Road technology
Base layer stabilisation with DUSTEX
Follow-up of R&D report no. 2008003393-1

FV 324, FV 181, Fv 302, FV 160 and FV 286
Summary

Up until 2006, in the districts of Nordmøre and Romsdal, DUSTEX-stabilised gravel was used as a base layer for a total of 17 km of county road. Two layers of soft asphalt (MA) were laid over the stabilised gravel as a road surface. All roads had a gravel surface layer before the DUSTEX stabilisation and were included in the so-called gravel road package for the county road network. This report focuses on the change in condition of the roads from reinforcement until 2017.

This report deals with five stretches:
- Fv 324-01 Todalen from 2002
- Fv 181-01 Eidsbygda-Nordvika from 2002
- Fv 302-01 Vågbo-Meisingset from 2005
- Fv 160-01 Flate from 2005
- Fv 286-02 Astad-Bjerkset from 2006

The change in condition of the roads has been evaluated in terms of rut development, and deflection measurements from before and after reinforcement. The result shows that 4 out of 5 roads have a normal road surface lifespan, with the exception of Fv 160-01 Flate. On this stretch there was premature cracking in the centre line of the road, which is presumed to be due to frost. Most likely, reinforcement with a different base layer would still lead to the same damage.

No major changes in the bearing capacity have been recorded on any of the stretches from before the reinforcement until now. The measurements correlate well together.
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1 BRIEFING

This report is reproduced from the previous R&D report 2008003393-1, with updated bearing capacity measurements from 2017 and rut and evenness data from 2016/2017.

Dustex consists of lignin, which is extracted from pine trees and is the binding agent that binds the wood fibres in trees together. The Dustex is delivered as an approximately 50% solution in water and has for many years been used for dust binding on gravel roads. It was observed that following a few treatments with Dustex, the road surface became more solid and less exposed to soaking during the spring thaw period. The Dustex was then also tried as a binding agent for base layer stabilisation. In the district of Nordmøre og Romsdal, Dustex-stabilised gravel was used as a base layer for 17 km of road until 2006. Two layers of soft asphalt (MA) were laid over the stabilised gravel as a road surface. Prior to the Dustex stabilisation, all the stretches of road had a gravel surface and were included in the so-called “gravel road package” for the county road network. In addition, Dustex was also used for 4 stretches of road totalling 12 km in 2007. The stretches from 2007 are not discussed in this report.

The two oldest stretches, Fv324 and Fv181 are from 2002. On these, deflection was measured both prior to stabilisation, immediately after, and in subsequent years with the exception of 2006. In the autumn of 2017, falling weight deflectometer measurement were conducted on the stretch, in order to show the trend over time.

The Dustex material and experiences with milling work are relatively extensively discussed in Internal Report 2302 from the Norwegian Directorate of Public Roads. The two sections from 2002, FV 324 and Fv 181 in Møre og Romsdal, are also discussed in the report. Laboratory and field trials with Dustex are discussed in SINTEF report STF22 A04377; "Deep stabilisation with milling - field trials in Budalen". Regarding the lab trials, Sintef writes that the samples with Dustex had a marked increase in resistance to permanent deformations, but that the samples did not survive the freeze/thaw process. Because Dustex is soluble in water, the lignin content cannot be checked in stabilised material using the laboratory methods we currently have available. It has also not been possible to drill core samples that are good enough for testing the indirect tension in order to examine the load distribution coefficient. When attempting to extract cores, it has been found that the water that cools the bit washes out the material. The advantages of Dustex are that it is a cheap and environmentally friendly binding agent that is easy to spray and easy to wash off the equipment. As with other deep stabilisation, the road is not raised more than the surface thickness and therefore width enlargement is avoided.

This report focuses on the change in condition of the stretches from when the surface was laid until 2017. Rut data is taken from the National Road Database (NVDB) and Pavement Management System (PMS 2010). Manual R610 specifies that the rut depth estimated by 90% of 20 metre values on a 1000 m stretch, must not exceed 25 mm, for roads with an AADT of < 5000 or a maximum rut depth on a simple 20 metre stretch at 40 mm. A visual review of the stretches has been conducted using the program ViaPhoto, which shows the road images from each year. The condition of culverts and manholes has not been assessed, but the condition of these will have a major impact on the overall standard of the road and the lifespan of the reinforcement.
2 SUMMARY OF THE STRETCHES

The stretches are reported in the chronological order that they were laid.

