Network and Project Bearing Capacity Surveys and Analyses Using Modern Techniques

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ABSTRACT: In recent years bearing capacity surveys in the Swedish Road Regions Mitt and Melardalen have been performed on network and project level using integrated analyses of modern road survey techniques. The survey methods include:

- Digital video capture
- Measurements of the structure with ground penetration radar
- Measurement of the bearing capacity using falling weight deflectometer
- Sampling and laboratory testing
- Visual inspection of the drainage
- Visual inspection of the road surface condition and damages
- Measurements of the road surface condition with laser profilometer.

The results of the measurements are assembled, linked together, processed and analysed using Road Doctor™ for Windows software. The results can be shown on the computer screen as a continuous longitudinal profile for each project. All data are linked to the right length position. For each project, rehabilitation measures can then be optimised for each location. Thereby the design work is facilitated and the resource use and the costs for maintenance and/or rehabilitation can be reduced.

This technology was used in a 5-year bearing capacity survey project in Road Region Mitt of the Swedish National Road Administration for the years 1998-2002. The total length of the road network surveyed was about 5 000 km. The condition of the road structure and the road surface are shown for each project in continuous longitudinal profiles and on GIS-maps as 500 m average values. Road surface roughness, measured as IRI, and rutting values have been used to calculate the remaining lifetime for each 500 m of the surveyed paved road projects. The remaining lifetimes, depending on roughness and rutting as well as the bearing capacity condition, are shown on the GIS-maps. For gravel roads the bearing capacity described in three different ways is illustrated in the same way. These maps can be used for planning and selection of maintenance and/or rehabilitation candidates.

KEY WORDS: Bearing capacity, non-destructive technique, integrated analyses, remaining lifetime, road condition.

1 INTRODUCTION

In 1998 the Region Mitt of the Swedish National Road Administration (SNRA) started a network bearing capacity – road condition survey to be used for planning and maintenance and rehabilitation design purposes. It was a 5-year project including surveys covering about 1 000 km of mostly low volume roads per year. The work was done by consultants chosen by yearly tendering for survey contracts including about 250 km of roads in each l area.

The main purpose was to collect information regarding the structural condition of the road network and to localize sections with insufficient bearing capacity. A secondary aim was to combine all road data for use in designing rehabilitation measures for sections with low bearing capacity.

2 SURVEY METHODS

In the survey modern non-destructive measurement methods were preferential. The survey methods included:

- Digital video capture
- Measurement of the structure with ground penetration radar (GPR)
- Measurement of the bearing capacity using falling weight deflectometer (FWD)
- Sampling and laboratory testing
- Visual inspection of the drainage
- Visual inspection of the road surface condition and damages
- Measurement of the road surface condition with laser profilometer.

Figure 1 GPR survey car mounted with 1.0 GHz and 400 MHz antennas.

2.1 Measurement with GPR and video capture

The GPR measurements were done with two different antennas; one 400 MHz ground coupled antenna to examine the lower layers in the road structure and assess the subgrade soil type; and one 1 GHz air coupled antenna to survey the pavement and the base course (see fig 1). The sampling density was 10 scans per meter. A video camera was fixed on the roof of the survey car to make a video of the road, which could be used to identify surface damages and drainage problems. The operator also provided commentary on the video, during collection of the GPR data, noting surface defects and drainage problems. The data was positioned using GPS, the optical encoder of the GPR system and a DMI (distance measurement instrument). The measurement speed was approximately 30 km/h.

2.2 Bearing capacity measurements

The bearing capacity was measured with falling weight deflectometer (FWD). Paved roads were measured with 10 measurement points per km and gravel roads were measured with 20 measurement points per km spaced equally on both sides of the road. The measurements were performed according to SNRA's method description VVMB 112.

2.3 Sampling and laboratory testing

The road structure was sampled at a frequency of one sample per km. Sieve analyses of the material in the unbound road base, the sub-base and the subgrade were performed. The samples were taken partly to verify the GPR interpretation results of structure thickness and partly to examine the technical properties of the material. Decisions regarding the location of the sampling points were based on the GPR results.

