SIKA AT WORK

CARAGUATATUBA AND SÃO SEBASTIÃO BYPASS ROADS

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PROJECT **DESCRIPTION**

The Caraguatatuba and São Sebastião Bypass Roads will form a safe and modern highway complex in the Paraíba Valley region and North Coast of São Paulo. The main benefits include faster, safer and more comfortable travel; direct access to the Port of São Sebastião; stimulation of tourism in the region; and direct benefits for the 249,000 inhabitants of Caraguatatuba, São Sebastião and Ilhabela.

The entire stretch will consist of 13.2 km of tunnels and 57 Special Engineering Structures – including bridges and overpasses. The new road will be 33.9 km long and up to two thousand new jobs will be generated.

The engineering plans and solutions have been thoroughly studied, aiming for the enterprise to generate minimal environmental impacts and always be guided by the best sustainability practices.

It is important to highlight that the Caraguatatuba and São Sebastião Bypass Roads are interconnected with the final stretch of the Tamoios highway, a project that is a proud milestone for Brazilian engineering. This project was awarded internationally with 2nd place for the V3 Overpass in the Infrastructure category of the ACI Excellence in Concrete Construction Awards 2021, in addition to holding several records, such as the longest tunnel in the country, measuring 5.55 km in uninterrupted length. Undoubtedly, this a key project for Sika worldwide, especially with the application of PP macrofibers as concrete reinforcement for tunnel linings, replacing the traditional wire mesh solution.


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PROJECT **REQUIREMENTS**

Among the various requirements established for a project of this magnitude, the following tables highlight the main tests, requirements and execution frequency to ensure mechanical performance and durability of the tunnel linings:

TEST	RECOMMENDED REFERENCE	FREQUENCY	MINIMUM VALUES TO ATTAIN
Adherence to the substrate	Item 10.6 of EFNARC 1996 or EN 14488 Part 4	100 linear meters of tunnel**	The mean value should not be less than 0.5 MPa and no individual value should be lower than 0.35 MPa
Compressive strength test of cylindrical specimens and extracted cores (fck)	NBR 5739 and NBR 7680	250 m2*/100 linear meters of tunnel**	Fck ≥ 25 MPa
Testing sprayed concrete – Part 3: Flexural strengths (first peak, ultimate and residual) of fibre reinforced beam specimens	EFNARC/EN 14488-3	Monthly*	Comply with EFNARC Class 1 shotcrete standard
Double-punch tensile strength	IBRACON/ABECE recommended practice	Weekly*	Min. 0.5 (MPa) – fr, 2.5
Water absorption by immersion and boiling	NBR 9778	100 linear meters of tunnel**	≤ 10% (V < 2500 cm³) ≤ 8% (V ≥ 2500 cm³)
Water penetration under pressure	NBR 10787	100 linear meters of tunnel**	The mean value should be no more than 50 mm and the highest individual value should be no more than 70 mm.
Shotcrete strength in the first hours controlled by means of penetration resistance of the constant energy penetrometer – PEC	NBR 14278 or EN 14488 Part 2	100 linear meters of tunnel	0.2 MPa to 1.2 MPa
Determination of setting times in Portland cement paste with or without the use of setting accelerator admixture – Cement/ admixture compatibility test	NBR 13069	–	–

Table 1: Summary table of primary lining qualification tests.

TEST	RECOMMENDED REFERENCE	FREQUENCY	MINIMUM VALUES TO ATTAIN
Adherence to the substrate	Item 10.6 of EFNARC 1996 or EN 14488 Part 4	100 linear meters of tunnel**	The mean value should not be less than 1.0 MPa and no individual value should be lower than 0.75 MPa.
Compressive strength test of cylindrical specimens and extracted cores (fck)	NBR 5739 and NBR 7680	250 m²*/100 linear meters of tunnel**	Fck ≥ 25 MPa
Thickness control and visual control	–	100 linear meters of tunnel**	Meet minimum design specification per treatment class
Residual Strength Class	EFNARC/EN 14488-3	Monthly*	Comply with EFNARC Class 1 shotcrete standard
Double-punch tensile strength	IBRACON/ABECE recommended practice	Weekly*	Min. 0.5 (MPa) – fr, 2.5
Determination of setting times in Portland cement paste with or without the use of setting accelerator admixture – Cement/ admixture compatibility test	NBR 13069	–	–

Table 2: Summary table of secondary lining qualification tests.

* Testing frequency of cores extracted from the sprayed panels.
** Testing frequency of cores extracted from the structure. Routine flexibilization after approval and keeping production variations under control.

