Base reinforcement for haul roads through the addition of polyethylene multidirectional rigid geogrids, for a mine in Minas Gerais, Brazil.

Wladimir Caressato Junior, TDM Tecnologia de Materiais Brasil Ltda., São Paulo, Brazil.
Carlos Antonio Centurión, Grupo TDM., Ciudad de México, México.
Leonardo Gomes Leopoldo, Anglo American, Conceição do Mato Dentro, Brazil.
Marina Cavalcante Yoshida, Anglo American, Conceição do Mato Dentro, Brazil.
Manollo Dos Santos Barros, Anglo American, Conceição do Mato Dentro, Brazil.
André Felipe Ferreira de Oliveira, Anglo American, Conceição do Mato Dentro, Brazil.

ABSTRACT
A large-scale test was performed to monitor the performance of a section of pavement reinforced with multidirectional polypropylene geogrids, commonly used on highways, but in this case, applied to stabilize the circulation paths of Komatsu 830E-AC haul trucks. These trucks carry loads greater than 400 tons when loaded, can carry more than 240 tons of iron ore per trip and can reach a maximum of 274 tons. The average circulation frequency ranges from 650 to 800 trips per day, empty and loaded. The test aimed to solve runway problems, especially during the rainy season, where traffic routes deteriorate more easily, resulting in large deformations and irregular and slippery surfaces, resulting in a reduction in the average speed of trucks and loss of production due to reduction of commuting per day.

The section reinforced with geosynthetics was approximately 70m long and 20m wide, a longitudinal slope ranging from 8 to 10% and 3 layers of local soil 0.40m thick reinforced by 3 layers of multidirectional polypropylene geogrids type TRIAX® TX160. The reinforced section underwent several performance tests, including turning and braking maneuvers, before and after heavy rains, using the mine's own trucks for this purpose. These tests demonstrated the best performance of the reinforced section versus the control section and allowed to achieve the objective of the test, which is to maintain the traffic capacity of haul trucks in the best possible way during the rainy season.

RESUMO
Um ensaio a grande escala foi realizado para monitorar o desempenho de uma seção de pavimento reforçado com geogrelhas multidirecionais de polipropileno, comumente utilizadas em rodovias, mas neste caso aplicada à estabilização das vias de circulação de caminhões fora de estrada do tipo Komatsu 830E-AC. Tais caminhões transmitem cargas superiores a 400 toneladas quando carregados, conseguem transportar mais de 240 toneladas de minério de ferro por viagem, podendo chegar no máximo em 274 toneladas. A frequência de circulação média oscila entre 650 a 800 viagens por dia, tanto vazios quanto carregados. O ensaio teve como objetivo solucionar problemas de rodagem de pista, principalmente durante o período chuvoso, onde as vias de circulação se deterioram mais facilmente resultando em grandes deformações e superfícies irregulares e escorregadias, acarretando a redução de velocidade média dos caminhões e perda de produção devido à redução de viagens por dia.

A seção reforçada com geossintéticos teve aproximadamente 70m de comprimento e 20m de largura, uma declividade longitudinal que variou entre 8 a 10% e 3 camadas de solos locais de 0.40m de espessura reforçadas por 3 camadas de geogrelhas multidirecionais de polipropileno tipo TRIAX® TX160. A seção reforçada passou por vários testes de desempenho, incluídas manobras de giro e frenagem, antes e depois de chuvas intensas, utilizando os próprios caminhões da mina para esse fim. Esses ensaios demonstraram a melhor performance da seção reforçada versus a seção controle e permitiu atingir o objetivo do ensaio que é manter da melhor forma possível a trafegabilidade dos caminhões fora de estrada durante o período chuvoso.

1. INTRODUCTION

Within the mining process, the mining method that configures a pit is known as an open pit mine. In this model, internal roads “haul roads” are developed through which large trucks pass, known as “haul trucks”.

These routes are vital resources in the production system, so much so that their projection and maintenance have a direct impact on the productivity and profitability of the mine. The surface conditions of the traffic routes depend fundamentally on the amount of tons of ore that are transported annually to the crushers (productivity) and on the production cost (profitability), which depend on parameters such as average working speed, fuel consumption, tire life life, safety and more.

