ROADEX Network

For better rural roads

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# GRAVEL AND FOREST ROADS -

## IMPACT OF TRUCKS: CALCULATIONS WITH ERAPAVE

Summary report 2026

# ABSTRACT

This summary report, as part of the ROADEX Network project 2025 – 2026 that focused on gravel and forest roads, provides information on the impact of heavy vehicles on those roads. The impact has been assessed by calculations performed using the EraPave software. The purpose of the calculations was to demonstrate how changes in the calculation parameters (different structures, axle and wheel configurations, axle loads, tyre pressures etc.) affected the stresses and strains, and further the remaining lifetime of a gravel or forest road structure. First the critical strains induced in the structure were calculated. The theoretical service life / remaining lifetime of the structure was then assessed using fatigue models for different materials, structural layers and subgrade. The remaining lifetime is presented as the number of heavy axles left for different layers of the structure, the relative effect on lifetime caused by changes in the calculation parameters is also given.

The difference between single and dual wheels is significant in the base course near the road surface. The lifetime can be up to 5 – 6 times longer with dual wheels. At the subbase level the effect is already reduced, but still the lifetime can be up to 4 times longer with dual wheels. At the subgrade level the difference is not very strong anymore, but still up to 1.7 times longer lifetimes can be obtained with dual wheels.

The effect of tyre pressure is great near the surface. With single wheels the lifetime can be up to 8 times, and with dual wheels up to 4 times longer where reduced tyre pressures are used. The effect of tyre pressure is already reduced at the subbase level, but the lifetime can still be double with reduced pressures. But it is important to note that tyre pressure does not have a significant effect anymore at the subgrade level.

The top part of a gravel or forest road structure is very vulnerable during the spring thaw season. The lifetime may be only about 10 – 20 % compared to the summer conditions. It is very beneficial to use dual wheels and reduced tyre pressures during the thawing season, in order to reduce the stresses in the upper layers. Based on the project results, the subgrade was the “weakest link” of all the other structural options calculated, except in the spring thaw case. On the other hand, the benefit of the frozen surface is clear. The loading effect caused by a heavy axle is already significantly lower with only 10 cm of frost on the top part of the pavement structure.

Calculations were also made for tandem / tridem axle configurations. The results showed that the loading effect of heavier axle groups is the stronger the weaker is the subgrade. The tridem axle especially causes a higher loading effect, if the road drainage is poor and the subgrade is weak.



## KEYWORDS

Gravel roads, Forest roads, Heavy vehicles, EraPave

# CONTENTS

# 1. INTRODUCTION

The ROADEX Network is a technical partnership between forest and public road organizations in Northern Europe, sharing road-related information and research. Launched as an EU pilot in 1998, ROADEX now serves as a hub for sustainable rural roads, covering asset and maintenance management, vibration issues, socio-economic effects, climate adaptation, and environmental protection. The collaboration has developed new technologies and policies for road surveys, winter maintenance, gravel and forest road management, and road-friendly trucks.

This summary report is a part of the ROADEX Network project 2025 – 2026 that focused on gravel and forest road test methods and performance standards. The report provides information on the impact of heavy vehicles on gravel and forest roads. The impact has been assessed by calculations performed using the EraPave software. The calculations were made for different example structures representing typical gravel road structures in the ROADEX countries, including wet / weakened structures, structures having frost on the top, and the spring thaw case. Different load and axle configurations were also used for the calculations covering single, tandem and tridem axles, single and dual wheels, as well as normal and reduced tyre pressures.

At first, the critical strains induced in the structure were calculated. The values determined were the vertical compressive strains in the base course layer, the subbase / filter layer and at the top of the subgrade. After that the theoretical service life / remaining lifetime of the structure was assessed using fatigue models for different materials, structural layers and subgrades. The remaining lifetime was presented as the number of heavy axles (Equivalent Standard Axle Load, ESAL) left for different layers of the structure. However, special interest was in the relative effect on lifetime caused by changes in the calculation parameters rather than in the exact number of ESALs.

This report presents a summary of the different parameters used, the results of the calculations and finally some conclusions based on the results.

# 2. DIFFERENT CALCULATION STRUCTURES

## 2.1. GENERAL

The purpose of the calculations was to demonstrate how changes in the calculation parameters (structures, axle and wheel configurations, axle loads, tyre pressures etc.) have an effect on the stresses and strains, and further the remaining lifetime of a gravel or forest road structure.

The structure representing a typical gravel road structure in the ROADEX countries was selected as the basis for the calculations. For this basic structure the moduli values of different layers were selected to represent normal summer conditions. For other calculations the parameters were modified to represent the same structure in different conditions / seasons during the year. The other structures represented wet conditions, the effect of frost on the top of the structure and the situation during the spring thaw season. The calculation structures are presented in detail in the following chapters.

## 2.2. BASIC STRUCTURE

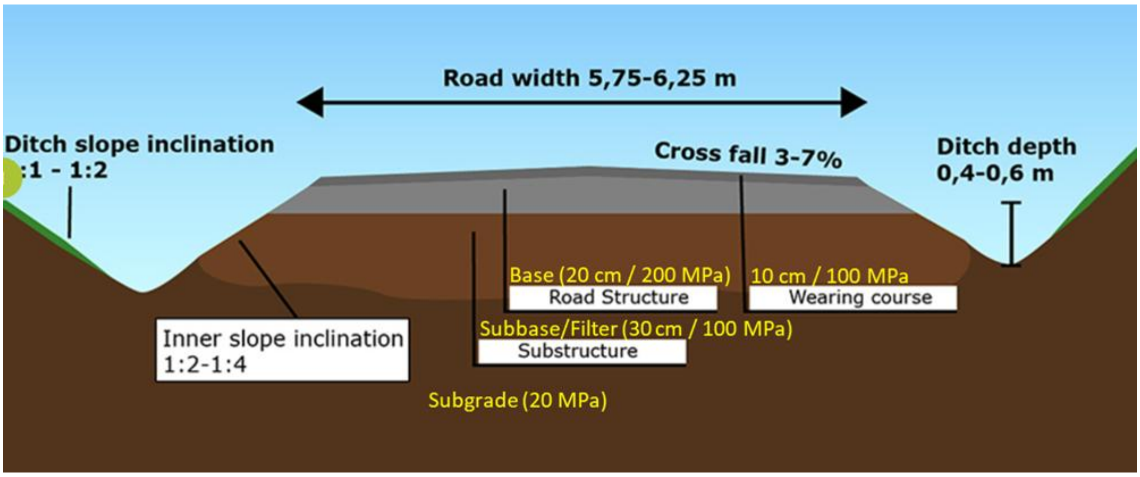


**Figure 1. Basic calculation structure representing a typical gravel road structure in the ROADEX countries in normal (summer) conditions**

This structure represents a typical gravel road structure in the ROADEX countries in normal (summer) conditions. It consists of the following layers from top to bottom:

- Wearing course 10 cm / 100 MPa
- Base course 20 cm / 200 MPa
- Subbase / Filter course 30 cm / 100 MPa
- Subgrade 20 MPa

The total thickness of the road structure is 60 cm. The subgrade modulus used is relatively low, representing e.g. silt or silty moraine.

## 2.3. WET / WEAKENED STRUCTURE

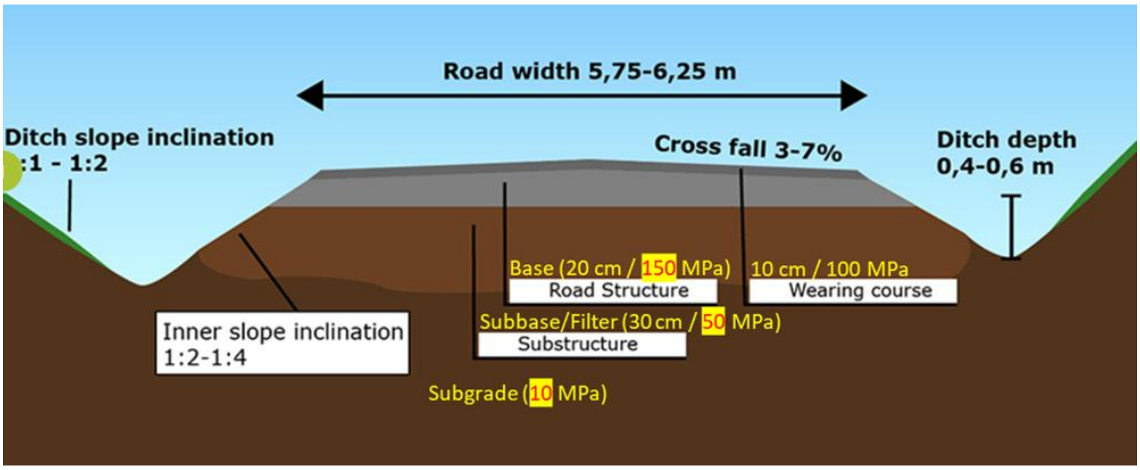


**Figure 2. Weakened calculation structure representing wet conditions**

This is the same typical gravel road structure as in Figure 1, but now it is weakened, representing wet conditions. This could happen in spring right after the frost is thawed, before the structure starts drying, or for example in autumn due to heavy rainfall. It can present also sections with poor drainage. The moduli values of the subgrade and all the other layers have decreased except the wearing course. The structure consists of the following layers from top to bottom:

- Wearing course 10 cm / 100 MPa
- Base course 20 cm / 150 MPa
- Subbase / Filter course 30 cm / 50 MPa
- Subgrade 10 MPa

## 2.4. 10 CM FROST ON THE TOP (WEARING COURSE IS FROZEN)

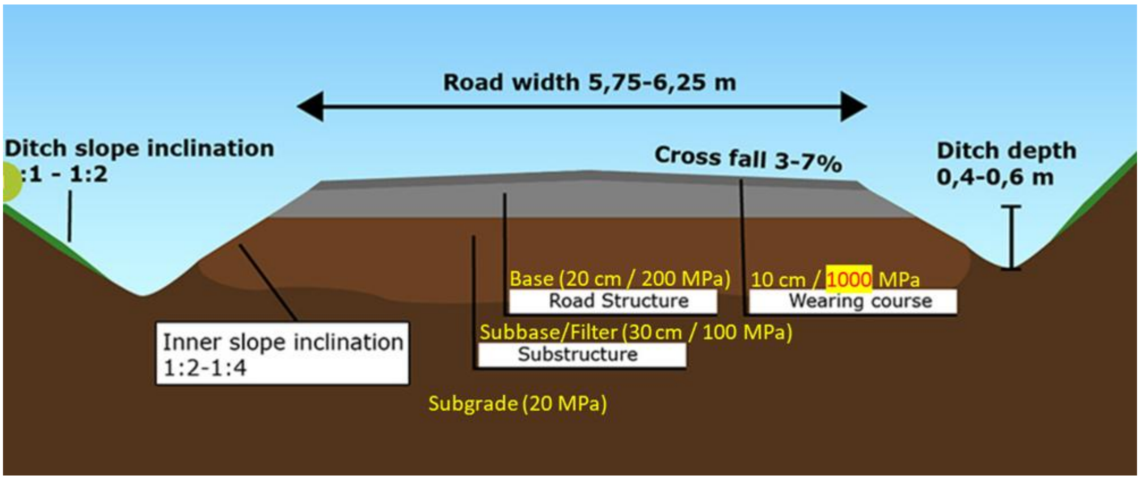


**Figure 3. Calculation structure representing 10 cm frost on the top (wearing course is frozen)**

With this case the effect of frost on the top of the structure is demonstrated. The layers are otherwise the same as in the basic structure, but now the wearing course is frozen (high modulus). This section presents conditions in early winter when the top part of the pavement structure starts to freeze. The structure consists of the following layers from top to bottom:

