# Report on the 1992 U.S. Tour of European Concrete Highways

France, Austria, Germany, Netherlands, Belgium

AASHTO - ACPA - FHWA - PCA - SHRP - TRB

# Report on the 1992

# U.S Tour of European Concrete Highways

# --- US TECH ---

*"When all is said and done, the main unifying factor was the political one, summed up in the famous dictum: 'All roads lead to Rome.' The 53,638 or so miles of main roads forming as they did the line of advance for army and commerce, the binding force between races and cultural influences, and the essential basis for the settlement and development of land and its colonisation and survey, served to unify the Roman world and so, at long remove, to create modern Europe."*

*Roman Roads*
*Raymond Chevallier*
*University of California Press*
*1976*

## SPONSORING ORGANIZATIONS

**American Association of State Highway and Transportation Officials**

**American Concrete Pavement Association**

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**Portland Cement Association**

**Strategic Highway Research Program**

**Transportation Research Board**

## ACKNOWLEDGMENT

**The sponsors and members of the U.S. Tour of European Concrete Highways (US TECH) team express their sincere appreciation and thanks to their many colleagues in France, Austria, Germany, Netherlands, Belgium, Spain, Portugal, Switzerland and Italy who were extremely helpful in many ways in explaining their concrete pavement technology. Many thanks also to the staff of CEMBUREAU who made presentations and helped organize the trip. Appreciation is expressed to Mr. John Sullivan of the Federal Highway Administration and Mr. Herb Harris of Sato Travel for assisting with the travel arrangements that were as smooth as a new concrete pavement with a low-noise surface. Special appreciation is expressed to Dr. Michael Darter and other Study Tour members for the preparation of this report.**

## Joint Statement by Members of the 1992 U.S. TOUR OF EUROPEAN CONCRETE HIGHWAYS (U.S. TECH)

The United States' highway system ties our nation together and provides the mobility needed to support our economy and everyday activities.

An important part of any highway is the pavement structure upon which we drive. While they have given us good service, the driving surfaces and supporting foundations of pavements on highways across America are wearing out, because of age, traffic volumes larger than projected, and truck loads heavier than expected. As a Nation we face the need to rebuild these pavements, many of which are constructed of portland cement concrete.

To better prepare for the task of rebuilding our highways we came together to examine some of Europe's major freeways and to talk with the experts who design, construct and maintain them, seeking knowledge of practices and experience that might aid us in the United States. Drawn from our Federal and State highway agencies, the American Association of State Highway and Transportation Officials, the Transportation Research Board, the Strategic Highway Research Program, the Portland Cement Association, and the American Concrete Pavement Association and some of its contractor members, our Group of 21 highway and pavement experts observed highways and met with experts in France, Austria, Germany, the Netherlands, and Belgium. We also had presentations by experts from four other nations, Italy, Portugal, Spain, and Switzerland, concerning portland cement concrete pavements in their countries.

The 21 participants adopted the following Mission Statement for their tour:

> The mission of the group is to review the European concrete pavement experience and obtain information relating to finance, research, design, construction, maintenance and performance to assist with development of appropriate actions for enhancing our nation's highway system, productivity and economic future.

### Findings

What did we find in Europe?

We found that the new and recently built portland cement concrete highways we observed are constructed with a common philosophy -- worry more about design, materials and construction excellence and less about cost. These highways featured well-conceived, durable concrete slabs placed on thick, well-drained bases, resulting in superior pavement structures.

The European pavements we observed were built with the best technology available, much of which has been developed in the United States.

We found a cooperative attitude among the various components of the European highway community - researchers, government engineers, contractors, suppliers and others, and a commitment to excellence.

These nations are building their portland cement concrete highways for the future with a 30- to 40-year designed service life compared to our 20 years. Their highways carry a large volume of trucks, with allowable axle weights substantially above those in the United States.

