Improvement of the Soil of Inbeatenearth Road: Application on the Road Lubumbashi - Kasomeno, DR Congo

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Absract: ***A in earthbeaten road meeting the requirements of the standards in force to meet the operating conditions according to the traffic constraints relating thereto; requires the mastery of the geotechnical parameters of the road. In this article, we have identified the geotechnical parameters of the Lubumbashi - Kasomeno road, particularly from the Kasenga road junction, subdivided into several sections for a good efficiency of the studies made. Since the geotechnical parameters found in the laboratory were low, to improve the soil quality and to have a good lift of the road, we considered the contribution of the good quality material to mix with the platform of the road by compaction. In order to minimize the cost of work, we suggested that the filler material be pulled in the vicinity of the road.***

Keywords: Soil; Beaten earth road; Compaction; Lubumbashi

1. Introduction

Having a good road is the major concern of any engineer during construction. The problem of the choice of the material, its preparation, its treatment and its implementation is strongly dependent on all the other natural conditions (climate, traffic)[1]. Soil is the main material used by the engineer as a foundation and construction material for civil engineering works and major works, including road construction[2]. The Lubumbashi - Kasomeno road is one of them. A good road is differently defined considering the use that one makes of it. In our context, a good road is a work in sustainable materials, on which the taking into account of determining factors such as traffic (load per wheel, distribution, repetition), local climatic and hydrological conditions, soil lift and the mechanical properties of the materials, is the primordial element to be considered [3]. The aim of this work is to characterize the ground of the Lubumbashi-Kasomeno road in order to propose improving solutions in the norms of a good beaten road. Our study considers the improvement of the Lubumbashi-Kasomeno road using the geotechnical parameters. This will enable the implementation of a technical model for beaten roads in non-standard conditions. The Lubumbashi - Kasomeno road passes through regions of Kibarian formations (shale, sandstone, limestone) and Pilopleistocene formations (sand and gravel); It is 140 km from the bend of the Kasenga road. The Lubumbashi-Kasomeno section does not have a continuous lift, which implies bad outfits in some places.Indeed, two agents play a role in the destruction of the road soils, it is a part of the traffic not compatible with the dimensioning of the road (the maximum load per axle, the inflation pressure of the tires, the frequency of application of the loads, the speed of circulation ...) imposed on the road, and on the other hand, climatic conditions. To overcome these agents, it is necessary to have a good quality of the road ground which is defined by good geotechnical parameters (the granulometry, the index of plasticity, the optimum water content, the C.B.R.). From the foregoing, in order to determine areas for improvement, we subdivided the road into sections and sampled these sections for geotechnical testing at the Lubumbashi Roads Laboratory. Then we conducted the same approach in the area to locate the filler material at a lower cost.

2. Material and Methodology

2.1. Compaction technique

The means that will be used to improve the road surface of the Lubumbashi - Kasomeno section is the compaction technique. In fact, whatever the method used to ground a soil, the density of the soil thus transformed depends on the water content. The Proctor test makes it possible to plot the dry density curve as a function of the water content, for a given compaction energy. This curve makes it possible to highlight an optimum density. This test makes it possible to determine two fundamental quantities, in particular for the progress and the control of earthworks, a maximum of dry density (δ_{dmax}) for an optimal water content (ω_{opt})[2]. The compacting technique consists of a mechanical action to increase the compactness of the soil by reducing the possibilities of deformation and improving the bearing capacity. This compression technique aims at rearranging and retightening grains to densify the soil and expel air and increase cohesion for complete drying to improve compressive strength [4]. Before moving to compaction on site, measurements must be carried out in the laboratory on identification materials. The problem of soil identification consists in characterizing the materials in a sufficiently clear manner to be able to compare different materials on which analogous constructions have been placed or else to compare the different states of the same material. Apart from the immediate identification (color, smell, condition), there is a series of laboratory tests that can do this with precision. Thus, compaction tests in the laboratory make it possible to realize the ability of the soil to be compacted. Among the laboratory tests to be carried out, we have: granulometric analysis; Atterberg limits; the Proctor test and the C.B.R. lift test. These tests qualify the soil by a more precise name (clay, sand, clay loam,). Such a name is very useful when it is rigorous; because for the soil mechanic, the simple name is a sufficient indication to list the properties to be studied, the possible risks and the main aptitudes.

2.2. Soil identification

2.2.1. Granulometic analysis

Principle: The principle of this analysis is to split the material into several categories of grains of decreasing size by means of a series of sieves. Each sieve is characterized by the dimension of the mesh (opening) of the canvas which constitutes its bottom. One will say refusal on sieve: the fraction of soil which will be retained; sieve: the fraction of soil that will pass through the sieve.

