IMPACT ANALYSIS OF KAUNISVAARA – SVAPPAVAARA ROAD IRON ORE TRANSPORTATION OPTIONS

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Abstract

In 2013 an iron ore mine will be opened in Kaunisvaara in Northern Sweden. Annually five million tons of ore concentrate will be hauled 157 km by trucks on public roads to Svappavaara railway dock. A risk analysis and socio economic analysis project was established by Swedish Traffic Administration and the mining company, together with the ROADEX project, to study the impact of different heavy haulage options on the current road condition and to evaluate the need for strengthening. Data collection was done using several different survey techniques.

Risk and lifetime analysis based on the data showed that severe damages will occur within one year of haulage starting, if no rehabilitation is done. New structures were designed to meet 20 years of service life. On the weakest sections the addition of a new third lane was recommended. Impact analysis of different truck options showed that the problem with heavier and longer trucks is the high vertical displacement in the weak subgrade sections during the spring thaw period and long recovery times. On the other hand all heavier truck options are friendlier to asphalt pavement compared to a standard 60 ton truck.

Many new technologies and analysis methods were used for the first time in the world, and these methods have proven to provide extremely valuable data for road diagnostics and design. Using this data in the actual design phase will also present major economical savings.

Keywords: ROADEX, Impact Analysis, Heavy Vehicles, NDT Survey Techniques, Strengthening Design

1. Introduction

Northland Resources Ltd has decided to open an iron ore mine in Kaunisvaara in Pajala municipality in Northern Sweden in 2012-2013. Starting in January 2013, the company plans to transport the mined ore concentrate on trucks to a new terminal in Svappavaara from where it will be hauled by train to Narvik harbor in Norway. Five million tons / year will be hauled when full production is reached, which Northland plans to do in 2015. The transportation route first follows road 99 to Pajala, then road 395 to Vittangi and further Rd 45 to Svappavaara and finally E10 to the Svappavaara railway dock intersection. The total length of the survey was 157 km. All of these roads are owned and managed by the Swedish Traffic Administration (Trafikverket) and the greatest part of them present as typical weak low traffic volume roads in Northern Sweden with problems including frost action and permanent deformation as well as weak peat subgrade. As such, Trafikverket wanted to have a risk analysis about the lifetime of the current road if and when heavy haulage begins. This was decided to be made using risk analysis technique proven to work well in the ROADEX project. In addition, new and emerging road survey technologies were selected to be used for the first time in this project.

Due to the enormous amount of ore concentrate to be hauled to Svappavaara, the mining company is naturally interested in optimizing the transportation costs which means, in practice, exemptions to allow for the use of heavier and longer trucks than standard 60 ton trucks. On the other hand the Swedish Traffic Administration is aware that the roads in this route are too weak even for haulage with standard 60 ton trucks and the road has to be strengthened before haulage starts anyway. Therefore it was also practical to analyze and evaluate the impact of heavier vehicles on the road. To make this analysis a range of different total weight options were proposed. After preliminary evaluations, the trucks options for final analysis were chosen to be 60 ton, 72 ton, 90 ton, 136 ton, 145,5 ton and 153 ton.

This article summarizes the survey and research during the project in 2011. Information is provided about road structures in three dimensions (3D) and their current structural and functional condition. The results from the final lifetime calculations for the road after the haulage starts are also presented. In addition the article presents new design structures and cost estimates for the road strengthening that should be completed before transportation starts. Finally, this article presents impact analysis results for different heavy haulage options in order to propose information for the socio-economic transportation evaluation.

2. Survey Techniques Used

The data collection was done in winter, spring and summer 2011 using 3D mobile laser scanning technique, ground penetrating radar (GPR), heavy weight deflectometer (HWD) with time history data, accelerometer, thermal camera, digital videos and visual inspection, drilling, sampling and laboratory analysis. In addition, old profilometer history data was analyzed and local maintenance experience was utilized.