The internal roads are composed of materials from the mine itself, compacted only by the passage of the loading and transport equipment itself. The circulation surface undergoes greater degradation and deformation in the rainy season and, therefore, requires greater maintenance. The rainy periods normally correspond to the months of October to May, where peaks greater than 200 mm can be reached per month.

Figure 1 illustrates the impact on crushing supply for the years 2017 and 2019 compared to the rains. The graph shows this difference in the first half of the years surveyed. The data for the year 2018 were not presented because the Mine was in “Layoff” in that period.

Within rain losses (hr), factors such as heavy rain, slippery track, lightning strikes, blocked accesses and downtime by infrastructure services can be considered. Through the graph, it is possible to observe that in 2017 the impacted feeding values were higher when compared to 2019, the year in which the multidirectional geogrid was already applied in two stretches on the mine tracks.

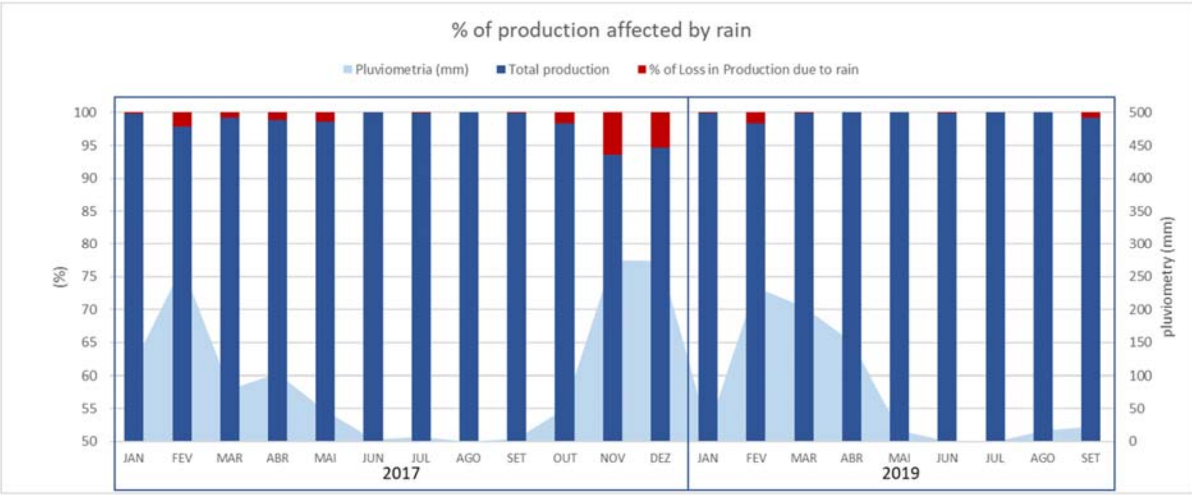

Figure 1. Percentage of production impacted by rain.

The rainfall intensity and the crushing supply are not directly proportional, however, the fact that it rains is enough to impact the supply. Throughout the month, the impact of rain can be diluted, however, on a rainy day the impact on crushing supply is on average 10.7%.