We found a commitment to early, preventive maintenance in Europe, and to undertaking timely rehabilitation and reconstruction.

In summary, Europeans are building excellent concrete pavement systems, and they are building and rebuilding their highways for very large loads and long life.

Should we be concerned about this European strategy? Yes, because Europe will be able to use those highways to better compete in the world economy. And yes, because better pavements will improve our mobility and efficiency, and help us to compete better economically.

Can the United States have better pavements? Yes, if we will commit the necessary resources to achieve excellence. We have the technical "know-how" and construction techniques in the United States to meet and exceed anything we saw in Europe.

## Action Plan

A full report on the results of our tour has been prepared. At this time we urge consideration of the following initial steps to help ensure world-class pavement structures in the United States:

- Commit to further improvement of our cement concrete pavement design, materials, and construction technology and equipment through innovation, research, and training.

- Develop a conceptual design catalog, similar to that employed by European Agencies, as a guide to help highway agencies and contractors focus on the best practices.

- Establish at the national level a focal point for collecting and distributing information about developments in the United States and other nations of pavement technology, to pavement engineers, researchers, and the construction industry. This effort should include and could be based upon the continuing SHRP effort, and should include a broad-based advisory board.

- Construct some selected highway projects to explore the applicability of certain European concepts to the United States. The SHRP SPS-2 effort might be employed for at least some projects.
- Organize a continuing training program for pavement engineers from highway agencies and contractors, to improve the design, construction and maintenance of concrete pavements.
- Encourage closer interaction among highway agency engineers, consultants, researchers, industry, and contractors, to promote better concrete pavements.

Conclusion

To a significant degree, this tour of Europe offered us a window of issues we in the United States may face tomorrow.

Europe is building highways for more and heavier trucks. They have higher population densities near their highways which are also developing in the United States. These population densities are causing Europe to pay increasing attention to the roadway environment, including construction of pavement to minimize road noise, the widespread use of sound walls, and the extensive use-of vegetation in and adjacent to the right-of-way. The need to conduct highway rehabilitation under heavy traffic is resulting in more full-width pavements in Europe, where the emergency lanes or shoulders can be used to temporarily carry heavy truck traffic. This same heavy traffic encourages Europe to construct more maintenance-free highways and to emphasize preventive maintenance. Recycling of pavements is on the rise, with Austria now requiring full recycling on site.

It is for us in the US to take advantage of what we learn from other nations - so that we can anticipate tomorrow's needs and build highways for the future.

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# EXECUTIVE SUMMARY

The US TECH Study Tour travelled in France, Austria, Germany, the Netherlands, and Belgium, and heard presentations from Spain, Portugal, Switzerland, and Italy. Traveling mostly by motor coach over thousands of kilometers of high-level motorways for 14 days, the Study Tour heard many presentations from government and toll road officials and engineers, contractors, university faculty, and industry representatives, and examined many pavements and construction sites. In addition, helpful literature and technical reports were provided, and many discussions were held with experts from all of these countries, which were very helpful to the Team's understanding of European practice.

The Study Tour members believe Europe represents a "window" through which some important issues concerning the future transportation infrastructure in the USA can be observed.

The most significant findings of this trip as determined by the 21-person Study Tour are briefly summarized in this Executive Summary. The report offers a comparison between Europe and the USA in Section 1. A synthesis of the technical aspects of the Study Tour findings is provided in Section 2. Considerable additional information is given for each country in Section 3.

## Technical Highlights

Europeans are building excellent concrete pavement systems, and compared to the USA, they are building and rebuilding their highways for very large loads and long life. Many concrete pavement design, construction, and material improvements which USA pavement engineers consider promising innovations for the future are already standard practice in European countries. The following technical highlights explain some of the characteristics of these pavements.