The collected data was analyzed in a variety of ways using different software packages. Most of the collected data was processed and analyzed using Road Doctor Pro –software. The software enables the combining of GPR, HWD, IRI, rutting, laser scanner and other data together with videos and maps. When all the data is linked together, an integrated data analysis utilizing comparisons and correlations between different factors affecting the road behavior is easier to make. The Road Doctor Pro software includes Elmod back calculation and Swedish Bearing Capacity calculation modules. The ROADEX Odemark dimensioning analysis, also built-in, was used for initial bearing capacity calculation. The Swedish PMS Objekt software was used in strengthening design. Elmod 6 is software used to back calculate the layer moduli values. Elmod 6 software was used in an integrated module with Road Doctor Pro software. In this project, Bisar software was used for strengthening design for extra heavy loads and for the evaluation and comparison of the different truck options. It is based on linear elastic theory. Bisar calculates the horizontal and the vertical stresses and strains induced to the different layers of the road structure by the given loads. It also outputs the amount of horizontal and vertical displacement in selected points of the subgrade and structural layers.

3. The Road and It's Surroundings

The Kaunisvaara - Svappavaara road is located in the municipalities of Pajala and Kiruna in Northern Sweden. The total length of the surveyed road is 157 330 m. The vertical geometry of the road is mainly even. The slope gradients varies mainly between -2% and +2%. Few steep hills were detected. The road is mostly built on embankment, but a great part of it is also located on side sloping ground, especially because of a long section where the road follows a river.

In the Kaunisvaara - Svappavaara road there are numerous houses and bigger villages nearby the road, which have to be considered when evaluating the impact of the transport on local human settlement. In order to check the risk for major vibration problems for the houses near the road, analysis was made to locate sections where the roughness (IRI) values of the current road were higher than 4.

4. Structural and Functional Condition of the Road

4.1 Road Structures and Subgrade Soil

In general, the thickness of the bituminous pavement in the whole Kaunisvaara - Svappavaara road is quite thin. It varies from a few millimeters to twenty centimeters, being normally 35 – 50 mm. Fourteen drill core samples were taken to provide references for the GPR interpretations. Pavement quality can also be evaluated through its moduli but in this case the pavement was mainly too thin to calculate reliable pavement moduli values. That is why, for instance in the back calculation of other layer and subgrade moduli values, the modulus of the pavement was fixed to 2000 MPa, which is quite typical for such pavements. Another pavement quality indicator is pavement strain calculated from FWD using Swedish bearing capacity formulas. The smaller the pavement strain value is, the longer the pavement lifetime and the smaller the risk for permanent deformations in the upper part of the road structure.

Because of the varying construction and rehabilitation history of the road, the thickness of unbound base course layers has great variation. The thinnest measured base course thickness was only a few centimeters and the thickest ones were more than half a meter. The base course is especially thick in sections, where old steelnets are located. The total thickness of the pavement structure also had great variations but generally it varied from 50 cm to 80 cm.

The quality of unbound base course was determined through samples using them to make a grain size distribution analysis and Tube Suction test. Eleven samples were taken from the road to be used in the tests. The Tube Suction test measures whether an aggregate adsorbs moisture, if and when it is available in its surroundings. The measured parameter in a TS-test is dielectric (Er) value which also provides an indication of free moisture and electrical conductivity levels. If the electrical conductivity (J-values) of the sample is high this means that the sample may contain high amounts of salts, or contain harmful weathering products from the aggregate minerals. The recommended classification of unbound base course materials based on the dielectric value from the Tube Suction test is as follows:

- If the Er value is less than 9, the material is a good-quality base course material
- If the Er-value is 9-16, the material is frost susceptible and questionable as base course material
- If the Er-value is more than 16, the material is inappropriate as base course material and will have problems throughout the year when it is wet.

According to the Tube Suction test results the quality of the base course on Kaunisvaara - Svappavaara road is questionable and practically all of the base course samples adsorb too much water and thus will have Mode 1 rutting and permanent deformation problems during the spring thaw weakening. Good news from the results was that J-values were quite low (varied from 4 to 32) indicating no major risk for weathering. The fines content of each sample was also determined. If dielectric value is high then the fines content should be less than 6 %, and in this case a great part of these samples had higher content. The poor quality of the base course materials was also verified from the Surface Curvature Index values of the FWD data which shows that SCI was mainly higher than 250 µm, a value that can be considered as an alarm value for paved roads.

Based on the FWD results the greatest part of subgrade modulus values belongs to class 40 – 80 MPa. The weakest subgrade can be found in road section 1 where a large part of the moduli were less than 10 MPa. In general the critical sections of subgrade were those located in peat and silt areas. The distribution of subgrade moduli is presented in figure 1.