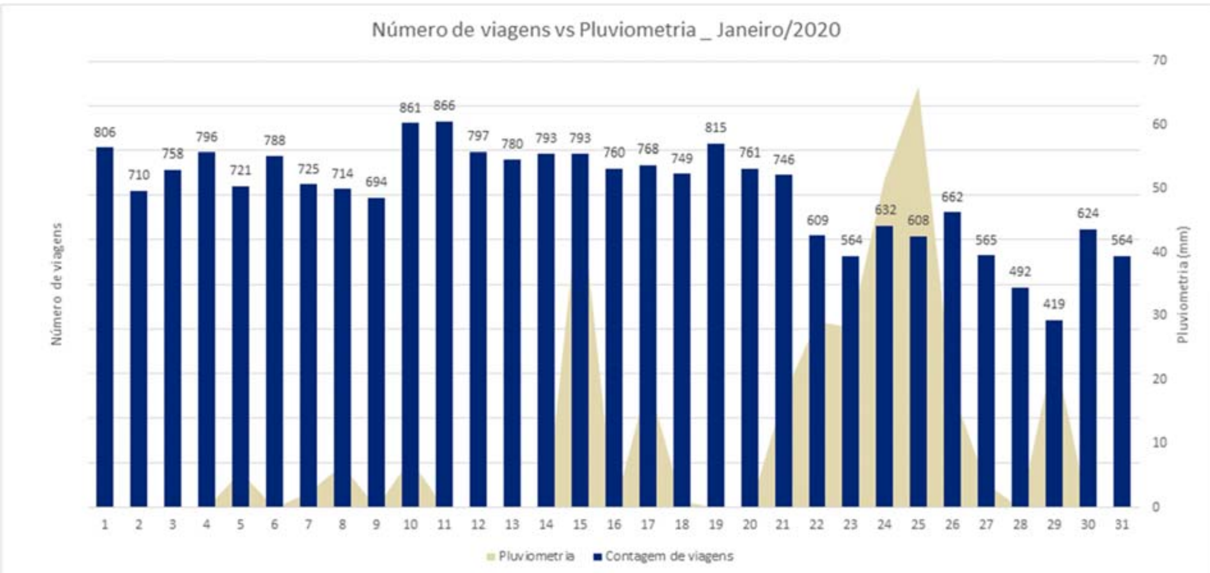

Figure 2. Number of trips versus precipitation

Figure 2 illustrates for January 2020 the number of trips versus rainfall and Figure 3 illustrates the average speed versus rainfall in the region of the project. We can see that when it rains, the number of trips is affected and, when the rain is more intense, the negative effect on the trips of the mine lasts longer.

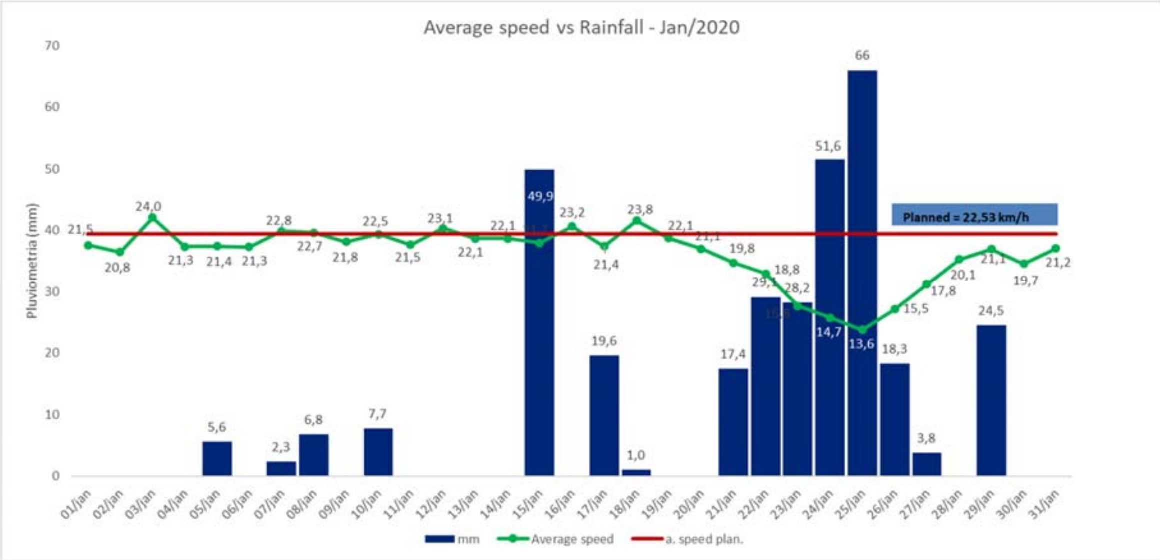

Figure 3. Average speed vs rainfall – Jan/2020

2. INITIAL SITUATION

The roads of the Anglo American iron mine in Conceição de Mato Dentro, are built following the recommendations of the NR22 standard, Mine Road Construction Manual and internal company standards, to resist the traffic of trucks called “haul road” of the type KOMATSU 830E-AC. These trucks can transport approximately 240 tones (about 150m3), totaling a gross load of 400 tones, distributed over its two axles, with 33% of front-wheel drive and 67% of rear-wheel drive.

The average supply production of the primary crusher is 150,000 tons per day, which generates an estimated frequency of 650 to 800 trips per day.