Embodiment: To arrive at finding the results, we take the mass of the soil to be analyzed Ms which must depend on the maximum size of the large particles. It is recommended, [5] 200 Dm <Ms <500Dm; with Dm representing the diameter of the largest particles, expressed in millimeters; Ms expressed in grams. This limitation of the mass is intended, on the one hand, to carry out the test on a fraction sufficiently representative of the soil, and, on the other hand, to carry out the successive sieving operations with a limited quantity of the particles in each sieve[6] Material: As material, we will use a sieve column of standardized openings, the sieves are nested in each other according to their decreasing mesh openings from top to bottom. The upper sieve with, usually, a 5mm mesh opening. The sieve column is completed by a lid placed on the upper sieve and a closed bottom container to recover the last sieve. ; A vibro-sieve; bins; a scale sensitive to the nearest centigram; an oven with thermostat and a wire brush.

2.2.2. Atterberg limits

Principle: The Atterberg limits are conventional water contents that establish a soil condition. One distinguishes: The limit of liquidity (LL%) which is the water content above which the ground behaves like a semi-liquid and flows under its own weight. The limit of plasticity (LP%) which is the water content below which the soil loses its plasticity and becomes friable. The plasticity index (IP) which is the difference LL - LP. It is even higher when the soil contains clay. A soil with an IP> 10 is quite clayey and for IP> 30 it is very clayey.

Embodiment: the measurements are made on the fraction of the lands passing through a sieve of 0.5 mm and are obtained by conventional tests, in particular the plasticity is defined by the possibility of forming under the finger a 3 mm roll of diameter. The comparison of the natural water content and the Atterberg limits gives an immediate idea of the state of the soil.

Material: Casagrande's apparatus and its components are used.

2.2.3. Proctor Trial

Principle: On site, during compaction, the compactness obtained is directly related to the water content; the less water there is, the less the grains are lubricated and the mixture can not be compacted to its minimum volume. And if there is too much water, the absorption effect tends to swell the mixture and the pressures of the compactors are damped by the water. Thus this test allows us to determine the optimum water content (ωopt) and the dry density (δdmax).

Embodiment and Material: The apparatus used comprises: C.B.R. (CaliforniaBeaning Ratio) and a lady C.B.R. constituted by a cylindrical sheep of specific dimensions. This test is carried out by two compactions of different intensity namely: the normal Proctor where the compaction intensity is only moderately pushed and the modified Proctor where the intensity of compaction is much more intense. 6 kg of oven-dried materials are used, which are compacted in 5 successive layers of approximately 2.5 cm thick, each compacted at the rate of 55 strokes distributed over the entire surface of the layer. After completion, the sample is removed and a quantity of water is added, usually 2% of the water content at which the first compaction was made. This will result in five compactions for the test to be judged sufficiently.

2.2.4. C.B.R.

Principle: The Californian Bearing Ratio (C.B.R) test is performed both on the foundation floor of a pavement structure and on the materials that constitute it [6]. From this test we define an empirical index called "Californian lift index". This index is used for sizing a pavement structure [7] Embodiment: the test necessitates the manufacture of specimens on which the punching is subsequently carried out. It will be necessary to know the optimal water content of compaction of our sample to study. When the maximum dimension of the elements of the material to be studied is less than or equal to 20 mm, all the material will be tested. It will be necessary to prepare 6kg of material for each specimen. The amount of water corresponding to the optimum water content is added to the material and the manually humidified material is kneaded or more preferably using the kneader. This quantity of material will then be put in place in the CBR mold at the bottom of which the spacing disc has previously been placed. The material will then be compacted to the compaction energy chosen with the material and under the conditions of the Proctor test[5] The mold containing the test piece will then be detached from the base plate, turned over so that the upper face of the test piece is in contact with the base plate. We will then proceed to the extraction of the spacer disk and then to the execution of punching or immersion in the desired lift index (immediate CBR, or CBR after immersion). For our study, as our land can sometimes experience upwelling or flooding, or receive rainy wet weather, we will run the CBR index after immersion.

Material: As material, we used a compression press with a minimum capacity of 50 kN with a stroke of at least 60mm. A CBR mold and the Proctor Normal and Proctor Modified compaction ladies, as well as a set of accessories.

2.3. Improvement of the section

As recommended, for the improvement of the section, we will bring material of a good quality and thanks to a tire compactor, we will carry out mixing with the platform. We know that the sizing of a road is standardized according to the traffic and the C.B.R of the platform. For the

Lubumbashi - Kasomeno road, traffic is weak; it is between 30 and 50 vehicles a day, but at the weekend it becomes more intense. Knowing all the required quantities of materials, we will determine in the amount of water to use considering the optimum content for a good compaction. So the materials will be mixed on site, the water tank will pass before compaction. The compaction will be at 98% of the maximum dry density of the optimum content and the number of passes will vary between 8 and 12. After improving the trunk of the road, a wearing course will be placed using compacted gravelly at 98%.

