THE ENGINEERING DESIGN OF THE TUA RAIL TRACK: EVIDENCE FROM THE ARCHIVES

PROJETO DE ENGENHARIA DA VIA-FÉRREA DO TUA: EVIDÊNCIA A PARTIR DOS ARQUIVOS

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Abstract Resumo

This paper intends to give a detailed overview of the different phases of the Tua line focused on the changes in the longitudinal and transversal outline and on the definition of the project of special structures (tunnels, bridges, aqueducts and stone walls). For this, a detailed investigation was carried on the archives of REFER, the company in charge of the management of the infrastructure of the national Portuguese railways. The Tua line fit the Nacional railways plan, defining the connection between the Douro region in Foz Tua and Mirandela in a first phase (1987) and Bragança in a second phase (1906). The construction of the Tua line aimed at flowing the products derived from the Douro region. Its construction was not an easy process, mainly in the first 20km due to the severe relief, composed of narrow valleys with impressive ravines, precipices and waterfalls. This difficulty was also associated to the lack of accessibilities and to the scarce technological resources, resulting in several accidents and human losses and to a huge physical effort. The first studies related with the Tua line date back to 1880 and the last ones are from 1883. However, due to changes imposed by the in situ geomorphological conditions, amendments to the project were made and presented in 1885. Several changes are identified between the previous studies, the project and rectified project.

Falta tradução PT do abstract

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1. INTRODUCTION

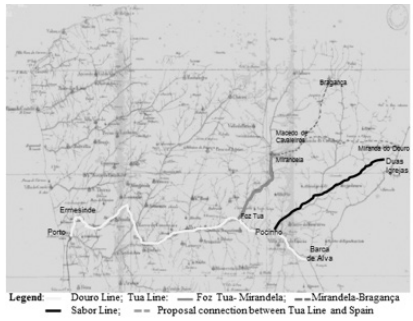
The Portuguese rail track only started in 1856, 36 years after the beginning of the rail track in England. Table 1 presents the year the railways were introduced in some countries of the world. From this information, it is evident the delay of Portugal in comparison with the other countries. other relevant data concerns the increase of the rail network in some countries up to the year 1885, namely in England, France, Germany, and Austria. Portugal in 15 years, after the year of 1856 just increased its railroad extension of about 850km.

Table 1 – Beginning of the Railway in the world (Gazeta nº19, 1955)

Country	Beginning Year	Extension from 1870 (km)	Extension in 1885 (km)
England	1825	25,153	30,983
France	1828	17,179	32,491
Germany	1835	19,619	37,555
Belgium	1835	2,890	4,410
Russia	1838	11,178	26,493
Italy	1839	6,208	10,561
Holland	1839	2,258	2,800
Austria	1841	9,580	22,613
Spain	1843	5,468	9,185
Denmark	1847	760	1,942
Switzerland	1848	1,390	2,797
Norway	1853	-	-
Sweden	1856	1,723	6,892
Portugal	1856	761	1519

The Tua line was constructed in a first phase connecting Foz Tua and Mirandela, in the period between 1884 and 1887, with an extension of 54km. The second phase, regarding the construction of the connection between Mirandela and Bragança took place between 1903 and 1907, having this connection an extension of about 80km. It was during the reign of D. Luís I that the Tua line was constructed as an integral part of the national railway plan, aiming to establish the connection between Porto and the Spanish border. The goal of this connection was to export Portuguese agricultural and winery products. After completion of the Douro line between Porto and Pinhão, in 1879, there were diverging opinions relative to the trajectory adopted to reach the Spanish border. Some engineers argued that when the Douro line reached Foz Tua, it should bend to the north, passing near Bragança until it reached the frontier. However, other engineers believed that the best alternative would be to follow directly to Barca d'Alva (see Figure 1).

Figure 1 – Portuguese Railway Map: Douro line, Tua line (with extension to Bragança) and the possible connection to Spain, by Miranda do Douro (adapted IMTT)



The decision about the place where the line should reach the border with Spain fell to Barca de Alva, but the union of railways to the north was not forgotten with the promise that later the line between Foz Tua and Mirandela would be built, with the certainty that it would be extended to Bragança. With this strategy, the joining of the line to the Spanish railroad system could become a possibility, where Macedo de Cavaleiros would be the starting point and Miranda do Douro the place where the line would reach the border. But in reality, this connection with the Spanish border was never built.

