Design-Construction Feature

The Pasco-Kennewick Intercity Bridge

Arvid Grant
Principal Engineer
Arvid Grant and Associates, Inc.
Consulting Engineers
Olympia, Washington

The author describes the planning, design considerations, quality control program, and construction techniques involved in building the 2503-ft (763 m) long Intercity Bridge. This structure is the largest precast prestressed cable-stayed bridge built in North America.

The recently completed Intercity Bridge (Fig. 1) crosses the Columbia River in Washington State, and connects the central areas of the cities of Pasco and Kennewick (Fig. 2). The new bridge, a half mile (nearly a kilometer) of concrete ribbon suspended over the Columbia from sloping stay cables, replaces an obsolete 56-year-old, narrow steel truss structure.

The new structure is a local government project, sponsored by the two small cities with the assistance of and partial funding by the Federal Highway Administration, U.S. Department of Transportation. Project planning began in 1972 and the work was dedicated to public use in September, 1978.

Total project costs were $30,000,000 of which $22,000,000 went for con-

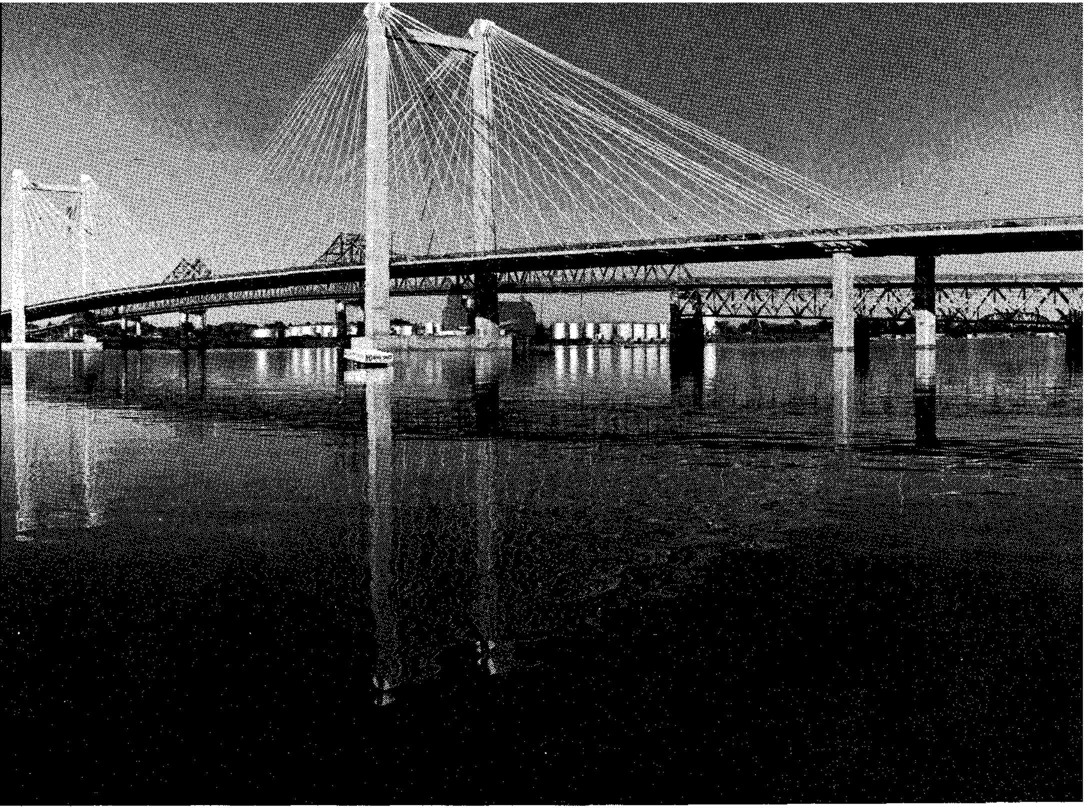


Fig. 1. The Intercity Bridge. At 2503 ft (763 m), it is the longest cable-stayed bridge in North America.

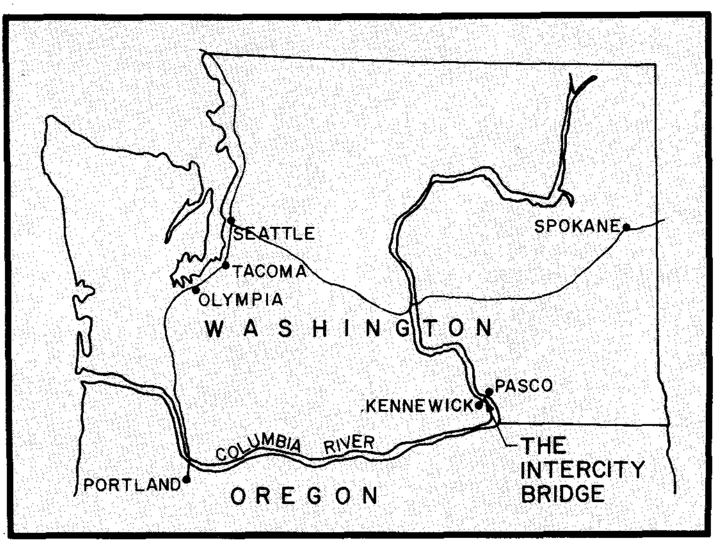


Fig. 2. Location of Intercity Bridge.

