2023 Outstanding International Project

# Shotcrete as Roadside Slope Protection in Brazil

*By André Bezerra de Menezes, Juliana Borella de Menezes, & Lucas Passos Santana*

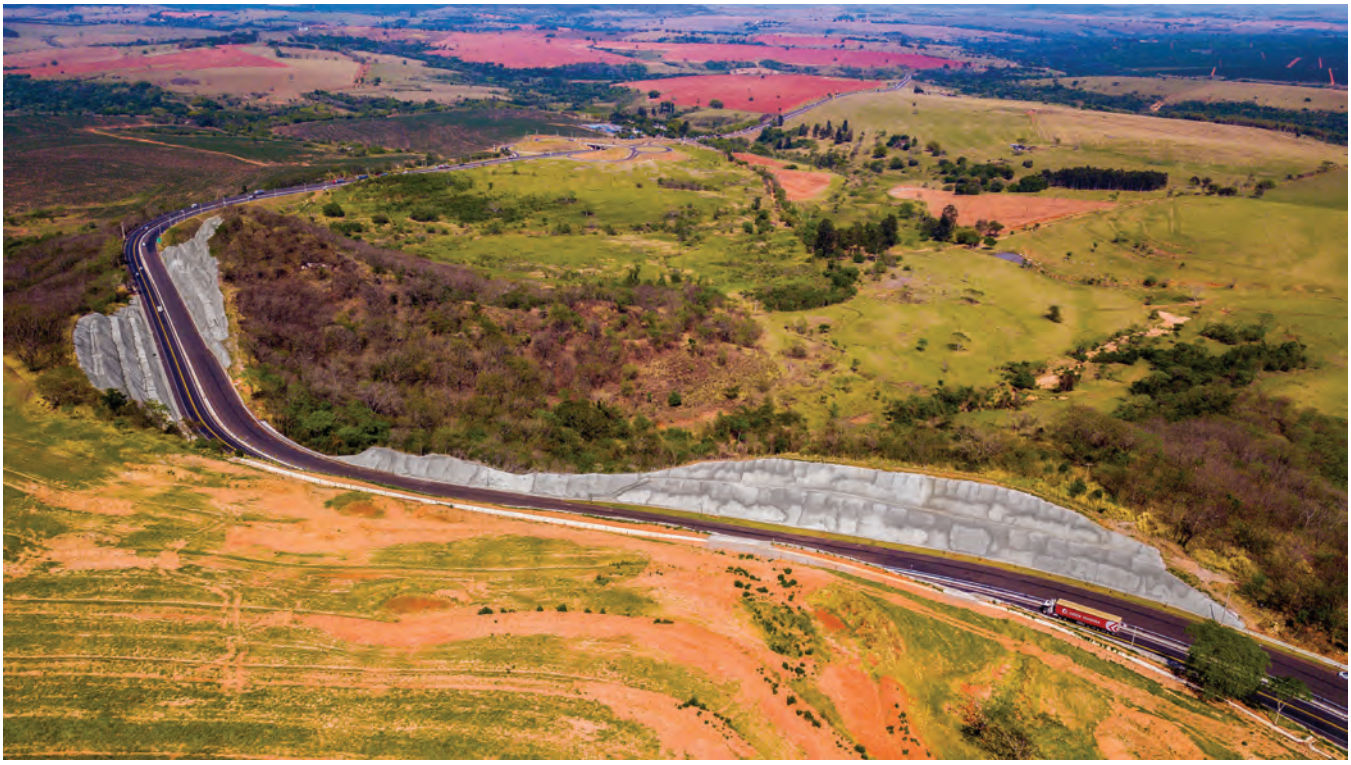

*Fig. 1: Completed roadside slope connecting the towns of Marília and Assis in the state of São Paulo, Brazil.*

The use of shotcrete has proven to be of paramount importance in the treatment process of the slopes along the margins of SP 333 highway in the interior of the state of São Paulo, Brazil. This application focused on a stretch covering kilometers 337 to 385, connecting the cities of Marília and Assis. The implementation of shotcrete in this challenging location represents not only a technical choice but also a strategic response to the specific challenges presented by the slopes along this section of the highway.