3. Results and discussions

3.1. Results of the tests

3.1.1. Results of the tests on the materials of the platform

To find the characteristics of the soils of the platform, a sampling of the representative samples of these various sections was made in a random manner to the following K.P.: 0+100 ;5+300 ;9+600 ;10+00 ;15+00 ;20+00 ; 30+00 ;40+50 ;50+00 ;60+00 ;70+00 ;80+00 ;90+00 ;100+00 ;110+00 ;120+00 ;130+00 et 137+00that is 18 samples in total.

The results of the analyzes are shown in Table 2 for which we have: dmax: the maximum dry density of the materials; W% O.P.M. : the optimum water content Proctor modified; I.P .: the plasticity index; C.B.R. ; A: Clays; G: Gravelous and GL: Lateritic gravelly.

3.1.2. Test results on road reloading materials (cottages)

The local materials found in each cottage, were chosen after the tests carried out in the laboratory, whose results are shown in table 3. According to the sections we see that the granulometry of the soil of the platform is discontinuous, spread and predominantly fines. The floors of the platform consist of clay, gravelly lateritic, gravelly alluvial and eluvial and fine sand. Thus we have following the K.P. (distance in kilometers according to the axis of the road):

K.P. 0 + 000 to K.P. 15 + 000: Weathering clay as well as gravelly;

KP 15 + 000 to KP 20 + 000: Alteration clay;

From K.P. 20 + 000 to K.P. 70 + 000: Clay and gravelly;

From K.P. 70 + 000 to K.P. 80 + 000: Clay;

From K.P. 80 + 000 to K.P. 110 + 000: Sand and Clay (yellow soil);

From K.P. 110 + 000 to K.P. 140 + 000: Alteration clay.

On this stretch of 140 km, we selected six sections according to the quality of soils and the bearing index (C.B.R). These sections are distributed as follows:

Table 1: Sections

No. Section	From K.P.	To K.P.
01	0+00	17+00
02	17+00	27+00
03	27+00	73+00
04	73+00	87+00
05	87+00	113+00
06	113+00	140+00

With: K.P.: Kilometric profile and K.P. (A + B): where A is the distance in kilometers on the axis of the road and B is the distance in meters on the axis of the road.