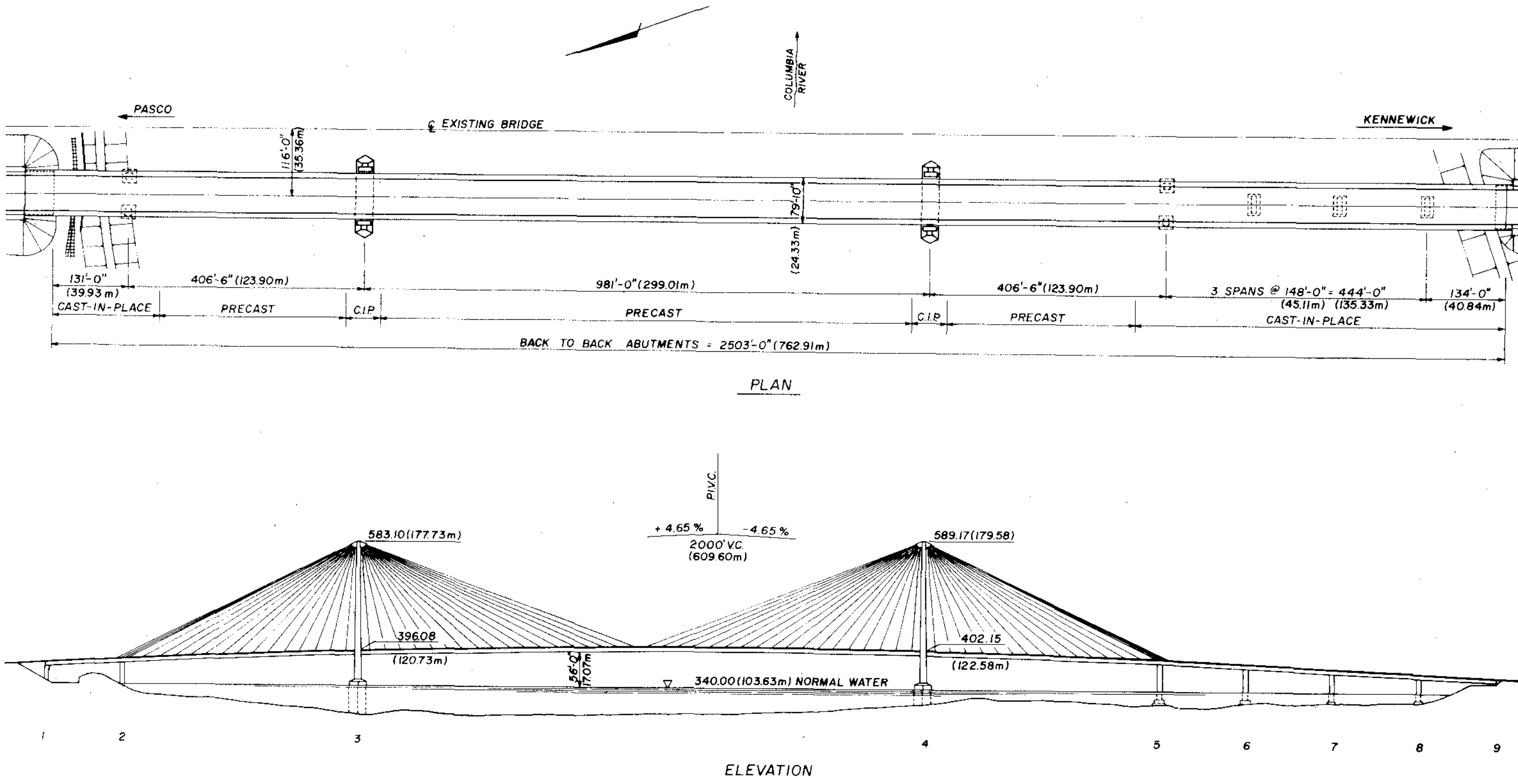


Fig. 3. Plan and elevation of intercity Bridge.

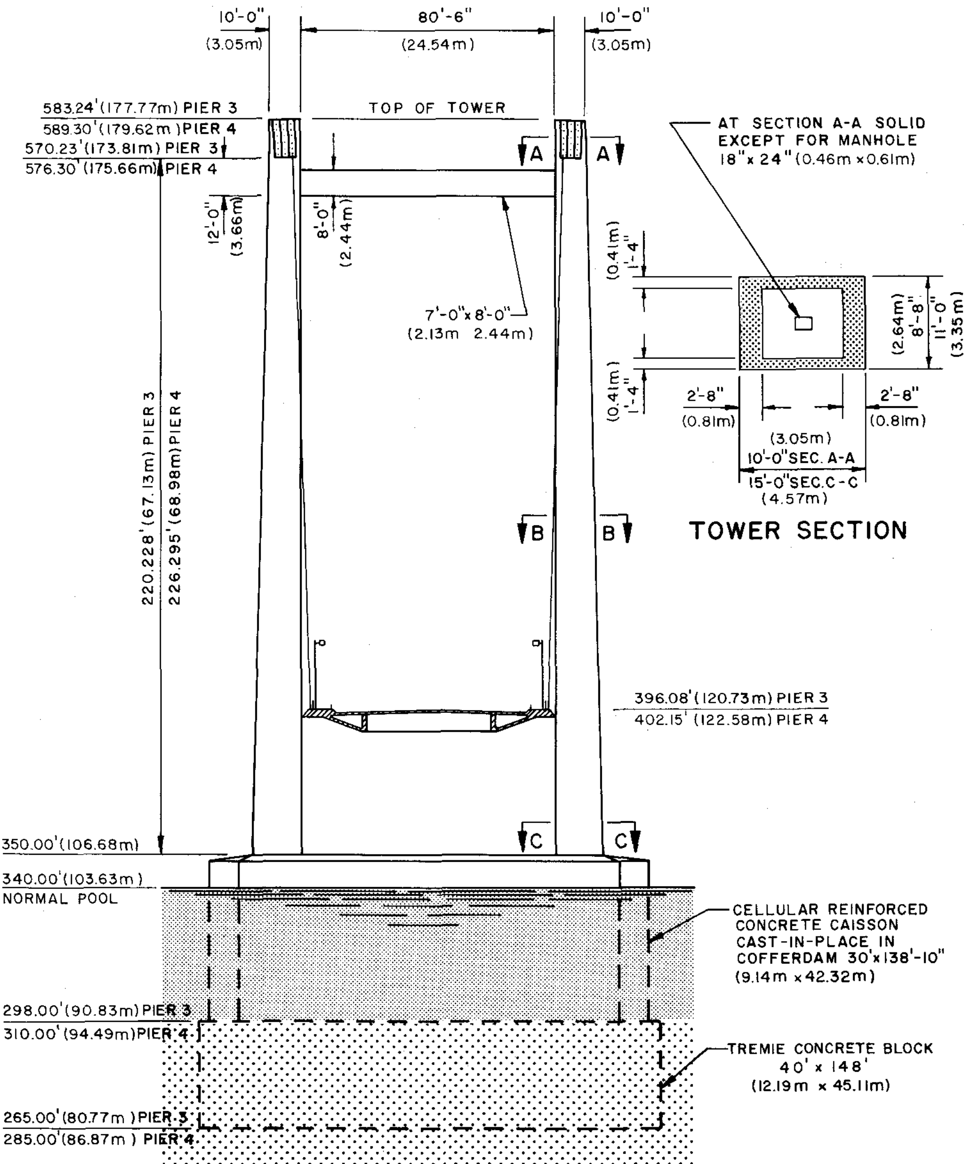


Fig. 4. Elevation of one of two twin towers, showing cross section of roadway girder, foundation, pylons, and the cable supported by the tower-top anchorage.

struction of the bridge. This amounts to about \$112 per sq ft (\$1206 per m^2) for the bridge.

The new bridge is 2503 ft (763 m) long, 80 ft (24 m) wide, carrying both sidewalks and four traffic lanes. Main spans are 407, 981, and 407 ft (124, 299, and 124 m). Fig. 3 shows a plan and elevation of the structure.

The bridge girder, structurally continuous along its entire length and suspended over 1794 ft (547 m) of its length, is assembled from large, separately precast, prestressed concrete

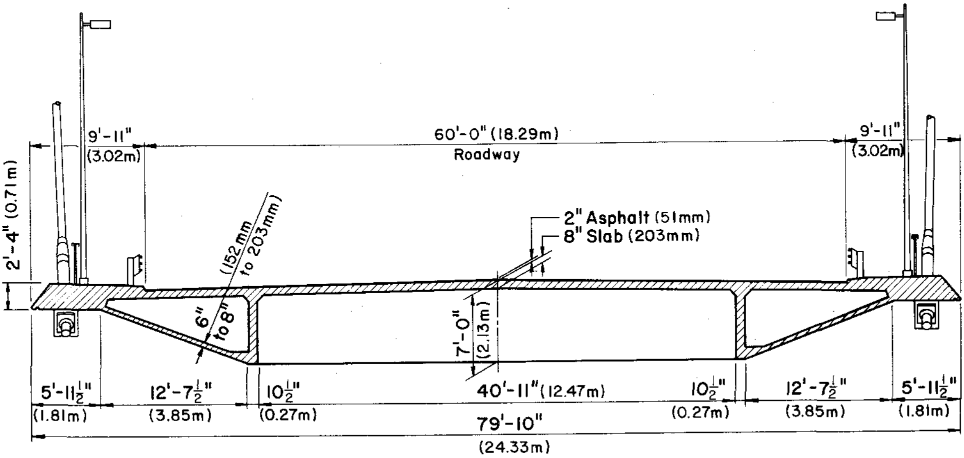


Fig. 5. Cross section of precast bridge girder element.

elements. Fig. 4 shows a section of the twin tower and Fig. 5 is a typical cross section of a precast concrete element.