## MARÍLIA AND ASSIS CONTEXT

Marília stands out as a bustling hub of the food industry. With a unique combination of abundant agricultural resources and efficient logistical infrastructure, the city has become home to a variety of renowned companies in the sector. From food processors to gourmet product manufacturers, Marília hosts a diverse range of enterprises that contribute significantly to the economy. The prominent presence of the food industry not only strengthens the city's economic base, but it also plays a crucial role in creating

*Fig. 2: Aerial view of roadside slope.*

employment opportunities for the local community. Furthermore, the synergy between the industry and the agricultural sector fosters an integrated supply chain that drives the development of both agricultural production and industrial activities.

Assis emerges as a crucial economic hub in the region as a result of its diversified industrial and commercial base. The city is known for its robust transportation infrastructure, which represents a strategic link in product distribution. With efficient road networks and railway connections, Assis significantly facilitates the flow of goods, which promotes logistical integration between suppliers, industries, and consumer markets. This logistical advantage not only strengthens the local economy but also elevates Assis to the status of a vital commercial hub in the region and a major contributor to the prosperity of both the city and the surrounding areas.

The synergy between the cities of Marília and Assis establishes a strategic alliance for the efficient distribution of food products on a global scale. While Marília stands out as a pulsating center of the food industry, Assis complements this scenario as a crucial economic hub by offering a solid transportation infrastructure. The logistical integration between these two cities, as facilitated by efficient road networks and railway connections, creates an environment conducive to the rapid and effective flow of goods. This collaboration not only strengthens local economies but also elevates the region to a strategic position in the international food industry landscape which contributes to joint prosperity and expands business horizons.

## NEED FOR HIGHWAY EXPANSION

Due to the notable economic importance of the food and transportation sectors in Marília and Assis, the expansion of the highway in this section became an imperative need. This undertaking involved not only duplicating the road but also the complex task of excavating and reprofiling the imposing mountains that defined its margins. The resulting slopes were predominantly composed of rock masses, especially sandstone, and had begun exhibiting some discontinuities, fractures, and surface erosions, all of which raised concerns about their stability.

After thorough geotechnical analyses, it became evident that the proper protection of these slopes was an essential priority. The intrinsic characteristics of rock masses, which were subject to erosion and fractures, demanded a precise technical approach to mitigate potential risks of erosion and landslides.

In the face of this challenging scenario, the choice of applying shotcrete emerged as an effective solution. The technique not only provides a robust protective layer against surface erosion, but it also proves instrumental in the structural consolidation of slopes—this ensures their long-term stability.

## PROJECT DETAILS

Unicom Engenharia, recognized for its expertise and pioneering work in the application of wet-mix shotcrete in Brazil, took on the responsibility for shotcrete application, soil nailing, and the installation of surface and deep drains in this remarkable project.

The comprehensive scope of the project covered 10 distinct sections, intervening in 16 slopes, each with varying heights between 10 and 38 m (33 and 125 ft). The slope inclinations varied considerably, ranging between 45° and 70°, and added an additional layer of complexity to the project execution. The total length of the project extended for approximately 2670 m (1.7 mi)—further indication of the scale of the challenge.

