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ROLLER-COMPACTED CONCRETE PAVEMENTS IN NORWAY

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Title

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Summary

This report contains a paper which was prepared for the seventh international conference of the bearing capacity of roads, railways and airfields in Trondheim, June 2005 and supplied afterwards.

Roller-compacted concrete, as the name suggests, is concrete that in its unhardened state will support a roller while being compacted. During the period 1985 - 1995 a total of 68 km of concrete roads was constructed in Norway using this method, of which almost 60 km was in tunnels. The annual average daily traffic (AADT) on these stretches ranges from 200 to 10 000 vehicles per day, the majority having low traffic volumes. By 2005, almost 15 km of these concrete roads will have been paved over with asphalt. The remaining 53 km are located almost entirely in tunnels or on bridges.
Experience indicates that:
- compressive strength should be greater than C45
- thickness of concrete wearing surface should be greater than 150 mm plus rut depth
- spacing between joints should not be greater than 6 - 8 m
- the full width of the road should be cast in one operation to avoid bad longitudinal joints
- only good quality aggregate with a max diameter of 22 mm should be used
- dust has been a problem in some tunnels during the first few years of operation
- quality of workmanship during casting has large implications for the final product
- annual measurements show very small increases in rut depth
- good maintenance and repair methods need to be further developed
- the performance of the concrete wearing surface is so good in some tunnels that it should last 50-100 years without any major maintenance

Key words

Pavement, concrete, roller-compacted, rut depth, evenness

CONTENTS

ROLLER-COMPACTED CONCRETE PAVEMENTS IN NORWAY 20 YEARS EXPERIENCE

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ABSTRACT: Roller-compacted concrete, as the name suggests, is concrete that in its unhardened state will support a roller while being compacted. During the period 1985 - 1995 a total of 68 km of concrete roads was constructed in Norway using this method, of which almost 60 km was in tunnels. The annual average daily traffic (AADT) on these stretches ranges from 200 to 10 000 vehicles per day, the majority having low traffic volumes. By 2005, almost 15 km of these concrete roads will have been paved over with asphalt. The remaining 53 km are located almost entirely in tunnels or on bridges.
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1. OVERVIEW

Roller-compacted concrete is a special concrete that is used for concrete pavements. The concrete is produced in a mixing plant, laid out with a suitable paver and is compacted in its unhardened state with a vibrating roller. To obtain a homogeneous concrete with a smooth surface and sufficient strength after rolling, stringent demands are placed on aggregate particle-size distribution, quantity of cement and water content. As the concrete pavement does not have dowels or reinforcement, it is important to reduce shrinkage and joint movements. The use of studded tyres in Norway during winter also places special demands on the aggregate’s wearing resistance and the properties of the concrete.

During the planning and production of roller-compacted concrete pavements the engineer is confronted with the following alternatives/decisions:

- Concrete mix design given the local conditions
- Mixing equipment and concrete transport
- Weather conditions
- Choice of paver and roller compaction equipment
- Cutting joints and concrete curing
- Quality control to obtain the specified concrete, thickness and evenness of the pavement surface

Several trials with roller-compacted concrete pavements were performed in Norway at the beginning of the 1980s. The concrete was placed with a normal road scraper/planer, but sufficient pavement quality was not obtained. In 1985 a new trial was performed in Nordland County in the northern part of Norway. This time an asphalt paver was used in addition to applied cement-stabilised subbase technology. During the period 1985 till 1995 a total of 68 km (centre line) of roller-compacted concrete pavement was constructed on national primary roads in four coastal counties.