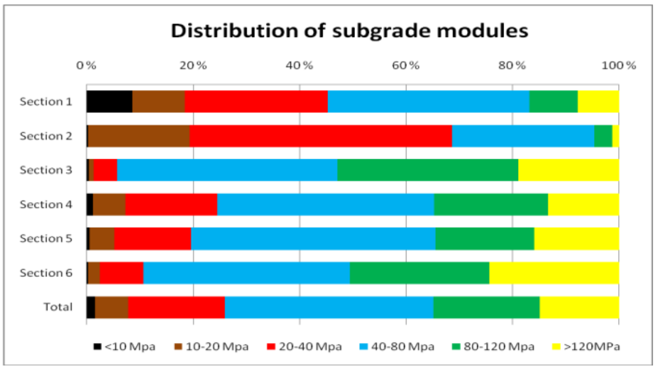

Figure 1 – The distribution of subgrade moduli

If the subgrade modulus is more than 80 MPa then the material is considered to be strong with good bearing capacity (for example gravel, sand or coarse grained moraine). If the subgrade soil modulus is less than 10 MPa, the subgrade is weak (for example peat and wet silt soils). Subgrade moduli 10 – 20 MPa are also quite weak and have great risk of losing their strength during the spring thaw period (for example clay, silt and moraine with high fines content).

Subgrade soils with modulus values ranging between 20 – 80 MPa can be classified as moderate bearing capacity subgrade soils (such as dry silt, wet silty sand or wet silty moraine).

4.2 Bearing capacity

The Odemark bearing capacity, calculated using the ROADEX Odemark method, varied substantially within and between different road sections. The lowest bearing capacities were calculated on Road 99 and the highest bearing capacities on the newer road section on Roads E10 and E45. In other road sections (Road 395) the bearing capacity varies between 150 MPa and 300 MPa. Here and there are some short weak (<150 MPa) and good (>300 MPa) sections. The results of bearing capacity analysis provide valuable information for road diagnostics. It is a good indicator of the initial condition of the road. It also gives important initial design parameters for the rehabilitation design.

4.3 Frost Related Problems

The Pajala road project utilized some very unique data. The continuous point evaluation of frost heave over the whole pavement area is likely the first time that this sort of data has ever been collected. Even though all the frost heave levels are not absolutely reliable, the data clearly shows the trends and places where the frost heave is much higher than in other places. This technique will be used to determine whether frost heave is related to poor drainage and shoulder deformation or if the highest frost heave occurs in the middle of the road (figure 2).

According to the laser scanner data, the highest frost heave values were found from road 99, where frost heave was mainly more than 12 cm and in some sections even more than 20 cm. In other road sections the frost heave is less and measured values varied from 4 cm to 12 cm. The smallest frost heave values were measured naturally from the newer section, where the majority of frost heave was less than 4 cm. The frost heave values were small also close to river banks, where the subgrade is mainly sand.

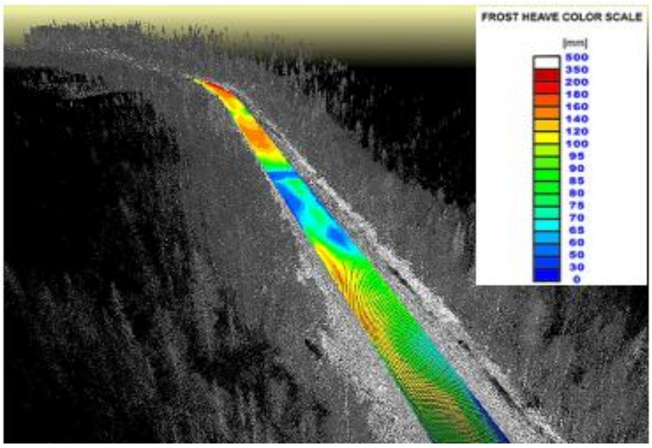

Figure 2 – An example of frost heave point cloud data

Figure 3 presents an example of a rainbow map showing the road surface topography. One rainbow color palette scale represents a 30 mm change in surface level and optimal road surface with two sided cross fall should resemble a perfect V-shape. A major shoulder deformation can be seen on the right side of the road.