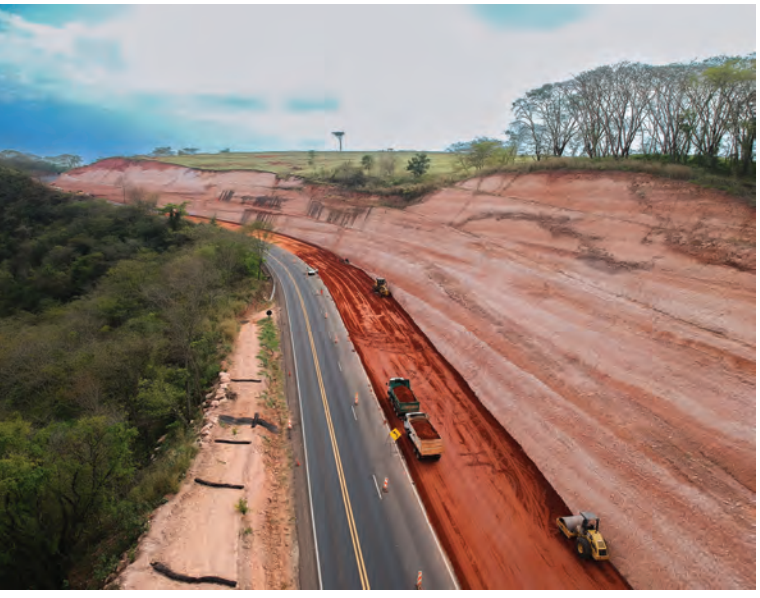

*Fig. 3: Excavation and slope process for highway expansion.*

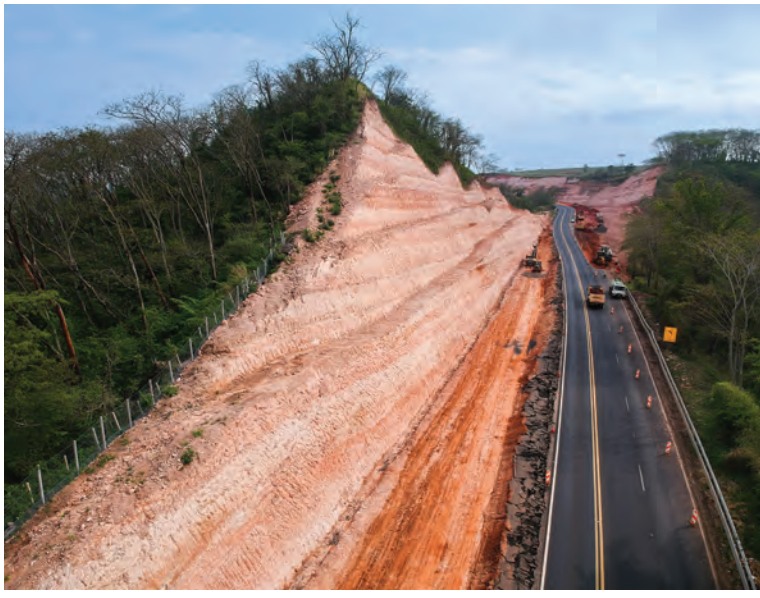

*Fig. 4: Additional view of the excavation and slope process.*

| Sections (Metric) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | km 341+800 West | km 341+200 West | km 341+200 East | km 362+000 West | km 363+400 West | km 363+800 West | km 364+000 East | km 364+100 East | km 371+000 West | km 350+000 East |
| **Slope** | 5 | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| **Height** | 38 m | 15 m | 25 m | 10,5 m | 17 m | 12 m | 18 m | 18 m | 12 m | 10 m |
| **Angle** | 50°-70° | 45°-50° | 50°-60° | 50°-55° | 55° | 60° | 65° | 50° | 45° | 45° |
| **Lenght** | 420 m | 250 m | 630 m | 170 m | 170 m | 170 m | 240 m | 120 m | 300 m | 200 m |

| Sections (Imperial) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | km 341+800 West | km 341+200 West | km 341+200 East | km 362+000 West | km 363+400 West | km 363+800 West | km 364+000 East | km 364+100 East | km 371+000 West | km 350+000 East |
| **Slope** | 5 | 2 | 4 | 1 | 1 | 1 | 1 | 1 | 2 | 2 |
| **Height** | 124 ft | 49 ft | 82 ft | 34 ft | 55 ft | 39 ft | 59 ft | 59 ft | 39 ft | 32 ft |
| **Angle** | 50°-70° | 45°-50° | 50°-60° | 50°-55° | 55° | 60° | 65° | 50° | 45° | 45° |
| **Length** | 459 yd | 273 yd | 688 yd | 185 yd | 184 yd | 184 yd | 262 yd | 131 yd | 328 yd | 218 yd |