Sixty-two bridge girder elements, 80 ft (211 m) wide, 27 ft (8 m) long, 7 ft (2.1 m) deep, and weighing about 300 tons (272 t) each, were made in a specially built casting yard, transported on the river, and assembled in the bridge system, using specially developed methods and equipment.

Planning the Project

The Columbia River in Washington State is wide and deep. In 1954, McNary Dam began operating downstream from the project site, raising the river level some 25 ft (7.6 m), making it more difficult to build bridges over its backwater pool.

The navigable river below required clearances for barge trains and tugs, and for recreational traffic. The high river level (same as the natural ground in both cities on each side) mandated rather steep vertical grades for approaches after the proper allowances for clearances, and for the depth of the structure proper.

To determine the best bridge design for this location, one had to review the state-of-the-art as it was practiced locally, and attempt to organize a solution that would best fit all constraints—geometry of the site, deep water, foundation soils, hydraulics of the river, needs of the project sponsors, and financial limits of the sponsors.

All known bridge systems were studied, and rated for their applicability. New rather sophisticated bridge building methods that had been developed in Europe were studied in depth and analyzed. In addition, some new bridge systems were planned and analyzed. The search for a design solution thus contained a comparative evaluation of:

- Steel plate girder spans.
- Segmental cast-in-place concrete girder bridges.
- Segmental incrementally launched concrete girder bridges.
- Steel box girder cable-stayed bridges.
- Segmentally assembled prestressed concrete cable-stayed bridges.

After review of the preliminary design findings, the two city councils chose the concrete cable-stayed bridge because:

1. They liked the design concept and the appearance of the structure.
2. The solution offered the least number of large piers in the deep river, pointing towards economy.
3. The design offered the flattest vertical grades for approaches, pointing towards greater operational safety.
4. Most of the work was to be of a local material, namely, concrete; thus the project would be less subject to market and materials price fluctuations elsewhere.

This choice mandated a complete integration of prior experience with steel cable-stayed bridge systems, local concrete technology competence, industrial organization and engineering management talent, and engineering planning, analysis, guidance and control to achieve a bridge that would be economical, functionally correct, and durable.

Cable-stayed bridges are economical for longer spans than girder bridges. They differ from the classical suspension bridges in their cable geometry, and the structural action. The cables are sloping; they are very stiff, and they dissipate all anchorage forces in the bridge girder proper rather than in special anchorages needed for suspension bridge main cables. The anchorage force dissipation in a bridge girder results in a longitudinal compressive force in the girder—tolerable if the bridge girder is steel, but beneficial if the bridge girder is concrete.

Concrete cable-stayed bridge girders are very heavy, more difficult to build than steel girders and require considerably different design provisions and treatment. No cable-stayed concrete bridge of similar size and type had been built before in North America.

Design Considerations

Non-traditional elements of the design are:

1. A slender beam on many yielding supports.
2. Simultaneous structural behavior in all three coordinate planes.
3. Dynamic and aerodynamic response to excitations—wind, vibrations, shocks.
4. Dimensional predictability and control requirements much higher than for ordinary concrete structures (all varieties).
5. Interdependence of structural arrangements and details with the details and methods of assembly and erection.

A simple system was developed, consisting of a concrete roadway slab, supported on transverse beams on 9-ft (2.7 m) centers, and held together in a thickened edge, able to assume the stay-cable anchorage stresses (Fig. 6). The 9-ft (2.7 m) transverse floor beam module was extended into a 27-ft (8 m) module for stay-cable anchorage spacing along the girder edges. Accordingly, the precast girder element size was also set at 27 ft (8 m).

While the analytical work necessary for verification and refinement of concepts and work details required large and complicated mathematical models, the end result is very simple in appearance and in its structural action. The structure has very low amplitude of stress fluctuations throughout all service modes.

In no loading condition do the structural concrete and steel exceed 45 percent of their stress capacity. The stress fluctuation amplitudes are less

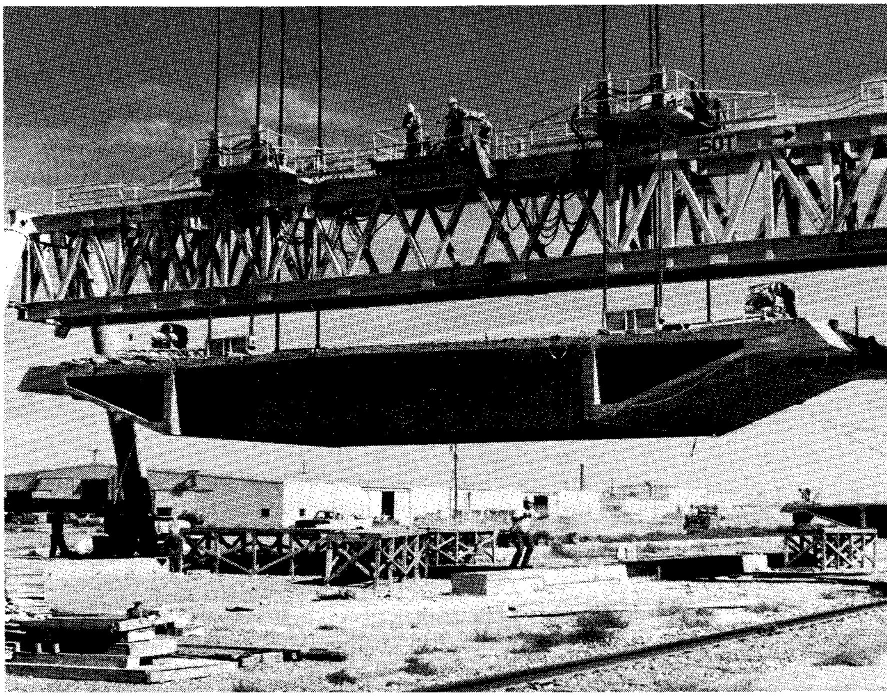


Fig. 6. Typical 300-ton (272 ft) precast girder element [80 ft (24 m) wide and 7 ft (2.1 m) deep]. An 8-in. (203 mm) roadway slab was placed on transverse beams on 9-ft (2.7 m) centers.

than 10 percent of the material stress capacity throughout; thus assuring little probability for onset of fatigue and insuring durability.

There are 144 stay cables, arranged in two planes, held at the tops of the two main pier towers in special welded steel tower-head assemblies, and anchored at 27-ft (8 m) intervals along both edges of the concrete girder.

With this structure a new bridge cable is being introduced into United States bridge practice. The cables are made up of ¼-in. (6.4 mm) diameter steel wires, as used for prestressing concrete, arranged into straight bundles. The number of wires in each cable of this bridge varies from 73 to 283, depending upon cable location and load.

Cables have a specially developed anchorage assembly at each end (Fig. 7). The wire bundles are encased in polyethylene pipes, and after installation the space between the steel wires and the pipe wall is filled with portland cement grout for protection against corrosion.

The high amplitude (Hi-Am) cable anchorages were developed in Germany and Switzerland for reducing the probability of fatigue failure. A full-sized cable specimen was fatigue-tested at the University of Texas laboratories before being adopted. Test results showed that no loss of strength or signs of fatigue occurred.