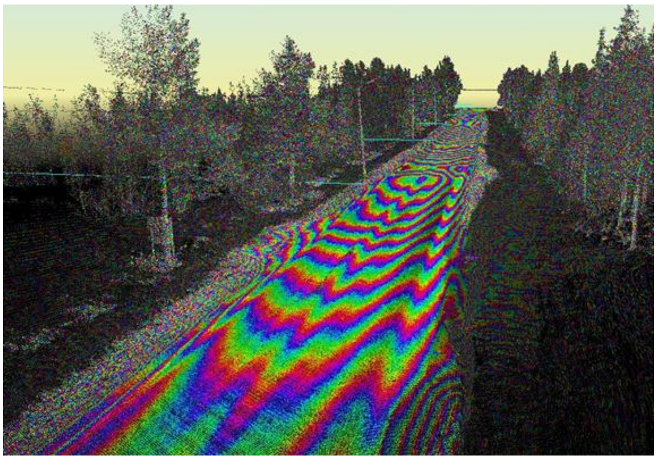

Figure 3 – An example of a rainbow map presenting the surface topography

5. Strengthening Design

5.1 Design Principles

In the first design process the road was divided into five risk classes (1 = best…5 = worst) according to the evaluations of the road condition based on, among other things, GPR data and FWD data. In this risk classification subgrade (moduli and BCI values) had a high weight, because previous analyses showed that the subgrade was the weakest link in the design. Layer thickness values were printed at 5m intervals and each structure section was examined statistically. For the PMS Objekt analysis, road structures were defined based on the worst quarter limit (values starting the worst 25%). The structure thickness values were defined from the summer GPR data taken from the line closest to the right wheel path. The PMS Objekt software was used to calculate bearing capacity, remaining lifetime and frost heaves of initial structure. In addition, calculations were made to define the strengthened structure, which would reach the theoretical 20 years lifetime both in the bottom of bound layers (Mode 1 rutting) and in subgrade / road structure interface (Mode 2 rutting).

After the strengthening structure was planned using PMS Objekt to the level of theoretical lifetime expectancy of 20 years, new calculations were started with Bisar software in order to detect and analyze the weakest structural sections. Based on the findings in the preliminary calculations, special interest was focused on the amount of vertical displacement in the subgrade. The results of Bisar calculations showed that the subgrade displacements in selected road sections, built on weakest subgrades, were too high, even if the road rehabilitation was designed to the theoretical lifetime expectancy level of 20 years according to PMS Objekt. The reason for that is that PMS Objekt design is based on standard loads. For that reason the proposal of the third lane sections was found to be beneficial.

After the "normal" structural design based on the standard 60 ton truck loading was finished, an impact analysis of different truck options was made. With Bisar software the subgrade displacement was calculated for the heaviest axle group of each truck option. For each truck option the cumulative effect of the consecutive axles or axle groups on the subgrade displacement was also calculated.

5.2 Remaining Lifetime of Current Road

The calculations of remaining lifetime if heavy haulage starts on the current road were made with PMS Object software. The results showed clearly that if the heavy haulage starts on the current road without strengthening the remaining lifetime of the road will be very short and 96% of the road length will have serious problems within the first year.

5.3 Structural Solutions

Structural solutions were designed and tested based on PMS Objekt software with a goal for designing a structure with a lifetime of 20 years. This analysis showed, for instance, the importance of 200 mm bound layer thickness on the top of new structure. Using 150 mm bound layer thickness gave only 6-8 year lifetime for the new structure. Based on evaluations of numerous structural options, three main structural solutions were selected with practically all structural solutions containing 200mm of bound layers. The most general solution is to add new layers (unbound base and bound layers) on the top after the old pavement has been removed and the old base has been shaped (figure 4). In the weakest sections (mostly risk class 5) it is recommended that a third lane is designed (figure 5). In this case, old road will not be so heavily strengthened: 100mm bound layer and 100mm unbound layer. In the extremely weak sections (peat areas) with potential pumping problems it is recommended that steelnets are used.

A special feature in the analysis of the current road was that the quality of unbound base course aggregates throughout the road was poor and these aggregates are susceptible to permanent deformation. That is why special attention should be given to the quality of the new base course material during the strengthening project. Finally the analysis of current road has shown that road shoulders are in many places very weak and that a wider road would be very beneficial for both road structural and traffic safety reasons.