- Wearing course 10 cm / 1000 MPa
- Base course 20 cm / 200 MPa
- Subbase / Filter course 30 cm / 100 MPa
- Subgrade 20 MPa

## 2.5. 20 CM FROST ON THE TOP (WEARING COURSE + HALF OF THE BASE COURSE ARE FROZEN)

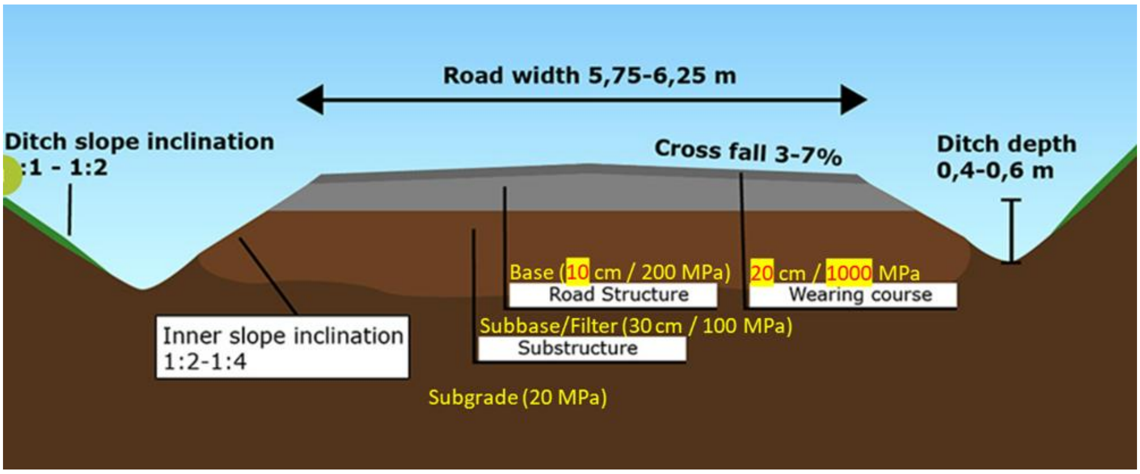


**Figure 4. Calculation structure representing 20 cm frost on the top (wearing course + half of the base course are frozen)**

This case also demonstrates the effect of frost on the top of the structure. The frozen layer is now thicker; the wearing course and half of the base course are frozen (high modulus), representing the situation a few days / weeks later compared to Figure 3. The structure consists of the following layers from top to bottom:

- Wearing course 10 cm / 1000 MPa
- Base course 10 cm / 1000 MPa
- Base course 10 cm / 200 MPa
- Subbase / Filter course 30 cm / 100 MPa
- Subgrade 20 MPa

## 2.6. FROST IS THAWING (50 CM FROM THE TOP)

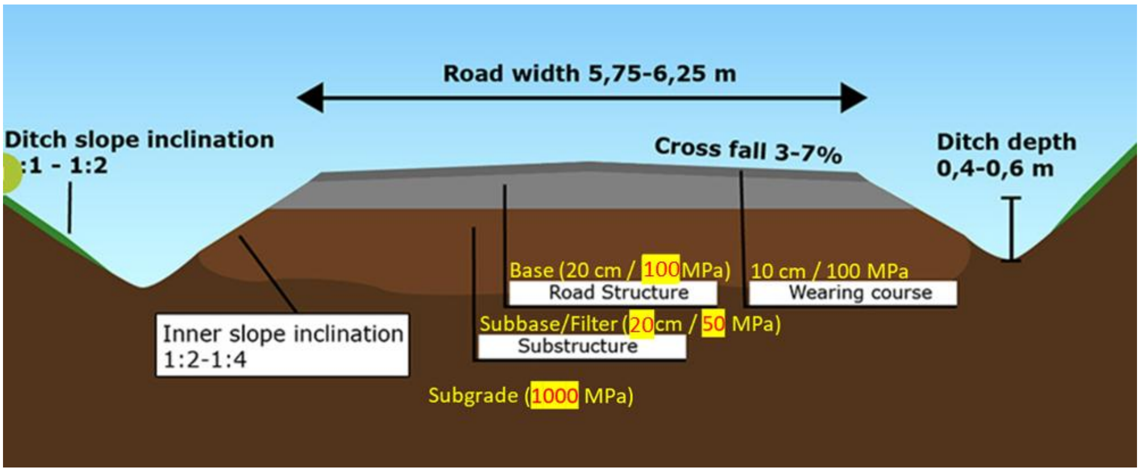


**Figure 5. Calculation structure representing the spring thaw season**

This case demonstrates the situation during the spring thaw season, when the top part of the structure has already melted, but there is still frost deeper in the structure and subgrade. This may lead to very wet and weak layers on the top part, while the lower part is stiff and impermeable. In this example the modulus of both base course and subbase / filter course is half compared to the original basic structure case. The structure consists of the following layers from top to bottom:

- Wearing course 10 cm / 100 MPa
- Base course 20 cm / 100 MPa
- Subbase / Filter course 20 cm / 50 MPa
- Lower part of subbase and subgrade 1000 MPa

# 3. DIFFERENT LOAD / AXLE CONFIGURATIONS

## 3.1. GENERAL

The purpose of the calculations was to illustrate how variations in the input parameters – such as structural layers, axle and wheel configurations, axle loads, and tyre pressures – affect the resulting stresses and strains, and consequently the remaining service life of a gravel or forest road.

Main part of the calculations was performed using single axle / single wheel or single axle / dual wheels configurations both with normal and reduced tyre pressures. Some calculations with tandem and tridem axle configurations were also made using both single and dual wheels but only with normal tyre pressure. The tandem and tridem axle calculations were performed using the same wheel loads as with the single axle and also using somewhat lower total loads, in order to better meet the actual loads allowed by regulations.

The axle and wheel configurations, axle loads and tyre pressures used are presented in detail in the following chapters.

## 3.2. SINGLE AXLE / SINGLE WHEEL

The single axle / single wheel configuration used for the calculations had total axle load of 100 kN, which means 50 kN load / wheel. The normal contact pressure (tyre pressure) used was 800 kPa. The reduced pressure used was 400 kPa, which is a typical value for CTI / TPCS systems.

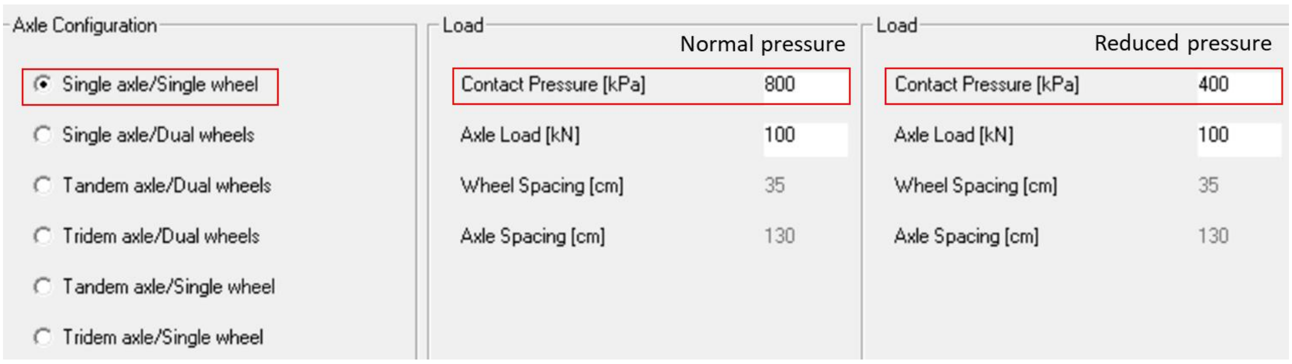


**Figure 6. Calculation parameters for single axle / single wheel configuration with normal (800 kPa) and reduced (400 kPa) tyre pressure**

## 3.3. SINGLE AXLE / DUAL WHEELS

The single axle / dual wheels configuration used for the calculations had total axle load of 100 kN, which means 25 kN load / wheel. The spacing between the dual wheel centre points was 35 cm. The normal contact pressure (tyre pressure) used was 800 kPa. The reduced pressure used was 400 kPa, which is a typical value for CTI / TPCS systems.

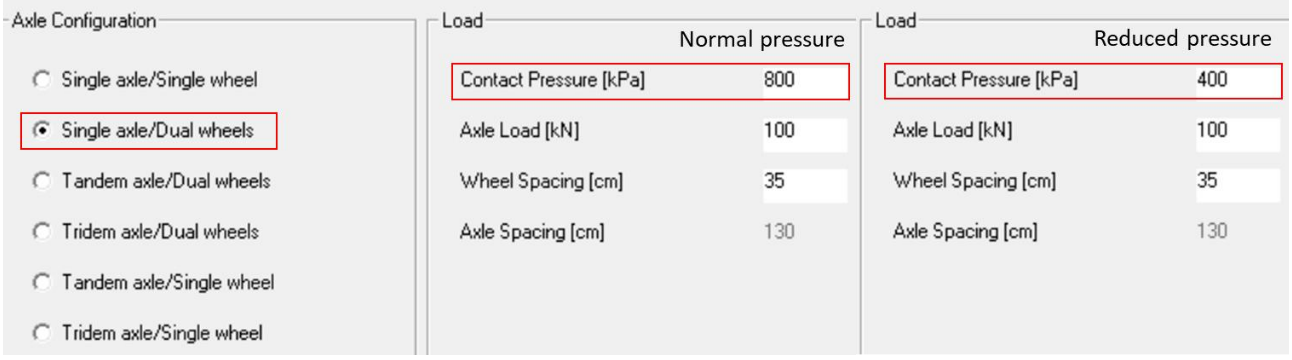


**Figure 7. Calculation parameters for single axle / dual wheels configuration with normal (800 kPa) and reduced (400 kPa) tyre pressure**

## 3.4. TANDEM AND TRIDEM AXLES

Near the surface the calculated difference in stresses and strains between a single axle and an individual axle of a tandem / tridem axle group is very small. When comparing the loading effect of a single axle with tandem / tridem axle groups, the interest is at the subgrade level, because at that level the loads from individual axles are partly summed. On the other hand, tyre pressure no longer has a significant effect at the subgrade level, which is why the tandem and tridem axle calculations were performed using only the normal 800 kPa contact pressure (tyre pressure).