In order to obtain the necessary structural behavior, the correct distribution of stresses in the structure in its final, assembled state, and the cor-

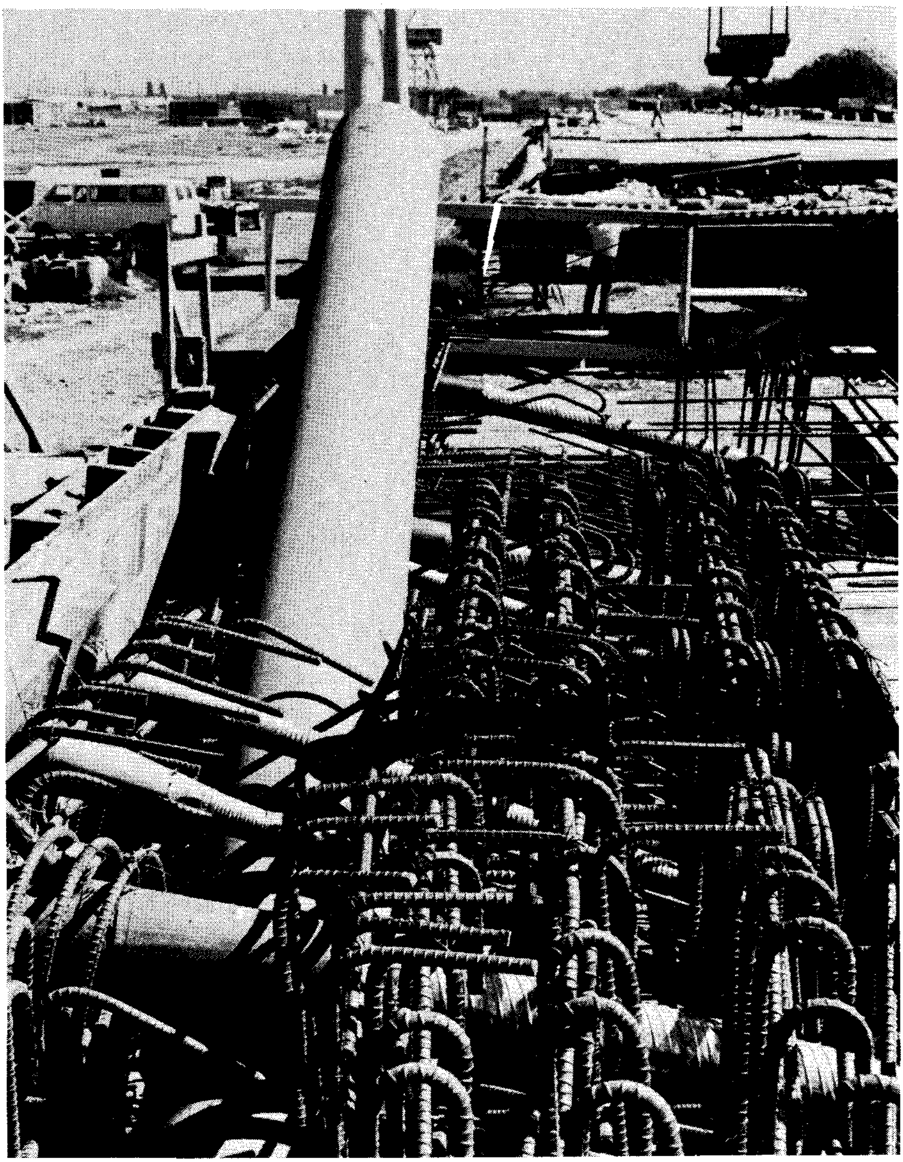


Fig. 7. Reinforcement detail and cable anchorage zone at girder elements edge. Post-tensioning tendon ducts surround the precisely set cable anchorage tube.

rect geometry, it was imperative that the cables and all of their appurtenances be manufactured to their precise fixed length and configuration before assembly.

The same rigid requirement applied to the 300-ton (272 t) precast concrete elements because they had to make up a straight bridge roadway with the proper amount of vertical curvature. All dimensional changes occurring before, during and after assembly had to be anticipated and provided for in the design.

The concrete girder is arranged to distribute vehicle loads through its supporting system, and to allow wind forces to pass without producing undue excitations (vortices). The stay cables (long, slender and stiff members) are subject to wind excitations which cause vibrations.

The cables are designed, however, to minimize or preclude vibrations, containing stiff neoprene damping inserts near the anchorages. The result is that, while in a partially completed state the cables could be excited by a light wind, in their finished state they do not vibrate visibly. The wind passing the girder shape attaches to it rather than separating to generate impulse producing vortices.

The 2503-ft (763 m) long bridge has only one expansion joint to provide for all temperature change and other necessary movements. The girder is freely suspended between the main pier towers (not connected or directly supported); however, it is fixed on the large abutment at the northerly end. If a longitudinal acceleration (such as an earthquake force) greater than that provided for in the design should occur, the vertical steel rods in the fixed bearing will fail in shear.

In its fixed condition, the bridge girder has a natural frequency of about 2 cycles per sec; upon release of the horizontal restraints, the freely suspended girder will obtain a natural frequency less than 0.1 cycles per sec, making it insensitive to further accelerations.

It was necessary during the design phase to develop the erection method of the structure, to predesign and to predimension the erection equipment and their appurtenances, to include all of their effects in the design development reasoning and analyses, and to so advise the prospective bidders. The contract plans contained the designer's assumed erection procedure and structural details.

Quality Control of Concrete

Concrete is the primary structural material in the bridge, accounting for 99 percent by volume of all structural elements. The choice of concrete was dictated by both engineering economics and system characteristics. Excellent aggregate for making concrete is abundantly available in the Northwest, and is less susceptible than other materials to price fluctuations. The cable-stayed system's built-in compressive stress improves concrete strength and in-service durability.

The concrete structure consists of:

1. Underwater cast-in-place, seals—Class D, footings—Class B, and pier shafts—Class AX;
2. Cast-in-place, towers and approach superstructure—Class PC; and
3. Precast, suspended and superstructure—Class PC.

The total concrete volume placed was 42,000 cu yd (32,100 m^3).

Because it is manufactured on-site, concrete in the structure (not in the cylinders) is only as good as the builders on the site make it. The most critical of all quality control elements are control of the dimensional accuracy of the concrete, concrete quality and consistency of concrete properties. Because concrete is a changing material, detailed consideration was necessary regarding time, loading, and weather-dependent shrinkage and creep effects. For this reason meticulous planning, organization and control of all work was required by the design engineer.

The concrete specifications were designed to minimize creep and shrinkage, to maximize strength and durability, and to insure consistency of properties throughout the structure.

Special provisions for Class PC concrete include:

- f'_c = 6000 psi (41.4 MPa) at 28 days based on cylinder tests.
- Mixing water to be the minimum amount needed for hydration and placement.
- Maximum water-cement ratio of 0.40.
- Maximum slump of 3 in. (76 mm).
- Water-reducing agents to be used.
- No intentional air entrainment.
- A minimum Vebe time of 7 sec.
- Probabilistic strength control standards (e.g., the probability of individual strength tests less than 5500 psi (37.9 MPa) shall be less than 1 in 100).

A very important provision was the requirement of concrete mix development and testing by the contractor prior to approval for use, and commencement of construction. The main variables in the testing were cement types and the various water-reducing agents. Frequent tests were conducted on shrinkage, strength, slump, and workability.

The final selection of the approved mixes was based on the combination of cement content and water-reducing agent which gave the most slump with a maximum 0.40 water-cement ratio. After the testing program, approvals were given and the established procedures were followed throughout the project.

Concrete durability is essential to durability of the structure, an aspect now of much concern in today's concrete structures. The most severely loaded section of the bridge is the roadway slab, particularly the upper 1- to 2-in. (25.4 to 50.8 mm) section. Historically, this section is the most porous and the most susceptible to microcracking. Special attention was given to consolidation and curing of the roadway slab in order to achieve maximum density and minimize shrinkage cracking.