2.4 Visual inspection of the road surface and the drainage

The purpose of the visual inspection survey was to locate and classify pavement distresses and classify the quality of the drainage system as well as to locate culverts in the road structures. The GPR data, video and video commentary from the surveys were used to complete the visual inspections.

2.5 Road surface measurements

In the survey road profilometer data from the databases owned by the Swedish Road Administration was used to analyse the history of roughness and rutting. The norm in Sweden is to measure IRI and rutting as an average of 20 m and 400 m.

3 INTERPRETATION, INTEGRATION AND VIEWING OF MEASUREMENT DATA

The GPR interpretation and the integration of all the measurement data were done with Road Doctor™ software. All data were positioned and stored in a menu tree from which the user can select data to be viewed on the computer screen. Figure 2 shows an example of a view from a paved road. On the left hand side of the view there is a video picture and a map. On the top right hand side the results from IRI and rutting measurements from three different years are shown. Underneath there are longitudinal bars expressing different condition classes of the drainage and the road surface defects. Different classes have different colours.

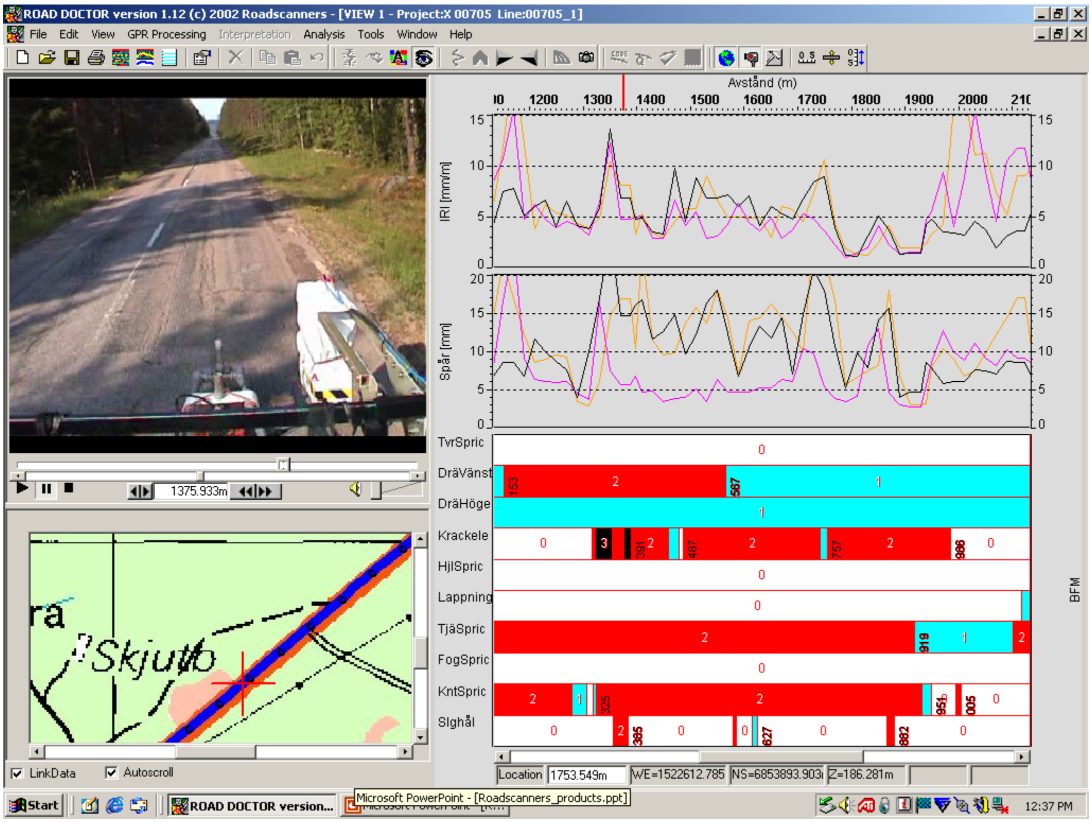

Figure 2 View in Road Doctor from a paved road with different road data.