Initially, two projects were presented for the construction of the Tua line connecting Mirandela and Bragança with the Douro railway. One of the projects stated the development of the line along the right margin of the Tua River and

another project indicated the line adjacent to the left margin of the Tua River.

The signing of the contract with the construction company took place on July 30,1884 and the beginning of the works occurred on October 16,1884. The opening of the railway between Foz Tua and Mirandela occurred on September 27, 1887. Only 16 years after the construction of this branch, efforts were made to promote the connection between Mirandela and Bragança. The construction of the branch between Mirandela and Bragança started on July 1903, having as the main promoter the Councilor Abílio Beça, who was deputy and Civil Governor of Bragança. Through his efforts, the government decreed the auction of the extension of the railway to Bragança. This branch was carried out under the direction of the engineer Manuel Francisco da Costa Serrão. In June 1905, the works were resumed to complete the section Mirandela to Bragrança. The branch was up to Bragança on December of 1906.

The Tua line is characterized by a great number of special structures, such as tunnels for crossing rock massif, viaducts to overcome steep slopes and narrow valleys, stone walls, aqueducts and bridges, mainly in the first branch connecting Foz Tua to Mirandela. In the first 21 kilometers, the railway is almost completely sustained by a battlement with a 118 stone walls equivalent to 170,000m^3 of stone masonry. The development of the plan outline is almost only done in curve.

This paper aims to provide a brief overview of the history of the construction of the first branch of the Tua line connection Foz Tua to Mirandela based on the information existing in the archives of Refer at Lisbon, relative to the engineering construction project of the Tua line.

2. GENERAL GEOMORPHOLOGICAL CHARACTERISTICS

The Tua region has a peculiar landscape and geotechnical features that endow this site with a unique natural beauty, with considerable slopes, ravines, precipices, and waterfalls that break along mountains cliffs.

In Foz Tua, the difference in level is too extreme, oscillating between 300 and 650m. The relief consists of numerous valleys where water lines fit , representing a series of hilltops and narrow valleys. The route of Foz Tua to Brunheda, with approximately 21km, appears to be an embedded valley with a rough appearance, flanked by scarps that reach 676m of altitude. Brunheda represents the transition between a steep relief to a less rugged and softer relief. It was precisely in these 21km that the construction difficulties were unimaginable,

with the need to cross steep cliffs and gorges, whose accessibility to the work site were nonexistent, therefore needing to proceed along the winding paths. Figure 2 highlights the high rocky crags that flank the railway on one side and the steep gorges on the other side, needing thus a vast number of supporting stone walls.

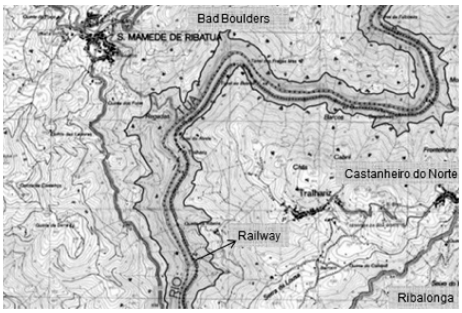
During the first 21km, the railway is almost entirely sustained by a fortress wall. In this extension, there are 118 supporting walls made of dry stone, forming a masonry volume of 170,000m^3. The work plan and profile was extraordinarily hard. However, , the development in curve is about 10,500m which represents half of the total extension, being the remaining composed of straight alignments. The largest alignment has a total length lesser than 500m.