Table 1: Slope Sections & Measurements (Metric and Imperial)

## KEY CHALLENGES

One of the prominent challenges faced during the execution of this project was the application of shotcrete in hard-to-reach areas, especially in the higher section reaching 38 m in height. The complexity of this task required the mobilization of a crane to overcome access restrictions; this elevated the need for rigorous safety criteria and personnel who were certified to handle this specific operation in challenging conditions.

Certification of safety criteria was essential not only to ensure the protection of the involved workers but also to ensure the structural integrity during the shotcrete application in hard-to-reach areas. The combination of significant heights and remote locations demanded an approach with the highest standards of safety and operational efficiency.

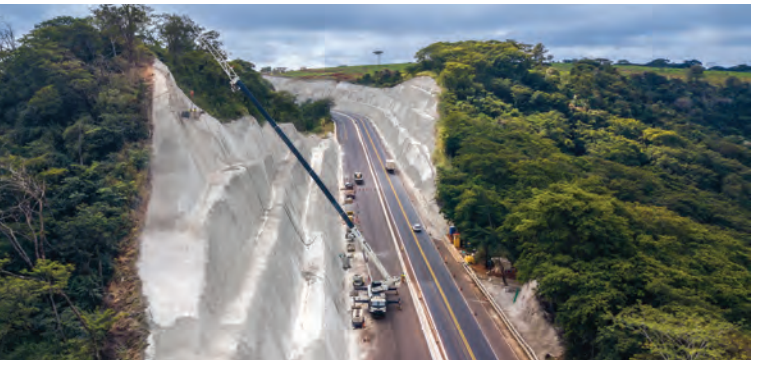

*Fig. 5: Application of shotcrete from a man basket using a crane.*

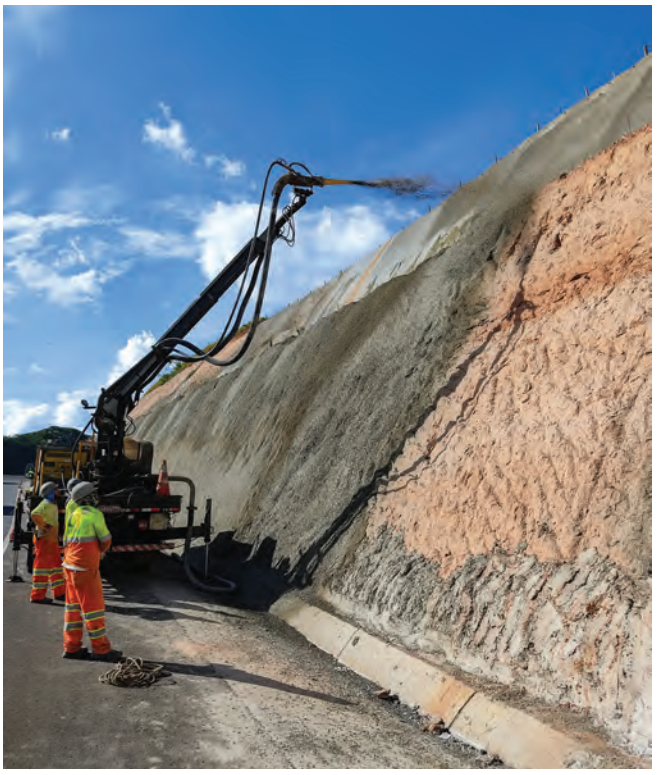

*Fig. 6: Application of shotcrete using a shotcrete placing robot.*

Additionally, efficient time management proved to be another challenging aspect of this project. Unicom adopted a simultaneous approach on three shotcrete fronts by implementing techniques such as rappelling, using an