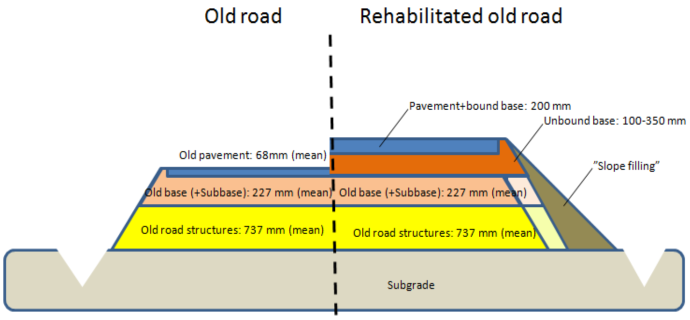

Figure 4 – The principles of the porposed basic structure for strengthening

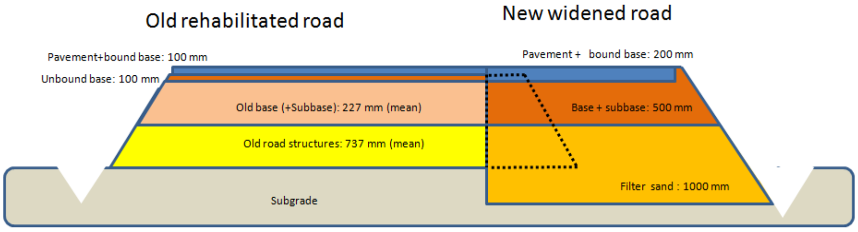

Figure 5 – The principles of the proposed third lane structure

6. Risk Analysis for Different Haulage Options

6.1 General

Throughout the time of the Pajala road project impact analysis process more than 30 truck options were analyzed and evaluated in order to find the technically most optimal truck configuration from the perspective of preserving the road structures. The possible truck concepts were evaluated based on the axle loads, number of axles, distances between axle groups, net loads etc. The tyre type used in the evaluations was selected to be dual tyre, because the experience from ROADEX project and a number of other earlier analyses have shown that on low volume roads dual tyres are much more road friendly compared to super single tyres. Major discussions in the work group concerned axle weights. The preliminary calculations showed that the most critical sections of the road are sections with the weakest subgrade conditions (10 MPa) prevailing especially during the spring thaw. During the evaluation process it became clear that the most beneficial axle load for the road is between 8 and 9 tons.

The analysis of pavement responses under the different loading options was made using multi-layer linear elastic modeling approach implemented in the software tool Bisar. The approach is worldwide generally accepted and very extensively used method to analyze the mechanical behavior of various types of pavement structures. As an output of the Bisar analysis stresses, strains and displacements in different directions at selected points inside of the pavement structure and subgrade are obtained. For the present purpose the most interesting result was vertical displacement on top of the subgrade which can be used as a convenient indictor of overall severity of the loading action due to the vehicle that is stressing the pavement structure.

6.2 Different Truck Options

The standard 60 ton truck option was an obvious choice for the final evaluations. "Boliden" 72 ton and "ETT (En trave till)" 90 ton options were also chosen, because they are more or less ready alternatives for the standard truck. The 136 ton "Double link" concept truck option was chosen, because it was calculated to be the best option for the pavement performance. The 145,5 ton and 153 ton "Double link" options were chosen in order to evaluate the effect of higher axle loads compared to the 136 ton option.

6.3 Impact Analysis of Different Haulage Options

As mentioned previously, the subgrade is the most critical part of the structure on the route. Because of that, the different truck options were compared with each other based on the displacement induced on the subgrade. The other critical part is the pavement for which another assessment approach, based on the “fourth power” evaluation method, was employed.

Subgrade Displacement
The comparison of the truck options on weak subgrade (modulus 10 MPa) based on the heaviest axle group of each option is presented in figure 6. The subgrade displacement induced is lowest for the standard 60 ton truck, but the 72 ton and 90 ton options are not much worse. The "Double link" options are somewhat worse, but compared with each other there is not very big difference between those options.