2.1 Fv 324-01 Todalen km 0.7 – 2.5
Year laid: 2002
Length: 1,800 m
Width: Approx. 4 m
AADT: 250, with 6% heavy vehicles (2017)
Costs (2002 price level): Stabilisation; 20 NOK/m². Total resurfacing; 530 NOK/Im.
Contractor: SVV Production

Equipment: Milling machine with binding agent nozzles; CMI Corp. Type RS500, grader, roller with steel drum, sprayer for impregnation and 2 tankers with trailers for the supply of binding agent.

The milling depth was gradually reduced due to problems with rocks:

<table>
<thead>
<tr>
<th>Km</th>
<th>Milling depth</th>
<th>Binding agent</th>
<th>(Ren Dustex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70 – 0.75</td>
<td>15 cm</td>
<td>8.0 l/m²</td>
<td>(4.9 kg/m²)</td>
</tr>
<tr>
<td>0.75 – 0.80</td>
<td>12 cm</td>
<td>7.2 l/m²</td>
<td>(4.4 kg/m²)</td>
</tr>
<tr>
<td>0.80 – 2.50</td>
<td>10 cm</td>
<td>6.0 l/m²</td>
<td>(3.7 kg/m²)</td>
</tr>
</tbody>
</table>

Base and sub-base prior to laying the road surface
Auger drilling showed a base with a thickness of about 0.45m. The top layer that was stabilised was well graded gravel 0/16 mm with 14 – 19% material <0.075 mm. The reinforcement layer was well graded gravel with 9 – 15 % material < 0.075 mm. The subsoil was sand and gravel in frost class T2 with a small amount of humus.
Rut development:

As can be seen in Figure 1, the rut depth is below the requirement for rut depth. The critical year for ruts is estimated to be 2021. The existing road surface is from the reinforcement in 2002. A 5cm layer of soft asphalt was laid then. This gives a road surface lifespan of 19 years. Figure 531.2 in N200 indicates that soft asphalt with an AADT ≤ 300 has a normal lifespan of 16 ± 2 years. The data therefore shows that the lifespan of the road surface is good.
Deflection measurement
Deflection measurements were taken with a Benkelman Beam prior to stabilisation, 3 weeks after stabilisation, 10 weeks after stabilisation, and annually until 2007, with the exception of 2006. In 2005, 2007 and 2017, falling weight deflectometer measurements were taken.

The result goes up and down according to the season and moisture conditions. The Benkelman Beam measurements from 2004 and 2007 have better results than the measurements from 2003 and 2005. The falling weight deflectometer measurements from 2017 are better than those from 2005 and 2007, but the difference is minimal. The Benkelman Beam measurements on the gravel road were taken after about 1 month of good weather with no rainfall and are largely higher than later measurements. It is difficult to say anything about the reinforcement effect from these measurements, as there will naturally be variations in the bearing capacity. The deflection measurements are included in chapter 6.1.

Visual assessment
There are sections with longitudinal cracks and crazing in wheel ruts. The development of this damage has occurred gradually over time, according to a review of road images from the years following reinforcement. Some of the damage is due to narrow roads and poor ditch depths on some sections. A good example of this is shown in Figure 5, where it can be seen that the road is below the verge and therefore the water will be forced into the road.
2.2 Fv 181-01 Eidsbygda – Nordvika km 3.0 - 4.9

Year laid: 2002
Length: 1,900 m
Width: Approx. 4 m
AADT: 100, with 10% heavy vehicles (2017)
Contractor: SVV Production
Equipment: Milling machine with binding agent nozzles; Wirtgen WR2500, grader, roller with steel drum, sprayer for impregnation, 2 tankers with trailers for the supply of binding agent.