Due to cable geometry, the roadway slab is under constant compression, which increases toward the towers. Where needed, supplemental longitudinal prestress was added to achieve minimum uniform longitudinal prestress of 1200 psi (8.3 MPa). In the transverse direction, a prestress of 300 psi (2.1 MPa) was used throughout the girder. In addition, the roadway was covered with a neoprene and fiberglass membrane, on which an asphalt overlay was placed.

Volume changes were most critical in the precast concrete elements, which required meticulous dimensional control and accurate prediction of creep and shrinkage strains. Control was accomplished by the mix design, dense placement with severe vibration (both internal and external), an overnight steam cure, wet cure of the top slab for 2 full weeks without regard to cylinder strength, and correct provisions for element storage.

A precast element was in the casting yard for an average of 6 months prior to incorporation into the structure. This insured that most of the shrinkage occurred during the storage period reducing the risk of misalignment due to uncontrolled shrinkage after erection.

Elements were supported by continuous concrete footings under the longitudinal web with uniform reactions which prevented warping. Supporting footings were 2 ft (0.6 m) high to permit uniform air circulation for uniform shrinkage. Shrinkage strain prediction was accomplished by assuming a construction schedule, and estimating element age at loading and the duration of loading before side and main span closures.

Analytical parameters included ambient relative humidity, concrete mix design, volume-to-surface ratio, age at loading, and load duration. The results were estimates of shrink strains as a function of time, and of creep strains as a function of time and duration of load. Parameters were updated from geometry control data as necessary to account for actual field conditions.

Quality control was maintained by continuous inspection, routine sampling and testing. Material specifications and testing were according to the Washington State Highway Construction Manual. Tests performed included aggregate moisture, slump, air entrainment, density, and Vebe consolidation tests. To insure aggregate uniformity, stockpile height was limited, and the aggregate watered as necessary.

The results to date indicate that all requirements for strength, durability and geometrical accuracy have been realized:

- Average 28-day concrete cylinder strength of all classes of concrete lumped together, based on a sample size of 727 cylinders, was 7574 psi (52.2 MPa) standard deviation of 606 psi (4.2 MPa), variance 8 percent.
- Slump tested from 2 to 3 in. (51 to 75 mm); water used averaged 95 percent of allowable (water-cement ratio of 0.38), and air entrainment (trapped air) averaged 2 percent.
- The vertical girder profile deviation was well within the planned cable length and stress adjustment amplitudes.
- The maximum horizontal tangential deviation of the superstructure in 2503 ft (763 m) was less than ½ in. (12.7 mm) without any shimming, and not detectable by the human eye.

Construction

For most types of bridges there are traditionally used and proven erection methods. These methods are often modified to fit physical conditions, available equipment and attitudes of the builders. There was no such tradition to build upon for the Intercity Bridge.

The planned and adopted erection process was as follows:

1. Prefabricate the bridge girder elements.
2. Make two sets of large lifting frames.
3. Place those on the initial segment of the girder.
4. Support the entire arrangement by temporary cables from the pier tower top.
5. Cover the contact surfaces with epoxy.
6. Attach them to the previously erected element.
7. Prestress the new element against the prior segment.
8. Allow the epoxy joint to cure.
9. Transfer all of the loads held by the temporary erection cables onto the newly installed permanent bridge cables—two in each newly-erected element.

Loads thus handled were huge. Large stress transfers had to take place, accompanied by dimensional changes caused by the changes in stresses. While most previous bridge assembly methods do permit some on-site improvisation, there was no room for experimentation here at all.

The girder elements were cast in a stationary steel form in a specially built casting yard on the bank of the Columbia River. In order to assure full continuity in the finished work, the element casting occurred in a prescribed sequence. Each element was cast against the previously cast element to obtain perfectly fitting contact

Fig. 8. Girder element match-casting site. The 80-ft (24 m) element on the left is in a stationary steel form.

surfaces (Fig. 8). The geometric relationship between the cast-against element and the form, and provisions for time-dependent and stress-dependent dimensional changes, had to be predetermined and their correctness assured before casting.

Each element used about 150 cu yd (115 m^3) of concrete, placed and compacted in the form without joints or interruptions. In order to reduce the range of expected concrete dimensional changes in the structure due to shrinkage and creep, the precast elements were stored and cured for about 6 months before transporting from the casting yard (Fig. 9).

The girder assembly occurred in a nearly balanced way symmetrically about each pier, permitting one element imbalance. In order to provide for stability on the narrow foundations in the longitudinal direction during girder assembly, the tower tops were restrained by temporary stay cables. The bridge girder assembly required about 6 months at each of the main piers and resulted in about 900 ft (274 m) of freely suspended girder for each. During assembly the stresses in all the cables were monitored for assurance that the process was proceeding as assumed in the design and in the detailed erection stress control calculations.

The girder assembly for both main piers was completed exactly as planned, reaching in its final state the prescribed geometry and condition. No intermediate geometry correction

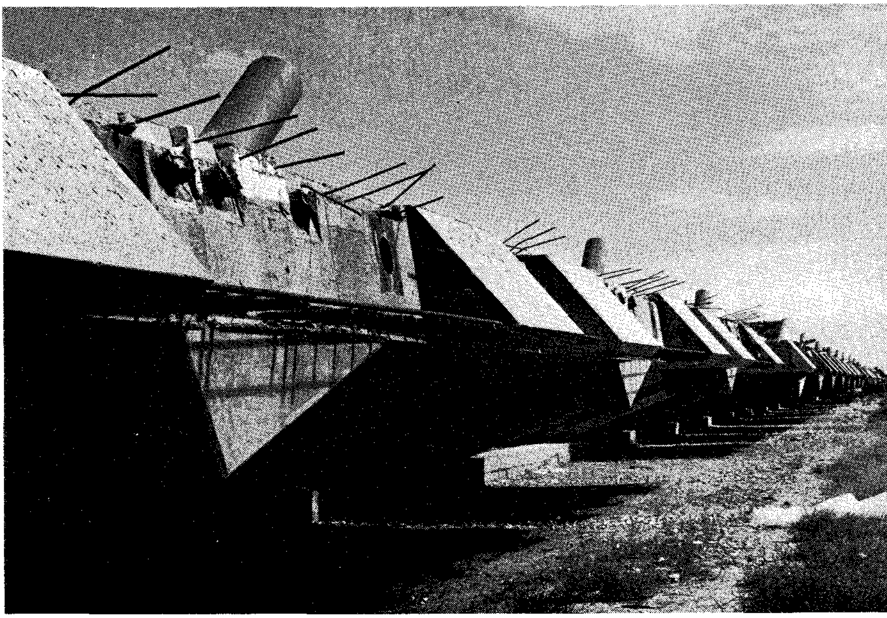
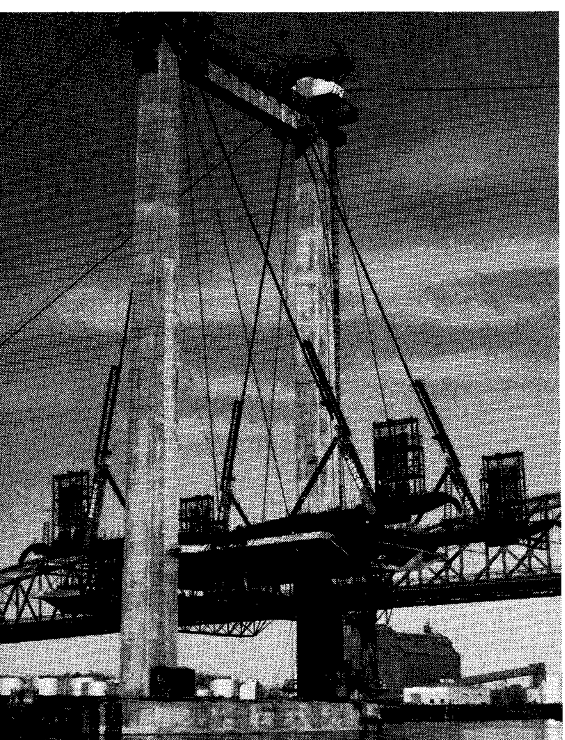


Fig. 9. After 2 weeks of wet cure, the precast girder elements were cured in a storage yard for about 6 months.



processes (such as shims between the concrete surfaces) were necessary or used. There were no accidents, no complexities, and no unforeseen developments or delays.