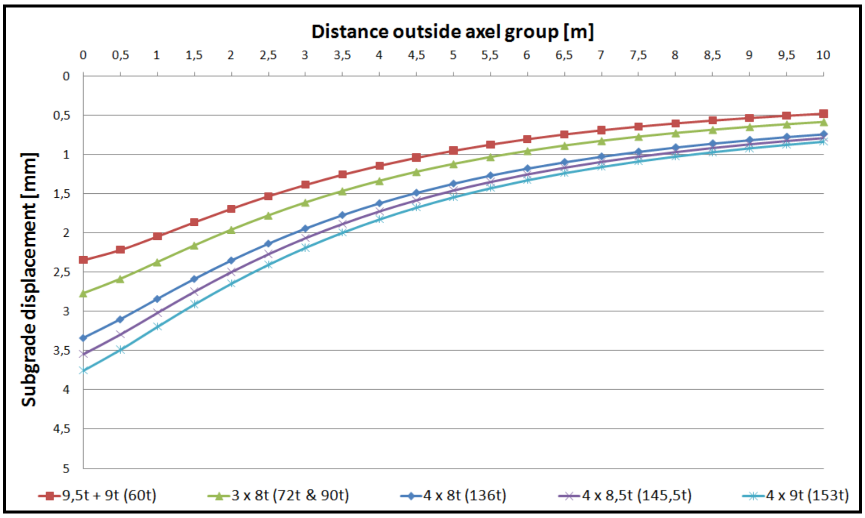

Figure 6 – Comparison of the truck options on weak subgrade (modulus 10 MPa) based on the heaviest axle group of each option

After this it was examined whether or not the subgrade displacement could be reduced by using even thicker bound layers. The designed bound layer thickness of 200 mm was increased to full depth asphalt of 300 mm. The results showed that increasing the bound layer thickness up to 200 mm has a very significant effect on the subgrade displacement, but increasing the thickness further to 300 mm diminishes the displacement only slightly. Another result was that the distance between axle groups should be at least 3 meters. A distance greater than 3 meters does not have a major effect on elastic response under a single axle group, but does have some effect on the cumulative loading effect of successive axle groups.

In order to find out the cumulative effect of the consecutive axles or axle groups on the truck combination the subgrade modulus was backcalculated with different HWD loading levels. The results showed that the backcalculated subgrade moduli values were very close to the 10 MPa value used above in the calculations. During springtime there may locally be even lower values than 10 MPa along the road. This confirms again that the subgrade is the most critical part of the structure. The results showed also that the subgrade modulus does not significantly depend on the stress level. Based on this fact it could be concluded that the subgrade displacement is cumulative. In other words, each axle or axle group of the truck combination increases the displacement if there is not sufficient time for the road structure to recover after it has been loaded.

Figure 7 shows the cumulative displacement of weak subgrade (modulus 10 MPa) calculated for each truck option. The horizontal axis presents the distance from the first axle of the truck. Zero is the first axle and the dots along the displacement curve represent the locations of the consecutive axles. On the vertical axis is the cumulative subgrade displacement calculated in one point. In this comparison 60 ton is the best option and the 72 and 90 ton options are approximately on the same displacement level. The "Double link" options with four axle groups are again worse. It should also be noted that the calculated cumulative subgrade displacement for the heaviest cases represent an optimistic / conservative estimate. This is because it is known that the subgrade recovery in real life is not as immediate as the Bisar calculation shows, for example due to development of excess pore water pressure.