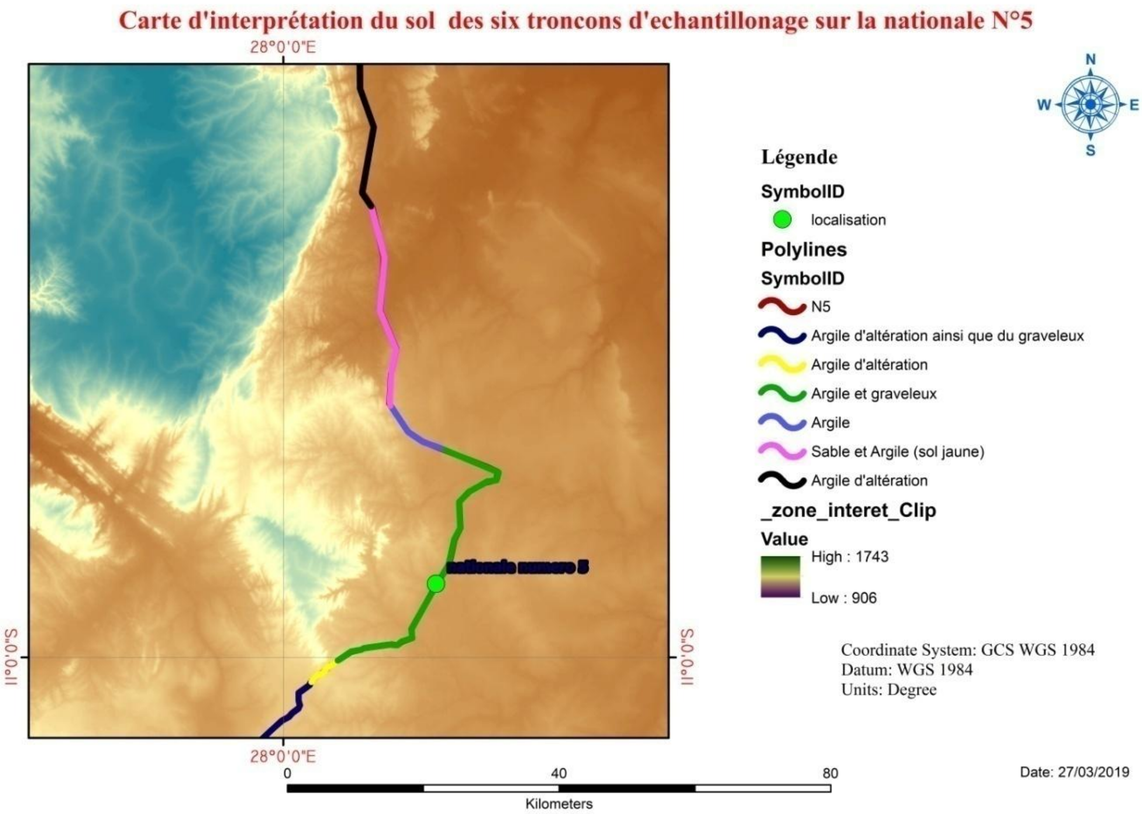


Figure 2: Soil interpretation map of six sampling sections on National Road N ° 3

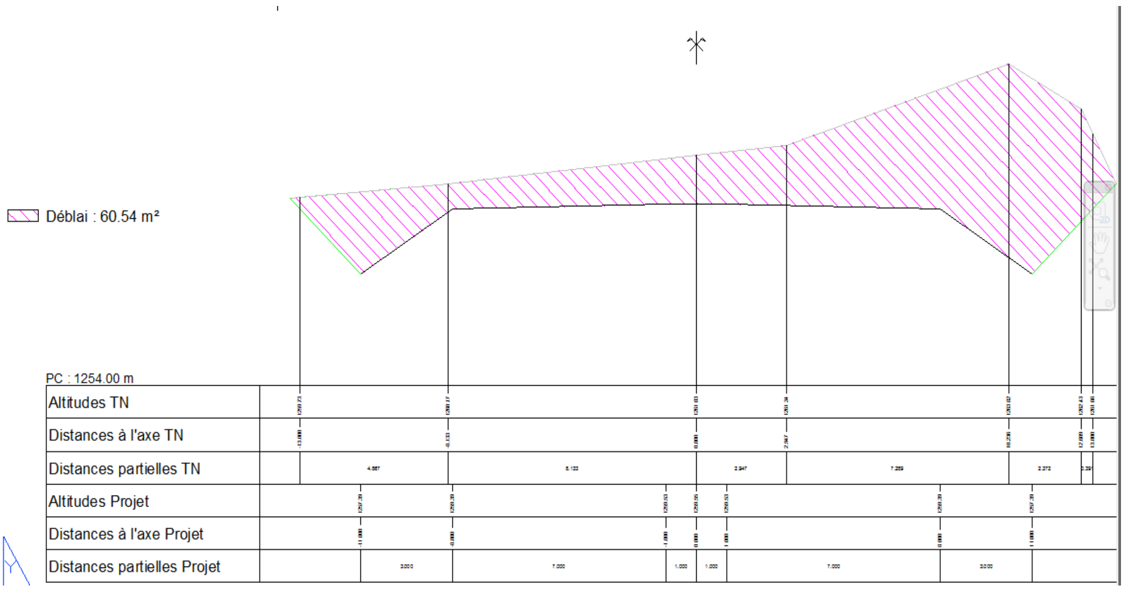
Table 2: Characteristics of the platform

