Interstate 90: For the 1990s and Beyond

First Phase Links Seattle to Bellevue, Washington

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Phase I of the Washington State Department of Transportation's seven-mile-long Interstate 90 between Seattle and Bellevue, completed in June 1989, is an ambitious project representing one-fourth of the unfinished mileage of the transcontinental freeway from Boston to Seattle. The Interstate highway is distinguished by a number of complex elements—a tunnel bored through Mount Baker Ridge; large concrete freeway lids built to reconnect communities, absorb noise, and control air pollution; construction of the Lake Washington floating bridge; and the installation of a sophisticated operation and control system—all carried out without interrupting the daily flow of up to 80,000 vehicles. With a construction cost of $1.464 billion, the project has been selected as one of eight outstanding engineering achievements of the past year by the National Society of Professional Engineers.

Design Engineering Challenges

Mount Baker Ridge Tunnel

Throughout the I-90 project's design, Seattle's Mount Baker Ridge loomed as a major obstacle. Many alternatives were examined to determine the best method to lay the freeway through the ridge, including open cut, cut-and-cover, and bored tunnel options. Because of significant environmental impact, community disruption, and right-of-way acquisition requirements associated with the first two alternatives, the bored tunnel option was selected.

The final design of the tunnel bore evolved over a 10-year period. Feasibility studies, constructibility analyses, and subsurface soil investigations were continually updated and expanded. Local and national experts on tunnel design and construction were consulted.

The result is the largest diameter soft-ground tunnel in the world, which begins at the west side of Mount Baker Ridge and ends near the shore of Lake Washington. The 1,332-foot bored tunnel has a cut-and-cover section of 72 feet at each end.

The tunnel core was excavated through a ridge of glacially over-consolidated clay, silt, and sand using the "stacked-drift" method. A flexible tunnel liner, consisting of 24 concrete-filled drifts, was first constructed to form a horizontal compression ring, followed by removal of the soil core. The bored tunnel has an inside diameter of 63 feet.

Monitoring devices were installed extensively to measure ground movement above and around the new tunnel. Using inclinometers, engineers were able to take weekly readings to measure the amount of horizontal earth movement. A comparison of readings can determine how much the earth is moving, in what direction, and at what speed. For some severe cases, measurements can be taken daily. Although up to 12 inches of settlement over the tunnel was considered acceptable, actual settlement over most of the tunnel was 2 inches or less. No damage occurred to structures over the tunnel or to the adjacent twin highway tunnels that remained in service.

The tunnel's interior structure accommodates three levels of traffic. It provides a 15-foot-wide bicycle-pedestrian concourse at the top, with the three westbound I-90 lanes on the center level. When the project is completed, the lower level will be used as a reversible roadway for buses and carpools. Eastbound traffic currently uses this roadway.

Freeway Lids

Massive concrete lids, or covered roadways, span the width of the highway in three locations, virtually eliminating freeway noise in the adjacent neighborhoods. Vehicle exhaust emissions from the lid areas are collected and dispersed high above these communities.

When the original roadway was built through Seattle and across Mercer Island in the late 1930s, its alignment severed a number of communities in its path. As work on the I-90 project progressed, residents saw an opportunity to reunite these areas. After considerable community discussion, it was decided that parks and recreation areas would be added on top of the lids to bring old neighborhoods together again.

Operation and Control System

The Washington State DOT has been implementing a region-wide surveillance, control, and driver information (SC&DI) system to facilitate efficient and safe operation of the freeway network in the Seattle area. The SC&DI system consists of ramp controllers, electronic surveillance, gates (for the center roadway operation), variable message signs, emergency telephones,