Throughout the structure assembly process, adherence to the erection stress and geometry calculations and prescriptions was meticulous. From those calculations the contractor developed a detailed process manual with all appropriate checklists for training his field personnel. The approved procedure excluded improvisations, and provided for safety and for correctness of the end result. (See Figs. 10 through 13 for erection progress.)

Fig. 10. Beginning of the suspended girder assembly. Two sets of 120-ton erection equipment were used on the initial section of the girder. The small cables are permanent while the large ones are temporary.

Engineering Highlights

The Intercity Bridge introduces the cable-stayed bridge system to American bridge engineering and bridge construction technology as a large segmentally assembled prestressed concrete system. The European development work with steel bridge systems has been expanded into the prestressed concrete technology, and combined with the necessary complex structural system engineering technology and management ability.

The special, and heretofore not common, engineering features of the completed structure are:

1. The structure was assembled from precisely manufactured components of predetermined size—fixed length steel cables, and very large precast, prestressed concrete girder elements; all with appropriate dimensional allowances for all deformations—elastic, shrinkage and creep —to obtain a finished structure with the correct geometry and initial stresses in all parts. Dimensional and stress control objectives were fully achieved without compensating shims or any other corrective procedures.

2. In order to provide for the utmost in-service structure durability, high quality concrete was required. As built, the average 28-day strength for all concrete was 7600 psi (52.4 MPa) with 8 percent standard deviation. In addition, the girder is prestressed longitudinally to 1200 psi (8.3 MPa) transversely, an average of 300 psi for preclusion of long-term microcracking and ultimate deterioration.

3. Maximum stress fluctuation amplitude in all stay-cables is small, about 7 percent of ultimate strength. The vertical components of the dead load reaction for all support points is practically uniform for the entire length of the girder. Therefore, bending and shear stresses in the girder are very low, and their fluctuation amplitudes for all service conditions are small, providing a great reserve for ultimate in-service durability.

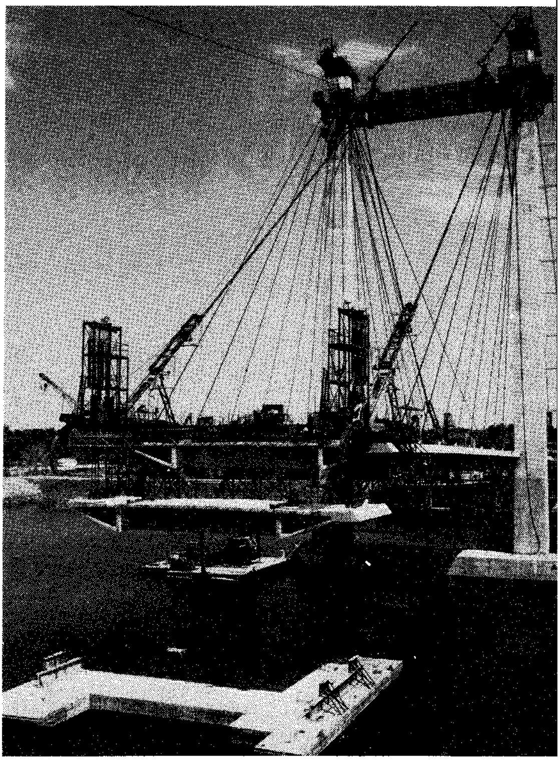


Fig. 11. The 300-ton (272 t) girder element in transit from barge to its final position. Initially, the lift took 6 hrs but later could be accomplished in less than 4 hrs.

4. The structure is insensitive to dynamic loads:

- Concrete is an excellent structural damping material.
- The structural system is non-harmonic and non-resonating—a result of the geometry and the elastic character of the concrete girder and steel cable stays.
- The steel cable stays are not excitable. The polyethylene jacket, the portland cement grout fill and the neoprene grommets at

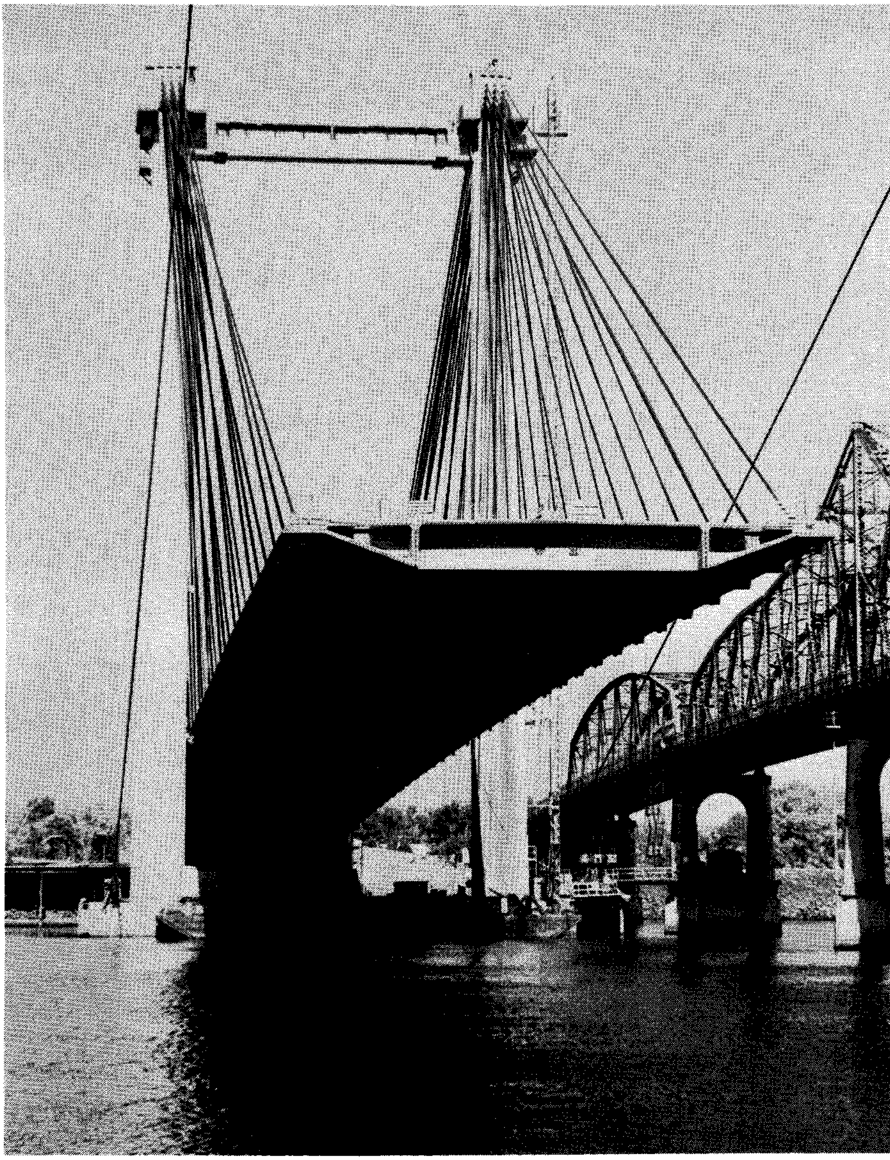


Fig. 12. Pasco half [900 ft (274 m)] of the suspended concrete girder finished. The same process was repeated about the pier near the Kennewick shore.

both ends damp out all vibrations.