4 ANALYSES OF MEASUREMENT DATA, PAVED ROADS

4.1 Bearing capacity

The Bearing capacity Index (BI) is a parameter calculated according to the following formula from SNRA's method description VVMB 114:

$$BI = \frac{1000}{\varepsilon_a},$$

where ε_a is the asphalt strain calculated from the temperature corrected FWD results. The lower the BI the worse the bearing capacity is. The BI is shown in the upper of the two lowest bars in the figure 4. The lower bar presents the mean Bearing Capacity value (BC) of 500 m long sections of the road. The BC value is calculated according to a specification described in method description VVMB 114 where the BI is related to the accumulated standard axles passing the road during the dimensioning period. The Bearing Capacity, shown in the bottom graph, is divided into 4 classes where Bearing Capacity class 4 is a very badly damaged road.

4.2 Remaining life time

To predict the remaining lifetime of a road length, calculations have been done by using the measurement results of rutting and roughness measured as IRI. The calculations have been performed using average values of 500 m road lengths. A regression line for rutting and IRI is drawn by means of at least three measurements coming from different years on each road project. Then the critical limit for the 500 m average value of rutting is from experience determined to 12 mm and the life length can be calculated. When the regression line hits the limit value in the time schedule it is the predicted time for a rehabilitation need (see figure 3).

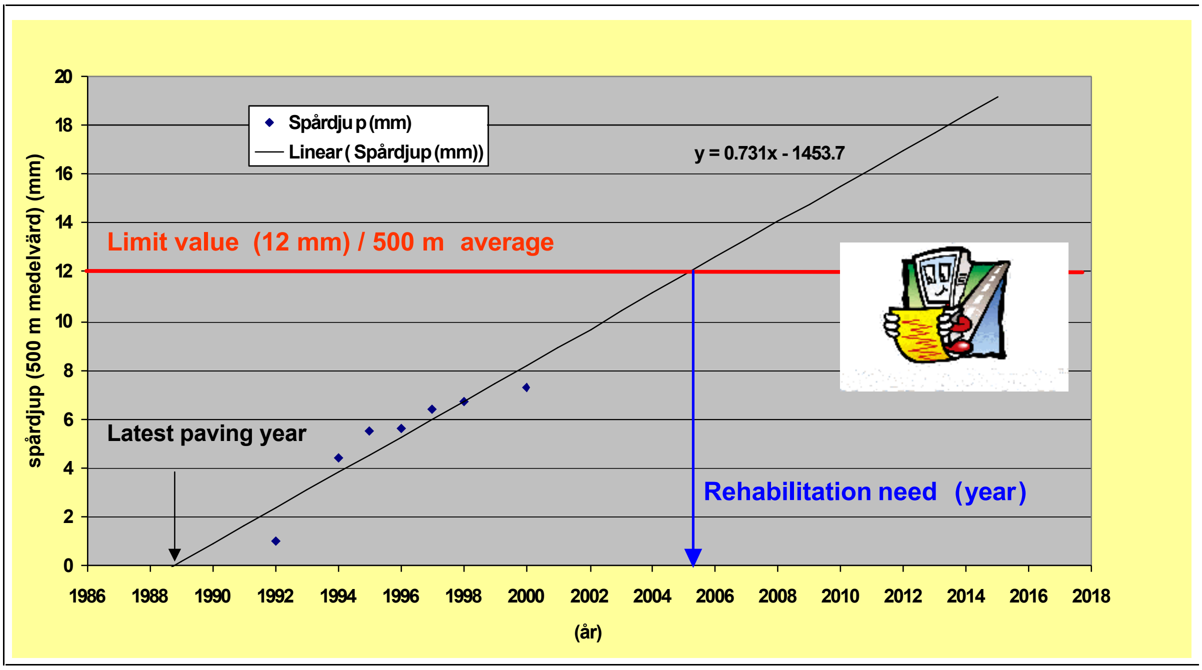

Figure 3 Principal for calculation of life length from rutting.