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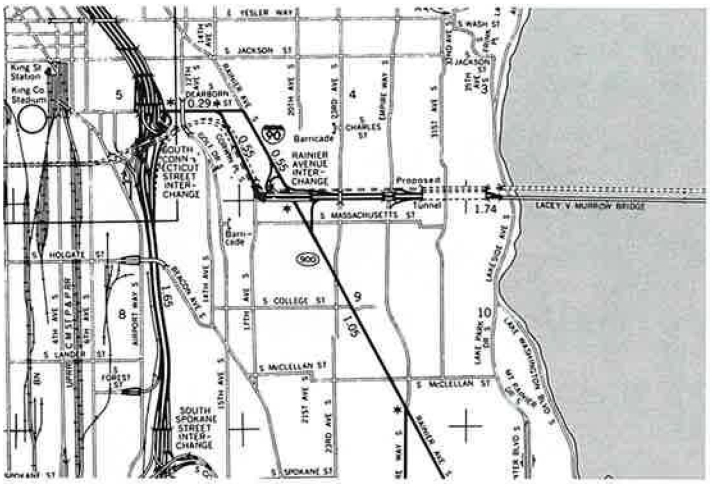


highway advisory radio, and closed circuit television. All of these components are being integrated into a single system through a computer to be installed at the Traffic Systems Management Center (TSMC) in Seattle. Although the entire SC&DI system will not be in operation until the completion of Phase II of I-90 some time in 1992, portions of it are now in operation.

This computer control system requires only one tunnel operator. Video cameras are used throughout the system to monitor traffic flow, and traffic detectors embedded in the roadway provide traffic data and an alarm in case of traffic blockage. Video recording is also used. Variable message signs at the portals present motorists with information and directions.

Radio reception is enhanced in the tunnel and lid complexes by rebroadcast systems, which include emergency, municipal, and maintenance frequencies as well as local AM and FM stations. For stranded motorists, telephones for emergency help are available within 300 feet.

A zoned, foam sprinkler system provides roadway fire control in the lids and tunnels, operating in conjunction with tunnel fan controls. Fire extinguishers and fire hydrants are available throughout the corridor, and emergency exits within the tunnel and lid allow for emergency evacuation.

Lake Washington Floating Bridge

There are five concrete floating bridges in the world, four of which were designed and built by the Washington State DOT. The original alignment of I-90 includes the first of these, the Lacey V. Murrow floating bridge, built in the late 1930s. This bridge will be incorporated into the completed I-90 roadway, but adjacent to it is a brand new I-90 floating bridge, as yet unnamed.

This type of span was selected for I-90 for several reasons. Lake Washington is nearly 1.5 miles wide and more than 200 feet deep at the bridge site, with a soft sediment layer on the bottom that is up to 200 feet thick. The sediments have little bearing capacity, making conventional substructure construction expensive. Under these conditions, a floating bridge is the most cost-effective design, costing about half as much as other types of bridges.

The new I-90 floating bridge is divided into three distinct structure types: the approaches, the transition spans, and the floating structure. The approach structures are cast-in-place box girders. The west approach is 1,364 feet long, and the east approach is 1,972 feet long. The segmental portion over the water was built using a balanced cantilever method, with a segment length of approximately 17 feet. The approaches are actually four individual bridges. The land piers are on spread footings. The water piers are supported by 500-ton, 48- and 52-inch steel pipe piles; the maximum depth of water in which the piles were driven was approximately 90 feet.

Two transition spans link the floating to the fixed structure. Each is approximately 200 feet long and consists of five 8-foot-deep trapezoidal steel box girders with a composite concrete deck. The spans are fitted with spherical bearings. Two of the world's largest expansion joint systems were required to accommodate the vertical, horizontal, and torsional movements of the floating structure.

The floating portion of the bridge is made up of 10 standard pontoons and 8 pontoons with elevated roadways. The standard pontoons are 354 feet long and 75 feet wide. Because there were no graving docks on Lake Washington for constructing the pontoons, they were built at two sites on Puget Sound—in Everett (38 water miles to the north) and in Tacoma (46 water miles to the south). The width of the pontoons was governed by the width of the locks on the Lake Washington Ship Canal, which connects Lake Washington to the Puget Sound.

After the pontoons were floated through the locks and into place on Lake Washington, cantilevers were added to each side to accommodate the 105-foot width of the roadway and pedestrian walkway. The elevated portion of the roadway was also added. The elevated superstructure consists of trapezoidal steel box girders with composite concrete deck supported by concrete cross beams and columns.

