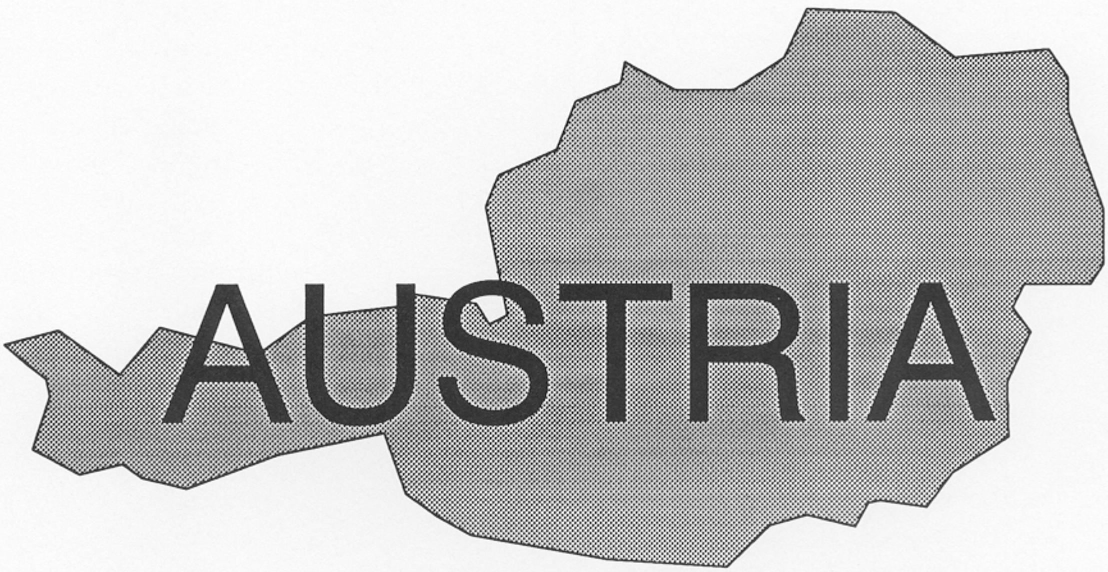
AUSTRIA

3.2 Austria

- Concrete Pavements in Austria

Austria began constructing concrete pavements in the 1940's and has constructed both JPCP and JRCP. Today many pavements older than 30 years and some 50 years old exist in Austria. The following table shows the extent of concrete pavements on Austria's main highways.

Table 3.1 Austrian highway mileage.

Pavement Type	km	Percentage
Asphalt concrete	834	54
Concrete	698	46
Total	1532	100

1 km = 0.621 mi

However, studded tires caused ruts of 2 to 3 mm (0.08 to 0.12 in) in the older pavements. Because Austria has a lot of ram some type of rehabilitation had to be performed. A thin polymerized asphalt layer has been placed over the truck lanes of many older concrete pavements to repair the studded tire damage. This layer has a life of only four to six years.

- Designs

Austria has developed a catalog of pavement designs for a 30-year period. Four different designs are considered: dowelled and undowelled with untreated granular base or cement-treated base. Ranges of current design thickness are as follows.

✓ 18-22 cm (7-9 in) JPCP (25 cm (10 in) for heavy traffic)
✓ 5 cm (2-in) AC interlayer
✓ 20-45 cm (8-18 in) untreated granular layer with less than 3 percent fines

✓ 18-22 cm (7-9 in) JPCP
✓ 5 cm (2 in) interlayer AC
✓ 18-20 mm (7-8 in) cement-treated base (only past five years)

The thickness values in the design catalog are based upon a minimum bearing capacity on the subgrade as determined by plate loading tests on site and defined as an acceptance limit in Austrian Specification RVS 8.24. The minimum bearing value is 35 MPa (5075 psi). If the soil does not achieve this level of bearing, soil stabilization, soil replacement by better materials or other methods to achieve the bearing capacity is required. The minimum bearing capacity for asphalt and concrete pavements is the same. The frost depth in Austria is 1.5 m (4.9 ft).