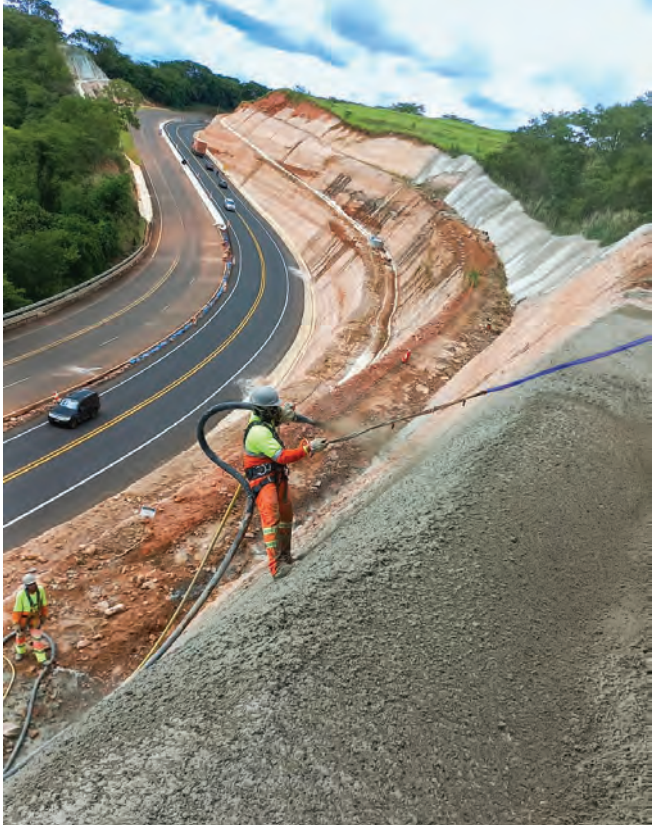

*Fig. 7: Application of shotcrete using the rappelling technique.*

articulating boom lift, and using a shotcrete placing robot. This multifaceted strategy allowed the team to achieve satisfactory productivity, which was exemplified by the volume of 72 m³ (94 yd³) of shotcrete applied in a single eight-hour working day.

The complexity of the project's height in certain areas required a specific approach to slope recomposition. In certain locations, the team opted for the "Rip Rap" technique, which involved the application of soil and cement bags to reinforce and recompose the slopes.

The compressive strength required for the shotcrete in the project was 25 MPa (3600 psi) at 28 days. As an additional measure to enhance the quality of the shotcrete, synthetic polypropylene microfiber was incorporated into the mix at a ratio of 5 kg/m³ (8.5 lb/yd³) of shotcrete. The fiber aimed to reduce the incidence of cracks caused by shrinkage, and it contributed to the durability and structural integrity of the material.

Furthermore, the presence of emerging water points on the slopes introduced additional challenges. To overcome this specific condition, a setting accelerator additive was incorporated during the shotcrete placement. This measure not only facilitated the efficient application of the material in wet areas but also contributed to the rapid attainment of the required strength; this was necessary to mitigate potential impacts caused by water.

The soil nailing service covered several stages starting with site preparation. The next phase involved rock drilling: a process aimed at creating holes for the installation of anchors. These anchors, which are fundamental components of the soil nailing system, were positioned to optimize the stabilization of the soil mass. The injection of cement grout bonded the anchors to the rock and provided their stabilizing function.