The tandem axle configurations used for the calculations had total load of 200 kN, which means the same 25 kN load / wheel with dual wheels and 50 kN load / wheel with single wheels, as it was in the single axle case. As Finnish regulations do not allow that high loads for tandem axles (with single wheels), the calculations were performed also with total load of 180 kN, which means 22.5 kN load / wheel with dual wheels, and 45 kN load / wheel with single wheels. The spacing between axles in the tandem axle group was 130 cm in all calculations.

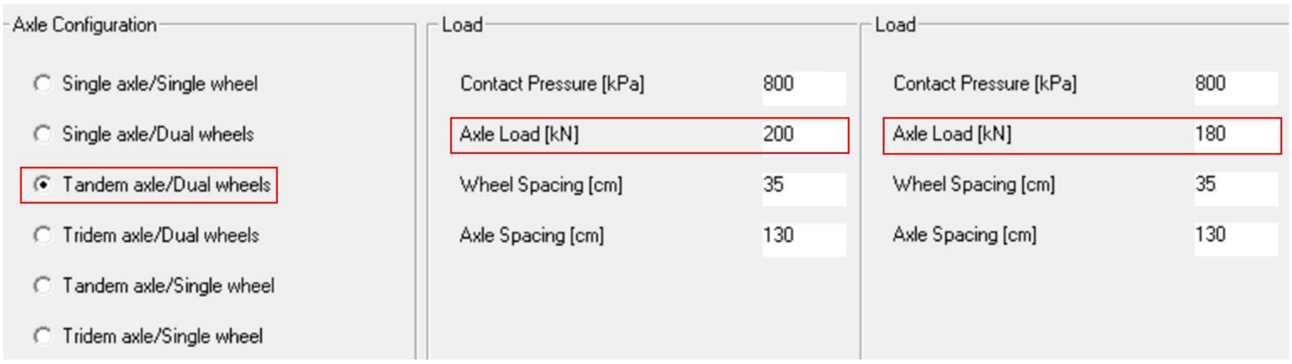


**Figure 8. Calculation parameters for tandem axle / dual wheels configuration with total load of 200 kN and 180 kN**

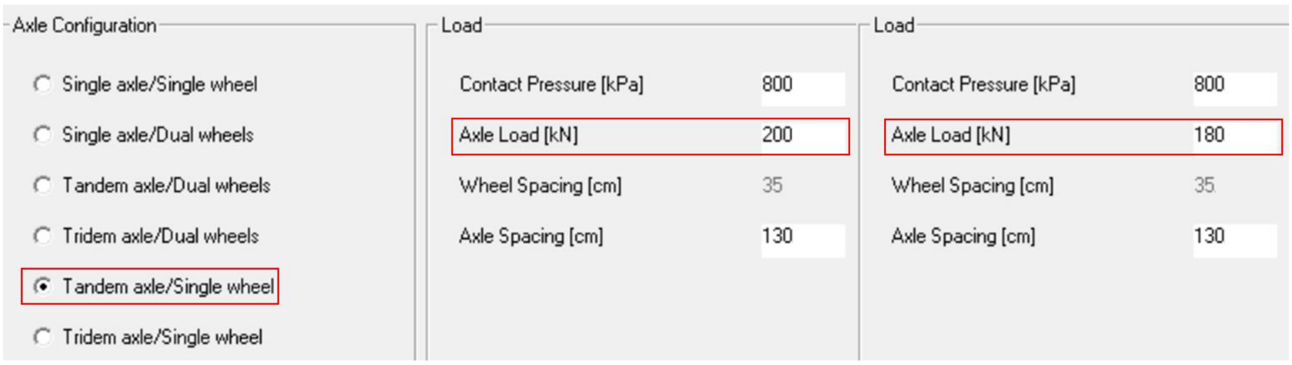


**Figure 9. Calculation parameters for tandem axle / single wheel configuration with total load of 200 kN and 180 kN**

The tridem axle configurations used for the calculations had total load of 300 kN, which means the same 25 kN load / wheel with dual wheels and 50 kN load / wheel with single wheels, as it was in the single axle case. As Finnish regulations do not allow that high loads for tridem axles, the calculations were performed also with total load of 270 kN, which means 22.5 kN load / wheel with dual wheels and 45 kN load / wheel with single wheels. The spacing between axles in the tridem axle group was 130 cm in all calculations.

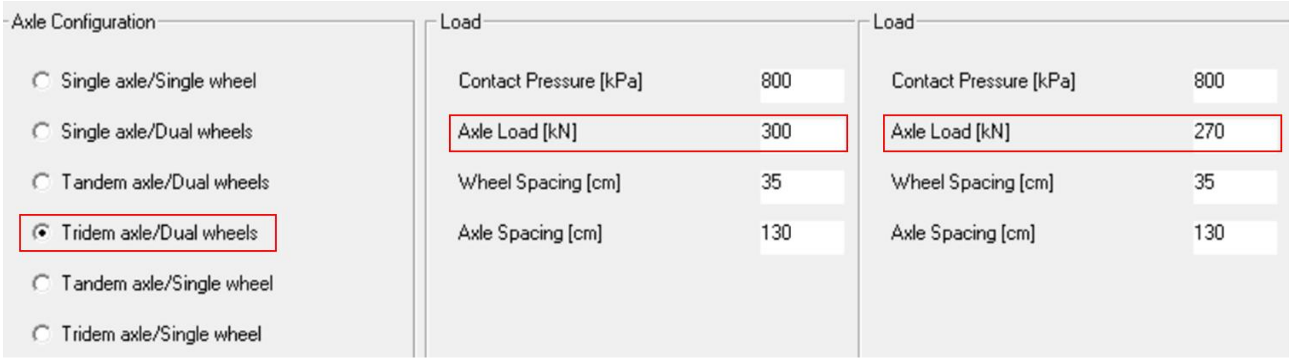


**Figure 10. Calculation parameters for tridem axle / dual wheels configuration with total load of 300 kN and 270 kN**

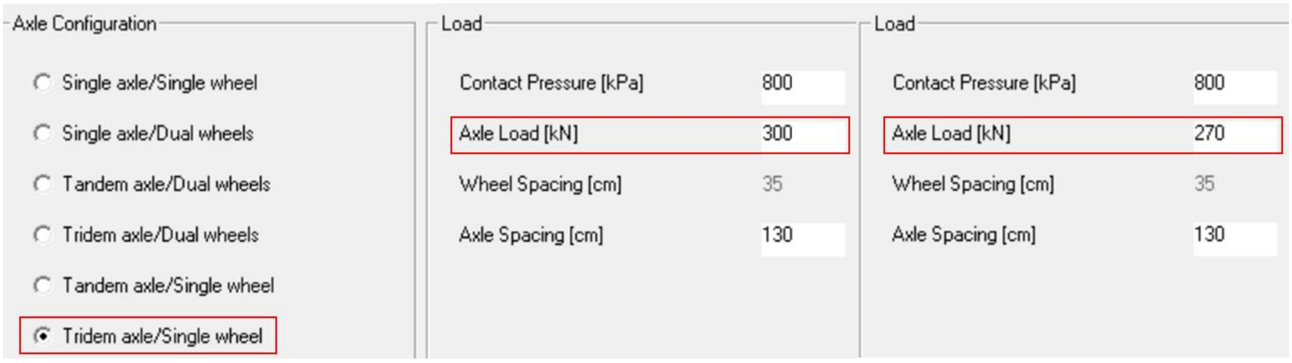


**Figure 11. Calculation parameters for tridem axle / single wheel configuration with total load of 300 kN and 270 kN**

# 4. REMAINING LIFETIME

The requirements for analytical / mechanistic load-bearing capacity calculations are: knowledge of the stiffness of the layer materials under the relevant loading conditions (modulus values), durability / performance prediction models of the materials corresponding to critical stresses and strains in the structure (fatigue models), and a computer program suitable for analyzing the stress-strain state of the structure.

The calculations were performed using the EraPave software (available for downloading on the Swedish National Road and Transport Research Institute (VTI) website: https://www.vti.se/en/research/highway-engineering-and-maintenance/pavement-technology/pavement-design-models-for-roads)

The critical strains determined were vertical compressive strains in the base course layer, subbase / filter layer and at the top of the subgrade. After that the theoretical service life / remaining lifetime of the structure was assessed using fatigue models for different materials, structural layers and subgrade from the 2004 Finnish design guideline supplement "Tietoa tiensuunnitteluun 71D".

The remaining lifetime is presented as the number of heavy axles (Equivalent Standard Axle Load, ESAL) left for the different layers of the structure. The values for single axle / single wheel and single axle / dual wheels configurations are presented in Table 1 below. However, special interest is in the relative effect on lifetime caused by changes in the calculation parameters rather than in the exact ESAL values. These are analyzed in the following chapters. The tandem and tridem axle configuration cases are analyzed separately in chapter 4.6.

**Table 1. The remaining lifetimes of different calculation cases for single axle configurations**

Remaining lifetime (number of heavy axles)

| Calculation case | Layer | Single wheel | Layer | Dual wheels |
|---|---|---|---|---|
| Basic structure | Base | 790 000 | Base | 3 700 000 |
| | Subbase/Filter | 98 000 | Subbase/Filter | 420 000 |
| | Subgrade | 23 000 | Subgrade | 39 000 |
| Basic structure – reduced tyre pressure | Base | 6 000 000 | Base | 14 500 000 |
| | Subbase/Filter | 212 000 | Subbase/Filter | 625 000 |
| | Subgrade | 24 200 | Subgrade | 39 500 |
| Wet / weakened structure | Base | 330 000 | Base | 1 570 000 |
| | Subbase/Filter | 31 000 | Subbase/Filter | 91 000 |
| | Subgrade | 6 500 | Subgrade | 10 000 |
| Wet / weakened structure – reduced tyre pressure | Base | 2 560 000 | Base | 6 300 000 |
| | Subbase/Filter | 55 000 | Subbase/Filter | 122 000 |
| | Subgrade | 6 800 | Subgrade | 10 050 |
| Frost is thawing (50 cm from the top) | Base | 155 000 | Base | 550 000 |
| | Subbase/Filter | 53 000 | Subbase/Filter | 186 000 |
| | Subgrade | > 100 million | Subgrade | > 100 million |
| Frost is thawing (50 cm from the top) – reduced tyre pressure | Base | 740 000 | Base | 1 500 000 |
| | Subbase/Filter | 103 000 | Subbase/Filter | 259 000 |
| | Subgrade | > 100 million | Subgrade | > 100 million |
| 10 cm frost on the top (wearing course is frozen) | Base | 1 270 000 | Base | 7 200 000 |
| | Subbase/Filter | 217 000 | Subbase/Filter | 870 000 |
| | Subgrade | 56 000 | Subgrade | 90 000 |
| 20 cm frost on the top (wearing course + half of the base course are frozen) | Base | 1 940 000 | Base | 11 700 000 |
| | Subbase/Filter | 425 000 | Subbase/Filter | 1 730 000 |
| | Subgrade | 81 000 | Subgrade | 130 000 |

## 4.1. BASE COURSE

The difference between single and dual wheels is significant in the base course, near the road surface. The calculated theoretical remaining lifetime with dual wheels was:

- With normal tyre pressure 3.5 – 4.7 times longer (black arrows)
- With reduced tyre pressure 2.0 – 2.5 times longer (red arrows)
- With frost on top 5.7 – 6.0 times longer lifetime (blue arrows)

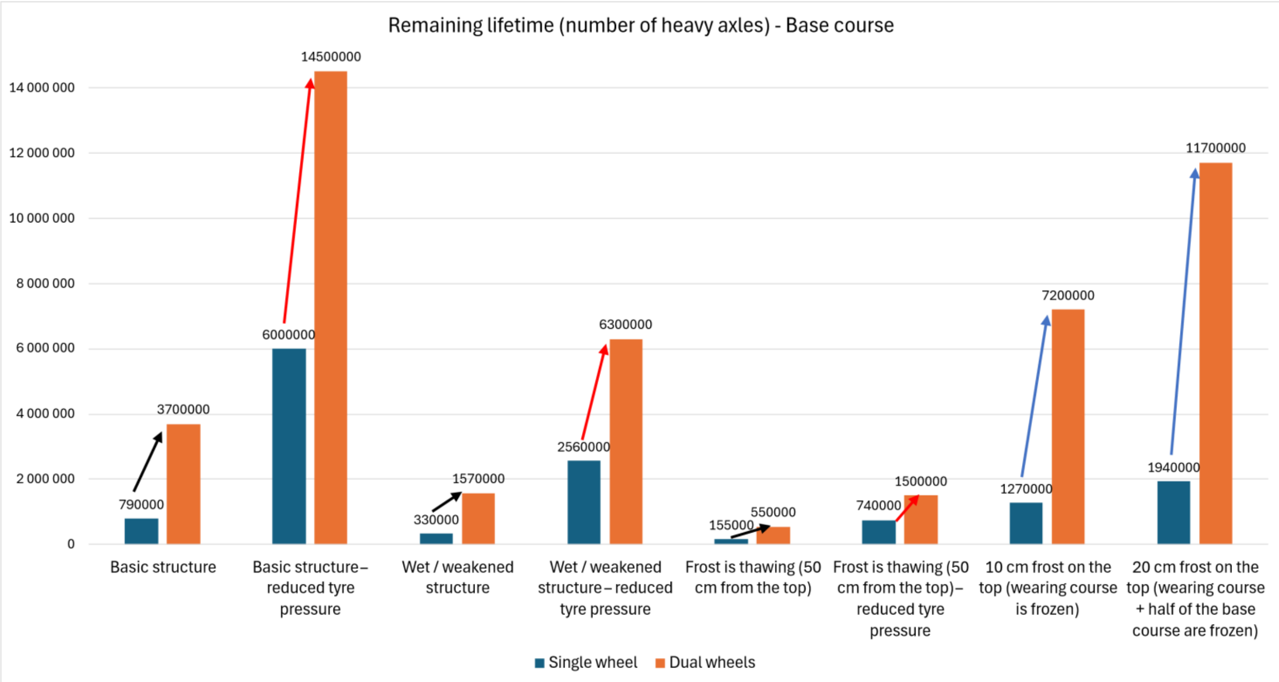


**Figure 12. The difference in remaining lifetime between single and dual wheels in the base course**

The effect of tyre pressure is also great near the surface. According to the calculation results, when reduced tyre pressures were used, the theoretical remaining lifetime was:

- With single wheels 4.8 – 7.8 times longer (black arrows)
- With dual wheels 2.7 – 4.0 times longer (red arrows)

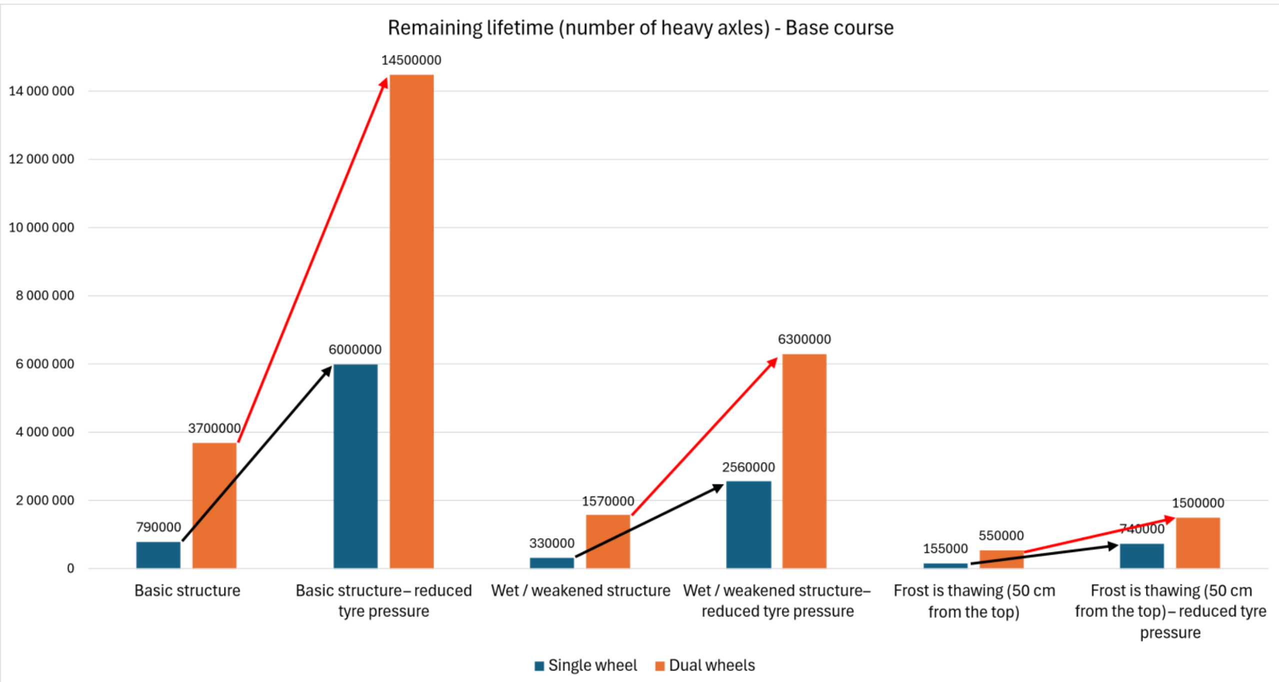


**Figure 13. The effect of tyre pressure in the base course**

The benefit of a frozen surface is clear. With 10 cm frost on the top (the wearing course is frozen), the calculation gives 1.6 – 1.9 times longer lifetime for base course compared to the basic structure (black arrows). And with 20 cm frost on the top (the wearing course + half of the base course are frozen) the factor is 2.5 – 3.2 (red arrows).

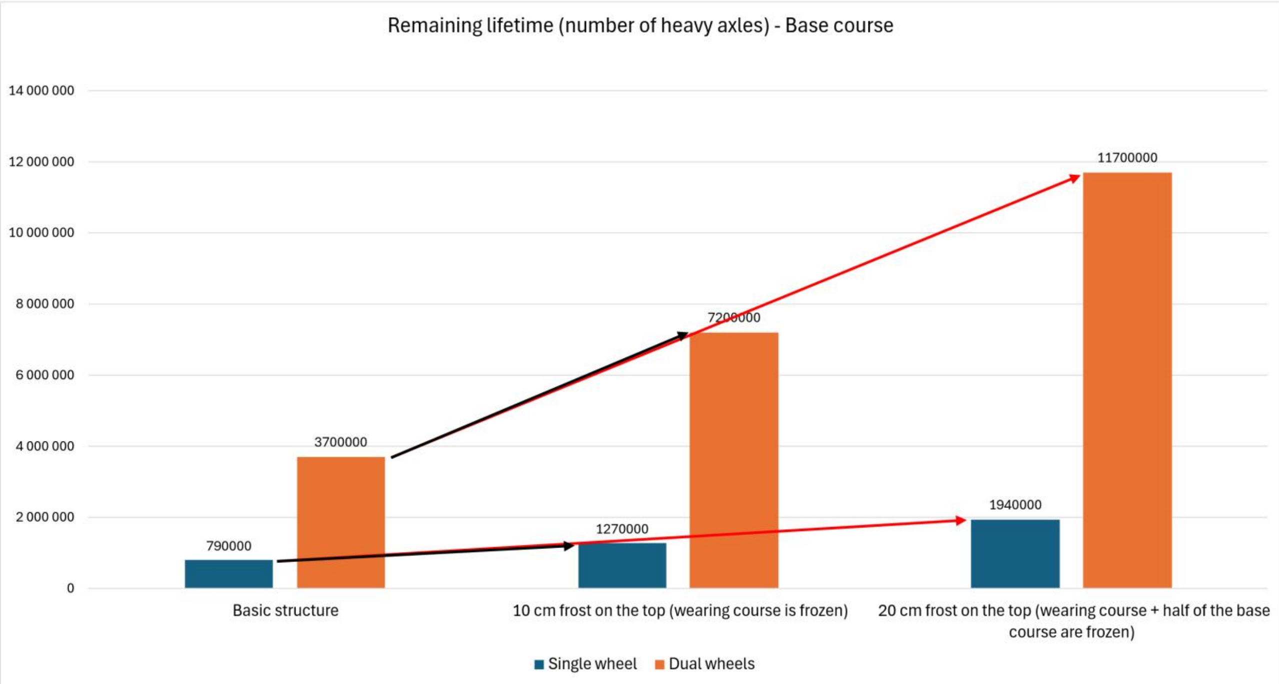


**Figure 14. The effect of a frozen surface in the base course**

Comparison of the calculated remaining lifetimes of the basic structure, the wet / weakened structure and the spring thaw case shows, that the top part of a gravel road structure is very vulnerable during the spring thaw season. The theoretical remaining lifetime is only about 10 – 20 % of the summer condition's lifetime. And even when compared to the wet / weakened structure, the lifetime during spring thaw is only about 25 – 45 %. However, it can be clearly seen that using dual wheels and reduced tyre pressures is very beneficial.