The typical joint spacing is 6 m (20 ft) for a 25-cm (10-in) slab. Dowels are 2.6 cm (1 in) in diameter and 50 cm (20 in) in length. For heavier traffic, the maximum joint spacing, in meters, is 25 T, where T is the slab thickness in millimeters. Thus, a maximum joint spacing for a 25-cm (10-in) slab is 6.25 m (20.5 ft).

Faulting of transverse joints is well controlled by dowels, which are essential. Austria found that dowels must be coated to prevent corrosion. On some early projects, dowels were not coated and corrosion was serious.

In the late 1970's, the sealing practice changed in some areas of the country. The initial saw cut for transverse and longitudinal joints was made 3 mm (0.12 in) wide and the joint was not sealed. This practice saved about 10 percent of the construction cost. There is controversy about this because some projects are sealed even today, and some feeling is that joint sealing would add life to the concrete pavement.

Included in the JPCP thickness is a 4cm (1.6 in) top layer of smaller-sized hard aggregate that is used to provide a low-noise, high-friction texture. The surface aggregates are exposed during construction as described later. Structural design for, pavements on bridge decks and in tunnels is also given in catalogs.

The full-width paving is 11.5 m (37.7 ft), and includes an inner lane and narrow shoulder of 4.75 m (15.6 ft), an outer lane of 3.75 m (12.3 ft) and a tied shoulder of 3.00 m (9.8 ft). The cross-slope of old pavements was 1.5 percent, but now all new pavements have 2.5 percent slope.

- Rehabilitation

Austria has tried several different ways to rehabilitate their concrete pavements. A few projects have been cracked and seated and overlaid with AC. An unbonded concrete overlay was recently placed on an old pavement with a 5-cm (2-in) AC separation layer. Its performance was very good, but it was found that it was more economical to recycle all pavement materials and reconstruct the pavement into either concrete or asphalt.

For rehabilitation projects, all site materials were recycled back into the rehabilitated pavement. Old concrete is recycled into a new concrete slab. Old aggregate base is used as part of a new cement-treated base. Old AC is crushed, some is used in new recycled concrete, and the remainder is used in the 5-cm (2-in) AC interlayer between the slab and cement-treated base.

See the project site description below for details of some rehabilitation projects.

- Noise Pollution

Increased sensitivity of Austrians with regard to traffic noise has resulted in a major noise-reducing efforts over the past decade through use of noise barriers, low-noise freight vehicles, and new low-noise pavement surfacings. Several surfacing techniques have been evaluated in Austria.

Porous asphalt surfacing was first constructed in Austria in 1984 and a lot has been constructed since that time. Measurements have shown that this surfacing initially reduces tire noise emission by 4 to 6 dB(A) at 100 km/hr (62 mi/hr) compared to conventional asphalt or concrete pavements, respectively. The porous surface also reduces hydroplaning and splash during rainstorms. However, problems have developed with this surfacing. Older porous asphalt surfaces have shown a significant decline in the noise-reducing effect due to the voids filling up with soil and abrasives and further compaction. (4) Porous asphalt would therefore need to be cleaned over time to maintain its low-noise characteristics. Another concern is that deicing salt requirement is about 15 to 50 percent higher to prevent icing. Even then icing cannot be prevented completely under critical weather conditions, such as freezing rain. (4, 6)

The use of slipform pavers with a super-smoother flattens any transverse waves reduced noise by 2 dB(A). Further improvements by 1 to 2 dB(A) were achieved by creating a fine-rough longitudinal texture using a burlap drag, instead of the formerly common transverse brushing with a broom. (4) The burlap drag is simple and inexpensive, but friction resistance is lower than with a transverse broom finish. Higher friction resistance can be obtained but the concrete must be rich in mortar and longitudinal grooves 2 mm (0.08 in) deep must be made using a plastic brush or metal tines. (6)

The exposed aggregate technique is similar to that described in Belgium. The main difference is that in Austria the slab is placed in two layers so that the top layer can contain a high quality, smaller aggregate (maximum size 7-8 mm (0.27-0.31 in)) to maximize noise reduction. The two-layer method is used in Austria because the aggregates that are resistant to wear and polishing are expensive. This technique was first constructed in Austria in 1990 with another four sites in 1991. This technique reduces noise emission through provision of a textured surface with selected hard aggregates in the upper 4 cm (1.6 in) of the slab, as shown in Figure 2.8. The surface is sprayed with a retarder, covered with plastic sheeting to prevent evaporation and the fine mortar on the surface is removed by brushing the next day, or a combination of a retarder/curing compound is used. (6)