Figure 2 – Examples of the craggy relief in the railway between Foz Tua and Mirandela in the initial 21Km

Along the extension of the initial 21km of the Tua line, only one single road exists, coming down from Castanheiro do Norte at Barca de Alva. In Figure 3 it is possible to observe the distance that was necessary to travel from Castanheiro do Norte to the construction site of the Tua line, including the location of Fragas Más (Bad Boulders). This path was intended for the circulation of pedestrians and horsemen, with steep slopes and the softer inclinations of 0.50m/m (Coelho,

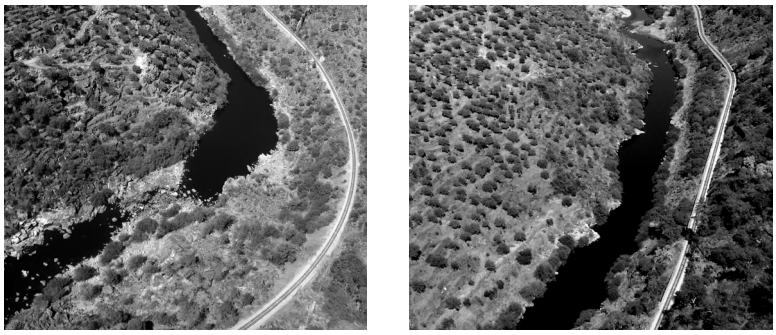
1887). Therefore, it was necessary to redesign this path to suit motor traffic. The steel for the viaducts of Presas, Fragas Más (Bad Boulders) and Paradela weighed about 260 tons, with pieces that weighed over one ton, and were transported by the referred path, which today ends at kilometer 9.

Figure 3 – Plant representations of the Castanheiro do Norte relative to the Tua River and the railroad



After the first 20-30km, the morphological characteristics change considerably and the ground is much more flat until Mirandela, and thereafter until Bragança, without great gorges and precipices, reducing the degree of difficulty with constuction. In Figure 4, the differences in terms of relief between the first 30km and after this branch can be seen. In Figure 4a, a steep slope with granitic rocks and curvy sections can be observed, and in the Figure 4b, extensive straight alignments can be seen, with evidence of flatter terrain without granite escarpments or cliffs.

Figure 4 – Features of the relief flanked the railway Foz Tua to Bragança: (a) in the first 30km, (b) after the 30km



In geological and lithological terms, the Tua region is characterized by granitic rocks and metasedimentary formations (mainly schist). Effectively, the rock massifs constituted a construction challenge to the engineers. Due to the impossibility to overcome the high granite massifs , the decision was made to move them through the construction of tunnels excavated in the rock, and viaducts for the connection of two points separated by gorges.

3. GEOMORPHOLOGICAL CONDITIONS AT THE SITE OF FRAGAS MÁS (BAD BOULDERS) AND PRESAS

The site of Bad Boulders is located between kilometer 5 and 6 of the Tua line and it is an area with high rock massifs, steep escarpments, and with the more serious precipices of the line, without the support base for construction of the railroad, which motivated the construction of a viaduct. This condition combined with the terrain difficulties resulted in some disappointment, due to the almost inexistence of studies on the tracing at this location. The Bad Boulders viaduct (Figure 5) is embedded between two tunnels, and only after opening them was it possible to access the site. When design and planning studies were carried out, it was not possible to foresee such onsite conditions, due to the absence of this information.

Figure 5 – Bad Boulders Viaduct (Medina, 2008)

The Viaduct of Presas (see Figure 6) similarly to the bad Boulders seems a balcony to sustain the line between two precipices. To perform the works at these sites, the workers went down with ropes sustained overhead, or planks which were quickly hoisted when the fuses were lit. This precaution lasted until they cut a path in the rock, which due to its small size its crossing was avoided by the less agile in physical terms.

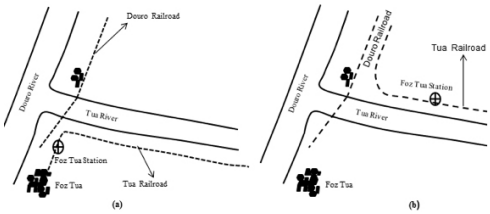
The difficulty in construction related to the geomorphological characteristics of the terrain, combined with the lack of technological resources that facilitated the execution of the works, led to numerous accidents, to a physical men and animals effort and inevitably to the death of some workers.