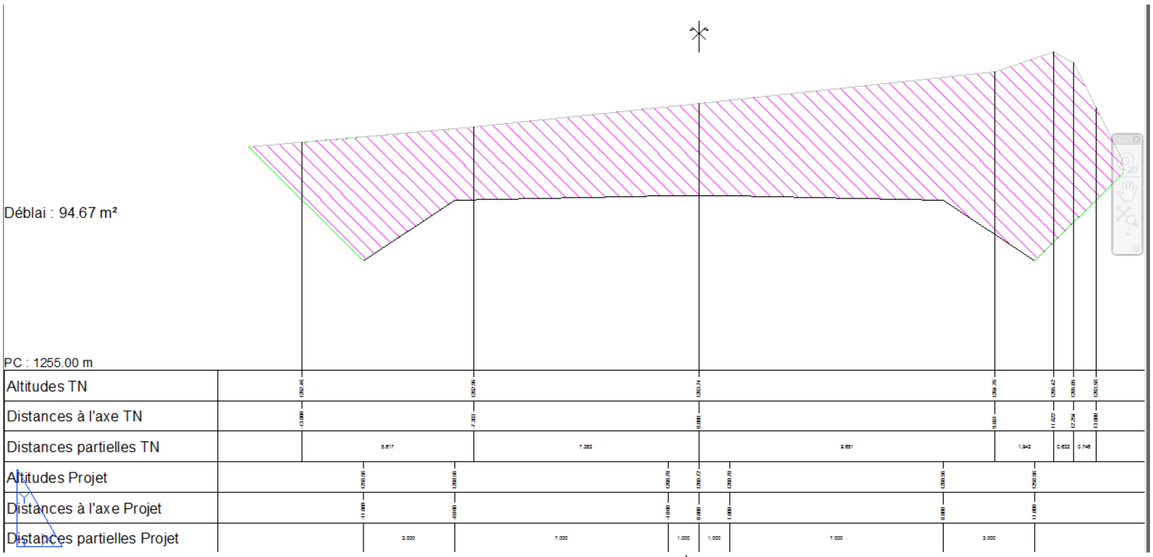
N°	K.P. sampling	Soil classification	Dmax	W% O.P.M	W%	Percentage of purposes	I.P.	C.B.R. à 95% O.P.M
1.	0+100	A1	2,05	10,9	17,4	69	14,6	16,4
2.	5+300	A2	1,80	18,9	20,4	89	24,1	24,3
3.	9+600	GL3	2,11	11,4	7,1	33	16,1	21,3
4.	10+00	A1	1,75	19	21,4	75	14,3	27,7
5.	15+00	G2	1,96	14,8	19,2	28	16,4	19,6
6.	20+00	A2	1,90	15,2	16,2	89	23,4	10,1
7.	30+00	G2	2,03	10	14,1	39	8,7	18,8
8.	40+500	G2	2,09	10,3	12,3	35	18,6	22,5
9.	50+00	A1	2,09	10,7	13,9	72	10,4	20
10.	60+00	A1	1,95	12,9	17,1	61	6,2	18
11.	70+00	-	2,15	9,2	11,2	24	8,2	69
12.	80+00	A1	2,02	12	18,3	90	7,1	11,7
13.	90+00	SIC	2,19	7,3	10,3	22	-	19,7
14.	100+00	SIC	1,83	7,1	9,5	23	-	18,8
15.	110+00	SIC	2,03	8,7	11,8	38	-	29,2
16.	120+00	A1	1,88	13,4	20,9	76	12,8	7,8
17.	130+00	A1	2,03	10,6	16,5	55	6,9	10,3
18.	140+00	A1	1,97	12,7	19,5	60	9,6	9,2

The sections consisting mainly of clay have a low lift index (I.P.), which should be increased in strength by providing a higher lift material. The sections consisting of clay and sand or clay and gravelly mix have good lift and require no improvement. Table 3 shows that the deposits consist of lateritic gravels (G.L) with a percentage of ends less than 40% and are good materials for reloading the road.

Table 3: Characteristics of the cottages

N°	K.P. sampling	Soil classification	dmax	W% O.P.M	Max grain size	Percentage of purposes	I.P.	C.B.R. à 95% O.P.M	Cubature
1.	1+700	G3	1,96	14	9,52	37	14,4	31,7	9.375 m^3
2.	3+600	G2	2,12	10	12,7	36	11,3	31,4	7.800 m^3
3.	15+700	G2	1,93	15	12,7	37	6,7	32	6.825 m^3
4.	27+400	G2	1,99	11	19,1	34	9	49	2.367 m^3
5.	31+600	G2	1,80	17,5	12,7	48	10,1	18,8	3.450 m^3
6.	34+400	GL2	2,03	11	12,7	30	11,6	31,7	17.467,8 m^3
7.	41+850	GL2	2,10	9,9	19,1	30	14,4	30,1	4.500 m^3
8.	52+350	GL2	1,96	12,5	9,52	29	10,6	46,3	5.794 m^3
9.	59+450	GL2	2,07	11,2	12,7	26	8,3	9,3	1.875 m^3
10.	65+500	GL2	2,17	10,2	9,52	29	10,4	37	6.825 m^3
11.	77+000	GL2	2,06	10,6	9,52	26	10	29,8	7.650 m^3
12.	80+000	GL2	2,12	11,6	12,7	28	8,4	32,5	14.062 m^3
13.	82+900	GL2	2,15	10,4	19,1	29	6,7	45,9	14.500 m^3
14.	90+000	GL1	2,07	11	12,7	14	8,5	63	12.600 m^3
15.	107+000	GL1	2,14	9,5	19,1	19	9,2	32	4.779 m^3
16.	123+500	GL2	2,15	10,1	9,52	27	13,8	41	15.375,5 m^3