Optimum noise reduction requires that the maximum aggregate size should be 7-8 mm (0.27-O-31 in) and the percent of particles 4-7 mm (0.16-0.27 in) or 4-8 mm (0.X-0.31 in) should be as high as possible, but there must be enough mortar between the particles to ensure excellent bond. The w/c ratio should be well below 0.40 and texture depth should not exceed 1.2 mm (0.05 in). The stone particles must consist of a wear- and friction-resistant material. In Austria, a 4-cm (1.6-in) top layer is constructed with the aggregates containing the above characteristics.

Figure 2.16 shows the beneficial effect of the exposed aggregate surface on noise emission reduction of as much as 7 dB(A) from that of old concrete. The exposed aggregate noise emissions are comparable to that of porous asphalt surfaces. Exposed aggregate is not likely to loose its noise-reducing properties as the porous asphalt does.

The exposed aggregate surface also provides a high level of friction resistance. (6)

During the trip along the Al freeway from Vienna to Salzburg the Study Tour stopped at the beginning of a new concrete section with the exposed aggregate surface. This section was adjacent a section with a porus asphalt surface. There was no discernable difference in traffic noise between the two sections. Both were very quiet.

Some additional details are given under the Al project site description.

- Concrete Materials and Construction

Concrete quality appeared to be excellent in Austria even though many freeze-thaw cycles occur and a lot of deicing salt is used. There are no reported occurrences of "D" cracking or ASR and only a few freeze-thaw durability problems. Cores from old concrete pavements have 100 MPa (14,500 psi) compressive strength.

All concrete mixes must be approved by an authorized and accredited laboratory.

Concrete compressive strength is specified to be more than 35 MPa (5075 psi) for the lower concrete layer and more than 40 MPa (5800 psi) for the top layer after curing for 28 days. The flexural strength must be 5.5 MPa (798 psi) for 12 by 12 by 36-cm (4.7- by 4.7- by 14in) beams in center-point loading. Austria believes primarily in the flexural strength test for concrete pavements.

The air void bubble spacing must be less than 0.22 mm (0.0087 in) and total entrained air content must exceed 2.0 percent.

Whenever concrete slabs are removed for rehabilitation, they are recycled into concrete or some other use on the project site. The maximum particle size is 3.2 cm (1.25 in) and natural sand is added to the mix.

Laboratory tests have shown that particles from old concrete pavements are better than many natural aggregates. The recycled concrete was superior to normal concrete made from gravel. Coarse recycled concrete from 4 to 32 mm (0.16 to 1.25 in) is being used as the coarse aggregate, the particles finer than 4 mm (0.16 in) are used for mixing with the in situ subbase (prior to cement stabilization).

In addition, the crushed concrete particles may contain up to 20 percent AC particles (originating from existing AC overlays on the concrete pavement) without essentially impairing the quality of the new concrete. This technique has been used on three reconstruction sites of the Al freeway although the percent of asphalt has been only 4 to 6 percent. Figure 3.5 shows a section of a concrete mixture containing AC material. This provides a more economical mixture and a way to reuse old AC material which is usually taken from thin AC overlays of concrete pavements. Extensive research on concrete recycling has been conduced by Dr. Sommer of the Research Institute of the Austrian Cement Maker's Association. (3)

- Project Sites Observed

One recently completed project and two under construction were observed by the Study Tour on the Al freeway which connects Vienna with Salzburg. This 300-km (186-mi) highway is a heavily trafficked east-west highway. It was all constructed of JRCP over 20 years ago, and some of it is over 30 years old. (2)