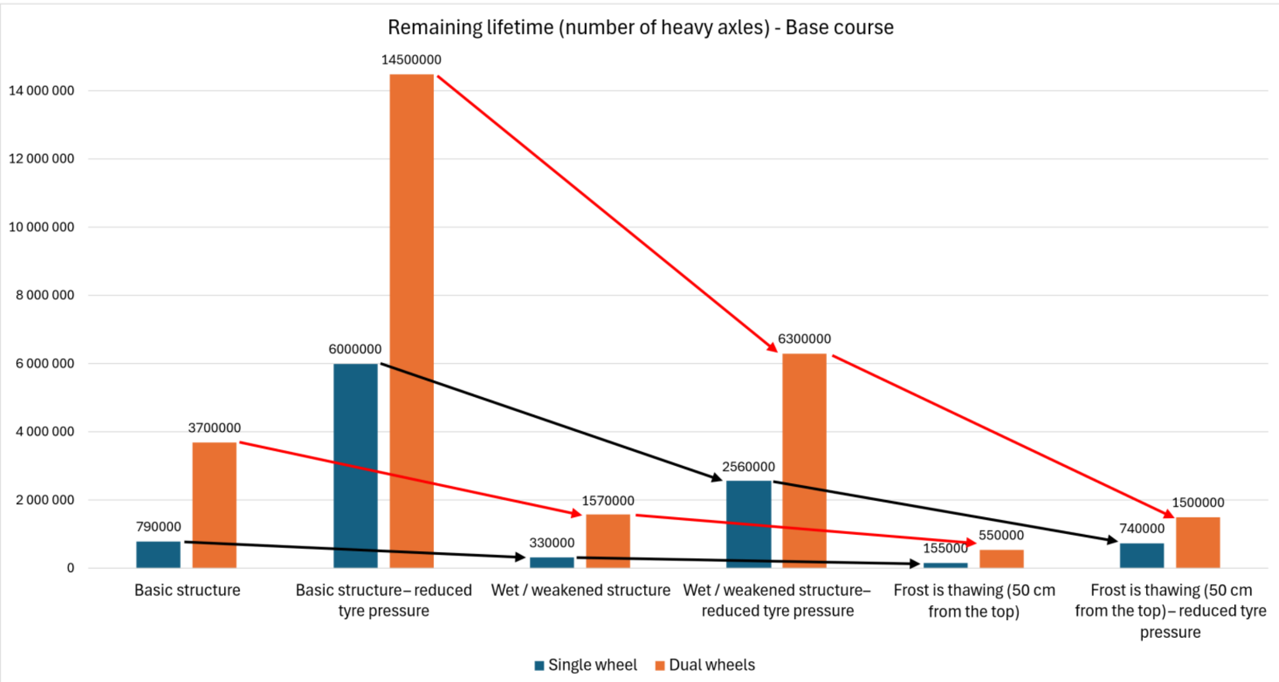


**Figure 15. Comparison of the calculated remaining lifetimes of the basic structure, the wet / weakened structure and the spring thaw case**

## 4.2. SUBBASE / FILTER COURSE

The difference between single and dual wheels is still significant in the subbase course as well. The calculated theoretical remaining lifetime with dual wheels was:

- With normal tyre pressure 2.9 – 4.3 times longer (black arrows)
- With reduced tyre pressure 2.2 – 2.9 times longer (red arrows)
- With frost on top 4.0 – 4.1 times longer (blue arrows)

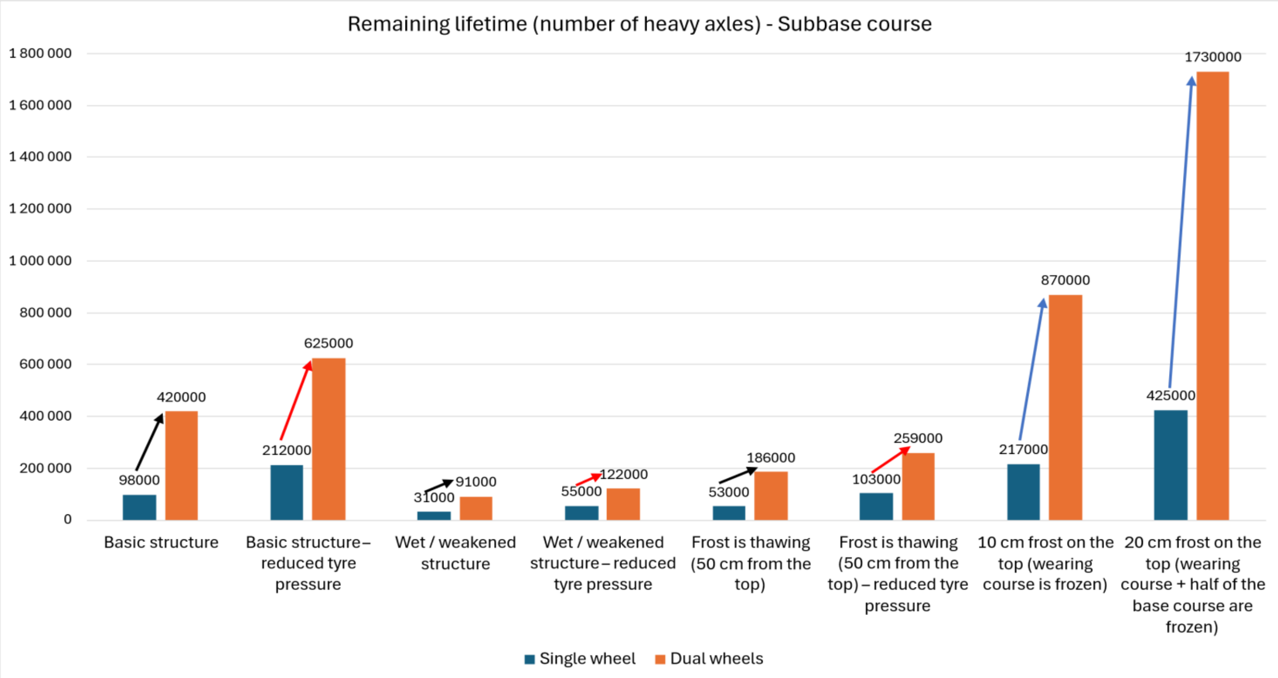


**Figure 16. The difference in remaining lifetime between single and dual wheels in the subbase course**

The effect of tyre pressure is already significantly reduced at the subbase level compared to the base course. According to the calculation results, when reduced tyre pressures were used, the theoretical remaining lifetime was:

- With single wheels 1.8 – 2.2 times longer (black arrows)
- With dual wheels 1.4 – 1.5 times longer (red arrows)

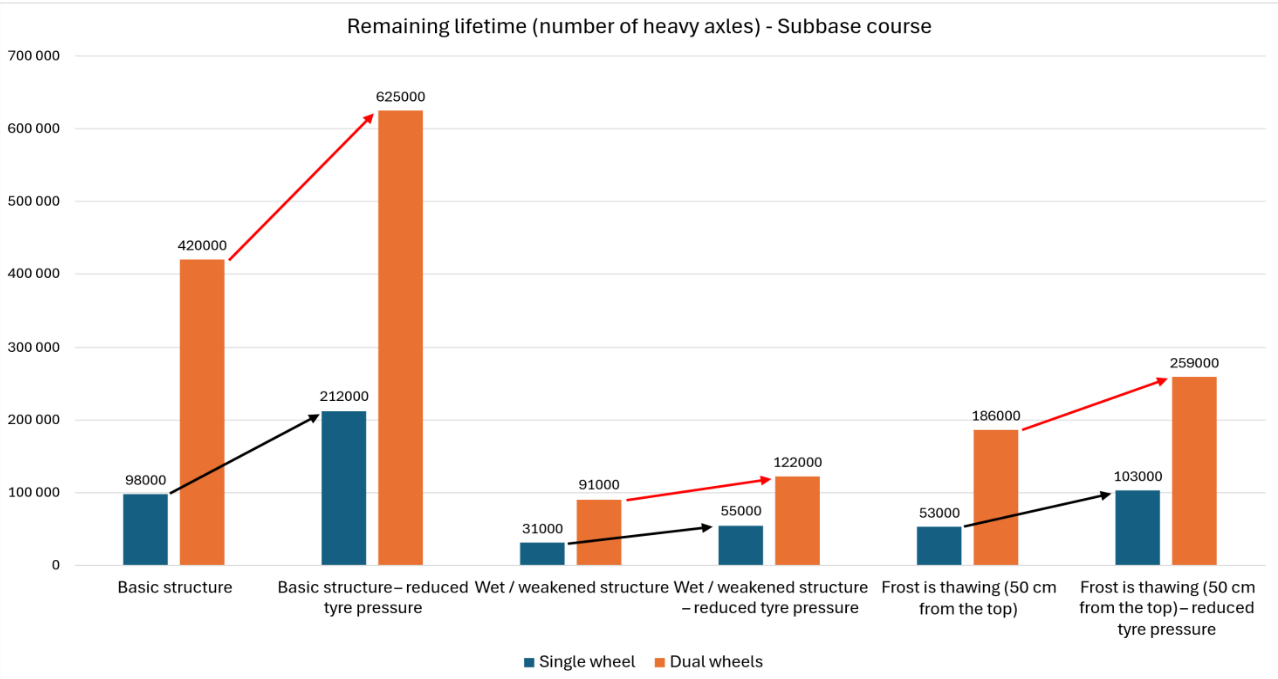


**Figure 17. The effect of tyre pressure in the subbase course**

In the subbase layer, the positive effect caused by a frozen surface is a little stronger than in the base course. With 10 cm frost on the top (wearing course is frozen), the calculation gives 2.1 – 2.2 times longer lifetime for the subbase course compared to the basic structure (black arrows). And with 20 cm frost on the top (wearing course + half of the base course are frozen) the factor is 4.1 – 4.3 (red arrows).

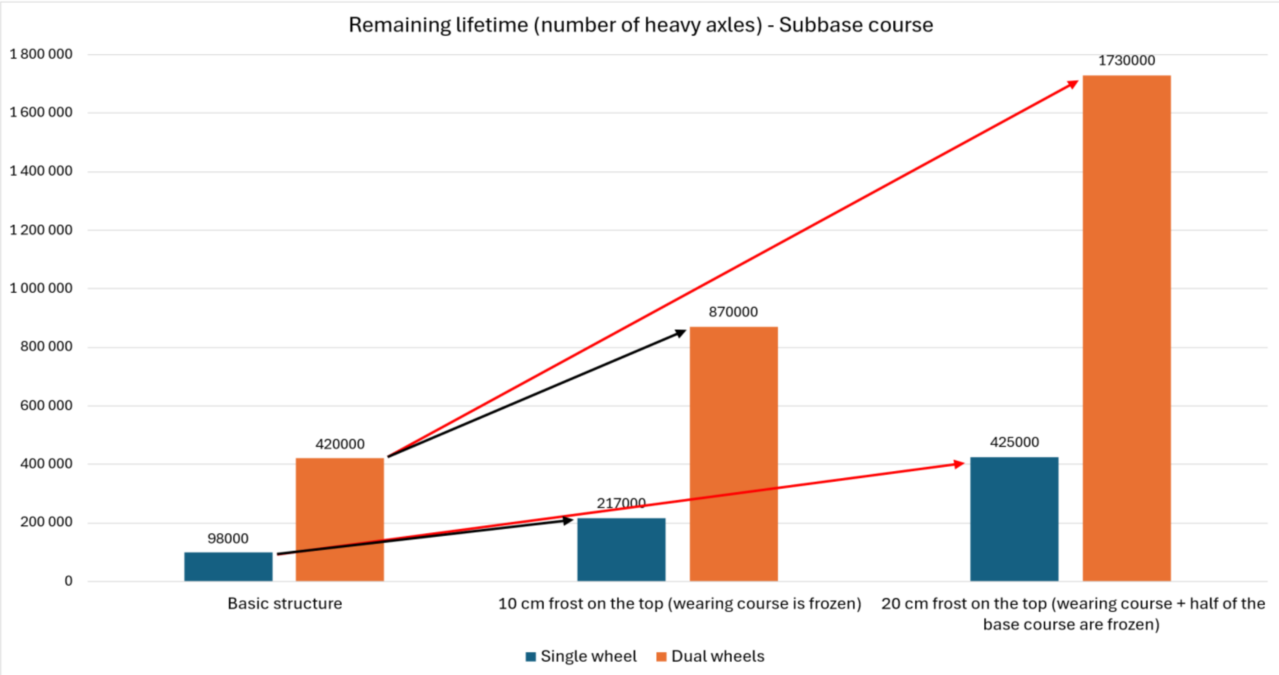


**Figure 18. The effect of a frozen surface in the subbase course**

## 4.3. SUBGRADE

The difference between single and dual wheels is not very strong at the subgrade level, but still the calculated theoretical remaining lifetime is 1.5 – 1.7 times longer with dual wheels. The reason for this is that the overall thickness of a gravel road structure is relatively thin, and there is no pavement on the surface that would distribute the wheel loads to a wider area.