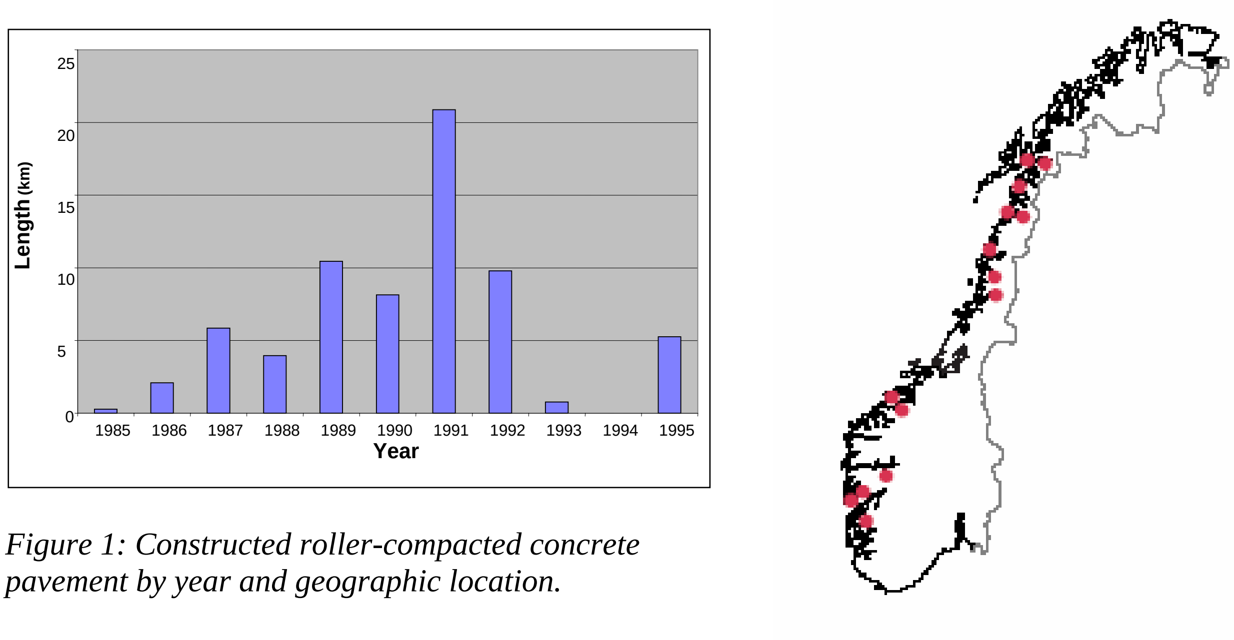

Figure 1: Constructed roller-compacted concrete pavement by year and geographic location.

Of the 68 km of roller-compacted concrete pavements, nearly 60 km are in tunnels.

Table 1: Examples of tunnels with roller-compacted concrete pavements

Tunnel name	County	Year	Length (m)	AADT (2004)
Steigen	Nordland	1989/1990	8100	200
Saksenvik	Nordland	1992	1150	1900
Sigerfjord	Nordland	1995	2150	1200
Flenja	Sogn & Fjordane	1989	5150	1500
Fjæra	Hordaland	1991	1500	2500
Sætre	Hordaland	1991	700	10000
Tussen	Møre & Romsdal	1990	2800	3900
Innfjord	Møre & Romsdal	1991	6000	1800

Roller-compacted concrete pavements were not constructed in Norway after 1995. There are several reasons for this:

- Roller-compacted concrete pavements are more expensive to construct than asphalt pavements
- Difficult to fulfil all the specifications
- Uncertainty concerning future maintenance
- Re-structuring of the Norwegian Public Roads Administration resulting in a reduced focus on product development

Figure 2: The picture shows a roller-compacted concrete pavement in Steigen Tunnel.

The tunnel is straight and built for small traffic volumes. Production of the pavement went well. However, each lane was paved separately resulting in a longitudinal joint of low quality that had to be repaired shortly after completion. Due to small temperature variations and low traffic loading, the pavement is in excellent condition after 15 years of service and a lifetime of 100 years is possible.

Roller-compacted concrete pavements were used as wearing surfaces on three bridges in Nordland County. None of these surfaces have been repaired since construction, but small damage is suspected in certain areas of the bridge deck.

Table 2: Roller-compacted concrete pavements were constructed on the following bridges

Bridge name	Year	Length (m)	AADT (2004)
Botnelv	1991	24	1700
Botn	1991	100	1700
Kvalnes	1991	128	1250

Approximately 15 km of the roller-compacted concrete pavements have been paved over with asphalt. The majority of these pavements are located outside tunnels or in towns. The reason for paving over with asphalt is in general pavement damage and unevenness which frequently occurred shortly after construction. Certain urban roads have also performed well. For example, on a stretch of the Olav V road in Bodø with AADT of 7000 to 9000, a roller-compacted concrete pavement has been in service for the last 17 years.

2. DESIGN AND JOINTS

Norwegian roads are designed for 10 tonne axle load and a 900 kPa tyre pressure. Roller-compacted concrete pavements are designed in a similar fashion to other un-reinforced concrete pavements where support from the underlying material is taken into consideration. A diagram is produced by NPRA, mostly from practical experience, where parameters are corrected for AADT and the support K-modulus. The basis for the diagram is a five meter long plate and compressive strength corresponding to a C35/45 concrete (EN206-1).