Figure 6 – Tunnel and Viaduct of Presas in Tua line at the km 1 (Meireles, 2011)

4. RAILROAD FOZ TUA TO MIRANDELA: TRACING FROM THE RIGHT OR LEFT MARGIN OF THE TUA RIVER?

As previously mentioned, two design projects were submitted for the construction of the railroad between Foz Tua and Mirandela based on distinct layouts: (1) one of them was presented by the engineer João José Pereira Dias and the driver Bernabé Roxo, under the leadership of engineer Sousa Brandão, indicating the development of the line along the right margin of the Tua River; (2) another project adjacent to the left margin of the Tua River was proposed by the engineer António Xavier Pinheiro. In Figure 7 it is possible to see the plan layout for the both proposals dating back to August 1883.

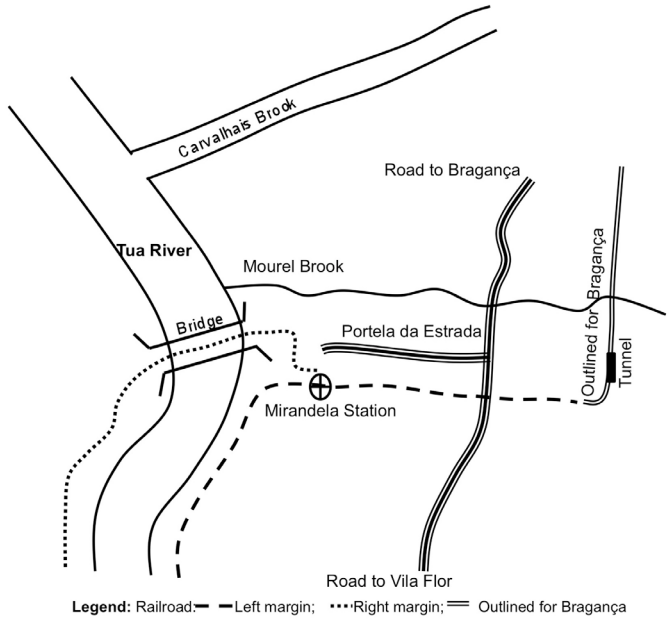
Figure 7 – Different possibilities for the layout of the Tua line: (a) planning by the left margin of Tua River; (b) planning by the right margin of Tua River (Adapted from REFER archives, 1883)



The winning project proposed the trajectory go by the left margin of Tua River. The choice involved: (1) economic constraints; (2) impositions of the project to establish a limit of 18m/m for the slopes and minimum radius curves of 150m; and (3) constraints related to the terrain's orographic conditions. In detail, the conditions that motivated the choice for the left margin were:

- The examination of orographic map showss that right margin is much cut by deep ravines, and is therefore assumed that this is much more irregular and rugged.
- On the other hand, the choice for the right margin of the Tua River requires the construction of Foz Tua Station in an unfavorable relief, which limits its size and would involve large sums in earthworks or the need to extend the Tua line by the Douro, in remarkable extension, in finding a reasonable place for the station.
- The choice for the right margin of Tua River requires the construction of a bridge with considerable extension to cross the Tua River (high coast) when the railways line of Foz Tua to Mirandela extends to Bragança. This situation can be observed in Figure 8.

Figure 8 – Plans for the railroad Foz Tua to Mirandela along the right or left margin Tua River



For a better comparison of the two projects, Table 2 the main features of both planes are provided. From the analysis of this information it is possible to conclude that: (1) the budget in regard to the project of the right margin is slightly higher than the left margin, and does not consider the cost of construction of the bridge in Mirandela to cross the Tua River; (2) the horizontal outline is higher in project of the left margin, and the curve outline is lower. With respect of the art works, it can be seen that the right margin has a total of 10 tunnels with 1307m total extension, against a total of 510m of tunnel extension of the left margin planning. In relation to the supporting walls, the volume of masonry is practically the same for both plans.