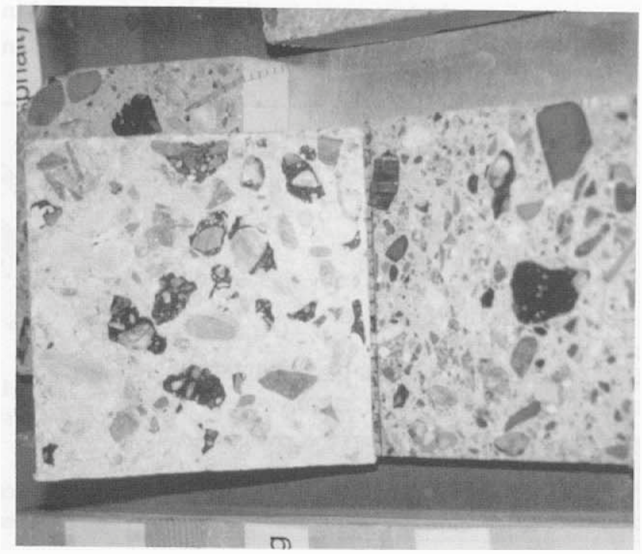

Figure 3.5 Cut section of an Austrian recycled concrete mixture containing old AC overlay material.

Al Freeway Unbonded Concrete Overlay. The original 1957 JRCP had a 24-cm (9.5-in) slab and 3 cm (1.2 in) of sand over an aggregate base. The old slab was cracked and seated, 5 cm (2 in) of AC was placed, and then a 20-cm (8-in) JPCP overlay was placed. (2)

Al Freeway Recycling and Reconstruction. The original JRCP (some portions included a thin AC overlay) was shattered using a Wirtgen Guillotine, hauled to a crushing plant on site and processed into several fractions. These fractions contain between 2 and 10 percent AC from the thin AC surface which was included in the recycled concrete (about 6 percent average was old AC material). The 0- to 3-mm (0- to 0.12in) fine fraction was placed on top of the old gravel subbase which contained 15 percent fines and the material was then stabilized in-place to a depth of 20-25 cm (8-10 in) with cement using a Bomag machine. The compressive strength requirement was 3 MPa (435 psi) at 7 days. A 5-cm (2-in) AC layer (which included some recycled asphalt pavement) was placed on top of the cement-stabilized layer to provide the concrete pavement with an erosion-resistant base. (3)

A JPCP 25 cm (10 in) thick with dowelled joints spaced at 5.5 m (18 ft) was placed using a slipform paver. Plastic-coated dowel bars, 26 mm (1 in) in diameter and 50 cm (20 in) long, were spaced at variable locations, 11 in the truck lane, 7 in the passing lane and 4 in the shoulder. The contraction joints were sawn 3 mm wide and left

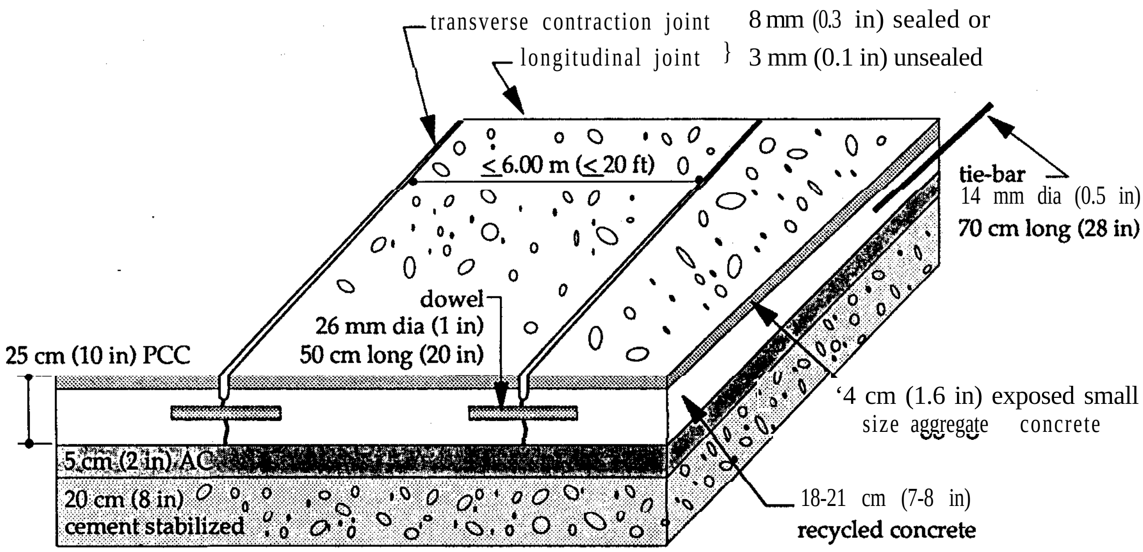

Figure 3.6 Cross-section of Austrian JPCP reconstruction on the Al.