<table>
<thead>
<tr>
<th>Km</th>
<th>Milling</th>
<th>Binding agent</th>
<th>(Ren Dustex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.00 – 3.80</td>
<td>20 cm</td>
<td>12 /m²</td>
<td>(7.4 kg/m2)</td>
</tr>
<tr>
<td>3.80 – 4.90</td>
<td>10 cm</td>
<td>6.0 l/m²</td>
<td>(3.7 kg/m2)</td>
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</tbody>
</table>

Base and sub-base prior to laying the road surface

The first 800 metres are located on a deep bog. There is also bog in the subsoil at the end of the stretch. Otherwise there is varying subsoil, partly clay and partly humus-containing.
Auger drilling showed there was a 0.65 – 0.8 m base of the same material throughout the entire stretch. The particle size analyses showed well-graded gravel 0/16 mm with 13 – 17% material < 0.075 mm.

Rut development:
Figure 6 shows the change in condition of the stretches from 2009-2017. The current rut depths indicate that the critical year for rutting will be 2035. From metres 3,000-3,750 a new road surface was laid in 2014. This can be seen in Figure 7 and Figure 8, where there is a significant decrease in rut depth from 2014 to 2017 on this stretch. The existing road surface is from the reinforcement in 2002, and from the resurfacing in 2014. A 6 cm soft asphalt road surface was added in 2014. Figure 531.2 in N200 indicates that soft asphalt with an AADT ≤ 300 has a normal lifespan of 16 ± 2 years.
The data show normal rut development on the stretch, so rutting is not considered to have been the trigger for the resurfacing in 2014.

**Figure 6 Rut development Fv 181-01**

**Figure 7 Rut depth area 1 Fv 181-01 m 3000-4700 Eidsbygda**
Deflection measurement

Deflection measurements were taken with a Benkelman Beam prior to reinforcement in 2002 and then each year, with the exception of 2006. Bearing capacity measurements were also taken in 2005, 2007, 2015 and 2017.

There will be natural variations in the bearing capacity throughout the year, which is due to precipitation and climate. Since the bearing capacity measurements are not taken during the same period and with the same conditions, variations must be expected. The Benkelman Beam measurements show that the bearing capacity measurement from 2002 is higher than from 2003, but lower than from 2007. The first 800 metres Benkelman Beam measurements show a lower bearing capacity than the falling weight deflectometer measurements. This is due to the fact that there will be greater deflection with the Benkelmann Beam than the falling weight deflectometer in such ground conditions. The falling weight deflectometer measurements show little variation in the bearing capacity, but the measurements from 2007, 2015 and 2017 are slightly higher than from 2005. The effect of the reinforcement cannot be judged from the deflection measurements. The deflection measurements are shown in chapter 6.2.

Visual assessment

The visual assessment is performed using ViaPhoto road images, from the reinforcement until 2017. A few years after the reinforcement, crack formation can be seen in the centre of the road and along the edges, but small in extent. In 2010, the extent of the crack formation is greater, but still within an acceptable level. From 2010 to 2017 a clear development in the extent of the damage can be seen. Localised areas with crazing and obvious frost cracking in the centre of the road.

As the width of the road surface is around 3.6-4.1 metres and the road sits partly on bog, the extent of the damage is as expected. Previous experiences show that the stabilisation of roads on bog with
bitumen produces poor results. The reason for this is that there is some movement in the bog, which easily causes cracking and crazing of the road surface, as the stabilised base layer will not provide sufficient load distribution. From the road pictures, no ditch clearing measures have been recorded, which indicates that the drainage is unlikely to be sufficient.

Figure 9 Road image Fv 181-01 m 4136 from 2014

Figure 10 Road image Fv 181-01 m 4132 from 2017
2.3 Fv 302-01 Vågbø – Meisingset km 4.6 – 12.46

Year laid: 2005.
Length: 7,860 m
Width: Mostly around 4 m, with some wider sections
AADT: 430, with 10% heavy vehicles.
Costs (2005 price level): Total resurfacing; 913 NOK/m
Contractor: Kolo Veidekke
Equipment: Milling machine with binding agent nozzles; Wirtgen WR, grader, tankers.