Table 2 – Comparison between the railroad project by the right and left margin Tua River

Right margin	Left margin	
Budget	1,336,300$ (6665€)	1,236,250$ (6166€)
Extension	53,262m	53,953m
Max. slope	$18\%_0$	$18\%_0$
Horizontal	17km (32%)	30km (56%)
Slope up	15 km (29%)	19km (35%)
Slope down	21 km (39%)	4.9km (9%)
Straight	34 km (63%)	37km (68%)
Curve	18.6km (37%)	17km (32%)
Tunnels	10 (1307m)	9 (510m)
Bridges	5	3
Viaducts	1	2
Support walls	$117m^3$	$124m^3$

It should be mentioned that the selection of the left margin the Tua River for the planning of the Tua line was strongly influenced by the fact that this avoided the need to build a bridge to cross the river, when the railway reach Mirandela.

5. TECHNICAL ASPECTS OF THE PROJECT OF TUA LINE

The first Portuguese line was inaugurated in October of 1856, establishing the connection between Lisbon and Carregado. An English company, pioneer in railroad construction, constructed the line, given that Portugal did not have sufficient experience, knowledge and economical resources to realize this kind of project. Actually, Portugal did not possess internal standards that defined the guidelines for a railroad project. Thus, the Portuguese government resorted to English, French and Belgian technical specifications. It is emphasized the importance of D. José de Salamanca in the construction of the Portuguese railways, a contractor who had worked in Italy and Spain, achieving the feat of converting the slow construction work to a pace unusual for that time.

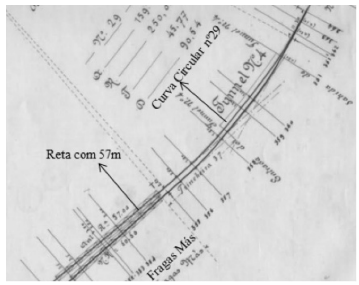
The Portuguese government started to create legislation when the first railway was constructed, enabling Portuguese engineers, namely designers of the Tua line, to base railroad projects on certain technical specifications. When no information existed about a certain parameter, the Portuguese designers adopted the same methodology of other projects applied in the others countries, citing them along the justificatory document .

Only in 2002 were European standards used to unify design criteria between European countries with regard to arithmetic parameters, stroke alignment and type of gauge, and to also establish the rules and admissible maximum and minimum values of various parameters, which rules the project of railroads (European standard ENV 13803-1).

The Tua line is composed of successive straight alignments, known as tangents, along with curves, constituted by circular curves. There are examples of where transition curves are used, namely transition curves of clothoid type. The greater advantage of the transition curves is the gradual change of the radius along of the curve, reducing the discomfort felt by passengers and promoting safety by preventing the sudden onset of centrifugal force. The first railroad line with the introduction of variable radius curves (clothoid type) was nicknamed the Brenner line in 1864. This line crosses the current border between Tirol (Austria) and Alto Ádige (Italy). The first publications reporting the use of clothoid in railroad tracing are from the United States, by Eliot Holbrook Railroad Alignment in Railroad Gazette (1880) and The Spiral by W. Railroad H. Searles (1882), and in Germany, The Theory of Alignment for Launhardt (1887) (DER/SP, 2006).

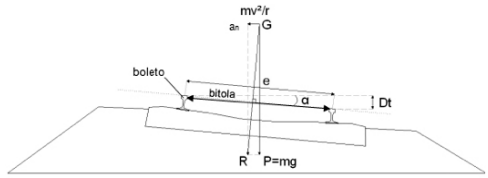
Although transition curves have been used since the eighteenth century being pioneer in railways design, the curves were used in the Tua line project (1883-1887) were mainly circular curves, without transition branches (see Figure 9).

Figure 9 – Plan Outlined between kilometer 5,450 and kilometer 5,720 in Fragas Más - Bad Boulders (REFER archives)



Another technical consideration of the railroads project is related to the scale (Dt), which is the difference in level between the axes of the two rows of rails, in accordance to what is indicated in Figure 10. In fact, in the curve branches there is the need to elevate the extrados of the curve so that the balance of centrifugal forces can be accomplished, in order to approximate the curve motion with the conditions of circulation in straight line. The Tua line project adopted the application of scale along of circular curves.

Figure 10 – Implementation of scale in the rails (Farelo, 2010)



The layout of the Tua line has its origin at kilometer 131,420.00 of the Douro line, 650m from the village of Foz Tua, being approximately parallel to the line of the Douro until near the village. The line crosses the Douro line with a radius of 150m, and follows the left bank of the Tua River until it reaches Mirandela. In general, the minimum radius of 150m was applied in the buttresses to decrease the earthworks, which are very constrained in places where there are large rock masses, like inside tunnels.