- **Traffic Loadings**

Truck traffic on European freeways is heavy by American standards in terms of volumes, axle weights, and tire pressures. Truck volumes are similar to those on major routes in the USA but legal axle weights are significantly higher. Single axle legal maximums range from 10 to 13 metric tons (t) (22,046 to 28,660 pounds), compared to 9.1 t (20,000 pounds) in the USA. The EC will apparently adopt a uniform 11.5 t (25,300 pounds) single axle as its legal limit. Tandem axle legal maximums range from 19 to 21 t (41,900 to 46,300 pounds) and tridem axle limits are 24 t (52,900 pounds).

However, actual maximum loads measured are greater than these legal limits. There appears to exist little legal enforcement of weights in Europe. Most trucks observed had super-single tires with high tire pressures. Expectations are that traffic will continue to increase with the economic growth that the EC is expected to bring.

. **Pavement Design**

Jointed plain concrete pavements (JPCP) are constructed most often in Europe and their design has been improved over time through effective research. Continuously reinforced concrete pavements (CRCP) have been built in several countries, most commonly Belgium and France. Design lives are typically 30 to 40 years. The new and rehabilitation designs in most countries are developed by teams of experts and placed in "pavement design catalogs" for use by project designers. The design catalog approach has several significant benefits, not the least of which is communicating the best practices to the field. Emphasis is on the design of the total pavement system, not just the thickness of the concrete slab. The Study Tour members were impressed with the overall designs from each of the countries. Typical design practice in Europe is summarized below:

| Pavement Type | Slab Thickness | JPCP Joint Space | Base | Subbase |
|---|---|---|---|---|
| JPCP | 18-25-30* cm (7-10-12 in) | 3.5-5.0-6.0* m (12-17-20 ft) (Dowelled) | Lean concrete | 20-90 cm (S-36 in) Granular layer |
| | | CRCP Reinforcement % | | |
| CRCP | 17-20-25* cm (6.7-S-10 in) | 0.60-0.67-0.85* | Lean concrete AC/LCB** | 20-90 cm (836 in) Granular layer |

* Low - Most Typical - High
** Some countries use 5 cm (2 in) AC interlayer between slab and lean concrete base.
Some countries bond the JPCP slab to the lean concrete base (which is also jointed).

Note that the slab thicknesses typically do not exceed those in the USA. Other factors are optimized to reduce thickness requirements. Concrete pavements typically have slabs that are 0.5 m (1.7 ft) wider, longitudinal subdrainage pipes and plastic-coated dowels to control faulting. Austria and Germany are bonding the jointed lean concrete base to the slab to reduce both load-related and environmentally related stresses. Trapezoidal cross-sections are used in two countries to optimize slab design for truck loadings.

The thick granular layer placed beneath the treated base provides a substantial level of bearing capacity, for uniform support, frost heave protection, and subsurface drainage.

Higher reinforcement content in CRCP (0.7 to 0.85 percent) has produced tight cracks and excellent performance. Rectangular, coilable steel strips (product name FLEXARM) for CRCP are innovative and have performed well in France.

A full-width concrete slab and base paving thickness for adequate traffic control needs during future rehabilitation is now provided in some countries. The shoulder is called an "emergency lane."

- Construction

Warranties for pavement construction work are used in Europe. Warranties for concrete pavement range from 4 to 9 years in different countries. The exact requirements and benefits of the warranties need further investigation. Two-layer slab construction is common in some countries for safety, noise and economic reasons. A hard high-quality aggregate is used in the upper 47 cm (1.6-2.8 in) of the slab. Two-layer paving equipment is available to place this pavement in one pass. A straight 2.5 percent cross-slope with no crown across traffic lanes is common in new construction. Liquidated damages equalled incentives rate per day for one construction project visited. Lean concrete was used as a temporary widening for traffic control purposes on another project. Reinforcement bar tubes were placed behind vibrators for CRCP in France to improve steel placement.