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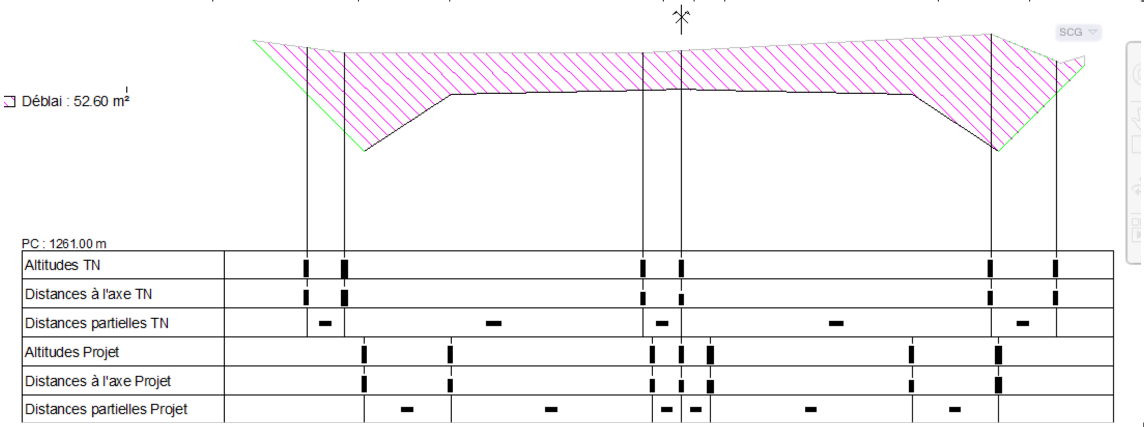
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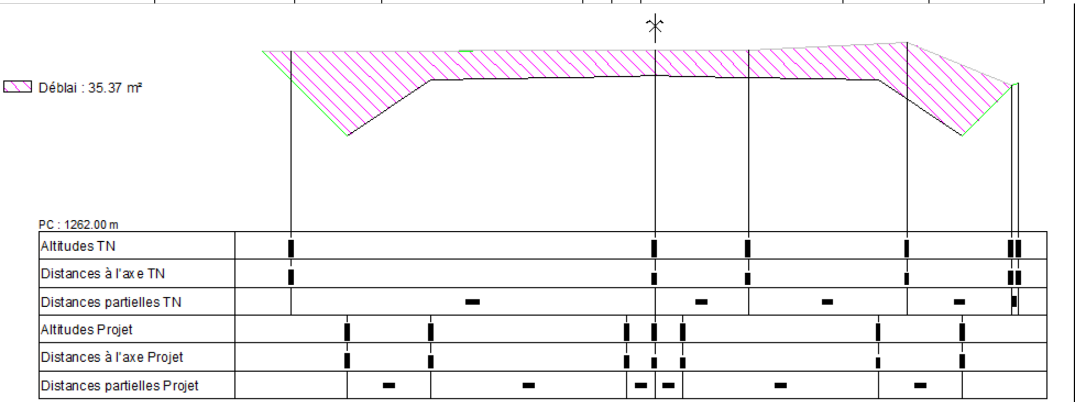
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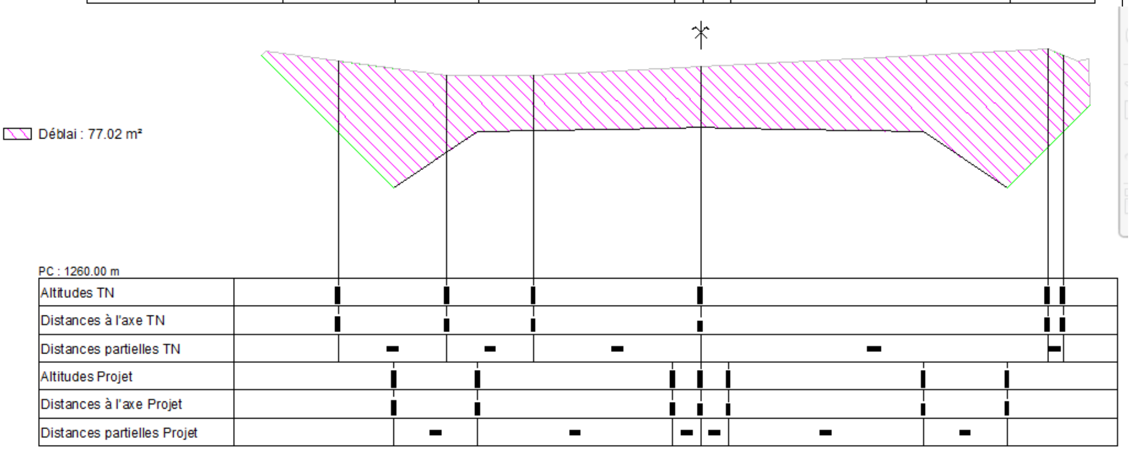
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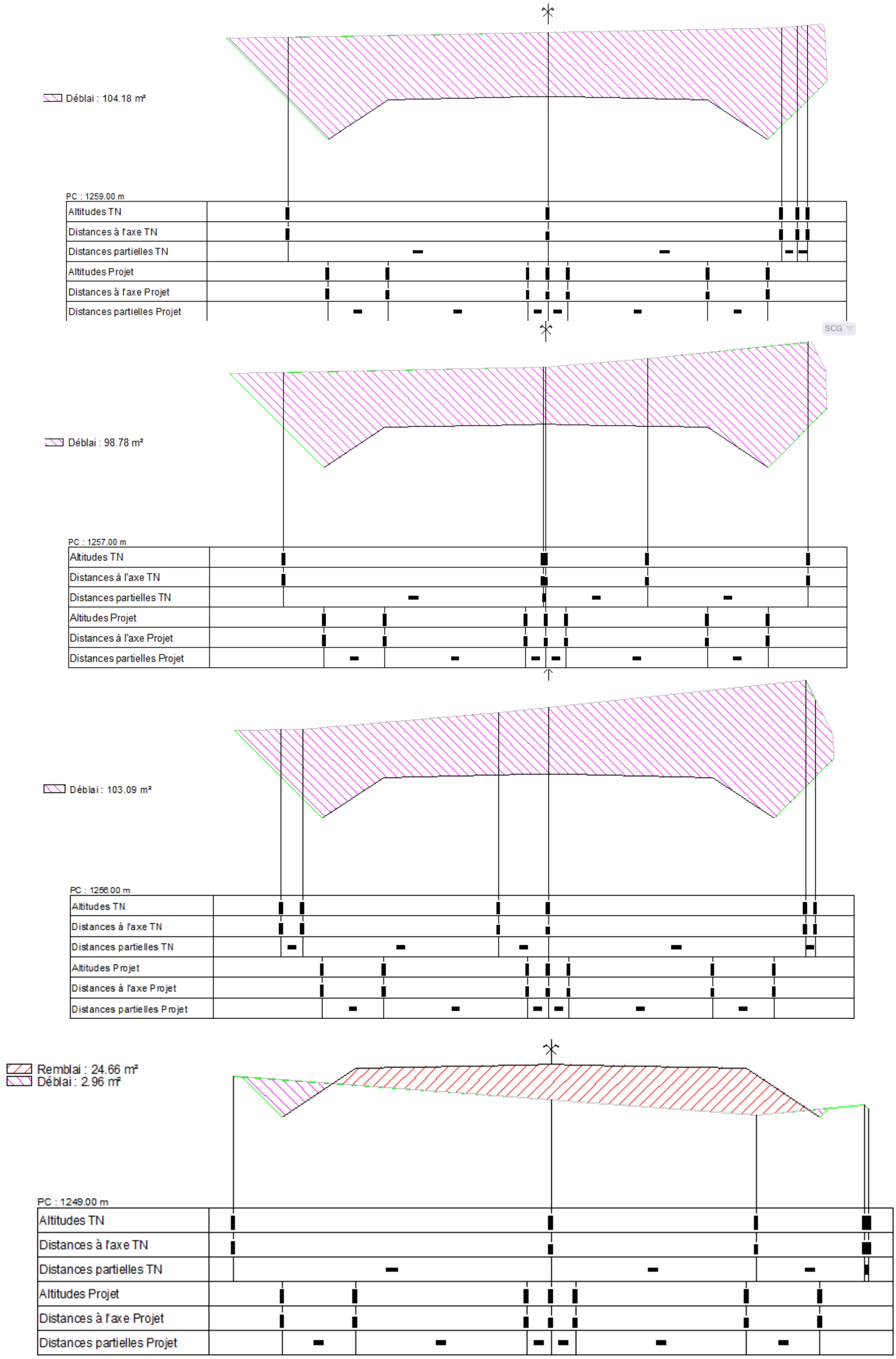