Technical specifications legislated

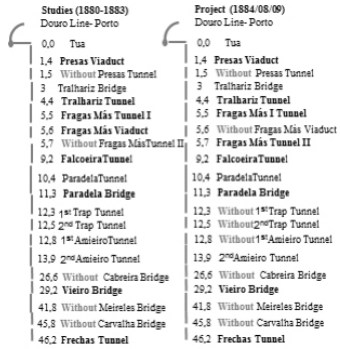
According to what was mentioned above, the Portuguese government imposed technical conditions for the project of the Tua line. These impositions were concerning: the type of gauge, the slope of the plan, the curve radius and the train velocity. All projects presented took into account these conditions. These specifications were published in April 1883 and consist of the following parameters (Colecção Oficial de Legislação Portuguesa do Ano de 1884):

- Gauge Type: meter gauge (track width 1m). The meter gauge was adopted due the difficulties with construction and economic restriction.
- Maximum slope was of 0.018 m per liner meter (18%).
- Minimum straight line between one curve and reverse curve was of 50m. The European standard ENV 13803-1 indicates the minimum value of 30m.
- Minimum radius of curves was fixed at 150m. The technical specification for interoperability of the rail system suggests that the railroads where trains run at low speed the minimum radius shall not be lesser than 150m.
- Weight of rails was fixed at 20kg per meter.
- Maximum speed was defined to be 50km/h for the curves with minimum radius of 150m and 70km/h for some straight alignments. Although the locomotives could operate at speeds of 70km/h, in fact for this line the locomotives could not exceed 50km/h, due the curves with a minimum radius of 150m and a lot of curves with sloped outline.

The Tua line between Foz Tua and Mirandela

In 1883, a draft project for the Tua Line between Foz Tua and Mirandela was published and in 1884 the final project was published. However, in 1885, a new project was published with some amendments to the final project, being designated as the rectified project. Through Figure 11 it is possible to compare the artwork foreseen in the draft project and in the final project and evaluated the differences.

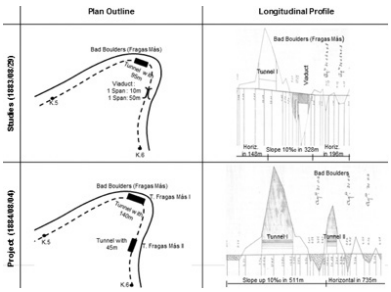
Figure 11. Schematic representation to the studies (1880-1883) and Project (1884) for the railway Foz Tua to Mirandela



The draft project included a greater number of tunnels than those that were effectively constructed, and also underestimated the size of some brooks not foreseeing the construction of bridges like the Cabreira Bridge, Meireles Bridge and Carvalha Bridge. The draft project also did not include the second tunnel in Bad Boulders. This vagueness was mainly related to the low level of knowledge of the real on-site existing conditions of the relief. When additional studies which were based on the organization of the project in 1884, were carried out, it was still not possible to carefully raise the transversal profiles, neither to perform the expropriations nor to obtain permission from the landowners to conduct land operations. These difficulties prevented that rigorous survey of the on-site conditions were inspected, leading to lack of information to define the profiles in detail . This also led to the need of modifying some artworks designed in project and to consider others that were not foreseen previously

For a better understanding of the alterations that the successive projects for the Tua line between Foz Tua and Mirandela had, it is necessary to additionally visualize the plan outline and the longitudinal profile in some sites of the planning of the design project. These plans and profiles are in Figure 12. The first difference is located at kilometer 5 (Bad Boulders – Fragas Más) and refers to the longitudinal profile defined in the draft and in the project. As already mentioned, the Bad Boulder zone is characterized by a severe relief with narrow valleys and impressive ravines. The accesses to the work place were also scarce and often nonexistent. Therefore, when the studies were conducted, it was not possible to obtain a correct profile, resulting in the difference found between the two projects. The project (1884) wrongly eliminated the Bad Boulders viaduct, but introduced a second tunnel at this location. This tunnel of 45m of extension allowed an increase of the horizontal section (from 196m to 735m).