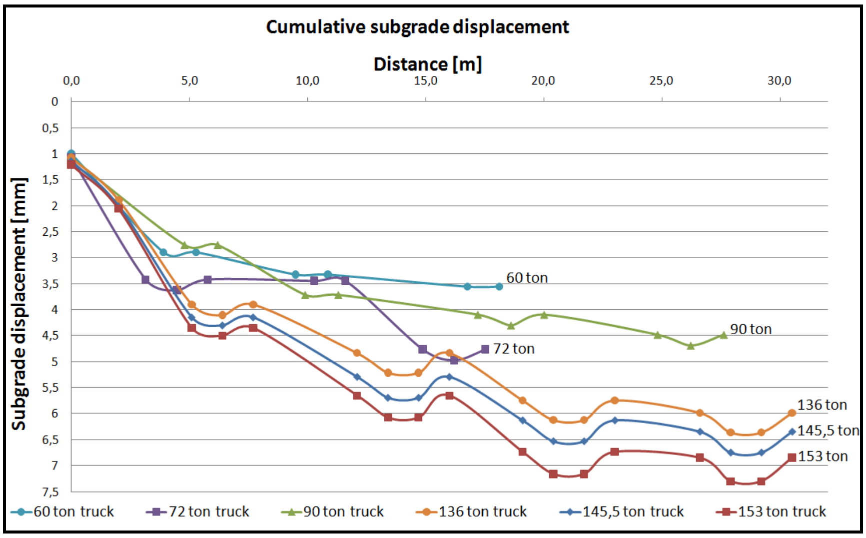

Figure 7 – The cumulative displacement of weak subgrade (modulus 10 MPa) calculated for each truck option

Pavement

Another challenge in comparing the different truck options was the effect of different trucks on pavement performance. That is because PMS Objekt calculations were based on standard axle loads. So, in addition to displacement calculations with Bisar software, another separate comparison of the truck options was also developed based on the classical "fourth power rule" used in pavement engineering. This rule slightly underestimates rutting and overestimates pavement distress but in general is still quite reliable in estimating pavement performance under different loadings. The rule was defined as EKV = $(p/p_{ref})^4$. The equivalent loading value was calculated for each of the truck option based on the number of axles and the axle load. After that the annual transportation of 5 million tons was divided by the net weight of the truck in order to obtain the number of truck loads. Finally the load effect of each truck option was determined by multiplying the number of truck loads by the corresponding truck equivalent. The results of the calculations are presented in table 1. The value in the last column is the factor of comparison to standard 60 ton truck and it shows that, based on this assessment, all truck options are better than the standard truck, 136 ton option being the best.

Table 1 - The results of the pavement performance calculations

Truck option & total weight	Axel loads					Truck EKV	Net weight	Truck loads	Load effect	Comparison to 60 ton
	7,5 ton	8 ton	8,5 ton	9 ton	9,5 ton		[ton]			
Standard 60 ton	1	2	0	3	1	3,918	38	131579	515581	1
"Boliden" 72 ton	0	9	0	0	0	3,686	49	102041	376163	0,730
"ETT (En trave till)" 90 ton	0	7	0	4	0	5,492	60	83333	457633	0,888
"Double link" 136 ton	0	17	0	0	0	6,963	109	45872	319413	0,620
"Double link" 145,5 ton	0	0	15	2	0	9,142	118,5	42194	385751	0,748
"Double link" 153 ton	0	0	0	17	0	11,154	126	39683	442607	0,858
Annual transportation (ton) =			5000000							
Stress exponent used in calculations =			4							

Recovery times

Recovery times were evaluated by the delay times of HWD measurements time history data, which can be considered as minimum recovery time but not the maximum. Results showed that high the load response was reasonably elastic in risk classes 2-4, but long delay times can be expected to take place in risk class 5 with low subgrade moduli values. Based on this analysis and the results from cumulative deflection modeling in figure 7, the minimum calculated delay time and distance of a heavy truck driving 80 km/h is roughly 1,5 seconds and 30-40 meters. This means that a long recovery time will even increase the effect of heavy trucks and there is a possibility that positive pore water pressure will develop. However the time interval between heavier trucks on road will be correspondingly longer and allow a real recovery time roughly 200 times longer than the delay time measured. But this means that the distance between trucks has to be controlled and convoy driving strictly forbidden.

7. Conclusions, Discussion and Recommendations

The impact analysis using PMS Object calculations showed that the road will have failures rapidly, if no rehabilitation is done. The basic strengthening structure for 20 years of service life should consist of 200 mm of bituminous bound layers and 100 – 350 mm of unbound base. In addition it is in many cases recommended that a new lane for heavy trucks is built in the weakest sections. This new third lane would also act as passing place for other cars. In those sections, where a third lane cannot be built, it is recommended that soil replacement structures are used and in some sections raising the gradeline is also an option. In addition to the new third lanes it is also recommended that at least two climbing lanes are built on the steepest hills of the road. Horizontal geometry of one section should also be improved due to traffic safety issues. All of the road intersections should also be redesigned and acceleration lanes for heavy trucks should be considered wherever it is possible. Drainage analysis showed that drainage in general is in relatively good condition. However drainage improvement is absolutely the cheapest option to improve bearing capacity of the road and therefore it is recommended to improve the drainage of the whole road to drainage class 1 before other strengthening works are undertaken. Mobile laser scanner analysis showed indications that, where private exit road culverts are clogged, frozen or missing, this had a great impact on road performance. These sections should also be checked and fixed because these sections will cause major vibration problems to houses close by. Total cost estimate of this basic rehabilitation is 377 million SEK for truck of 60 ton. Costs of rehabilitation of bridges and traffic safety are not included. If the trucks will be heavier, the estimated extra costs for strengthening would be 12,5 million SEK.