- Rehabilitation

Rehabilitation of pavements is performed at a higher level of condition than in the USA. Unbonded CRCP and JPCP overlays are common on old concrete pavements which are often cracked and seated or picked up and crushed and used as base. They are also used on AC pavements. Jointed, steel-fiber-reinforced concrete overlays of existing concrete and AC pavements have been used successfully in Belgium.

Total recycling of concrete and other materials, required by law, was observed on a job site in Austria. Recycled concrete that includes up to 10 percent recycled AC material is used routinely in Austria for economy, and to accommodate its mandatory recycling law. Some interesting lane reconstruction design sections exist and the addition of a 31-cm (12.9 in) CRCP truck lane on an AC pavement was observed. The French LCPC/ Freyssinet load transfer device for JPCP is being used to reduce faulting and control reflection cracks under porous asphalt surfaces.

- Concrete Materials

Concrete durability problems do not exist in Europe. Higher-strength concrete is used in several countries. Compressive strengths of 55 MPa (7975 psi) is specified in Belgium at 90 days. Typical flexural strengths of 7.5 MPa

(1,087 psi) in third-point loading at 28 days are specified. A thick (40 cm (15.8 in)) porous concrete slab that provides a free draining non-hydroplaning surface, noise reduction and storm runoff reservoir capabilities has been constructed in Paris. Lean concrete shoulders have proven successful in France.

- Surfacings

Reduction of pavement-tire noise levels is an important environmental issue in Europe. Several methods are being used that reduce noise levels yet still provide adequate friction. For new pavements these include longitudinal texturing with a burlap drag with smaller top-sized aggregates, longitudinal texturing produced by a combination of brush and comb achieving both a microtexture and a macrotexture, porous asphalt surfacing (this is very common), porous concrete surfacing (the Netherlands), and exposed aggregate surfaces (these are also very common). Noise reduction treatments for existing pavements include a surface layer of epoxy/fine-grained aggregate, a double surface treatment of polymerized asphalt on the surface with two layers of chips, and diamond grinding of a coarse-textured surface.

- Research and Development

Excellent cooperation between government and industry exists in Europe that provides many benefits in terms of increased innovation and implemented research results. Major accelerated field testing of concrete pavements is underway in France that was very impressive. Their circular track is somewhat comparable to the FHWA ALF but is able to provide many more loadings in a shorter period of time. Most European countries appear to be conducting more pavement research than the USA as a percentage of total funding spent on the highway network Significant innovation in pavement design, construction and rehabilitation is apparent in several European countries. Significant efforts are made in several countries to implement research findings. The researcher guides the field implementation along with engineers from operations and industry until the procedure or product is working as intended.

- Engineering Expertise

Impressive groups of experienced pavement engineers exist in most of the countries visited. It appears that it is the general practice for individuals to make their careers in pavement engineering. Many of these engineers have the ability to travel to international conferences and serve on committees (PIARC and TRB).

- Toll Road Financing and Engineering

The Study Tour was very impressed with the French toll road companies. The pavements were in very good condition and the toll road companies appeared to make exceptional efforts to provide a high level of service to toll road users.

Recommendations

Based upon observations during the study tour, the participants urge the consideration of the following points to help ensure world-class pavement structures in the USA:

✓ Commit to continuous improvement of our concrete pavement design, materials, and construction technology and equipment through innovation, research, and training. Increased government and industry cooperative research is urged.

✓ Develop a conceptual design catalog, similar to those employed by European agencies, as a guide to help highway agencies and contractors focus on the best practices. Consider using longer design lives for pavement design.

✓ Establish at the national level a focal point for collecting and disseminating information about pavement technology developments in the United States and other nations, to pavement engineers, researchers, and the construction industry. This effort should include and could be based upon the continuing SHRP effort, and should include a broad-based advisory board.

✓ Construct experimental highway projects to explore the applicability of certain European concepts to the United States. These might include the German JPCP design, and the French coilable reinforcement in CRCP. The SHRP SPS-2 effort might be employed for at least some projects.