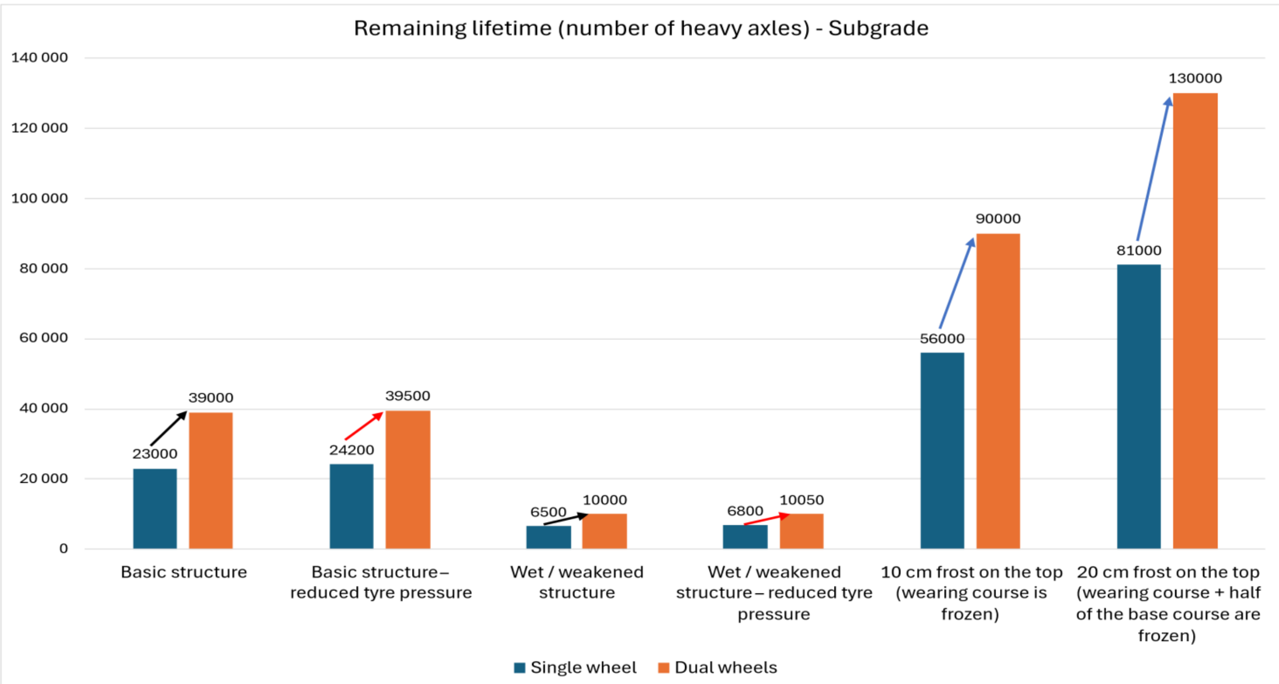


**Figure 19. The difference in remaining lifetime between single and dual wheels at the subgrade level**

Tyre pressure on the other hand does not have a significant effect anymore at the subgrade level, as can be seen from Figure 20. The calculated remaining lifetimes are very close to the same, both with normal and reduced tyre pressures. It is important to note that CTI / TPCS systems do not have effect on the stresses and strains induced in the subgrade.

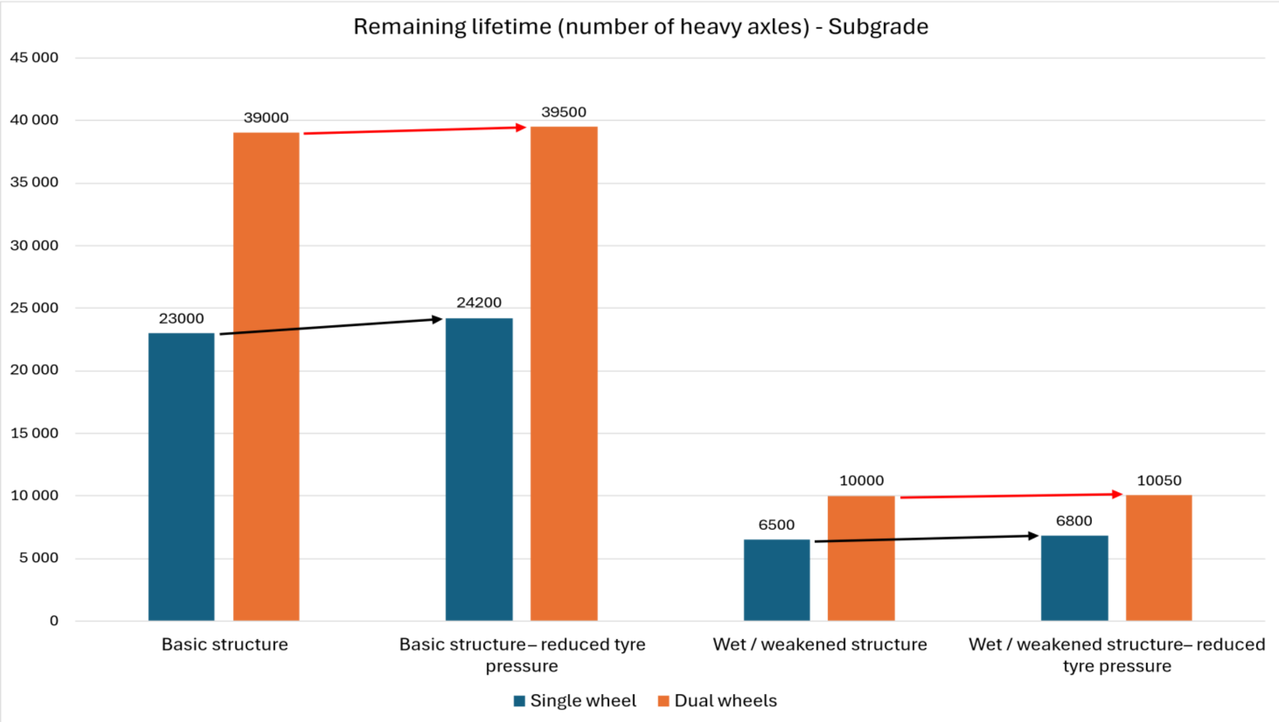


**Figure 20. The effect of tyre pressure at the subgrade level**

At the subgrade level, the positive effect caused by the frozen surface is still strong. With 10 cm frost on the top (wearing course is frozen), the calculation gives 2.3 – 2.4 times longer lifetime for subgrade compared to the basic structure (black arrows). And with 20 cm frost on the top (wearing course + half of the base course are frozen) the factor is 3.3 – 3.5 (red arrows).

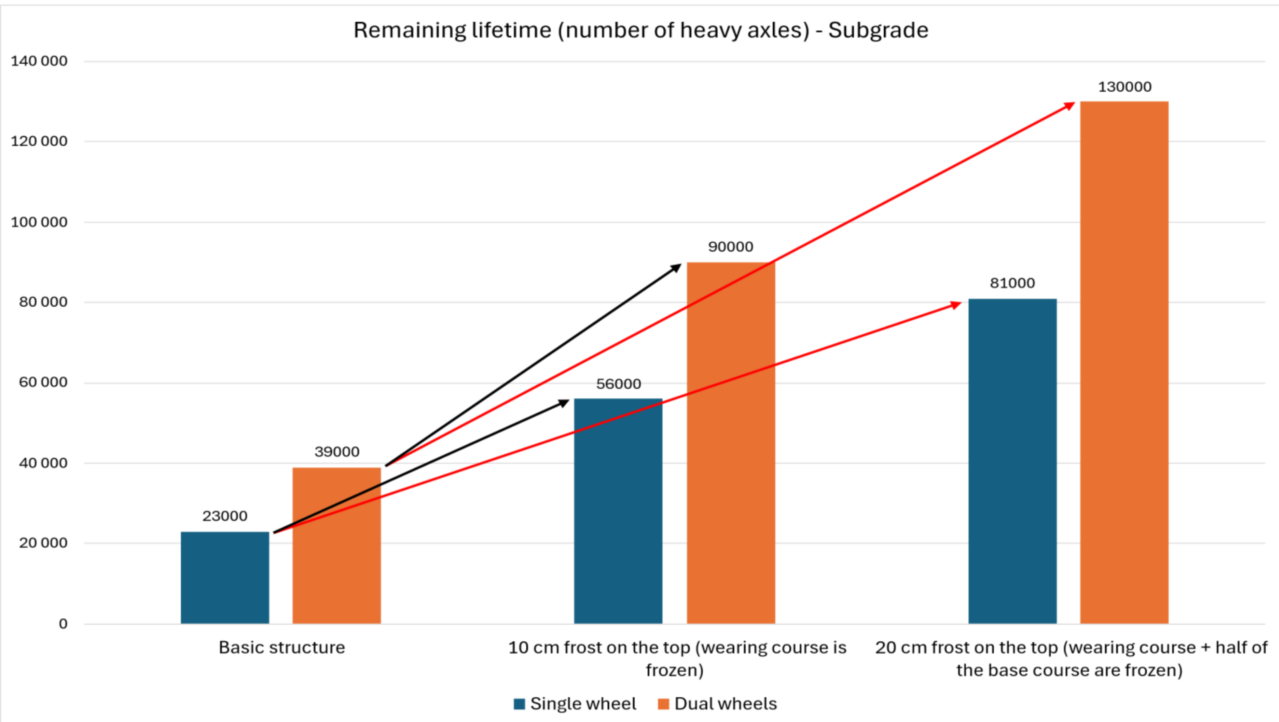


**Figure 21. The effect of frozen surface at the subgrade level**

## 4.4. ALL LAYERS TOGETHER

When the calculated remaining lifetimes of all layers are viewed side by side, it can be clearly observed that subgrade is the "weakest link" of this layered structure. The only exception to this is the spring thaw season, when the subgrade is still frozen and the layers on top of it are wet and weak. During the thawing period the top part of a gravel road structure is very sensitive to permanent deformations.