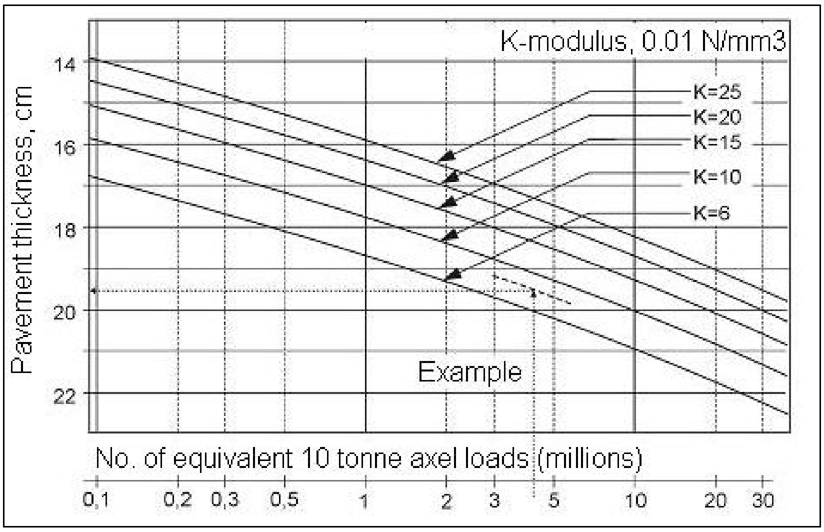

Figure 3: Pavement thickness from corrected AADT and K-modulus (1).

The K-modulus of the subgrade or underlying support can be obtained from a plate loading test (AASHTO T222-78). Accepted or reference values can also be used, they are more common for practical purposes. The subgrade is divided in six bearing capacity groups in the Norwegian design system. Each group is assigned a characteristic K modulus value. This value is then corrected for the actual pavement thickness and the load distribution coefficient of the subbase (the load distribution coefficient is part of the Norwegian index method and gives load distribution relative to a gravel subbase, which has a coefficient of 1,0).

For concrete compressive strengths higher than C35/45, the pavement thickness can be reduced using accepted correction factors. As studded tyres are common in winter, the design of the pavement must also take this into consideration. High compressive strength concrete is more resistant to rutting by studded tyres.

Roller-compacted concrete pavement thickness in Norwegian tunnels varies between 120 and 200 mm, with the majority being over 150 mm. From practical experience the minimum roller-compacted concrete pavement thickness is specified in Norwegian Guidelines as 150 mm plus rut depth.

To avoid uncontrolled cracking due to shrinkage and temperature, roller-compacted concrete pavements must have joints. However, longitudinal joints are not necessary when the pavement width is two lanes or less. The pavement can be cast continuously without dowels. Transverse joints are created by making cuts in the fresh concrete. The depth of the cut/joint is approximately 1/3 the pavement thickness and through cracks soon develop under the cut.

Figure 4: Inclined joints after approximately 15 years service. Longitudinal centre joint was repaired after uncontrolled cracking.

Several trials were performed with different joint spacings. Uncontrolled cracking was observed for spacings up to 25 m. For 12 m joint spacing in a tunnel, large joint deformations were observed when heavy load vehicles passed. The problem was greatly reduced by cutting new joints at 6 m spacing. In the Norwegian Guideline, joint spacing is specified as 6-8 m.
In some tunnels, inclined joints are cut in the concrete as this reduces noise and loading on the edge of the joint.

3. CHOICE OF MATERIALS

3.1 Aggregate

Natural deposits of sand and gravel were used in the first projects. Focus then turned to high strength concrete which required large volumes of high quality crushed stone. This resulted in several casting/paving problems and high costs. Focus was then redirected towards more inexpensive pavements, intensive quality control and readily available natural aggregates. The aggregate used in the final projects was frequently 0-8 mm natural/crushed and 8-16 mm crushed stone and rock. Crushed natural stone in the 0-8 mm fraction gave higher splitting tensile strength than natural stone. The ratio between natural and crushed stone aggregate has important consequences for compaction during paving. Increased quantities of natural stone improve the compaction. For the final projects the ratio was 3:1 natural/crushed stone. In addition, aggregate grading close to the recommended upper limit for roller-compacted concrete was used in the final projects in order to improve the surface finish. At the same time, maximum aggregate size was reduced to 16 mm in order to reduce the risk of separation.

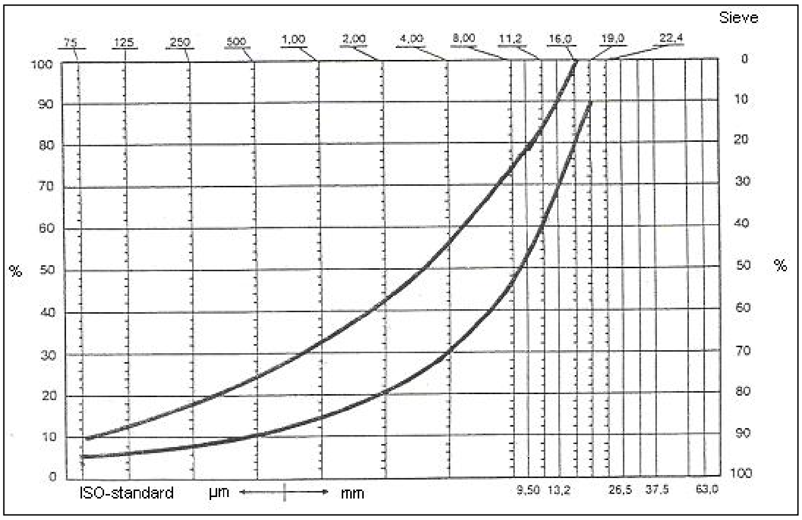

Figure 5: Recommended aggregate grading limits for roller-compacted concrete (1).