The entire floating section is held in position by an anchor cable system. Forty cables prevent the pontoons from moving sideways and an additional 12 cables are used to hold the bridge in the longitudinal direction. Anchor cables are 2-3/8 inches in diameter, with a breaking strength of 334 tons. Each cable is attached to an anchor that holds it to the lake bottom. Reinforced concrete fluke anchors are used where the soil is soft and anchors can be excavated or jetted into the lake bottom; tandem steel I-beam pile anchors are used in shallow water where the soil is hard; and gravity anchors (reinforced concrete boxes filled with gravel) are used where the soil is too hard for jetting and too deep for pile driving.

The pontoons are joined with 2 1/4-inch diameter bolts to form one continuous structure. The superstructure pontoons are held together with posttensioning strands. The pontoons have been compartmentalized to resist progressive failure caused by flooding.

The old and the new I-90 floating bridges are approximately 75 feet apart.

The area between the two bridges serves as a drainage basin. A specially designed boat serves as an oil skimmer and trash remover to keep the lake clean at this site. With a look to the future, the new I-90 floating bridge has been designed to accommodate a light rail transit system, should the decision be made to build one along this alignment.

Retaining Walls

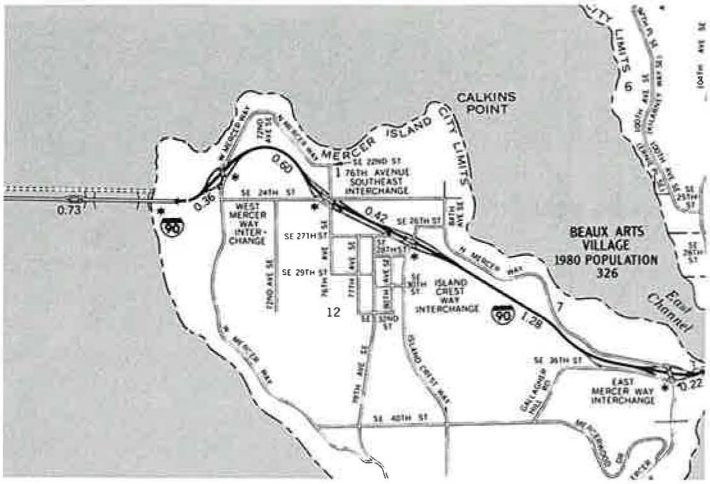
There are approximately 21 miles of retaining walls along the I-90 corridor. By far the most challenging problem in designing these systems was how to meet the requirements imposed by the difficult ground conditions along the entire seven-mile length of the project.

The predominant terrain in Seattle and on Mercer Island consists of a series of north- and south-trending ridges and valleys. The area has been glaciated at various times in the past, producing a hodgepodge of soil conditions. These conditions change dramatically over short distances.

The valleys are filled with recent deposits of colluvium, a weak, variable soil. The ridges are composed of lacustrine clays with locked-in stresses and fissures intermixed with water-bearing sand layers. A large portion of the soils is weak and prone to movement if any existing condition is altered.

To solve these soil problems, meet earthquake standards, and provide a margin of safety, the DOT used a variety of wall types and designs. In areas where only noise or access control was required, a precast, tilt-up wall was used. There were also many areas where standard cantilever walls could be used if special attention was paid to foundation design. Other areas required special design walls. These wall types include tie-back soldier pile, slurry, cylinder pile, tangent pile, construction fabric, and reinforced earth.

To ensure that these details were applied uniformly and consistently throughout the project, all of the items were collected in an architectural standards manual. This manual was provided to all designers involved in the project.