5 cm of 8/16 mm shingle was added which was mixed with 10 cm of road gravel by dry milling. The material was then stabilised by adding 7.5 l/m² of 50% Dustex solution and milled to a depth of 15 cm.

Base and sub-base prior to laying the road surface

The auger drilling showed several sections with bog/humus in the subsoil, but apart from in two places there was at least 70 cm of gravel over the organic masses. The minimum recorded gravel thickness was 40 cm.

The reinforcement layer was partly well-graded gravel 0/20 mm, with 15 – 18% < 0.075 mm, partly gravel with sand ballast and 6 – 11% < 0.075 mm. Many of the samples contained humus. The gravel road surface had 15 – 19% < 0.075 mm and max. stone size 16 mm.

Rut development:
Figure 11 shows the change in condition from 2009-2017. The rut and evenness shows that forecasted lifespan for the road surface is until 2026. This gives a road surface lifespan of 21 years. In 2005 a 6 cm soft asphalt road surface was added. Figure 531.2 in N200 indicates that soft asphalt with an AADT of between 301-1500 has a normal lifespan of 13 ± 2 years. Based on this the lifespan of the road surface is good.
Figure 12 and Figure 13 show the rut depth on the stretch from 2007, 2012 and 2016.
Deflection measurement
There will be natural variations in the bearing capacity throughout the year, which is due to precipitation and climate. Since the bearing capability measurements are not taken during the same period and with the same conditions, variations must be expected. A bearing capacity measurement was taken in area 1 in 2004 (prior to reinforcement), area 1 in 2007 and both areas in 2017. The readings show little change in the bearing capacity from 2004 until 2007 and 2017, if not a "more even" bearing capacity. The effect of the reinforcement cannot be judged from the deflection measurements. The deflection measurements are shown in chapter 6.3.

Visual assessment.
A few years after the reinforcement, crack formation can be seen occurring in the centre of the road and along the edges, but small in extent. From 2010 to 2017 a clear development in the extent of the damage can be seen. Localised areas with a lot of crazing and obvious frost cracking in the centre of the road, sections with poor edge stability can also be seen in several places.

Given the narrow width of the road surface (some sections down to 3 metres), quite a bit of heavy traffic, and shallow side ditches, the damage development is as expected.
Figure 14 Fv 302-01 m 4921 in 2016

Figure 15 Fv 302-01 m 4930 in 2010
2.4 Fv 160-01 Flate km 0.0 – 0.9

Year laid: 2005.
Length: 900 m
Width: Approx. 4 m
AADT: 250, with 6% heavy vehicles
Costs (2005 price level): Total resurfacing; 955 NOK/lm
Contractor: Kolo Veidekke
Equipment: Milling machine with binding agent nozzles; Wirtgen WR, roller, grader, and tankers.

Base and sub-base prior to laying the road surface
The auger drilling showed that the sub-base was largely bog/humus, but the recorded base was at least 0.6 m.

The reinforcement layer was well graded gravel with 16 – 20% material < 0.075 mm. There was humus in a some of the samples.
The gravel road surface (upper 10 – 20 cm) had 17 – 19% material < 0.075 mm.

Rut development:
The road surface that was added in 2005 was 6 cm with soft asphalt (MA). The life span of a Ma road surface with an AADT of 250 is 16 ± 2 years according to fig. 531.2 in N200. Rut and evenness measurement have been taken systematically on the stretch since 2007. The data shows fast rut development, which meant that the road surface had to be renewed in 2014. A 6 inch thick asphalt gravel concrete (AGB) road surface was then added. This gives the road surface a lifespan of 9 years, which must be considered as abnormally low.
Deflection measurement

There will be natural variations in the bearing capacity throughout the year, which is due to precipitation and climate. Since the bearing capacity measurements are not taken during the same period and with the same conditions, variations must be expected. Deflection measurements were taken with a falling weight deflectometer measurement prior to reinforcement in 2005 and in 2017. The measurements show little change in the bearing capacity from 2005 to 2017, and the measurements correlate well together. The bearing capacity ranges from 6 to 14 tons. The effect of the reinforcement cannot be judged from the deflection measurements. The deflection measurements are shown in
chapter 6.4.