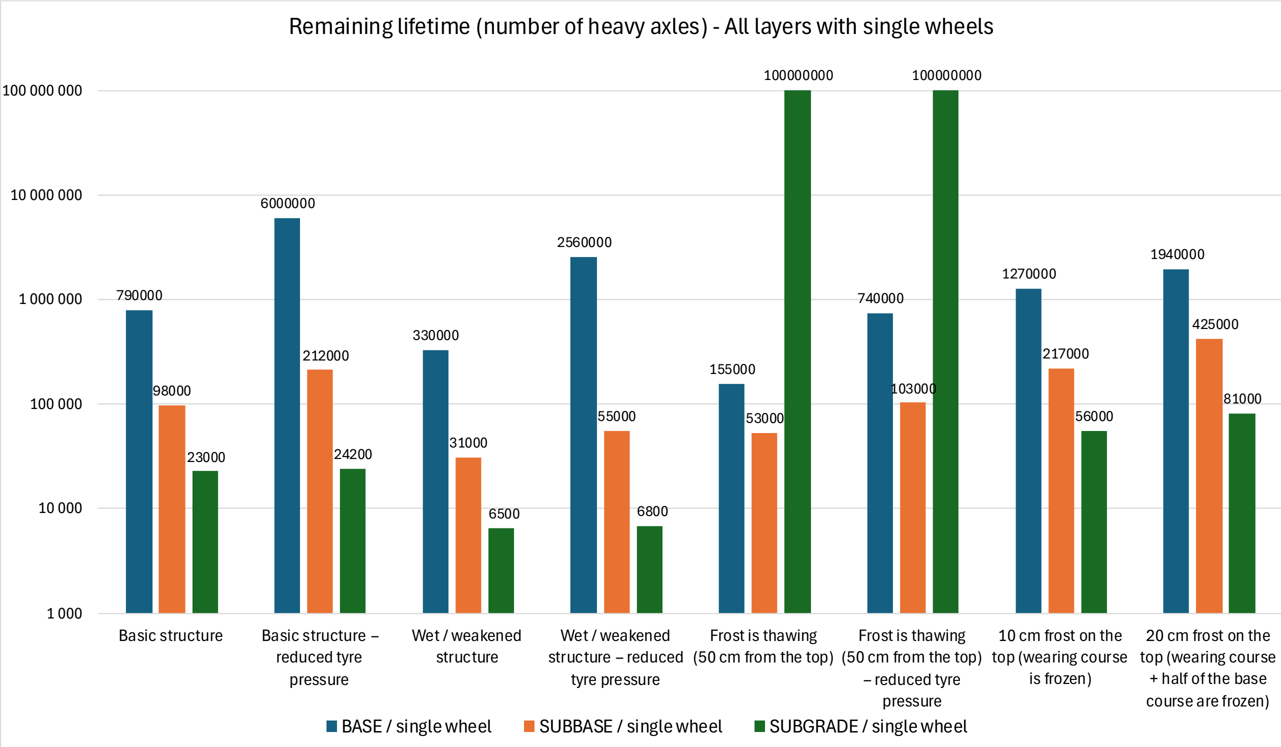


**Figure 22. The calculated remaining lifetimes of all layers with single wheels (Note: Logarithmic scale)**

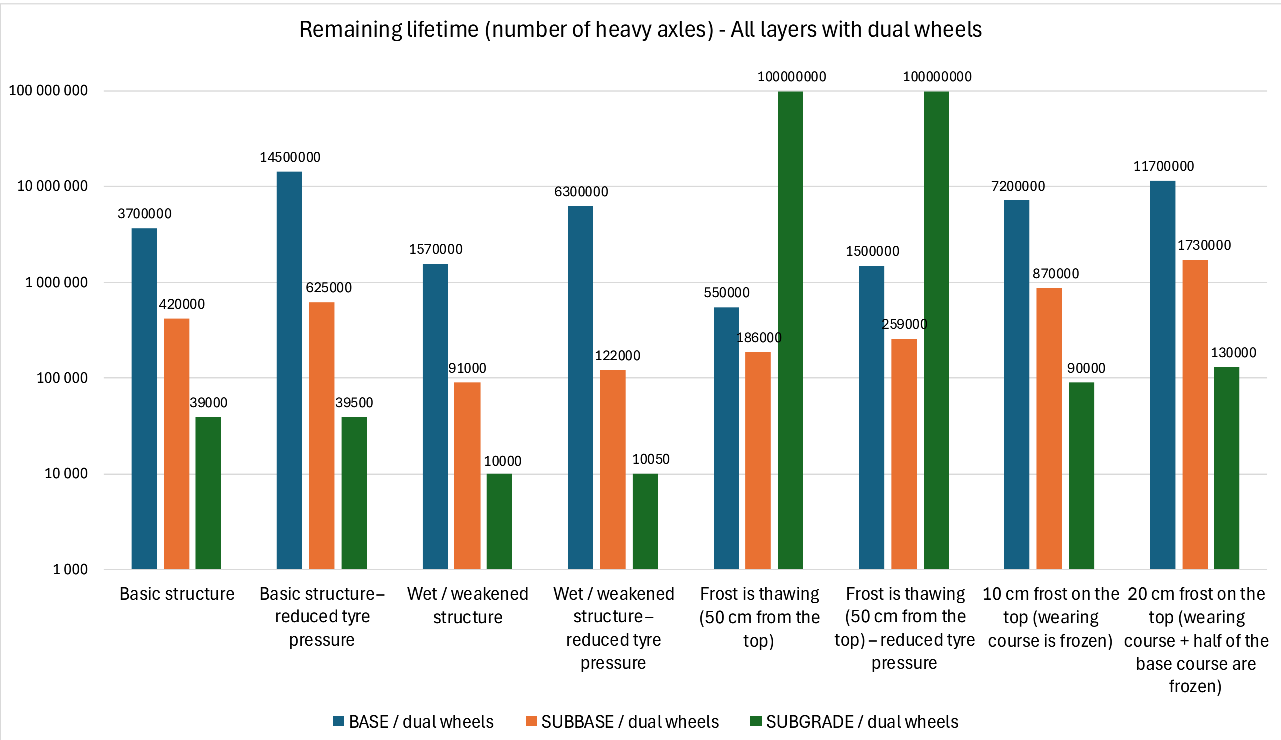


**Figure 23. The calculated remaining lifetimes of all layers with dual wheels (Note: Logarithmic scale)**

## 4.5. SINGLE AXLE VS. TANDEM / TRIDEM AXLE COMPARISONS

Near the surface the calculated difference in stresses and strains between a single axle and an individual axle of a tandem / tridem axle group is very small. When comparing the loading effect of a single axle with tandem / tridem axle groups, the interest is at the subgrade level, because at that level the loads from individual axles are partly summed. Especially on weak subgrades heavy vehicles cause accumulation of displacement in the subgrade, as illustrated in the Figure 24 below. Weak subgrades do not behave in a fully elastic fashion and because of this, with a long vehicle combination, deflections / deformations do not have enough time to recover before the next consecutive axle or axle group loads the same spot. However, these calculations do not deal with this accumulation, only the loading effect on the subgrade level caused by a single axle compared to tandem and tridem axle groups.

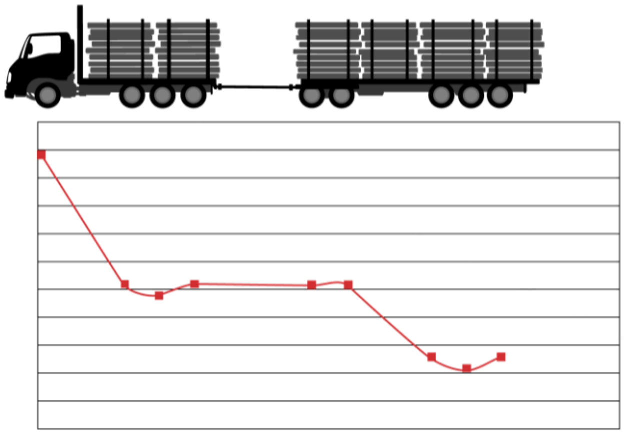

**Figure 24. On weak subgrades heavy vehicles cause accumulation of displacement in the subgrade**

At first, comparisons were made for the basic structure. It can be observed from the results that both with single and dual wheels, the calculated remaining lifetimes with 180 kN tandem axle and 270 kN tridem axle are close to the value of a corresponding 100 kN single axle. According to the calculation, the 180 kN tandem axle is stressing the subgrade even less than the 100 kN single axle. But if the tandem axle load is raised to 200 kN and tridem axle load to 300 kN, the decrease in remaining lifetime can be clearly seen.

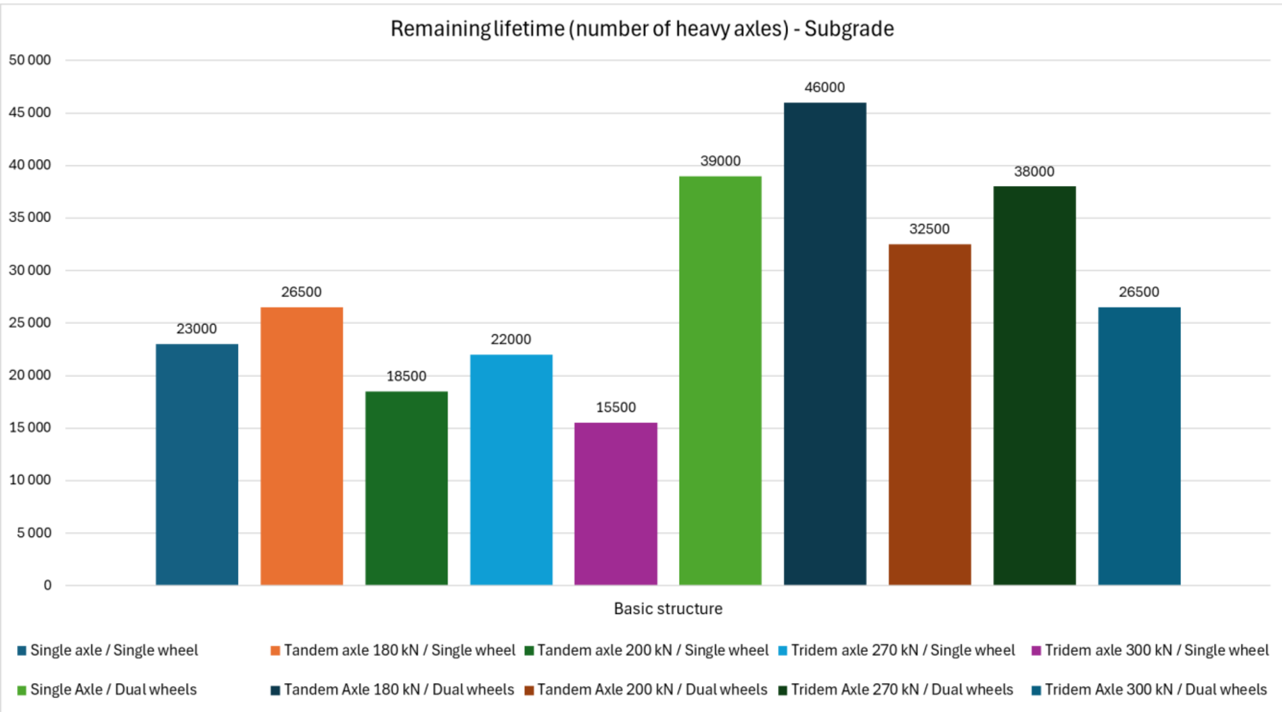


**Figure 25. Comparison of remaining lifetimes of subgrade (as number of heavy axles) between single, tandem and tridem axles for the basic structure**

With a wet / weakened structure the results are slightly different. Now the calculated remaining lifetimes with the 180 kN tandem axle are reduced to almost exactly the same as with the 100 kN single axle, both with single and dual wheels. But with a weaker structure and subgrade, the 270 kN tridem axle groups are at the same level as the 200 kN tandem axle options; 30 % worse than the single axle. And with 300 kN tridem axle the remaining lifetime is only half compared to the single axle. It can be concluded from the results, that the loading effect of heavier axle groups is the stronger the weaker is the subgrade.