✓ Organize a continuing training program for pavement engineers from highway agencies and contractors, to improve the design, construction, and maintenance of concrete pavements.

✓ Encourage closer interaction among highway agency engineers, consultants, researchers, industry, and contractors, to promote excellence in concrete pavements.

# SI* (MODERN METRIC) CONVERSION FACTORS

## APPROXIMATE CONVERSIONS TO SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | **LENGTH** | | | |
| in | inches | 25.4 | millimeters | mm |
| ft | feet | 0.305 | meters | m |
| yd | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |
| | **AREA** | | | |
| $in^2$ | square inches | 645.2 | square millimeters | $mm^2$ |
| $ft^2$ | square feet | 0.093 | square meters | $m^2$ |
| $yd^2$ | square yards | 0.636 | square meters | $m^2$ |
| ac | acres | 0.405 | hectares | ha |
| $mi^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | **VOLUME** | | | |
| fl oz | fluid ounces | 29.57 | milliliters | ml |
| gal | gallons | 3.765 | liters | l |
| $ft^3$ | cubic feet | 0.026 | cubic meters | $m^3$ |
| $yd^3$ | cubic yards | 0.765 | cubic meters | $m^3$ |

NO1'E: Volumes greater than 1000 l shall be shown in $m^3$.

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | **MASS** | | | |
| oz | ounces | 26.35 | 9 - s | 9 |
| lb | pounds | 0.454 | kilograms | kg |
| T | short tons (2000 lb) | 0.997 | megagrams | Mg |
| | **TEMPERATURE (exact)** | | | |
| °F | Fahrenheit temperature | 5(F-32)/9 or (F-32)/1.6 | Celcius temperature | °C |
| | **ILLUMINATION** | | | |
| fc | foot-candles | 10.76 | lux | l |
| fl | foot-Lamberts | 3.426 | candela/$m^2$ | cd/$m^2$ |
| | **FORCE and PRESSURE or STRESS** | | | |
| lbf | poundforce | 4.45 | newtons | N |
| psi | poundforce per square inch | 6.69 | kilopascals | kPa |

## APPROXIMATE CONVERSIONS FROM SI UNITS

| Symbol | When You Know | Multiply By | To Find | Symbol |
|---|---|---|---|---|
| | **LENGTH** | | | |
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.26 | feet | ft |
| m | meters | 1.09 | yards | yd |
| km | kilometers | 0.621 | miles | mi |
| | **AREA** | | | |
| $mm^2$ | square millimeters | 0.0016 | square inches | $in^2$ |
| $m^2$ | square meters | 10.764 | square feet | $ft^2$ |
| $m^2$ | square meters | 1.195 | square yards | ac |
| ha | hectares | 2.47 | acres | $mi^2$ |
| $km^2$ | square kilometers | 0.366 | square miles | |
| | **VOLUME** | | | |
| ml | milliliters | 0.034 | fluid ounces | fl oz |
| l | liters | 0.264 | gallons | gal |
| $m^3$ | cubic meters | 35.71 | cubic feet | $ft^3$ |
| $m^3$ | cubic meters | 1.307 | cubic yards | $yd^3$ |
| | **MASS** | | | |
| 9 | 9 - s | 0.035 | ounces | oz |
| kg | kilograms | 2.202 | pounds | lb |
| Mg | megagrams | 1.103 | short tons (2000 lb) | T |
| | **TEMPERATURE (exact)** | | | |
| °C | cekius temperature | 1.8C + 32 | Fahrenheit temperature | °F |
| | **ILLUMINATION** | | | |
| lx | lux | 0.0929 | foot-candles | fc |
| cd/$m^2$ | candela/$m^2$ | 0.2919 | foot-Lamberts | fl |
| | **FORCE and PRESSURE or STRESS** | | | |
| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per squareinch | psi |

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 or ASTM E380.

(Revised August 1992)