Mine roads before the use of geosynthetics were made as follows:

- 1.00 meter composed of fragments of rocks retained in the sieve of the primary crusher, rising laterally to the surface of the track.
- 0.7 meter of thickness of the sub-base, formed by material called “Itabirito”, rock with high iron content, compact or semi-compact or, in some cases, by a mixture of 50% of rocks with a diameter of 50 at 100 mm and fines of 50%, or also crushed aggregate in sizes between 19 and 25 mm, locally called "Brita 2".
- A 0.30m thick wear layer, used only as a surface finish, for maintenance with the motor grader. Typically formed by sedimentary materials called “cangas” with low clay content or, in some cases, by layers of friable itabirite or crushed aggregate of 9.5 to 19 mm in diameter called “Brita 1”.

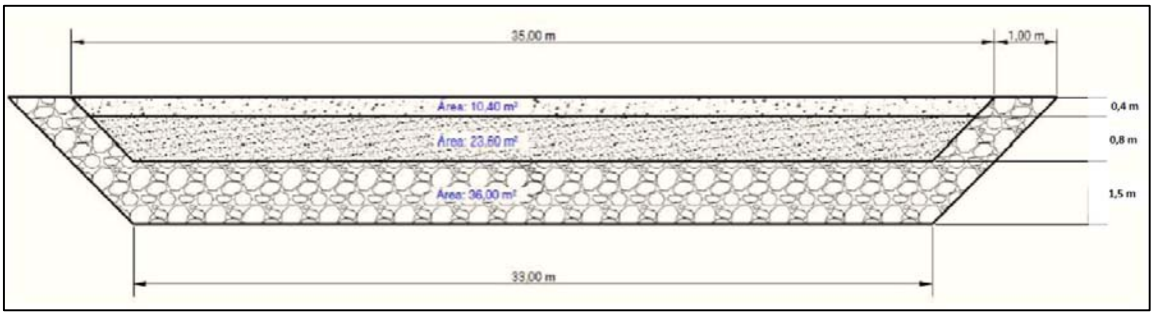

Figure 4. Typical section of mine roads without subgrade reinforcement.

The layers that make up the pavement structure are placed without complying with any degree of compaction, that is, no specific percentage of the maximum density of the standard PROCTOR, as there are no compacting rollers in the mine. It is common for the layers that make up the mine roads to be deposited and compacted by operational and infrastructure equipment.

Such pavement structures proved to be highly susceptible to rainwater and runoff generated by exposure to the region's heavy rainfall. During rainy periods, road surfaces lose support capacity, form wheel tracks that accumulate water on their surface, which leads to two main problems, which are the infiltration of water to the lower layers of the pavement, causing movement lateral and resurfacing (sinking) of the rocks that make up the stabilization layer, which was also deep deformations, and unstable slippery surfaces for transit of the KOMATSU 830E-AC haul road at constant speeds, which are dragging the final finishing layer leaving exposed the lower granular layers and entering a vicious circle that ends up destroying the road.

3. PROPOSED SECTION WITH GEOSYNTHETICS

An estimate by the Geotechnical Management of the mine allowed to define the resistance of the foundation soil in 12 strokes according to the SPT test. Therefore, using literature correlations, a value of 2.30% was defined as the foundation's CBR. One of the conditions to guarantee the success of the project was to be able to use the material available in the mine, so that a sterile classified as sandy sludge was selected for the construction of the track, identified in the mine as sterile and with a CBR value of approximately 30%.

After defining the calculation parameters, the SPECTRA PAVE 4.0 software was used, freely available on the market and calibrated to apply the Giroud - Han (2004) methodology, to determine the minimum thickness of the improvement layer composed by sterile. Through the use of rigid multidirectional geogrids of the type TX160, it was possible to reduce the stabilization layer formed by rocks, from 1.00m thick, to just 0.40m. The geogrid's function is to restrict the lateral movement of sterile particles, as well as, with the help of a non-woven geotextile, to create a separation between the foundation and the subgrade stabilization layer to avoid the pumping effect of fines.