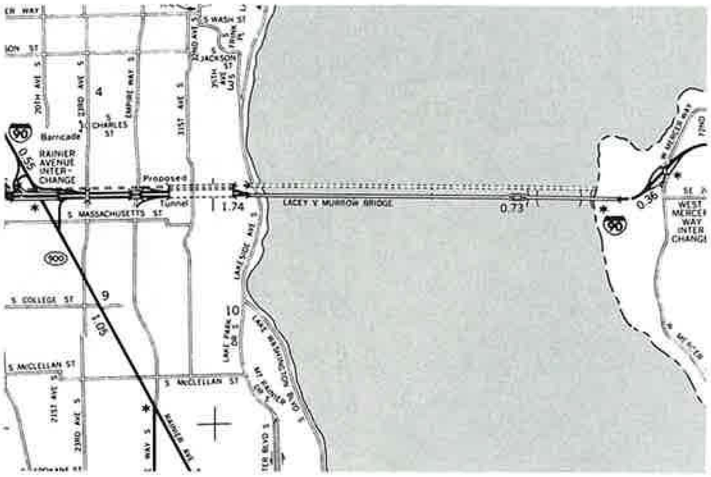


The top of the wall was designed to be level, with changes in elevation accomplished with vertical steps rather than by sloping the top of the wall. Horizontal alignment was attained by using tangent sections with angle points of 45, 60, or 75 degrees rather than curves. The alignment was designed to create planting areas of different sizes and shapes without making the wall appear too bulky.

The walls were also designed as a system, using in some cases a series of up to three smaller parallel walls rather than one large one. To solve the problems of noise and access control, the walls were extended 3-1/2 to 4-1/2 feet above ground, rather than the normal 1 to 2 feet. In areas in which there was a problem with noise, the wall was extended to the elevation required to reduce its impact.

When the structural portion of the walls was completed, a fascia wall was constructed to provide aesthetic details. A batten texture was cast into the exposed roadway face of the walls. The entire wall and bridge system of the I-90 project were finally coated with an earth tone pigmented sealer to eliminate the institutional concrete color and to provide color uniformity throughout the I-90 alignment.

I-90 Seattle access.



Project Management Challenges

Multidisciplinary Team

The goal in developing the I-90 project was to design and build a safe, convenient highway that was acceptable to motorists and neighboring communities alike. It was clear that such a goal would require the skills of specialists from many disciplines, but a project of such magnitude could monopolize DOT engineers so that little else could be accomplished. It was therefore decided to divide the project into three sections and hire three consultant teams to provide the preliminary engineering. These teams were composed of civil, electrical, mechanical, and structural engineers, architects, environmental experts, landscape architects, and artists.

Design Review Board

The department also established a design review team, consisting of a bridge architect and a landscape architect from the department, as well as a private architect to coordinate all the visual aspects of the project to ensure uniformity of design throughout the seven miles of the new roadway.

As the preliminary design neared completion, each high-cost section was value engineered—in all, more than $717 million worth of project elements—resulting in $115 million in savings. The most notable accomplishments were

- Interstate 5 to Corwin Place. This stretch of I-90 was completely redesigned through the value engineering process, resulting in a cost saving of more than $50 million.
- I-90 Floating Bridge. Savings of more than $13 million were accomplished by extending the approach structures and adding 15-foot posttensioned wings on the pontoons, which allowed passage through the locks on the Lake Washington Ship Canal.
- Interim Roadway. An interim roadway was designed and constructed on Mercer Island to be used while the permanent westbound and center roadway were under construction. This resulted in a savings of $600,000 by eliminating the need for multiple traffic switches and preventing deadly head-on collisions that occurred on the original alignment.

The project was then parceled into multiple contract packages, which were turned over to more than a dozen consultants to prepare contract plans. Detailed design began in earnest in 1983. Again, each consultant formed a team with all necessary disciplines fully involved in the process.

DOT staff members and the architectural review committee maintained full control to ensure that the design was cost-effective, all mitigation commitments were met, the project's visual continuity was carried through, all project components were integrated, and the project could be

built within the time frame established. A management team was assembled to coordinate and oversee these steps.

In May 1984, a project management contract was awarded to a joint venture of Morrison-Knudsen Engineers Inc. of San Francisco and H. W. Lochner Inc. of Chicago (referred to jointly as "M/K-L"). M/K-L evaluated the construction plan, estimate, and management structure.