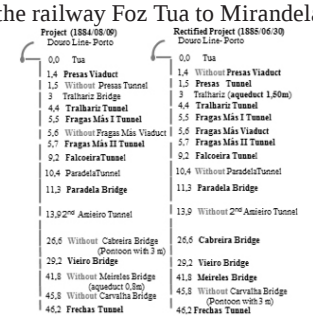
Figure 12 – Plan outline and the longitudinal profile for railway between Foz Tua and Mirandela in Bad Boulders (Fragas Más) for the studies and project (adapted REFER archives)



The second situation represented in Figure 12 is referred to the as the Trap (Armadilha). The project eliminated the tunnels in the Trap planned in the studies. This happened because of the same reasons pointed out before related to the incorrect survey of the profiles. The granite blocks of this region have hundreds of meters in diameter, which led to many changes to the initial project. The degree of difficuly expected in the works, essentially resulting from manual labor to disassemble the rock through equipment, such as hammers and chisels, by the absence of road header was the main reason leading to the discrepancy.

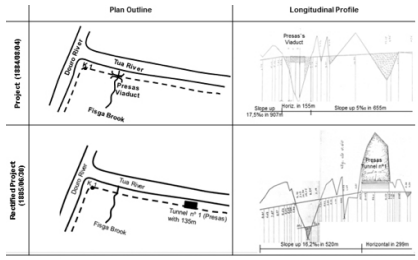
Even if the construction of the Tua line started in 1884 after the project had been approved, in 1885 a rectification of the project was carried out resulting from additional knowledge of the local conditions due to the direct contact of the engineers with the job site according to the progress of the works. The rectified project is seen as an update of the final project with the introduction of changes due to different conditions found in the ground and not covered in the previous projects (see Figure 13).

Figure 13 – Schematic representation to the project (1884) and rectified project (1885) for the railway Foz Tua to Mirandela



The rectified project (see Figure 14) considered the possibility of avoiding the Viaduct of Presas considered in the studies and in the project, being this replaced by an aqueduct and a supporting wall. This occurred because in the project (1884) a trench at kilometer 1.20 was designed according to the conditions of the transversal profiles obtained from the initial studies. However, after a rigorous on-site survey, it was observed that there would be a trench with 28 to 30m of length, and it would be necessary to perform a landfill, with a great depth.

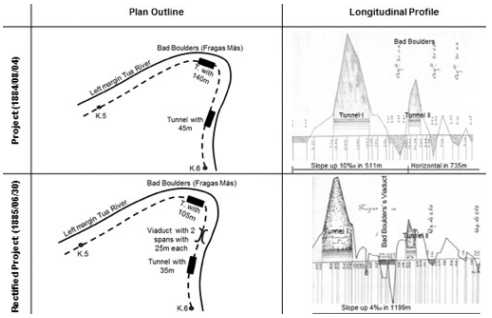
Figure 14 – Plan outline and the longitudinal profile for railway between Foz Tua and Mirandela in Presas site for the project and rectified project (adapted REFER archives)



The knowledge of these conditions determined the need to change the plan on the mountain to foresee the construction of a tunnel. For this reason, the Presas tunnel was introduced into the rectified project with an extension of 135m. The elimination of the Presas viaduct in the rectified project, did not in fact occur, not due of the importance of the water course, which is insignificant, but to avoid a landfill with a maximum height of 21.5m which would require a substantial supporting wall.

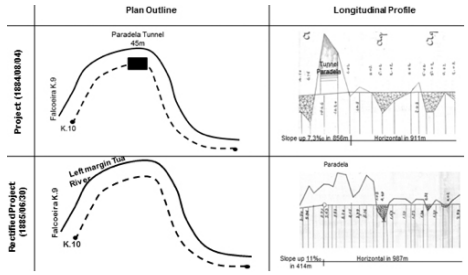
Another alteration indicated in Figure 15 refers to the region of Bad Boulders, with the introduction of the viaduct encased between two tunnels. This viaduct was constructed to avoid a supporting wall over 30m high and with the foundations in the Tua River. In the rectified project, both tunnels in the Bad Boulders suffered one reduction in its extension. It should be noted that all projects adopted for the first tunnel had the minimum radius of 150m. The use of this radius decreases the work of earth leveling and integral excavation of the massif. Although the rectified project for the Bad Boulders site eliminated the horizontal sections, the ascendant slopes of 10% planned in the preliminary draft and in the project that were excluded passed to 4% at 1199m.