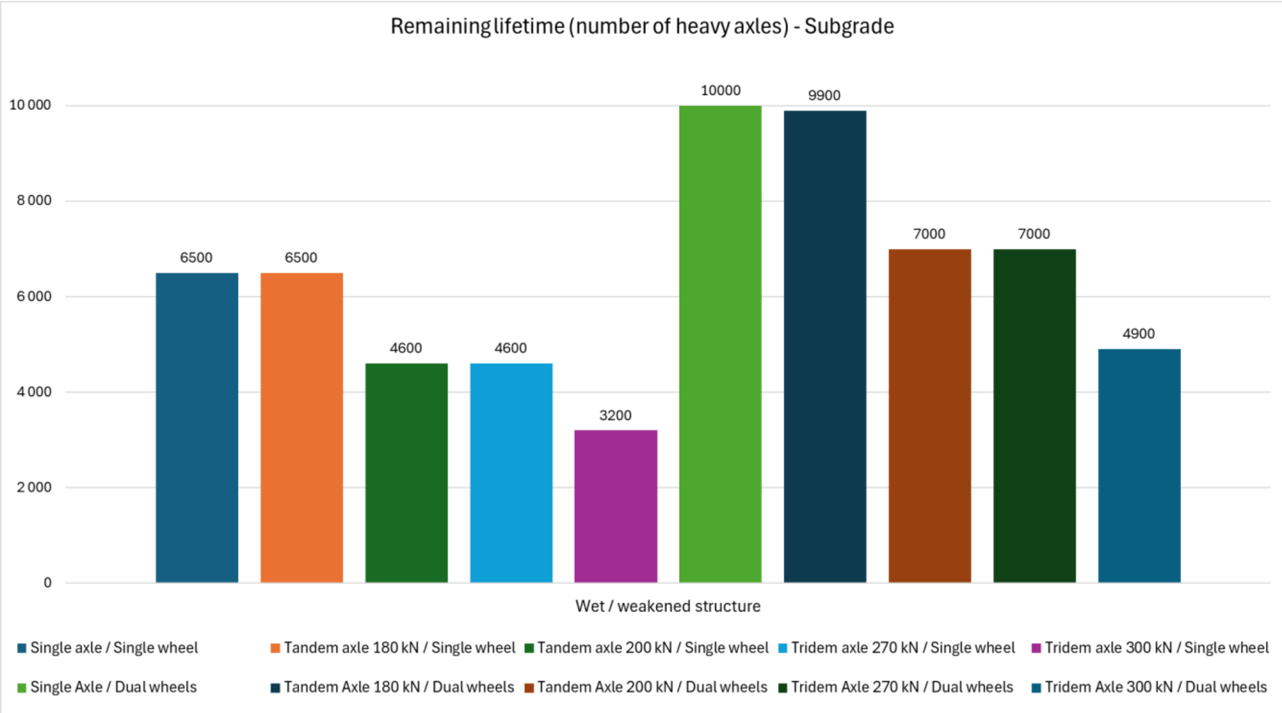


**Figure 26. Comparison of remaining lifetimes of subgrade (as number of heavy axles) between single, tandem and tridem axles for the wet / weakened structure (Note: The vertical axis scale is 5 times smaller than in Figure 25)**

# 5. SUMMARY / CONCLUSIONS

Base course / top part of the road structure:

- The difference between single and dual wheels is significant in the base course, near the road surface. The calculated theoretical remaining lifetime can be up to 5-6 times longer with dual wheels.
- The effect of tyre pressure is also great near the surface. With single wheels the lifetime can be up to 8 times, and with dual wheels up to 4 times longer, if reduced tyre pressures are used.
- Comparison of the calculated remaining lifetimes of the basic structure, the wet / weakened structure and the spring thaw case showed, that the top part of a gravel road structure is very vulnerable during the spring thaw season. The lifetime is only about 10 – 20 % compared to the summer conditions. And even when compared to the wet / weakened structure, the lifetime during spring thaw is only about 25 – 45 %. However, it can be clearly seen from the results that using dual wheels and reduced tyre pressures during the spring thaw season is very beneficial.

Subbase level:

- The difference between single and dual wheels is quite similar compared to the base course, but the factors are a little bit smaller. Still the remaining lifetime can be up to 4 times longer with dual wheels.
- The effect of tyre pressure is already significantly reduced at the subbase level, but the lifetime can still be up to 2 times longer, if reduced pressures are used.
- Although the base course is also very weak during the spring thaw season, the calculation results showed that the subbase was even weaker, and the “weakest link” of this example structure.

Subgrade level:

- The difference between single and dual wheels is not very strong at the subgrade level, but still up to 1.7 times longer lifetimes are obtained with dual wheels. The reason for this is that the overall thickness of a gravel road structure is relatively thin, and there is no pavement on the surface that would distribute the wheel loads to a wider area.
- Tyre pressure does not have a significant effect anymore at the subgrade level. It is important to note that CTI / TPCS systems do not have effect on the stresses and strains induced in the subgrade.

Frost on the top:

- The benefit of a frozen surface is clear. With 10 cm frost on the top (wearing course is frozen), the calculation gives about double lifetime on all levels.
- With 20 cm frost on the top (wearing course + half of the base course are frozen) the calculated lifetime is up to 3-4 times longer on all levels.
- The positive effect caused by a frozen surface may be even a bit stronger on deeper levels than in the top part of the structure.

When the calculated remaining lifetimes of all layers are viewed side by side, it can be clearly observed that subgrade is the “weakest link” of the structure. Except for the spring thaw season when the subgrade is still frozen and the layers on top of it are wet and weak. During the thawing period the top part of a gravel road structure is the “weakest link”, and sensitive to permanent deformations. This can be seen also from Figure 27, presenting an additional comparison of remaining lifetimes for the different calculation structures in the form of number of trucks.

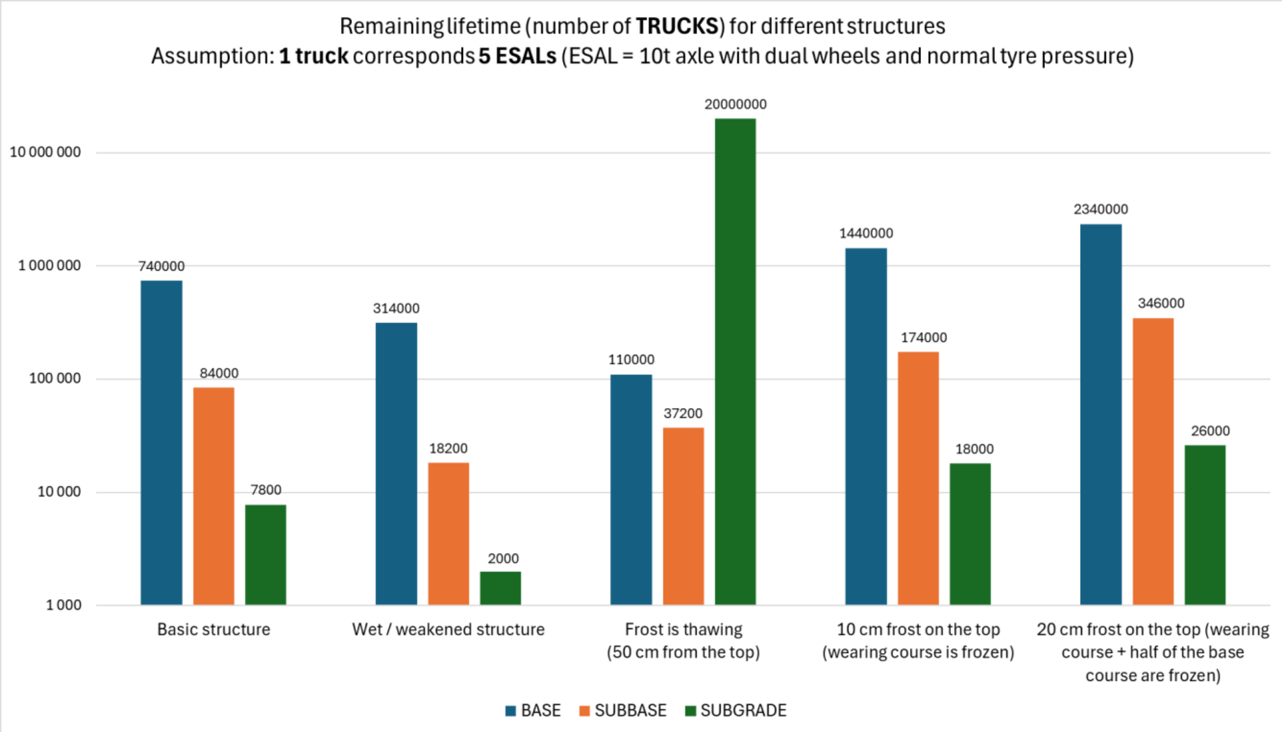


**Figure 27. Comparison of remaining lifetimes for different calculation structures as number of trucks, if it is assumed that one truck corresponds five ESALs. (Note: Logarithmic scale)**

Single axle vs. tandem / tridem axle:

- With the basic structure, the calculated remaining lifetimes with the 180 kN tandem axle and the 270 kN tridem axle are close to the value of the 100 kN single axle, both with single and dual wheels. The tandem axle stresses the subgrade even less than the single axle. If the tandem axle load is raised to 200 kN and tridem axle load to 300 kN, the decrease in remaining lifetime is clear.
- With a wet / weakened structure and subgrade, the calculated remaining lifetimes with the 180 kN tandem axle are reduced to the same level as with the 100 kN single axle, both with single and dual wheels. But now the 270 kN tridem axle groups are at the same level as the 200 kN tandem axle options; 30 % worse than the single axle. And with the 300 kN tridem axle the remaining lifetime is only half compared to the single axle.
- It can be concluded from the results that the loading effect of heavier axle groups is the stronger the weaker is the subgrade. Especially the tridem axle causes a higher loading effect, if road drainage is poor and subgrade is weak.

**ROADEX Pilot (1998–2001)**

**ROADEX II (2002–2005)**

**ROADEX III (2006–2007)**

**ROADEX IV (2009–2012)**

**ROADEX Network (2012–)**