Brittleness and abrasion were earlier two special material parameters used in Norway to classify stone. Low brittleness and low abrasion values are usually representative of aggregates that have high wearing resistance to studded tyres.

Mechanical strength characterised by brittleness values indicate the aggregates ability to resist impact loading. This is determined by a standardised test method called the impact crushing test.

Abrasion values characterise the aggregates wearing resistance and is determined by measuring aggregate volume reduction resulting from standardised grinding.

The brittleness values for the natural aggregate used varied from 39 till 58 while the abrasion values varied from 0.49 till 0.67. For crushed stone, the corresponding values varied from 43 till 50 and 0.52 till 0.56. Brittleness and abrasion values for high quality aggregate are approximately 30 and 0.38.

3.2 Cement and admixtures

In general, Norwegian P-30 cement from Norcem, Kjøpsvik was used. The quantity of cement was normally between 16 and 17 % of dry aggregate weight, which corresponded to 340–350 kg/m3. Fly ash, silica fume or admixtures were not used when NPRA produced concrete with a continuous blade mixer. One trial was performed with 5% silica fume and 1% plasticizer by weight of cement.

Seven projects were performed with concrete from a batch mixer plant with silica fume and superplasticizer. Three of these projects had the following concrete mix: 350–380 kg rapid cement (RP38) from Norcem, 2.9–5.5% silica fume and 1% plasticizer /superplasticizer.
When using the continuous blade mixer plant, the water content was targeted 0.5–1.0% below the optimal water content determined by the Proctor method. For batch plant concrete was the w/c ratio 0.30–0.42.

Experience has shown that the quality of the concrete and the finished product is improved by using admixtures. The extent of this improvement is dependent upon several aspects, both during production and casting, with the human factor playing an important role. Training and experience are the most important factors in obtaining a good end product.

4. EQUIPMENT AND MANPOWER

Concrete for all the projects in Nordland county, were mixed in a converted, mobile blade mixing plant, model Oredsson 741. Production capacity was roughly 50m^3/hour. In addition, there were two aggregate silos with band conveyor feeder, cement tank and water supply.

The cement dosage was automatically controlled by cement screws in relation to the weighed quantity of aggregate. For the last few projects, this automatic system was upgraded and a concrete with very homogeneous quality was produced. In these projects, all construction work was performed by NPRA personnel and equipment. The concrete for all the remaining projects was purchased from ready-made concrete mixing plants (Sakko or Røback blade mixers) with a capacity of 20 m^3/h. For certain projects, capacity was increased to more than 40 m^3/h by securing delivery from two mixing plants.

The choice of road paver is critical for the quality of the pavement as homogenous compaction of the fresh concrete must be performed as soon as it is laid. For the first projects a relatively light paver was employed, but from 1986 heavier equipment (ABG) with double tamper knives and vibration plate was used. From 1991, a paver with a special screed (VØGELE) for high speed compaction was used. The ABG paver had hydraulically powered variable screed width and the possibility of laying widths up to 4.5 m and 8 m, while the VØGELE paver had constant screed width intervals of 0.5 and 1.0 m.

Figure 6: Casting roller-compacted concrete on one of the first projects.

Placing of the concrete pavement was performed in several ways. Initially, the paver was not wide enough to cast the full width of the road in one operation. Thus one lane was cast at a time which resulted in a longitudinal cold joint, poor bond and the prompt appearance of damage along the joint. To resolve this, the paver moved from lane to lane so as to cast a longitudinal “warm joint”(concrete still workable). On some projects, two pavers, with one in each lane, were used. This improved the quality of the “warm joint” and reduced the unevenness caused by moving the paver from lane to lane. On some projects, full road width pavers were used. Production speed varied from 2–6 m/min for the earliest projects but was reduced to 1–1.5 m/min in order to improve quality and increase the pavement thickness.
The roller-compaction equipment that was used for the first projects was too light. After several trials a 10–11 tonne rubber coated tandem roller (ABG and HAMM) was used. Rolling patterns and number of passes was determined by compaction measurements performed with a nuclear gauge (Troxler).