The same procedure is used to calculate the life length based on roughness expressed as IRI. Then the limit for the IRI-value is determined to 5 mm/m as an average of 500 m when a rehabilitation measure is needed.

4.3 Presentation of survey results

The results from every project are presented on paper in longitudinal profiles as follows:

- GPR profile containing
    - Layer thickness
    - Subgrade material type
- Roughness expressed as average IRI-values over 10 m from three measurements
- Rut depth from three measurements
- FWD data displayed as deflection bowls
- Road surface condition expressed in four classes
- Drainage expressed in three classes
- Bearing capacity index (BI) and Bearing capacity class.

Classified data is shown in different colours making it easy to locate the bad spots. A standard Road Doctor bearing capacity data analysis view can be seen in figure 4. There are also some annotations like culverts and crossings at the bottom of the figure. All the data are linked together so it is possible to a virtual trip on the road to see how the road conditions are changing throughout the ride. Combining all of the road condition data makes it possible to make a thorough investigation and then an accurate diagnosis of the causes of a road's problems which, in turn, facilitates the selection of optimal rehabilitation measures and their implementation in the right place.

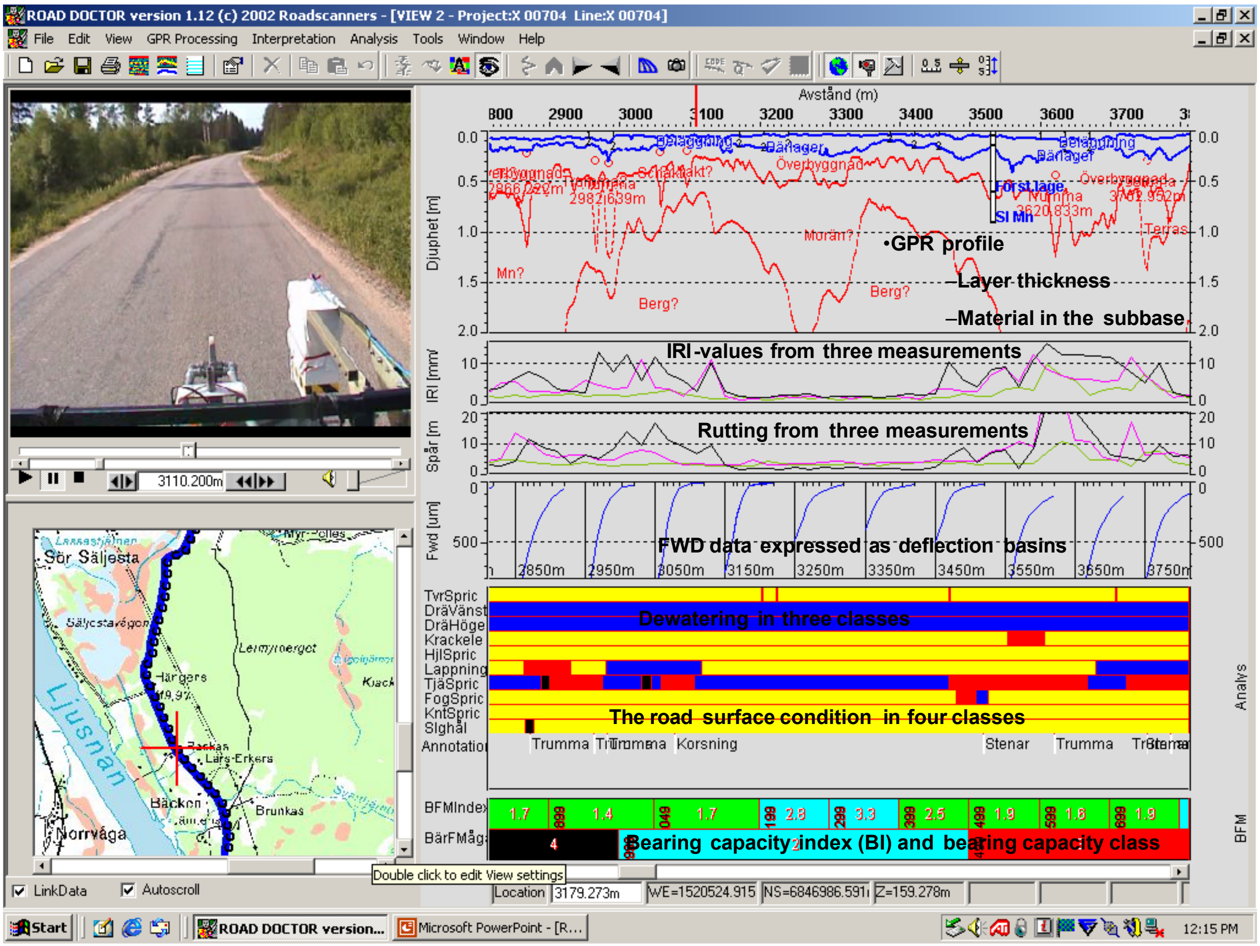

Figure 4 Road conditions viewed in a longitudinal profile.

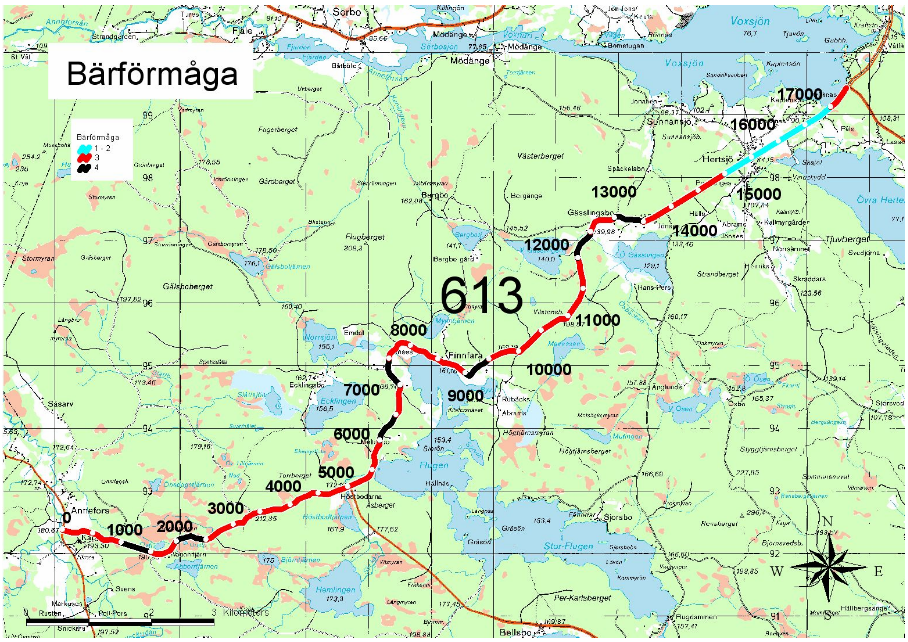

Figure 5 Example of bearing capacity results on road 613 in Gevleborg county

The bearing capacity results and the results from the life length measurements are shown on GIS maps in an interactive Power Point presentation. For every paved road the following results are shown:

- Bearing capacity class 1-4 including distribution in percent for every class in the project
- Bearing capacity class, statistics for the county and survey year
- Lifetime depending on development of roughness expressed as IRI
- Lifetime depending on development of rutting
- Distribution of IRI and rutting
- Photos of bad spots.