unfilled on this project. Note that on some projects the joints are sawn 8 mm (0.3 in) wide and sealed with a bituminous filler. Paving width was 11.5 m (38 ft). (3) Figure 3.6 shows a cross-section of the completed pavement.

The slab was designed to have two layers: a bottom layer of recycled concrete and a top layer with high-quality hard aggregate (called chippings) to provide a low-noise, high friction surface. The slab was placed in two layers by a single modified "double-decker" Wirtgen slipform paver. This paver placed two separate layers of slipformed concrete "wet-on-wet" to form a monolithic structure. (5) The Wirtgen SP1600 slipform paver with the integrated two-layer paving kit performed the following operations:

Bottom Layer (21 cm (8.5 in)):

✓ Spread the top layer concrete over full width (11.5 m (38 ft)),
✓ Liquify and compact the bottom layer,
✓ Form the bottom layer by extrusion,
✓ Insert the dowel bars at transverse joints,
✓ Insert the tie-bars on longitudinal joints, and
✓ Restore the surface of the bottom concrete slab after insertion of dowels and tie bars with the first oscillating beam.

Top Layer (4 cm (1.6 in)):

✓ Convey top layer concrete from truck mixer over the paver main frame and discharge into a hopper feeding in the spreading augers,

- ✓ Liquify and compact the second layer with a high-frequency vibration system (vibration is controlled in frequency to avoid causing additional vibration to the bottom layer),
- ✓ Form the top layer by extrusion, and
- ✓ Finish the top layer with a second oscillating beam and the super smoother.

The 21-cm (8.5-in) bottom layer contained the recycled crushed concrete plus natural sand. Cement content was about 360 kg/m^3 (607 pounds/yd^3) and also contained entrained air (3.5 percent). The flexural strength at 28 days ranged from 6.5 to 9.5 MPa (942 to 1378 psi) with a mean of 7.75 MPa(1124 psi).

The top 4-cm (1.6-in) layer contained a high percentage (65 percent) of hard stone chippings having a maximum size of 8 mm (0.3 in) and about 35 percent sand (O-l mm (O-0.04 in)). Cement content was 450 kg/m^3 (758 pounds/yd^3). The mixture had air entrainment (4 percent), plasticizer, retarder and a water/cement ratio of 0.38 for durability and low shrinkage. A retarder was used for the top concrete to prevent it from stiffening more quickly than the bottom concrete. The stone chippings (4-8 mm (0.16-0.31 in)) had an LA abrasion value of less than 19 and a polished stone value greater than 50. The surface of the concrete was sprayed with a retarder and covered with a plastic sheeting or sprayed with a film-forming curing compound to prevent evaporation. The next day the surface was brushed to expose the chippings and sprayed with a curing compound. Texture depth was about 0.9 mm (0.035 in) by the sand patch measurement method.

A discussion of the noise characteristics of this surface was previously given. Smoothness specifications were applied using a profilometer. Joint sawing was done through the plastic sheeting.

The concrete crusher and plant that produces the lower recycled concrete layer was visited. Approximately 10 percent recycled AC is included in the concrete mixture. The specifications allow up to 20 percent but this requires too large a cement content to be economical. A separate plant mixes the top layer. Only recycled concrete is used for the coarse aggregate in the lower layer.