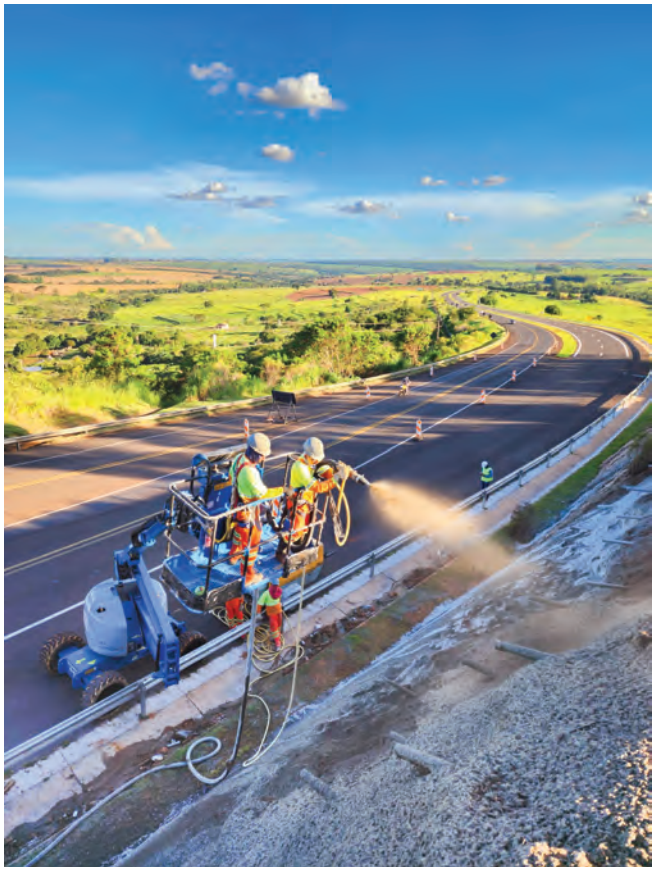

*Fig. 8: Application of shotcrete using an articulating boom lift.*

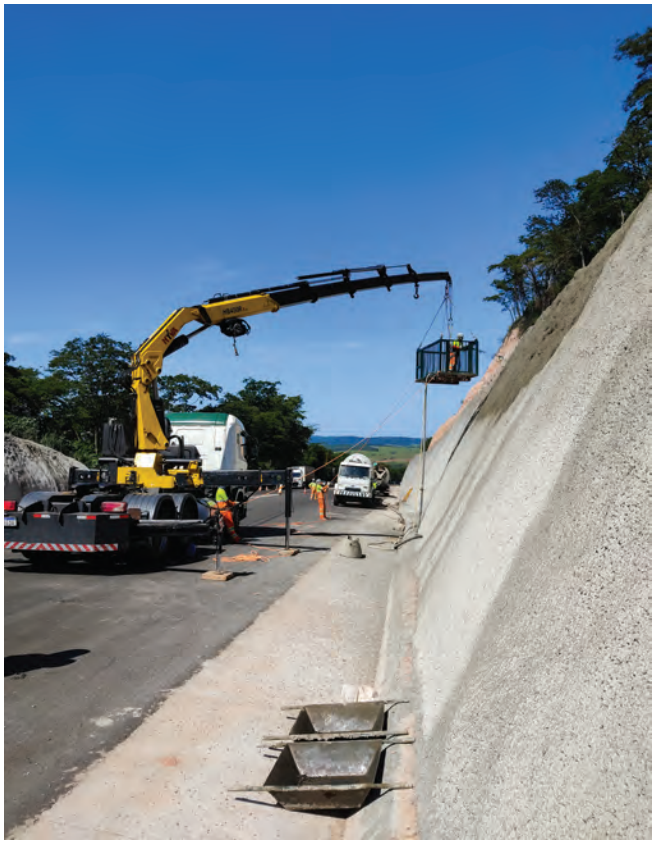

*Fig. 9: Application of shotcrete using a truck-mounted crane.*

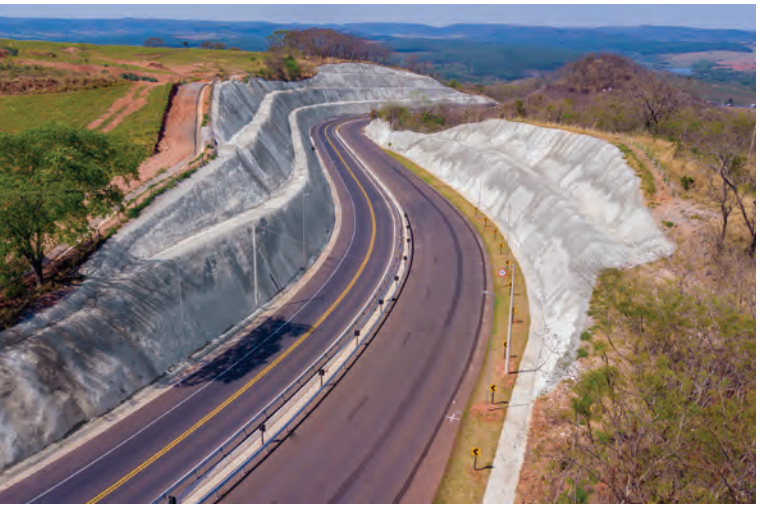

*Fig. 10: Slope after shotcrete application.*

*Fig. 12: Aerial view of the completed slope.*

To ensure the full functionality of the system, the installation of surface drains was implemented, which was an effective mechanism for managing water drainage and preventing potential soil saturation issues. Additionally, deep sub-horizontal drains were installed in areas that required control of the ground water table. The application of steel mesh complemented this process, providing an additional layer of strength and support to the structure. The final stage of this procedure involved the application of shotcrete by consolidating all measures taken to ensure the effectiveness and durability of the system.

The efficiency of the soil nailing system was validated through pull-out tests. These tests are essential to assess the quality of the interaction between the soil and the cement grout; this ensured not only the immediate stability that was necessary but also the long-term durability of the intervention.

## RESULTS

Unicom Engenharia carried out the application of 2,866 m³ (3750 yd³) of shotcrete, which covered an area of 31,220 m² (336,000 ft²). Additionally, 310 m² (3340 ft²) of soil nailing was incorporated, which involved rock drilling and the placement of 708 m (2320 ft) of anchors with the injection of 29,800 kg (65,700 lb) of cement in the corresponding grout. This activity was complemented by the installation of 986 m (3230 ft) of surface drains, 674 m (2210 ft) of deep sub-horizontal drains, and the recomposition of 290 m³ (380 yd³) of the slope through soil-cement bags (Rip Rap).

The significant volume of shotcrete applied and the challenges that were overcome during this intervention highlight the growing importance of this technology for infrastructure in Brazil. More than a mere construction solution, shotcrete proves to be a vital element for regional development and the expansion of road networks.

Furthermore, highway expansion, facilitated by the application of shotcrete, plays a strategic role in facilitating the flow of agricultural and food products. This efficient flow contributes to the sustainability of the sectors—food products reach markets quickly and effectively. Thus, reinforced infrastructure not only benefits the regional economy but also plays a global role in feeding thousands of people worldwide.