Figure 3: Different road profiles

3.2. Results of the improvement of the road

Table 4 gives us the C.B.R. medium by section. According to these results, two distinct groups emerge, namely: Sections 2, 4 and 6 where the C.B.R is between 7% and 15%; Stretches n° 1, n° 3 and # 5 where BCR is greater than 15%. Thus sections No. 2, No. 4 and No. 6 must be improved. The French geotechnical reconnaissance unit, 1995, says that for a CBR between 7% and 15% a 20 cm improvement layer and a 15 cm wearing course in gravel material for traffic between 30 and 100 vehicles a day is wise. We also see that these sections consist of alteration clay materials that loses its stability during the rainy season, especially in the tropics. The stability will be achieved using materials whose CBR is equal to or greater than 30% of natural gravels. From the foregoing, we end up with the dimensions listed in Table 5. Considering for the road Lubumbashi - Kasomeno, a width of 9 m, we obtain the quantities of the materials to be brought for the improvement of the bottom of the road. The cubage found is the compacted volume of material that will be improved (Table 6). The road construction standards recommend to take 7% of the material volume set up as a dosage for the improvement and with an expansion factor of 1.5; we find the volumes shown in Table 7. The filler material is a lateritic gravel of good quality to which we will add clay whose quantities for the three sections are shown in Table 8. Indeed referring to the table 3, these materials come from the cottages indicated below: For the section n ° 2, the materials come from the cottages number 1, 2 and 3; For the section n ° 4, the materials come from the cottages number 11, 12 and 13. For the section n ° 6, the materials come from the cottages number 15 and 16.