Depending on weather there was one or two pavers, a crew of 15–18 people was normal for production and casting roller-compacted concrete pavement. These were distributed as follows:

- 3 persons at the mixing plant, incl. loading onto lorry
- 3 persons on each paver
- 1 person per roller
- 1 crew leader
- 2–3 persons for field/laboratory work (quality control)
- 5–7 lorry drivers to transport the concrete from mixing plant to site

5. CONDITION

Roller-compacted concrete pavements cost twice as much as a normal asphalt road, subbase included. To have a net socio-economic benefit the concrete pavement must have clear advantages in the form of longer service life, reduced maintenance costs, traffic safety and other advantages for road users. As roller-compacted concrete pavements have been in service more than 10 years, it is possible to identify trends in their long-term service condition.

5.1 Rutting depth and unevenness

Wheel tracks or rutting gives problems in Norwegian roads, also due to the widespread use of studded tyres. In particular for AADT over 3–4000, studded tyres have being the dominant cause for surface replacement, especially for asphalt wearing surfaces. This results in re-asphalting every 3–6 years with correspondingly relatively high costs.

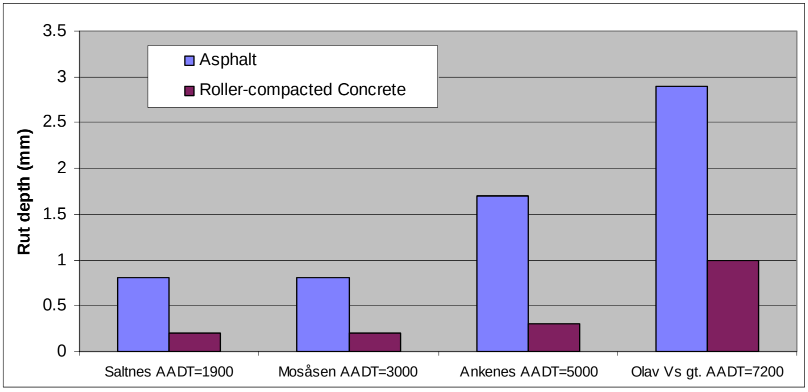

Figure 7: Observed rutting per year (mm) for stretches of road with asphalt and roller-compacted concrete pavements.

The condition of concrete pavements in tunnels is recorded every year by the ALFRED measurement vehicle in accordance with standard procedures. Rut depth and IRI (International Roughness Index) are calculated for 20 m sections and are used in the PMS (Pavement Management System) for detailed planning of maintenance activities for rolling six-year periods. Over 95% of the national road network is measured in this way every year. The results are stored in NPRA's Road Data Bank.

Figure 8: Vehicle "ALFRED" used for measurement of road surface unevenness and texture.

Measurements performed on roller-compacted concrete pavements show very small annual increases in rut depth and IRI. Based on measurements performed the last 10 years, the annual average increase in rut depth for all roller-compacted concrete pavements is 0.3 mm/year. Where the AADT is close to 10000 vehicles, the increase in rut depth is 1–2 mm/year.

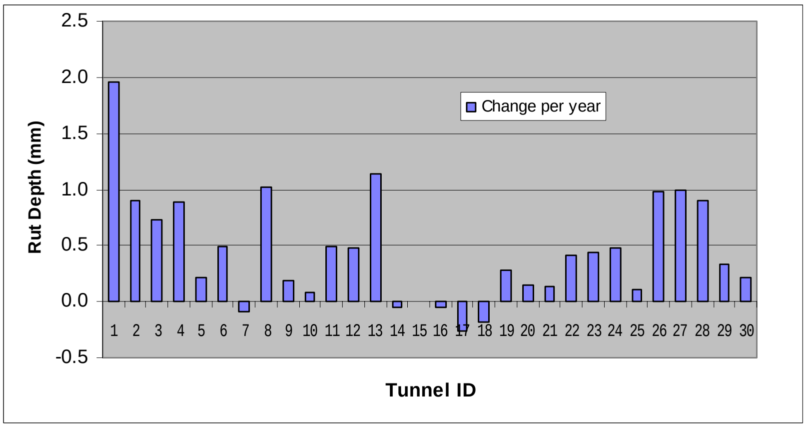

Figure 9: Annual development (change/year) of rut depth for 30 tunnels with roller-compacted concrete pavements. Small rut depths and scatter in the measurements results in certain tunnels being attributed with negative rut depth.