Examples of results are shown in figures 5 to 7.

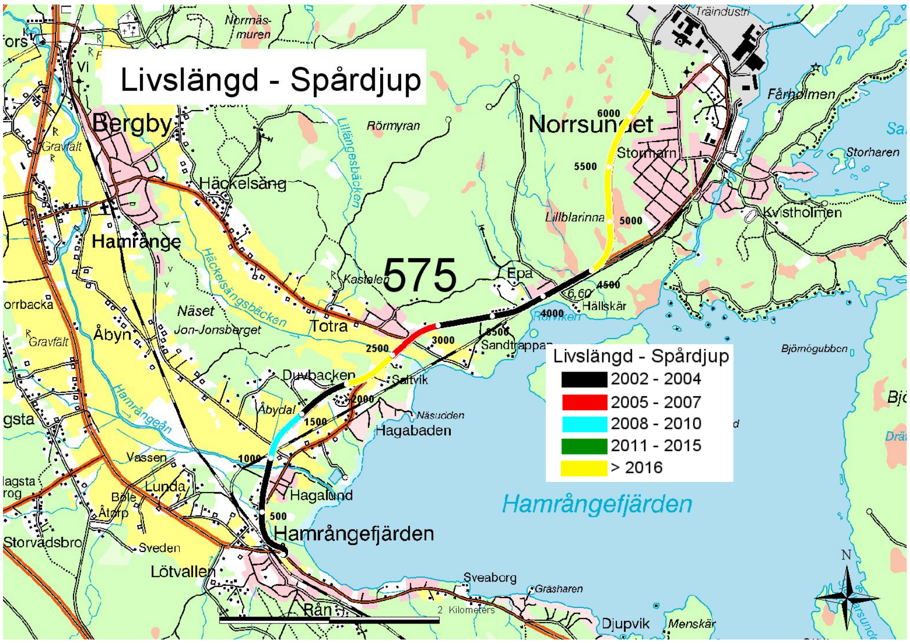

Figure 6 Example of lifetime depending on rut depth on road 575 in Gevleborg county

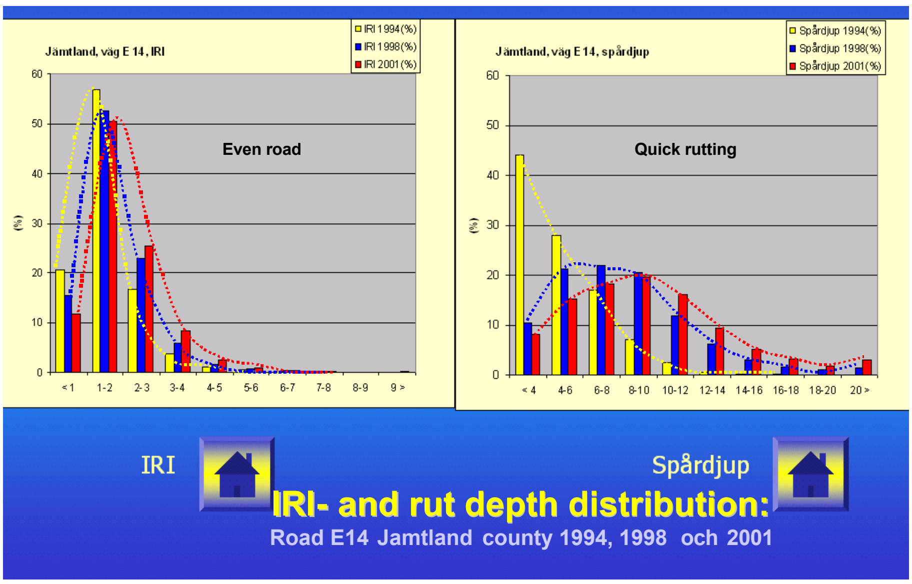

Figure 7 Example of IRI and rut depth distribution on road E14 in Jemtland county.