5. There is only one bridge expansion joint for the entire 2503 ft (763 m) length. The system's natural period after a large earthquake shock becomes 12 sec, rendering it insensitive to further excitations.

6. Construction costs were the lowest of all major contemporary bridges over bodies of water: \$112 per sq ft (\$1206 per m^2).

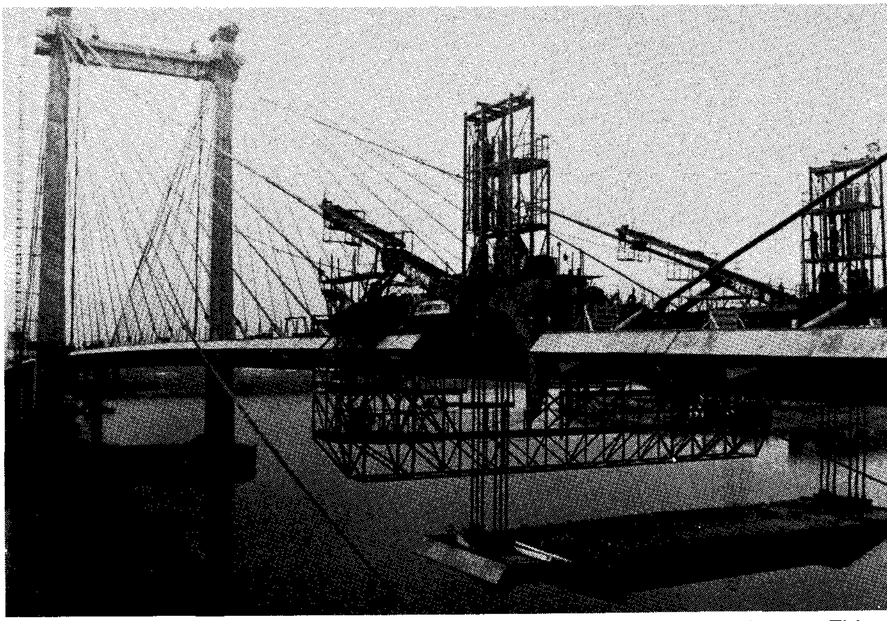


Fig. 13. The last element in the middle of the 981-ft (299 m) span coming up. This operation was the most dramatic time in the entire assembly, which took 1 year to complete.

7. Simplicity was achieved in structural form, geometry and appearance. The correct structural solution resulted in an appearance with good aesthetic quality.

8. Achievement of all of the above required a departure from the traditional construction contracting procedures towards the design engineer's control of construction, similar to the European design-build process.

Table 1 shows the amounts of concrete, cable, prestressing steel, mild steel reinforcement, and epoxy in the completed bridge. Miscellaneous amounts of neoprene, teflon, stainless steel, polyvinyl, asphalts and other materials were also used.

Table 1. Quantities of materials.

Materials used	U.S. units	Metric
Concrete, various classes (in bridge girder)	42000 cu yd	32000 m^3
¼ in. (6 mm) diameter high strength wire in bridge cables	7,392,000 ft (1,400 miles)	2253 km
Prestressing steel	419 tons	380 t
Reinforcing and other steel	2470 tons	2241 t
Epoxy bonding agents	600 gal	2728 l

Chronology of Intercity Bridge Project

July 1968	Pat Thomson, Franklin County Engineer, and member of the Urban Arterial Board, obtains $72,000 UAB grant to perform bridge project feasibility study.
December 1968	Pasco City Council, on behalf of the Cities of Pasco and Kennewick, engages Arvid Grant and Associates, Inc., Engineers, (AGA) to perform a comprehensive bridge project planning study.
July 1969	Councils of the Cities of Pasco and Kennewick accept AGA project Reconnaissance Report, recommending a new 2-lane, steel plate girder bridge adjacent to the present bridge as a first phase.
September 1970	Both Cities pass a General Obligation Bond election to partly finance the work; $2.46 million raised.
October 1970	Ed Hendler assumes chairmanship of 3-man Intercity Bridge Committee.
December 1970	President signs legislation containing Bridge Replacement Act, and providing Federal support for bridge projects.
June 1971	State Highway Commission allocates $1.5 million Federal Urban Aid monies for the project, later partly retracted.
July 1971	FHWA allocates $2.5 million of Bridge Replacement monies for the project.
September 1971	AGA begins data collection for design—old bridge foundation investigations, soil investigation in the Columbia River, topography mapping and other work.
December 1971	AGA authorized to prepare preliminary design for a 2-lane steel bridge; Design study completed May, 1972.
May 1972	Roy Tokerud, FHWA, suggests inquiring into 4-lane structure feasibility.

Closing Remarks

Large public projects, like the Intercity Bridge, require a very long time—12 years or more—from initiation until completion. More than half of that time is consumed by the multitude of administrative procedures to which public projects are subject.

Project Administration and Guidance

Frequently, upon completion of all prescribed administrative processing steps, the sponsoring agency can no longer afford to fund and build the work. This problem was recognized early in the Intercity Bridge project, and circumvented.

The two small City Councils, the sponsors of the work, delegated all administrative authority for this project to a specially appointed representative body—the Intercity Bridge Committee. The Committee consisted of two City Managers and a jointly chosen citizen at large, the Chairman. The two City Councils prescribed policy and made appropriations. The Committee assumed the expedition of

June 1972	AGA authorized to perform preliminary design studies for a 4-lane bridge. Additional Federal monies added to budget. Study completed November, 1972. Of five alternate bridge systems evaluated, Cities choose the cable-stayed prestressed concrete bridge design alternate for implementation.
June 1973	AGA authorized to prepare the final design (contract plans and documents) for the cable-stayed concrete bridge. Design completed September, 1974.
January 1975	DOH, on behalf of the Cities, calls for construction bids. Bid call stopped March, 1975, reissued April, 1975.
February 1975	3-man Intercity Bridge Committee changed to 5-man Committee.
June 19, 1975	Construction bids received. Low bidder, Peter Kiewit Sons' Co.—$23,700,000.
July 1975	Federal Highway Administration allocates additional monies for the project.
July 1975	Construction contract awarded to Peter Kiewit Sons' Co., Construction begins August, 1975.
July 1976	Pier 3 foundation completed.
February 1977	Pier 4 foundation completed.
March 1977	First 300-ton bridge girder element lifted and erected.
September 1977	Assembly of Pasco half of bridge girder completed.
March 1978	Kennewick half of the bridge girder assembly completed with lifting of the last 300-ton girder element in the middle span. 62 precast concrete elements lifted and incorporated in the bridge girder.
May 1978	Structural assembly of bridge completed.
September 1978	Bridge approaches completed. Work dedicated to public.

all administrative procedures. The Engineer, who reported to the Committee and its Chairman, and only occasionally to the two Councils, was given all support and assistance as and when necessary.

No objections or resistance came forth from any citizen organizations and groups.

The objectives of the Committee, its Engineer and the two cities prevailed: minimum time was lost for nonproductive administrative processes. The project budget was protected, and the project implemented within the budget, and within the allotted time.