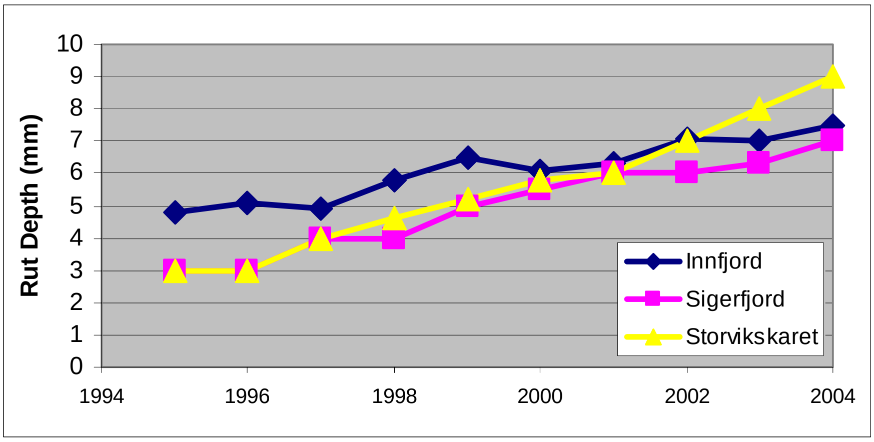

Figure 10: Development of average rut depth with time for three tunnels in the period 1995–2004.

5.2 Joints and surfaces

In general, there have been no problems with joints during the period the concrete pavement has been in service. Some damages have occurred, in particular where joint spacing was too much (20 m). Joint damage has also occurred where the concrete quality was very uneven or the subbase was not properly constructed.

At some locations, water seepage and pumping has accelerated the damage. Damage of longitudinal centre joints occurred in general due to cold joint construction.
Concrete separation during paving occasionally caused cracking and erosion of material in the longitudinal joint. Most of the damages have been repaired by surface repair.

An advantage of roller-compacted concrete pavements in tunnels, where there are small temperature variations, is that joint dowels are not necessary and problems associated with dowels are thereby avoided.

For the majority of the projects, the pavement surface is generally good and dense even after 10 years of service. Individual projects which had a good quality control system and competent personnel display nice and even surface characteristics today.

On some projects a thin surface and honeycombing occurred due to concrete separation during mixing, transport or casting. Local repairs have been performed with a satisfactory result.

Figure 11: Example of a joint.

Rubber coated rollers were used during paving to increase the proportion of aggregate in the surface layer, as this gives a better surface resistance against studded tyres.

Figure 12: Example of good distribution of aggregates on the surface.

5.3 Dust and light

Concrete has in general a better surface resistance to studded tyres than asphalt and thereby produces less dust. However, there have been certain dust problems during the first year of service. This is due to the thin layer on the concrete surface. When opened for traffic, this layer will be quickly worn down by studded tyres producing dust. Concrete dust also remains suspended in the air longer than asphalt dust which is more adhesive. Surface impregnation and increased ventilation was used in a 6.6 km long tunnel in an attempt to reduce dust problems. However, this initiative had little effect. When the concrete aggregate is exposed through wear, dust production decreases notably. The problem is thus only temporary. A concrete pavement has a light coloured surface from day one while an asphalt pavement has a dark coloured surface until the aggregate is exposed by wearing. A concrete surface will normally have a lighter surface colour than asphalt also after some wear. The lighter surface colour gives a more even lighting in tunnels and increased safety.

6. MAINTENANCE

Maintenance of roller-compacted concrete is difficult and demands expertise. Experience to date concludes with two main repair methods: different forms of milling or new layer of asphalt over the existing concrete pavement.

The most inexpensive repair method is milling with a face/stud milling machine, which costs approximately 1/3 the cost of a new asphalt layer. This is of course assuming that the joints are not heavily damaged and that there is no uncontrolled cracking or potholes in the pavement.

The following repairs methods have been performed, albeit to a small extent, in Norway:

- rut filling trials
- face/stud milling
- grinding
- asphalting

Laying a new layer of asphalt has been the most common method. This method is frequently chosen as Norway has little expertise concerning the repair of concrete pavements, while expertise and availability of asphalt is plentiful. For the majority of roller-compacted concrete pavements in tunnels that were cast some 10 years ago, there has been no need for repair, thus experience with performing repairs and their associated durability is lacking.

Figure 13: Concrete surface with test cores.