Table 4: C.B.R AverageSections

Sections	From K.P.to K.P.	LES C.B.R	C.B.R Moyen
Section1	From K.P. 00+00 to K.P. 15+00	16,4	21,86
		24,3	
		21,3	
		27,7	
		19,6	
Section2	From K.P. 15+00 to K.P. 20+00		10,1
Section3	From K.P. 20+00 to K.P. 70+00	18,8	29,66
		22,5	
		20	
		18	
		69	
Section4	From K.P. 70+00 to K.P. 80+00		11,7
Section5	From K.P. 80+00 to K.P. 110+00	19,7	22,6
		18,8	
		29,2	
Section 6	From K.P. 110+00 to K.P. 140+00	7,8	9,1
		10,3	
		9,2	

Table 5: Dimensioning of the different sections

Section	From K.P.to K.P.	C.B.R of the platform	Improvement layer	Rolling layer	Total thickness
01	0+00– 17+00	15%	-	15 cm	15 cm
02	17+00-27+00	7%-15%	20 cm	15 cm	35 cm
03	27+00-73+00	15%	-	15 cm	15 cm
04	73+00-87+00	7%-15%	20 cm	15 cm	15 cm
05	87+00-113+00	15%	-	15 cm	15 cm
06	113+00-140+00	7%-15%	20 cm	15 cm	35 cm

Table 6: Calculations of Materials for Improvement

From K.P. to K.P.	Distance in meter (D)	Width of the road in meter (l)	Layer of improvement in meter (c)	Cubature in m3 (D*l*c)
17+00 au 27+00	1000	9	0,2	18.000
73+00 au 87+00	14000	9	0,2	25.200
113+00 au 140+00	27000	9	0,2	48.600

Table 7: Cubing of the materials

Sections	Cubage of compacted material in m3	7% Cubage in m3	7% cubed cubic meters in m3
N°2	18000	1260	1890
N°4	25200	1764	2646
N°6	48600	3402	5103

Table 8: Clay Quantities

Sections	Cubage of compacted material in m3	Cubage of expanded material in m3	7% cubed cubic meters in m3	Cubage of expanded material en m3	Amount of clay in m3
N°2	18000	1260	1890	27000	25110
N°4	25200	1764	2646	37800	35154
N°6	48600	3402	5103	72900	67797

Table 9: Quantities of water

Sections	Cubage of compacted material in	Cubage of expanded material	7% cubed cubic meters in m3	Cubage of expanded material	Amount of clay in m3	Optimum content of the Section	Quantity of water in m3
N°2	18000	1260	1890	27000	25110	15,2	410400
N°4	25200	1764	2646	37800	35154	12	453600
N°6	48600	3402	5103	72900	67797	12,2	889380

Table 10: Final Results

N°	Section	Cubature of gravelly in m3	Cubature of clay in m3	Quantity of water in m3
02	17+00-27+00	1890	25110	4104
03	73+00-87+00	2646	35154	4536
04	113+00-140+00	5103	67797	8894

4. Conclusion

Soil is the main material used by the engineer as a foundation and construction material for civil engineering works and major works, including road construction [2] The Lubumbashi - Kasomeno road that was the focus of our work was one. A good road is differently defined considering the use that one makes of it. In our context, a good road is a work in durable materials, on which circulates the traffic answering the requirements of the bad weather, the comfort, the number and the weight of the vehicles. The aim of this work was to characterize the ground of the Lubumbashi-Kasomeno road in order to propose improving solutions in the norms of a good beaten road. Our study envisaged the improvement of the Lubumbashi-Kasomeno road using the geotechnical parameters. Indeed, two agents play a role in the destruction of the road soils, it is a part of the traffic not compatible with the dimensioning of the road (the maximum load per axle, the inflation pressure of the tires, the frequency of application of the loads, the speed of circulation ...) imposed on the road, and on the other hand, climatic conditions. To overcome these agents, it is necessary to have a good quality of the road ground which is defined by good geotechnical parameters (the granulometry, the index of plasticity, the optimum water content, the C.B.R.). From the foregoing, in order to determine areas for improvement, we subdivided the road into sections and sampled these sections for geotechnical testing at the Lubumbashi Roads Laboratory. Then we conducted the same approach in the area to locate the filler material at a lower cost. This work opens a door to future research we think in the near future to the economic study of the improvement of the road.

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