Figure 15 – Plan outline and the longitudinal profile for railway between Foz Tua and Mirandela in Bad Boulders (Fragas Más) for the project and rectified project (adapted REFER archives)



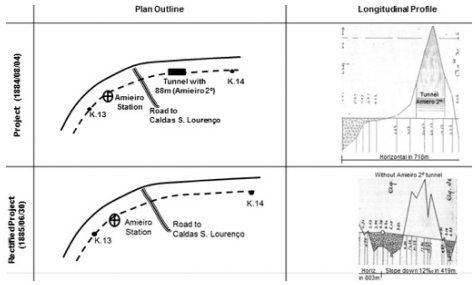
As can be seen from Figure 16, the Paradela tunnel was eliminated in the rectified project. This elimination occurred because the correct longitudinal and transversal profile demonstrated that its construction was not necessary.

Figure 16 – Plan outline and longitudinal profile for railway between Foz Tua and Mirandela in Paradela site for the project and rectified project (adapted REFER archives)



From Figure 17 it can be seen that in the rectified project (1885), the second Amieiro tunnel was also eliminated, because the ground did not have an enough thickness and was relatively inclined, contrarily to what had been previously foreseen.

Figure 17 – Plan outline and longitudinal profile for railway between Foz Tua and Mirandela in Amieiro site for the project and rectified project (adapted REFER archives)



The main differences between the studies, the project and the rectified project are presented in Table 3.

Table 3 – Comparison between the studies, project and rectified project for railway between Foz Tua and Mirandela (REFER archives)

	Study (1883)	Project (1884)	Rectified (1885)
Max. Slope	18‰	17.5‰	17.5‰
Length without slope	30 km (56%)	31.6 km (59%)	25.5 km (47%)
Average Radius	221m	225m	243m
Curve outlined	17.1 km (32%)	17.4 km (32%)	19.4 km (36%)
Straight outlined	36.9 km (68%)	36.5 km (68%)	34.5 km (64%)
Extension	53,953m	53,940m	53,917m

The maximum slope of the layout decreased for the project and rectified project, reducing the train traction effort. The average radius increased for the rectified project, this situation improved train safety, and allowed the vehicles' movement at higher speeds. The remaining parameters of Table 3 contain approximate values.

6. CONCLUSION

Due to the complex geomorphological conditions, the beginning of the Tua line construction in 1984 was preceded by several studies aiming to decide details

about the plan and longitudinal outline of the line. The first studies date back to 1880 and the last ones are from 1883. The project for the construction was dated from August 1984. However, due to changes imposed by the different in situ geomorphological conditions, amendments to the project were made and presented in 1885. In this respect, the Bad Boulders (Fragas Más) zone is a real example of the extreme hard geomorphological conditions that engineers and workers had to face. Several changes were identified between the previous studies, the project and rectified project, with the addition of a bridge as it was impossible to use high size stone walls due to the huge difference in level in the connection of both tunnels foreseen.

In general, the construction of the Tua line between Foz Tua and Mirandela was a hard process, with numerous changes identified between the studies (1883), the project (1884) and the rectified project (1885), which resulted from: (1) previous inaccurate survey of the ground conditions (lack of proper equipment, difficult access to the sites); (2) only after the contact with reality, some important changes related to the special engineering structures were considered or updated; (3) the difficulty of the first 21km of the Tua line, mainly in Bad Boulders and Trap site, is reflected directly in the construction works, namely 118 support walls (total of 139 support walls in project) with 170,000 m^3 of stone masonry walls, the two unique viaducts of the line are located in this first 21 km and 5 tunnels in a total of 6 for the Tua line between Foz Tua and Mirandela.

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