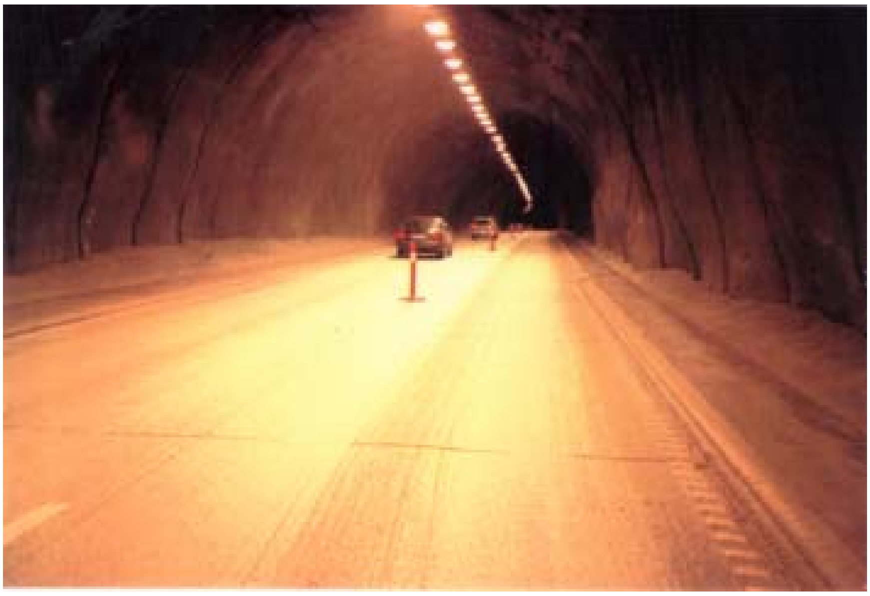

Figure 14: Picture from a tunnel with face/stud – milling work. There are very little experiences with this method in Norway.

7. CONCLUSION

Throughout a ten-year period from 1985 until 1995, considerable experience was gained by the Norwegian Public Roads Administration and private contractors in the construction of roller-compacted concrete roads. This experience was taken into account in the updated design guide 018 (1). Today several tunnels have roller-compacted concrete pavements with excellent traffic and maintenance properties. It is probable that several of these pavements, which are in tunnels with relatively small traffic volumes, will have a service life of 50-100 years with only minimal maintenance.

If roller-compacted concrete pavements are to be constructed in Norway in the future, a long-term competence and project strategy must be developed. Tunnels with an AADT under 10 000 are most suitable.

Figure 15: Studded tires, one of the main problems for pavement maintenance.

REFERENCES

1. Norwegian Public Roads Administration, Guidelines Handbook 018 "Road Construction", (In Norwegian), NPRA 2005.

APPENDIX

Project	Road	County		Length (m)	AADT (2003)	Construction
Leirfjord	E6	Nordland	Road	270	600	1985
Olav Vs gt I	Rv80	Nordland	Road	380	8700	1986
Olav Vs gt II	Rv80	Nordland	Road	440	8700	1986
Olav Vs gt III	Rv80	Nordland	Road	120	8700	1986
Olav Vs gt IV	Rv80	Nordland	Road	455	8700	1986
Holandsfjorden	Rv17	Nordland	Road	690	400	1986
Tosen	Rv76	Nordland	Tunnel	5855	250	1987
Tømmerneset	E6	Nordland	Road/Tunnel	922	1000	1988
Ankenes	E6	Nordland	Road	2190	4400	1988
Sila 1	Rv17	Nordland	Road/Tunnel	855	400	1988
Sila 2	Rv17	Nordland	Tunnel	2315	400	1989
Steigen 1	Rv835	Nordland	Tunnel	3000	200	1989
Flenja	E16	Sogn Fj.	Tunnel	5128	1500	1989
Steigen 2	Rv835	Nordland	Tunnel	5079	200	1990
Moståsen	E6	Nordland	Tunnel	255	3200	1990
Tussen	Privat	M&R	Tunnel	2800	3850	1990
Brattli	Rv827	Nordland	Tunnel	3605	350	1991
Nipvik	Rv827	Nordland	Tunnel	980	350	1991
Tømmerås	Rv827	Nordland	Tunnel	565	350	1991
Botnelv	E6	Nordland	Bridge	24	1700	1991
Botn	E6	Nordland	Bridge	100	1700	1991
Kvalnes	E6	Nordland	Bridge	128	1250	1991
Fjæra	E134	Hordaland	Tunnel	1500	2500	1991
Elljarvik	E134	Hordaland	Tunnel	110	2500	1991
Sætre	E16	Hordaland	Tunnel	700	10000	1991
Dale-Bolstad	E16	Hordaland	Tunnel	7176	4000	1991
Innfjord	E136	M&R	Tunnel	6000	1750	1991
Stetind	Rv827	Nordland	Tunnel	2760	350	1992
Efjord	Rv827	Nordland	Tunnel	1620	350	1992
Kista	Rv17	Nordland	Tunnel	410	300	1992
Straumdal	Rv17	Nordland	Tunnel	3230	300	1992
Saltnes	E6	Nordland	Tunnel	465	1000	1992
Dalmovik	E6	Nordland	Tunnel	165	1900	1992
Saksenvik	E6	Nordland	Tunnel	1150	1900	1992
Kjøpsvik	Rv827	Nordland	Tunnel	785	550	1993
Storvikskaret	Rv17	Nordland	Tunnel	3120	650	1995
Sigerfjord	E10	Nordland	Tunnel	2135	1200	1995

Table 3: An over-view of all projects constructed with rolled-compacted concrete in Norway from 1985 to 1995.