Al Freeway Salzburg Recycling and Reconstruction. This 17-km (10.6mi) project was nearly identical to the previous Al freeway project. Truck traffic was heavy on this section (3500 per day). The original JRCP was overlaid with a thin AC overlay which was sawed and sealed. This layer was debonding from the slab and large pieces were coming off, which precipitated the rehabilitation. This project was to be completed in 26 weeks and the bonus per day and penalty per day were equal. The study tour observed the old concrete pavement removal process, which included slab fracturing and a large backhoe loading pieces of concrete into a truck Figure 2.8 shows a photo of a core from this project. Figure 3.6 shows a cross section of the slab showing the recycled concrete base and the top surfacing for noise reduction. The westbound lanes, shown in Figure 3.7, had been completed the previous year.

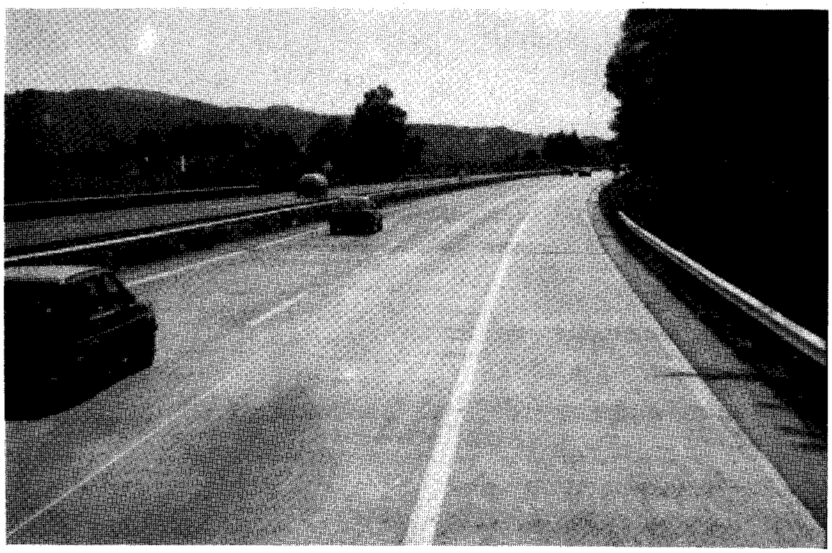

Figure 3.7 Photo of the Al recycled concrete pavement near Salzburg, Austria.

- Traffic Loadings

The Austrian freeways carry heavy traffic loadings. The typical ADT is 25,000 (up to 100,000) with an average of 12 percent trucks. The growth rate in highway freight transport is high (7 percent per year). The single-axle load limit is 10 t (22,046 pounds) and the tandem-axle limit is 16 tons (35,300 pounds). A large number of overloads exist. Austria is likely to increase its legal axle weights to the 11.5 t (25,353 pounds) EC maximum for single axles.

Concrete pavements are designed for 30 years of traffic, taking into consideration different traffic lanes, distribution within traffic lane (from 0.6 for a lane more than 3.5 m (11.5 ft), to 0.9 for 3-3.5 m (10-11.5 ft), to 1.0 for a lane less than 3.0 m (10 ft)), the annual growth rate, and the design period. Equivalency factors are used to calculated equivalent single-axles of a 10-ton (22,046 pounds) standard single-axle.

- Summary for Austria

Austria has constructed many jointed plain and reinforced concrete pavements since the 1950's which have performed very well under heavy truck traffic. Studded tire damage caused severe problems resulting in the requirement to place thin polymerized AC overlays on the truck lanes. The old pavements have excellent concrete durability.

The current design for new or reconstructed pavements is for short-jointed dowelled JPCP with tied concrete shoulders and a thin AC layer between the slab and the granular or cement-treated base. Rehabilitation, including unbonded JPCP overlays on fractured slabs and AC overlays on fractured slabs, is underway on many old pavements. The most used technique to date has been the complete recycling of an old concrete pavement into a new concrete pavement with a full 11.5-m (38-ft) width.

There is a very strong emphasis on highway noise reduction in Austria. The use of the exposed aggregate surface in conjunction with the two-layer slabs (the top layer containing small hard aggregates) has shown significantly reduced noise levels and high friction,

Dr. Sommer of the Cement Research Institute stated that the level of effort needed to implement something (get it working) is greater than the original research effort. He believes that the researcher should guide the field implementation until the procedure is developed. This is an interesting concept which should develop a needed partnership between research and operations.

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