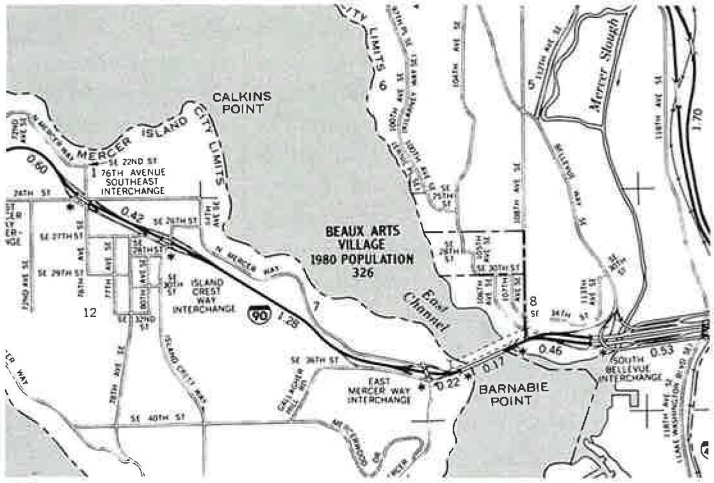
The DOT I-90 Management Team is headed by a project manager who is supported by a design manager, a construction manager, an operations manager (responsible for cost and schedule tracking), and M/K-L. The management team oversees 12 project offices (design and construction).

To further expedite decision making and approval, a management review board was established with voting members from the I-90 management team, the state's assistant secretary for highways, and the area representative for the Federal Highway Administration. The management review board approved any large changes required and reviewed any problems encountered in the project. No management process can be successful, however, unless the contractors are provided the information and tools they need to operate effectively and efficiently.

Pre-Bid Procedures

With so many complex, specialized pieces of the I-90 project, it was apparent that certain specific contracting methods would have to be used to control costs. The Mount Baker Ridge tunnel bore contract became the testing ground for such contract features. These contracting methods and procedures were:

- Contractors had to be prequalified to receive copies of the contract plans;
- Pre-bid conferences were conducted;
- A test tunnel was dug to allow observation of actual strata; and
- All design, preliminary engineering, and geotechnical studies and calculations were fully disclosed to bidding contractors.



Contract Management Provisions

Contract provisions were also reviewed for ways to reduce bid costs and better control time and cost overruns. The methods used generally fell into the two categories of shared liability and claims management. The DOT agreed to share liability on some contracts by assuming material and labor cost escalation caused by inflation, repairing damaged city streets and any settlement damage above the Mount Baker Ridge Tunnel resulting from up to one foot of settlement. Additionally, the department purchased such long-lead items as tunnel fans, tunnel luminaires, tunnel control panels, and computers.

To keep construction claims to a minimum, the following methods were employed, which contributed to the completion of this project on time and within budget:

- Dispute review boards were established on all large contracts,
- Contractor bid documents were required to be placed in escrow,
- Critical path method scheduling requirements were established,
- End-product specifications were established on some items,
- Cost-reduction incentive proposals were encouraged,
- Liquidated damages were set high enough to cover actual state costs should a delay be caused by the contractor, and
- Incentive pay was used for some critical items if they were completed early.

In June 1989 traffic was switched onto a completely new roadway—four lanes for westbound traffic (one of which is a transit-carpool lane) and three lanes for eastbound traffic. When Phase II is completed in 1992, the freeway will still carry three lanes of general traffic in each direction. The eastbound traffic currently uses the center road (lower level of tunnel), which will ultimately be converted into lanes for transit and carpools.

Opening ceremonies for I-90's Phase I took place in June. Phase II—in some ways an even greater challenge—will encompass construction of three eastbound lanes south of the center roadway, completion of the lids on Mercer Island and in Seattle to cover the new eastbound lanes, and refurbishing of the Mount Baker Ridge tunnels. High winds and floodwater recently caused sections of the original Lacey V. Murrow Floating Bridge to sink. Discussion now centers on whether the 50-year-old bridge can be salvaged or whether a new bridge will be constructed in its place.

The I-90 project has called for a diverse, multidisciplinary team to address immense challenges: political, geographical, environmental, geotechnical, and societal. The design response to these challenges has created a freeway that not only meets a critical transportation need but also enhances the surrounding communities.

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Mercer Island Roadway.