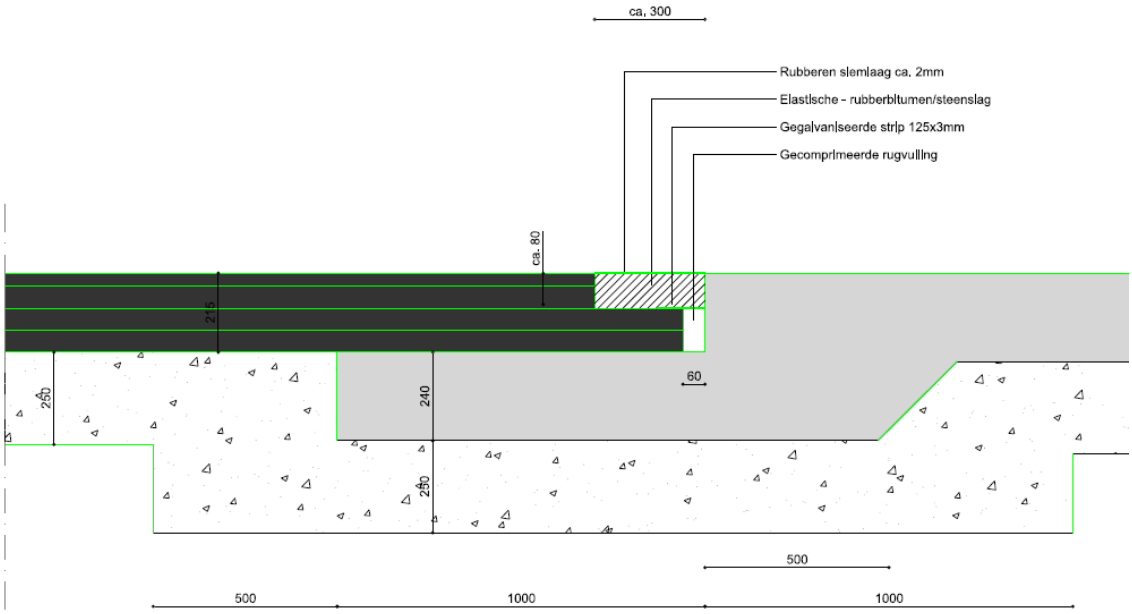

Figure 5: flexible joint for connection between concrete and asphalt

Execution

Some relevant photos of construction:

Figure 6a and 6b: Formwork for sleeper slab (l) and for connection concrete and asphalt

Figure 7a and 7b: Concrete for sleeper slab (l) and for connection concrete and asphalt


Figure 8a and 8b: slipformed concrete curb (RWS-type) and asphalt intermediate layer

Figure 9: Manual application of concrete for roundabout


Figure 10 a and 10 b: Fibre mixed concrete and fibre mixture

Figure 11: Roundabout in use

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