Visual assessment

A visual assessment of the route has been conducted using road images from ViaPhoto, in the period 2006-2017. It was recorded in 2006 that cracking had occurred on the centre line, on larger parts of the stretch. These cracks are considered to be frost cracks. The cracking probably has nothing to do with the quality of the base layer, but is instead due to a lack of ditches, and a high humus and fines content in the reinforcement layer.

Prior to resurfacing in 2014, cracking of the centre line and edge cracks occurred along much of the stretch. In 2017 some cracking in the centre line was recorded, but otherwise there was very little damage to the road surface. This can be explained by the fact that AGB is stiffer than MA, thus allowing better weight distribution.
2.5 Fv 286-02 Astad – Bjerkeset km 0.72 – 4.15 + km 5.4 – 6.8

Year laid: 2006
Length: 4830 m (km 0.72 – 4.15 + km 5.40 – 6.80)
Width: Approx. 4 m
AADT: Approx. 200
Cost: Gravel and stabilisation: 27 NOK/m2. The actual stabilisation cost 17.50 NOK/m2.
Contractor: Most
Equipment: Sprayer (fertiliser sprayer), grader, roller.

Dustex was used on two sub-sections of Fv 286. The rest of the route was reinforced with geonet and a base layer of crushed rock due to bog in the subsoil and a thin base. The Dustex-stretches were not milled. The binding agent was sprayed on the gravel using a fertiliser spreader and mixed in by grading. 5 cm of road gravel was then added and stabilised in a similar way. Overall, at least 10 cm would be stabilised. The addition of the binding agent could only be controlled as average consumption.

From a visual assessment, the DUSTEX-stabilised layer appeared firm and homogeneous prior to laying the road surface.
Base and sub-base prior to laying the road surface

The 10 cm thick gravel road surface had 15 – 18% material < 0.075 mm. The auger drilling went to a depth of 1 m and did not show any layer distribution beneath the road surface. This "reinforcement layer" had a very variable fines content, from 9 to 30% < 0.075 mm and a humus content of up to 5% according to the glow method.

Rut development:

The existing road surface is 7 cm soft asphalt (MA). Figure 531.2 in N200 indicates that soft asphalt with an AADT of between 301-1500 has a normal lifespan of 13 ± 2 years. PMS indicates a critical year for ruts in 2020. This gives the road surface a life span of 14 years, which is considered normal.

Figure 20 The change in condition Fv 286-02 M 720-6800
Figure 21 Rut depth Fv 286-02 m 720-4150 and 5400-6800 area 1

Figure 22 Rut depth Fv 286-02 m 720-6800 area 2

Deflection measurement:
No deflection measurements were taken prior to reinforcement. A deflection measurement was taken with a falling weight deflectometer in 2017. These measurements show large variations in the bearing capacity of the stretch (from 4-15 tons). Since no measurements were taken prior to reinforcement, the project cannot be assessed based on the deflection measurements. The deflection measurements will be presented in chapter 6.5.
Visual assessment
The visual assessment has been made on the basis of road photos from 2017. On the two stretches, sections were observed with a lot of crazing, and some longitudinal cracks. The cause of this damage is assumed in several places to be due to poor drainage and it being a narrow road.

Figure 23 Fv 286-02 m 5477 from 2017
3 CONCLUSIONS AND ASSESSMENTS SO FAR

All the roads that have been reinforced with Dustex have now been in place for 11-15 years. The change in condition on most of the roads is as expected, with what N200 specifies as the "normal lifespan" of a road surface being dependent on rut development. The exception is Fv 160-01 Flate, which had an abnormally low lifespan. However, the problem here would most likely have occurred, regardless of the type of base layer, as it is frost that causes the problems.

Deflection measurements taken before and after the reinforcement show that the bearing capacity has remained stable at the same level, before and after the reinforcement. This indicates that the road base has the same "strength" now as it did in the period immediately following the reinforcement.