Project	**Year**	**Concrete Strength**	**Concrete Strength**	**Aggregate**
		Planned	**Done**	
Leirfjord	1985	C25		0-50mm
Olav Vs gt I	1986	C55	C60	0-28mm
Olav Vs gt II	1986	C55	C60	0-28mm
Olav Vs gt III	1986	C55	C60	0-22mm
Olav Vs gt IV	1986	C55	C60	0-22mm
Holandsfjorden	1986	C30		0-28mm
Tosen	1987	C35	C33	0-22mm
Tømmerneset	1988	C35	C65	0-22mm
Ankenes	1988	C50	C55	0-16mm
Sila 1	1988	C35	C64	0-16mm
Sila 2	1989	C35	C56	0-18mm
Steigen 1	1989	C35	C59	0-18mm
Flenja	1989	C40	C42	0-16mm
Steigen 2	1990	C35	C47	0-18mm
Mosåsen	1990	C65	C57	0-18mm
Tussen	1990	C45	C46	0-16mm
Brattli	1991	C45	C28	0-18mm
Nipvik	1991	C45	C38	0-18mm
Tømmerås	1991	C45	C38	0-18mm
Botnelv	1991	C65	C51	0-16mm
Botn	1991	C65	C63	0-16mm
Kvalnes	1991	C65	C59	0-16mm
Fjæra	1991	C50	C50	0-22mm
Elljarvik	1991	C50	C50	0-22mm
Sætre	1991	C60	C58	0-16mm
Dale-Bolstad	1991	C50	C50	0-19mm
Innfjord	1991	C45	C54	0-16mm
Stetind	1992	C45	C45	0-22mm
Efjord	1992	C45	C50	0-22mm
Kista	1992	C45	C55	0-22mm
Straumdal	1992	C45	C48	0-22mm
Saltnes	1992	C45	C47	0-16mm
Dalmovik	1992	C45	C55	0-16mm
Saksenvik	1992	C45	C46	0-16mm
Kjøpsvik	1993	C45	C50	0-22mm
Storvikskaret	1995	C45	C56	0-16mm
Sigerfjord	1995	C45	C42	0-16mm

Table 4: For all projects, concrete aggregate and concrete compressive strength as planned, and after casting.

Project	**Year**	**Pavement Thickness**	**Pavement Thickness**	**Spacing**	**Other**
		Planned	**Done**		
Leirfjord	1985	15cm	15cm		
Olav Vs gt I	1986	17,5cm	17cm	25 and 40m	
Olav Vs gt II	1986	17,5cm	17cm	25 and 40m	
Olav Vs gt III	1986	17,5cm	17cm	25 and 40m	
Olav Vs gt IV	1986	17,5cm	17cm	25 and 40m	
Holandsfjorden	1986	18cm	18cm		
Tosen	1987	12cm	12cm	12,5 and 20m	
Tømmerneset	1988	18cm	20cm	23 - 25m	Cement in big bag
Ankenes	1988	18cm	18cm	12 - 15m	Cement in big bag
Sila 1	1988	18cm	16cm	10 - 15m	
Sila 2	1989	18cm	13cm	10 - 15m	2 layer. R-CC over 10cm Cg
Steigen 1	1989	15cm	16cm	10 - 12m	Silica and cement
Flenja	1989	15cm	14cm	10 - 12m	
Steigen 2	1990	15cm	13,5cm	10 - 12m	
Mosåsen	1990	18cm	19cm	10m	
Tussen	1990	16cm	14-18 cm	12m	
Brattli	1991	15cm	12cm	12m	Spacing up to 25m
Nipvik	1991	15cm	12cm	12m	Spacing up to 25m
Tømmerås	1991	15cm	15cm	12m	Spacing up to 25m
Botnelv	1991	7cm	7 - 8 cm		Bridgedeck
Botn	1991	7cm	7 - 8 cm		Bridgedeck
Kvalnes	1991	7cm	7 - 8 cm		Bridgedeck
Fjæra	1991	15cm		6m	
Elljarvik	1991	15cm		6m	
Sætre	1991	22cm		6m	Problem with mixing plant
Dale-Bolstad	1991	15cm		6m	Bad aggregate
Innfjord	1991	16cm	13-19 cm	6m	Bad end of day joints
Stetind	1992	15cm	15cm	17m	Spacing up to 25m
Efjord	1992	15cm	15cm	17m	Spacing up to 25m
Kista	1992	15cm	19cm	10m	Full-size paving
Straumdal	1992	15cm	15cm	10m	Full-size paving
Saltnes	1992	15cm	15cm	10m	
Dalmovik	1992	15cm	15cm	10m	
Saksenvik	1992	15cm	16cm	10m	
Kjøpsvik	1993	17cm	18cm	10m	Full-size paving
Storvikskaret	1995	15cm	19cm	10m	2 pavers and full-size
Sigerfjord	1995	15cm	15cm	10m	

Table 5: Joint spacing and pavement thickness as planned/done.

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