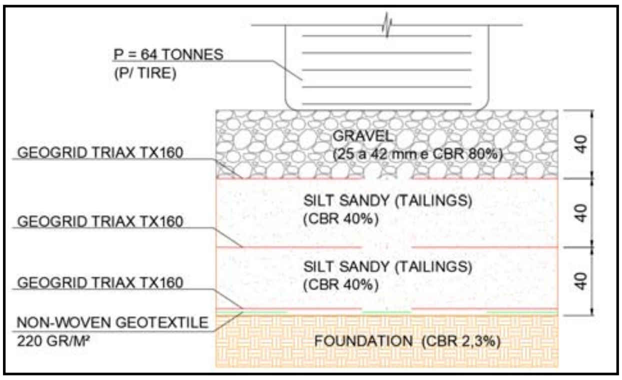

Figure 5. Proposed section with geosynthetics

Figure 6. Multidirectional geogrid used in this project.

The reinforced pavement structure was placed on the stabilization platform, calculated using the software *Pavement - Transportation Computer Assisted Structural Engineering (PCASE),* developed by the United States Corps of Engineers and calibrated for use and application of *Unified Facilities Criteria (UFC)* manuals*.* The calculated structure was formed by two layers of 0.40m, the bottom formed by a sterile sandy silt reinforced by a TX160 type multidirectional geogrid and a superficial wear layer formed by 25 to 42mm diameter gravel, also reinforced by a geogrid multidirectional model TX160.

4. LARGE-SCALE PERFORMANCE PROOF

One of the challenges to be overcome, before the massive implementation of the reinforced section on the mine roads, was to demonstrate to the mining company, the field performance of the proposed solution, under real working conditions, in the section with the most critical conditions possible. It was defined that the test section would be located on soils as close to CBR = 2.30%, in a curve sector and with a longitudinal slope of more than 7° (in the range of 8 to 10%). The area selected for the initial test was identified as an "third clue"*.*

Figure 7. Excerpt selected for the test

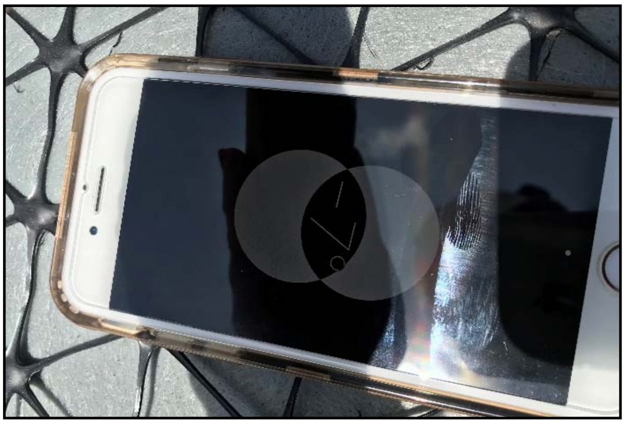

Figure 8. Slope of the test run

The test was carried out in September 2018, with a construction sequence that occurred without any problems, without rain that could generate delays or external agents that could hinder progress. The installation of non-woven geotextile and geogrids was extremely fast, reaching productivity values of more than 2,000 m2 per working day. The construction process will be detailed below.

Figure 9. Installation of the non-woven geotextile of separation

Figure 10. Installation of the first geogrid layer

Figure 11. Installation of tailings on the rigid geogrid

Figure 12. Installation of the final layer of gravel

Figure 13. Reinforced mine road completed

Figure 14. Performance proof after rains

The measurement of the performance of the road was purely qualitative, that is, engineers from the mine's operations and geotechnics areas were present before and after rains assessing truck traffic tests of the KOMATSU 830E-AC trucks on the reinforced roads. This is because the roads are not permanent and a service life of several years is not necessary, the vast majority of mine roads are temporary, so the purpose of the reinforced roads is fundamentally to withstand the intense periods of rain without being affected on its surface in order to ensure stable surfaces for the traffic of haul road. Therefore, after discarding variations (reduction) in speed in the truck route, surface deformations or problems with surface slipping, the solution was approved and released for application in other different roads of the mine, where currently the geogrids have been installing and working with excellent results.