The most critical sections are sections with weak subgrade (10 MPa) and these sections are especially weak during the spring thaw. On the basis of the impact analysis it can be stated that the 72 ton and the 90 ton truck options are almost as good as the standard 60 ton truck when the displacement of the subgrade is examined. Therefore it can be concluded that the "normal" rehabilitation designed for the 60 ton truck is also enough for those options. For the "Double link" truck options the calculated additional base course thickness needed is approximately 250 mm. Calculations showed that displacement in subgrade with the heaviest truck configurations can be two times higher in comparison to a normal truck. On the other hand the cumulative load impact of heavier trucks to the pavement is much less than if haulage was done using standard 60 ton trucks. Recovery time measurements and calculations showed that road recovery will be an issue especially on the weakest the road sections. Positive pore water pressure will be generated under repeated axle loads and this will reduce the stiffness of the subgrade further. Calculations showed that heavier truck options will need more recovery time but that will be the case anyway if these trucks are used and distance between trucks is controlled. On the other hand if almost all of these class 5 risk class sections will be replaced with well designed and built third lanes, recovery times will not be an issue.

In this project many new technologies and analysis methods have been used for the first time in the world. These methods have proven to provide extremely valuable data for road diagnostics and design. Examples from the earlier ROADEX projects have shown that potential savings in the strengthening costs will be tens of millions of SEK, but it also ensures that there should not be any unpleasant surprises when the road has been strengthened and heavy haulage starts. The analysis also provides solid background information for the Swedish Traffic Administration and the mining company when discussing the options for heavy load premiums. However, the performance of the road should be monitored continuously after rehabilitation and a special winter maintenance plan should also be made.

8. The Use of Impact Analysis Report in Final Design

The final design of the rehabilitation measures is made by Vectura. Concerning road E45 the report "Impact Analysis" has been used to get a quick and perspicuous view of the road condition and the need for rehabilitation. To get into details the input data, on which the report is based, have been studied by means of the Road Doctor Viewer software. In the first place the video has been used combined with the sampling record, the GPR interpretation, the damage survey results and the moduli. The moduli have not been used with their absolute values but more to make relative comparisons between different sections of the road. Also other data, e.g. rutting, drainage analysis and frost heave measurements have been interesting.

For the dimensioning design PMS Objekt has been used to check all the surveyed points. The selected solutions though are overall combinations of the geometric pre-requisites implying a raise of the road profile, principally limited to 30 cm to stay within the existing road area, the choice to widen the formation with existing structure material to minimize differences across the road, data from Roadscanners and the results from PMS Objekt. Dimensioning considering frost heave has involved some problems. The calculations made in PMS Objekt will give unpermittedly high frost heave with the selected solution, based on the sampling results from the subgrade, in spite of the raise with 30 cm. Against this stands, that measured frost heave during the winter 2011 has proved to be very limited. The judgement is that PMS Objekt gives too high frost heave, that might depend on several reasons, like drainage conditions, that the sampling from the subgrade is not representative on the depth, etc. On the other hand there is uncertainty whether the measured values are representative for all winters the next 20 years. Thus we find that the planned raise will give an adequate frost protection.

To sum up the selected measure will give an over dimensioning concerning bearing capacity, but the measure is assessed to be motivated considering the frost heave calculations. The measure is also motivated by some weak road edges in places are completely eliminated by the construction of ”box excavations”, giving the edges full bearing capacity. Another motive is that the pavement of the road will be equipped with a mid-relief, resulting in that the heavier and denser traffic will be more track bound and drive closer to the road edge.

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