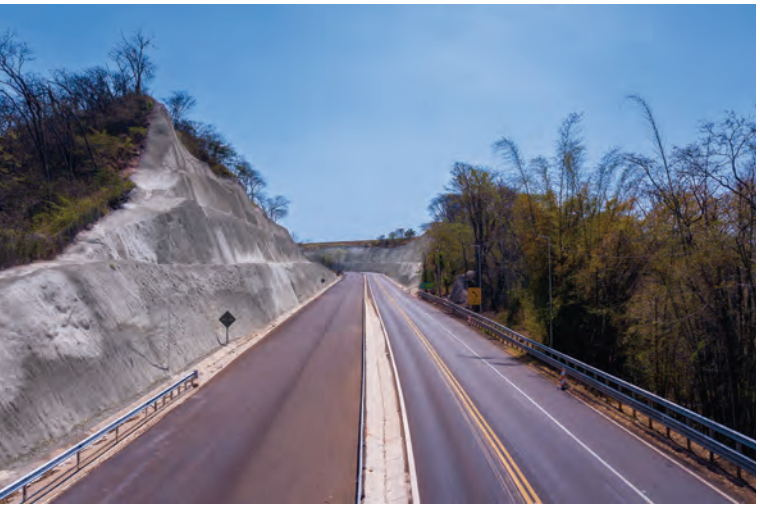

*Fig. 11: Another view of the slope after shotcrete application.*

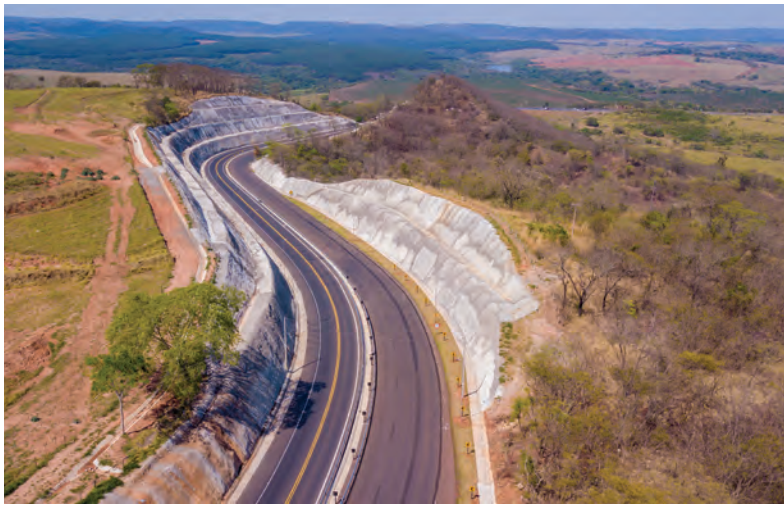

*Fig. 13: Another aerial view of the completed slope.*

## 2023 OUTSTANDING INTERNATIONAL PROJECT

*Project*
**Shotcrete as Roadside Slope Protection in Brazil**

*Project Location*
**SP 333 Highway, São Paulo, Brazil**

*Shotcrete Contractor*
**Unicom Construções e Tecnologias Construtivas LTDA**

*Materials Supplier*
**MCC Muriam Concreto LTDA**

*General Contractor*
**Entrevias Concessionária de Rodovias S.A.**

*Owner*
**Entrevias Concessionária de Rodovias S.A.**

***André Bezerra de Menezes*** *is a Civil Engineer with a degree from the Universidade Estadual Paulista – UNESP, one of Brazil's top universities. During his undergraduate years, he served as the Chief Executive Officer of Pro Junior – Projetos e Consultoria, showcasing his exceptional leadership skills. Currently, he holds the position of Director of Engineering and Co-Owner at Unicom Engenharia, where he has amassed extensive experience in projects involving shotcrete, soil nailing, anchored curtain walls, and more. Under his leadership, Unicom Engenharia has experienced exponential growth and gained international recognition.*

***Juliana Borella de Menezes*** *is a Civil Engineer, holding a degree from Pontifícia Universidade Católica de Campinas – PUC CAMPINAS. She holds an MBA in Economics and Business Management from Fundação Getúlio Vargas – FGV, one of the most prestigious business schools in Brazil. Juliana serves as the Commercial Manager and Co-Owner of Unicom Engenharia, bringing extensive experience to the commercial leadership of infrastructure projects, including shotcrete, soil nailing, anchored curtain walls, among others. Under her management, Unicom has consistently achieved and surpassed ambitious targets, propelling the company to ever-increasing prominence in the industry.*

***Lucas Passos Santana****, a Civil Engineer, earned his degree from Centro Universitário de Itajubá – FEPI, with a portion of his studies completed at Budapest University of Technology and Economics – BME (Hungary/EU). He holds a Master's degree in Infrastructural Engineering from Széchenyi István University (Hungary/EU). Lucas serves as a Geotechnical Engineer and leads the technical team at Unicom Engenharia. His proficiency spans projects involving shotcrete, soil nailing, and anchored curtain walls. Lucas brings a wealth of experience and an international perspective to his role.*