LOP AND RESIDUAL STRENGTH – EN14488-3

The flexural tensile strengths (first peak, ultimate and residual) were determined according to the test proposed by EN14488-3. This test is performed by reading the load according to the predetermined crack opening in the core, where a strength is generated for each crack opening.

This test was used to approve the shotcrete mix, releasing it to the operational process and also used as control during execution. Due to its greater operational ease, the Barcelona test – Double punch tensile strength, was also used for routine control during execution of the tunnel linings. The requirements and features of this novel methodology will be detailed later on. **fr4 ≥ 1.0 MPa**

DOUBLE-PUNCH TENSILE STRENGTH – IBRACON/ABECE PRACTICE

The double punch tensile strength, also known as the Barcelona test, was defined as the routine quality control test for the composite, given its operational ease and feasibility to be performed in the site laboratory. The test is described in the Ibracon/ABECE Guide: Quality control of fiber-reinforced concrete, which served as the basis for ABNT NBR 16939:2021 – Concreto reforçado com fibras - Determinação das resistências à fissuração e residuais à tração por duplo puncionamento - Método de ensaio. **fr, 2.5 ≥ 0.5 MPa**

ASSUMPTIONS CONSIDERED IN THE FIRE SITUATION ASSESSMENT

Fire curve ISO 834

Fire duration 150 minutes

Maximum temperature 1200 °C

Verification of support conditions under the action of fire, with characteristics that meet the ISO 834 (1975) curve, which is recommended by NBR 14432: 2000 and NBR 5628:1980.

To ensure passive fire protection, the use of synthetic microfibers was defined, at the dose defined and certified through unprecedented tests carried out at the São Paulo University Institute for Technical Research (Instituto de Pesquisas Tecnológicas da USP – Universidade de São Paulo).

SIKA **SOLUTIONS**

The great challenge of the Caraguatatuba and São Sebastião Bypass Roads was to understand the technical requirements of the project and develop the best concrete admixture formulation. In addition to the superplasticizer admixture, the wire mesh used in the shotcrete application was replaced by an optimized solution with macro and microfiber, which enabled great productivity gains for the construction company. In addition, we know that based on a generic life cycle assessment (LCA), concrete reinforced with SikaFiber® brought several benefits and sustainable advantages to the project, compared to the initial solution of concrete reinforced conventionally with steel mesh.

RESULTS ACHIEVED BY THE CUSTOMER

In terms of logistics, with **SikaFiber® Force PP-48** synthetic fibers, approximately 1/5 of the volume of metal fibers was used, which resulted in less transportation, storage and handling.

The use of synthetic fibers reduced the inherent risk of installing wire mesh, as well as the risk for operators and equipment in unstable areas with the danger of rock displacement. Synthetic fibers are also the best option for harsh environments, as both wire mesh and metal fibers suffer oxidation.

In addition, synthetic fibers enabled less wear on equipment (hydraulic pump, hoses, rotors) and productivity gains with the application of shotcrete.

As Engetec Construções e Montagens produces some of the materials used in the concrete, the **Sika® Viscocrete®-6090 SK** admixture made it possible to use just one fine aggregate in the mix, namely, artificial sand. This allowed for a sustainable solution from a technical, economic and environmental standpoint, as all the aggregate used came from the crushing of rocks extracted during excavation of the tunnels, thus eliminating the use of natural sand, an increasingly scarce resource nowadays.

The **Sika® Viscocrete®-6090 SK** admixture also enabled workability of up to 3 hours without loss of workability and without changes in compressive strengths, facilitating transportation and productivity gains in the application of structural concrete or shotcrete.

For the secondary lining, the **Sigunit® L-650 AF** was essential for achieving better performance, translated by the greater incorporation of fibers into the shotcrete due to lower reflection, in addition to significant 25% gains in the residual flexural tensile strengths (EN14488-3) in relation to other conventional accelerators.

PRODUCTS USED

Sigunit®-L-500 (APP – Setting Accelerator for Shotcrete)
Sigunit®-L-650 (APP – Setting Accelerator for Shotcrete)
Sika®Viscocrete®-6090-SK (RA-2: Type 2 Water Reducer/Superplasticizer)
SikaFiber®-12 Micro PP and Sika® Fibermesh®-150 PP (Synthetic microfiber)
SikaFiber® Force PP-48 (Synthetic macrofiber)

PROJECT SUMMARY

Location: Caraguatatuba/São Sebastião, North Coast of São Paulo
Two-way Tunnels (extension):
101 – 272 m
102 – 395 m
301 – 2,262 m
302/401 – 3,438 m
402 – 235 m
Total: 6,602 m
Tunnel excavation method: NATM

COMPANIES INVOLVED

Customer: Tamoios Concessionaire
Construction Company: Engetec Construções e Montagens
Project: CJC Engenharia

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