Aesthetics and Public Acceptance

Structural system planning and design does not occur by searching for striking architectural or sculptural expression. The structure design problem, if solved correctly, expresses the flow of loads through the structural system. The system that provides for the correct flow of loads thus has a form; that form communicates its purpose, and the work it does, to the viewer. There is much room for resourcefulness, wit and elegance in providing for a flow of loads through a

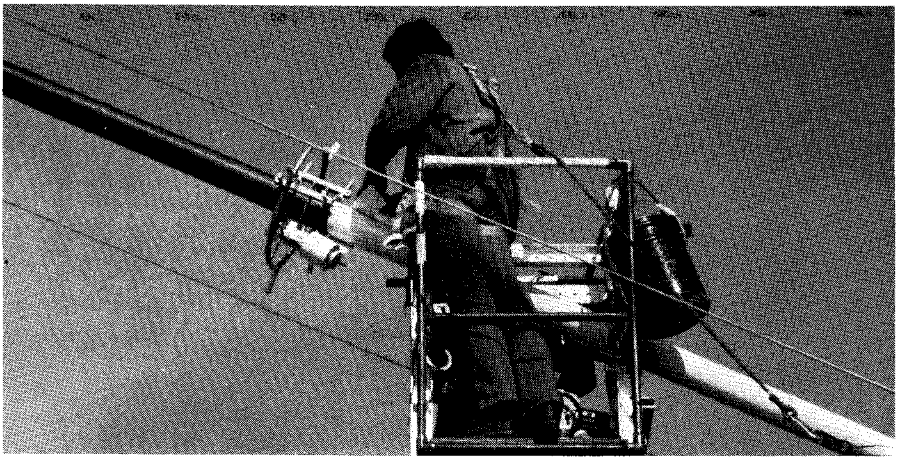


Fig. 14. The 144 cables were wrapped in white plastic to reduce thermal shock and to enhance their appearance, an example of engineering and aesthetics working together.

responsive structural system. This is the domain of the structural designer.

The viewer who—not knowing of the many routes of reasoning, the multitudes of analyses, and the sequence of design decisions necessary and used to arrive at the final, simple whole but feeling and sensing the strength of the order and logic displayed in the work—may find it in agreement with his own feelings and may subconsciously or consciously conclude that the work is aesthetically acceptable.

Good design is always simple—in fact, an engineer's design is not complete if it contains elements that are not needed. This principle was strictly followed while planning the Intercity Bridge (Fig. 14). Appreciation of the aesthetic value of the bridge have been expressed by many as in the article by Barbara E. Gurth reprinted following this paper.

The now-abandoned old bridge was used to its full capacity, carrying 14,000 vehicles per day. During the first week of operation of the new bridge, the vehicle volume rose to 19,000 vehicles per day. Two months later, the average daily traffic volume was well over 20,000, indicating the practical, as well as the aesthetic, success of the bridge (Fig. 15).

Awards for Intercity Bridge

- Consulting Engineers Council of Washington, Grand Conceptor Award (1979).
- ASCE Pacific Northwest Council, Outstanding Civil Engineering Achievement Award (1978).
- ASCE Tacoma Section, Outstanding Civil Engineering Achievement Award (1978).
- Prestressed Concrete Institute, Engineering and Architectural Excellence Award (1978).
- The Washington Precast Concrete Industry, Award of Excellence (1978).
- Washington Roadside Council, Honor Award, for Excellence in Bridge Design (1978).
- Arvid Grant, Engineer of the Year, Washington Society of Professional Engineers (1978).
- Arvid Grant, Engineer of the Year, Consulting Engineers Council of Washington (1977).

Credits

Owners: The Cities of Pasco and Kennewick, Washington.

Major Sponsor: U.S. Department of Transportation, Federal Highway Administration—Bridge Replacement Funds.

Project Design Engineer: Arvid Grant and Associates, Inc.; also responsible for construction quality and stress control.

Professional Collaborator: Dr. Ing. Fritz Leonhardt, Leonhardt und Andrae; Stuttgart, Germany.

Soil Mechanics Engineer: Dr. Neil H. Twelker, Seattle, Washington.

General Contractor: Peter Kiewit Sons' Company, Inc.; Vancouver, Washington, and Omaha, Nebraska.

Major Subcontractors: All concrete—Central Premix Company, Kennewick, Washington; stay cable manufacture, prestressing—Prescon Corporation, San Antonio, Texas; bearings and bridge expansion joint—Watson-Bowman Company, Buffalo, New York.

Materials Testing: Pittsburgh Testing Laboratories, and Washington Department of Transportation.

Construction Contract Administration: Washington Department of Transportation and the Federal Highway Administration.

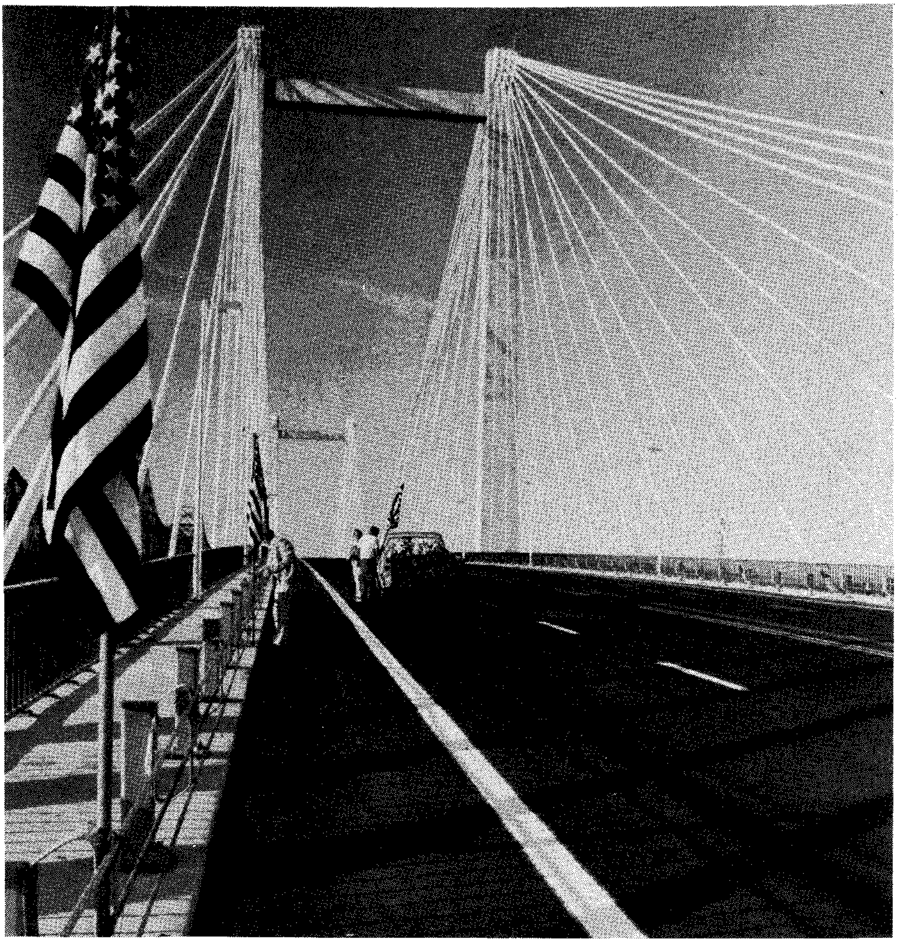


Fig. 15. Completed bridge is readied for opening ceremonies.