5 ANALYSES OF MEASUREMENT DATA, GRAVEL ROADS

5.1 Bearing capacity

The analyses of the bearing capacity are based on drainage, structural evaluation with ground penetration radar (GPR), surface curvature index (SCI) and base curvature index (BCI) from falling weight results. The SCI is a measure of the stiffness in the upper part of the structure, D0-D200 and the BCI is a measure of the stiffness in the lower part of the structure, D900-D1200. A classification has been done with three classes for each parameter. The lack of bearing capacity for gravel roads is defined as an index of the classified parameters named above made up from the following formula:
Bearing Capacity Problem Index =

(0,25*dewatering + 0,33*SCI + 0,27*BCI + 0,45*structural GPR) * 10

Then three classes for the index are defined as follows:

- Class 1, no deficiencies or minor deficiencies - Index between 0–19
- Class 2, evident deficiencies - Index between 20–29
- Class 3, major deficiencies - Index between 30–39

5.2 Presentation of results

The results from every project are presented on paper in longitudinal profiles as follows:

- GPR profile containing
    - Layer thickness
    - Subgrade material type
- Roughness is evaluated from GPR 1,0 GHz antenna bouncing data
- SCI and BCI values derived from FWD data and expressed in vertical bars s
- The road surface condition expressed in four classes
- Drainage expressed in three classes
- Bearing capacity problem index.

The bearing capacity results are shown on GIS maps in an interactive Power Point presentation. For every gravel road the following results are shown:

- Bearing capacity problem index for every 500 m in classes 1-3
- Distribution in percentage for every class in the project
- Statistics of bearing capacity problem index for the surveyed roads and year
- SCI and BCI classified in four classes
- Photos of bad spots in each project.

An example of results is shown in figure 8.

6 CONCLUSIONS

The 5-year survey has produced a lot of useful valuable data, which can be used for planning, rehabilitation design and statistical analyses of the functional and structural condition of the road. This method has also proven to be efficient in evaluating where and what type of bearing capacity problems can be found in the road network. These advanced bearing capacity and remaining lifetime analysis results produced for this project in Region Mitt were made possible through the development of Road Doctor™ software.

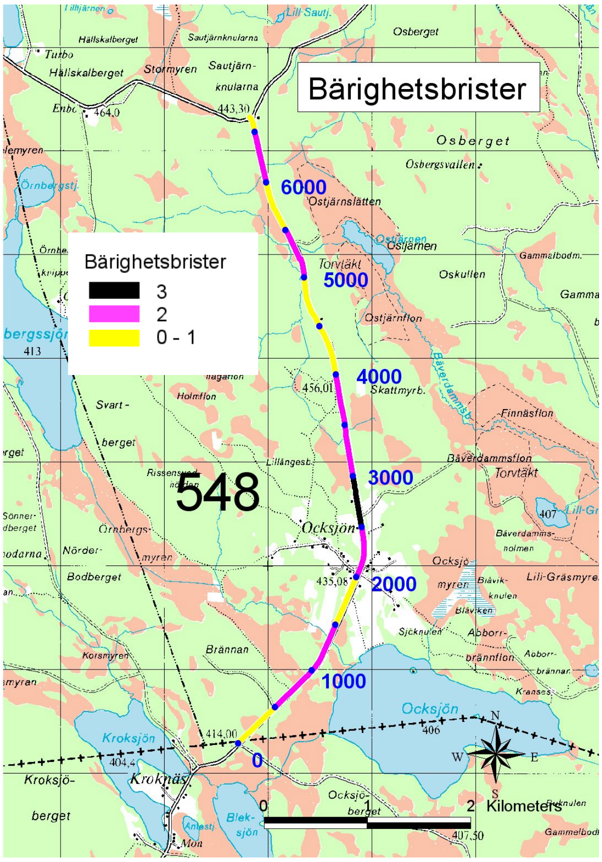

Figure 8 Example of Bearing capacity problem index on road 548 in Region Mitt.