It is important to complement that, in the section “Third clue”, built and reinforced with the geogrid, a lateral drainage channel was built, formed by 10 cm tall high density polyethylene geocell, filled with 25 to 42 mm gravel and non-woven geotextile at the interface of contact with the foundation ground, to ensure adequate drainage of the final structure.

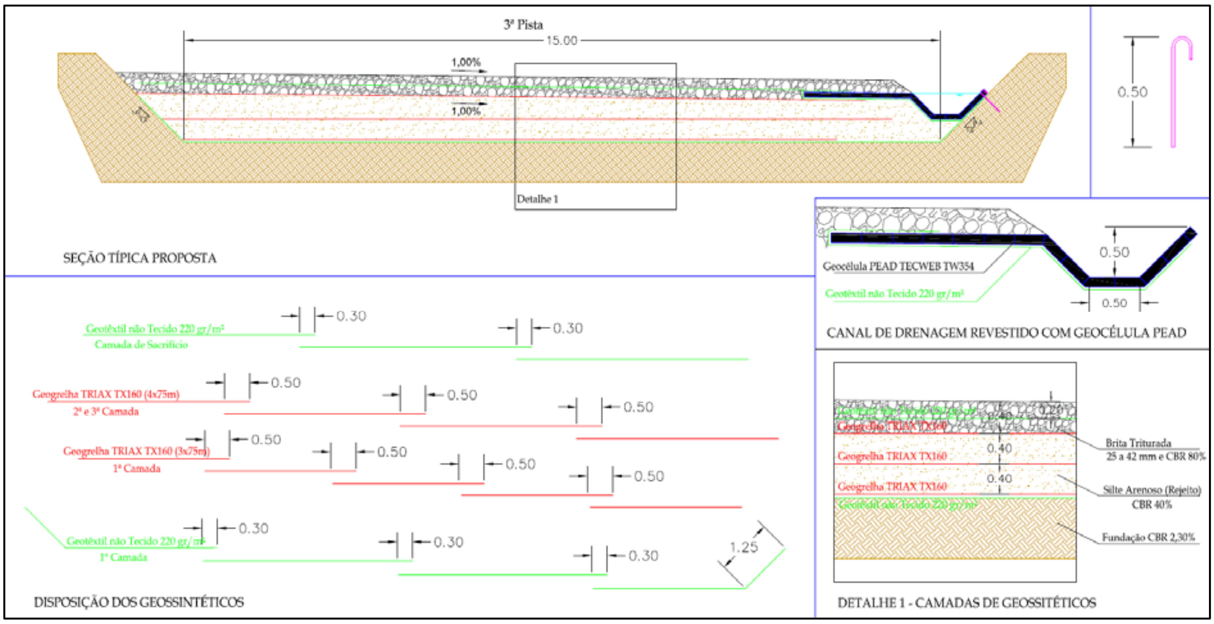

Figure 15. Executive design model of geogrid-reinforced mine roads.

5. CONCLUSIONS AND RECOMMENDATIONS

- The use of multidirectional polypropylene geogrids allowed to build roads for stable haul road trucks, with excellent performance before and after periods of heavy rain. It also made it possible to reduce the conventional thicknesses of the pavement used up to that moment.

- The improvement of the subgrade with rigid multidirectional geogrids allowed to create a stable platform, eliminating the use of large blocks of rocks, the same ones that when depositing or sinking in the presence of water, generated deformations on the road, affecting its operation and reducing speed, thus affecting the number of trips of the haul trucks.

- The reduction in the superficial wheel track, measured directly in the field, comparing the test section with the control section, was approximately 40% less.

- After 1 year of operation, the section in which the solution was applied remains with excellent performance, supporting a flow of KOMATSU 830E-AC vehicles of more than 650 trips per day, also positively impacting the decrease in the demand for road maintenance.

6. REFERENCES

MARY ADOLF, P.E. (2010). Pavement - Transportation Computer Assisted Structural Engineering - PCASE2.09. User Manual. US Army Corps of Engineers.

J.P. GIROUD and J. HAN (2004). Design Method for Geogrid-Reinforced Unpaved Roads”. Part I. Development of Design Method. Technical Paper ASCE.

J.P. GIROUD and J. HAN (2004). Design Method for Geogrid-Reinforced Unpaved Roads”. Part II. Development of Design Method. Technical Paper ASCE.