When selecting sections for Dustex stabilisation, sections with a thin base ( < approx. 0.6 m) over bog or humus have been avoided. On such stretches, the reinforcement has instead been done with geonet, FK (crushed rock) and a MA road surface. Stretches with a lot of large boulders near the surface have also been avoided.

The work on the sections from 2002 was controlled by the client and SVV paid for the actual costs. This resulted in reasonable costs. From 2003, all initiatives in the gravel road package have been exposed to competition. In a few cases, Dustex was included in the tender basis as an alternative to reinforcement with geonet, FK and MA. The Dustex option was then priced so that there was no monetary profit in it and the option was therefore not chosen. The reason is probably that "ordinary" road contractors are not so interested in a solution where they need to hire subcontractors with special equipment, and that involves additional logistics requirements and a more weather-dependent reinforcement method. On the stretches that have been done since 01/01/2003, contractors were obliged to use Dustex. It seems, however, that the contractors add a bigger margin than for traditional work. The equipment is similar to that used for bitumen stabilisation, but the asphalt industry probably has little interest in adopting a binding agent other than bitumen. If the extent of Dustex stabilisation increases, the market situation may change.

For SVV there should be an argument that the binding agent is environmentally friendly and harmless. In some cases there has been some run off of brown coloured water into the ditches, but this will have no other effect other than fertilising the vegetation. It does not have the environmental disadvantages that bitumen emulsion has. Lignin is also a renewable resource.

Deflection measurements are taken using a Benkelman Beam and falling weight deflectometer. The measurement methods are conducted in different ways, which means that the results cannot be directly compared. This must be taken into account when the results are being compared.

4 FURTHER WORK

No samples have been taken to determine the Dustex content in the base for this report. Sampling should therefore be carried out in order to determine the Dustex content.
5 REFERENCES

Sintef STF22 A04377; "Deep stabilisation with milling - field trial in Budalen." (2004)


6 Appendices
In the graphs below, the falling weight deflectometer measurements are given the designation “bearing capacity” and Benkelman beam "Benkelman Beam“ in the label name. F1 = area 1 (right area) and F2 = area 2 (left area).
### 6.1 Fv 324-01 Todalen

**Fv 324-02 area 1**

![Graph showing bearing capacity over time for Benkelman Beam tests](image)
### 6.2 Fv 181-01 Eidsbygda-Nordvika

#### Bearing Capacity [tons]

<table>
<thead>
<tr>
<th>Date</th>
<th>Measurement Date</th>
<th>Bearing Capacity</th>
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<tbody>
<tr>
<td>2005</td>
<td>26/08/2002</td>
<td>Fv 181-01 area 1</td>
</tr>
<tr>
<td>2007</td>
<td>31/03/2003</td>
<td>Benkelman Beam</td>
</tr>
<tr>
<td>2015</td>
<td>05/07/2007</td>
<td>Benkelman Beam</td>
</tr>
</tbody>
</table>

![Graph showing bearing capacity measurements over distance](image)

- **Bearing capacity F1 2005**
- **Bearing capacity F1 2007**
- **Bearing capacity F1 2015**
- **Bearing capacity F1 2017**

Distance measurement range: 3000 to 4700
6.3 Fv 302-01 Vågbø-Meisingset

Fv 302-01 metre 4600-12460 area 1

Bearing capacity in tons

Bearing capacity F1

Distance measurement

Bearing capacity F1 2004

Bearing capacity F1 2007

Bearing capacity F1 2017
Fv 302-01 metre 4600-12460 area 2

Bearing capacity in tons

Distance measurement

Bearing capacity F2 2017
6.4 *Fv 160-01 Flate*

![Bearing capacity area 1 diagram](image)

**Fv 160-01 metre 0-900 bearing capacity area 1**

Distance measurement

- Bearing capacity 2005
- Bearing capacity 2017 F1
- F1
6.5  Fv 286-02 Astad-Bjerkestet

Fv 286-02 m 720-6800 area 1

Bearing capacity in tons

Distance measurement

Bearing capacity 2017 F1