Interstate 664 Submerged Tunnel Crossing of Hampton Roads–Newport News, Virginia

WILLIAM J. GADDIS

The Virginia Department of Highways and Transportation determined that by 1995 traffic crossing the Hampton Roads harbor area would be too great to be handled effectively by the James River Bridge and the Hampton Roads Bridge-Tunnel. A third crossing, Interstate 664, was planned to assume a major portion of the projected traffic load. The two portal islands, each reached by an approach bridge, provide tunnel access north and south of the Newport News navigation channel. Construction of the islands involved removal of the top layer of muck soil from the bay floor, backfilling with sand, and placing hydraulic sand fill within a stone dike system. Four-lane I-664 crosses the islands first at grade and then within an open approach structure until it reaches the multistory ventilation building. It then passes through a lower level of the building and enters a sunken tube tunnel that takes it under the navigation channel. The circular-steel-shell, concrete-fill construction concept was used for the double-bore tunnel 4,454 ft long face-to-face of the ventilation buildings. The structure is the fourth sunken tube highway tunnel in the United States with twin bores. Each bore contains a 26-ft-wide roadway for two lanes of traffic. The tunnel is placed in an excavated trench and then backfilled. The tunnel-island project is to be completed in 1990.

The Virginia Department of Highways and Transportation (VDH&T), on the basis of several studies and traffic projections, determined that by 1995 the volume of traffic crossing the Hampton Roads harbor in the Tidewater area of Virginia would be too great to be effectively handled by the current roadways. After a corridor location study (*1*) and an environmental impact statement (*2*) had been completed the location of Interstate 664 (I-664) was established in 1975. The total 20-mi route connects I-64 in the city of Hampton with I-64 in Suffolk. Included in the length is the Hampton Roads crossing that connects Newport News with Suffolk (Figure 1).

Because of both commercial and naval considerations, a tunnel was mandated to carry the highway under the Newport News navigation channel in Hampton Roads (Figure 1). The corridor study developed the general highway alignment and the approach requirements to reach the tunnel. These included a viaduct structure from the north (within Newport News) and a trestle for the remaining crossing of Hampton Roads. The study also documented the need for man-made portal islands at each of the tunnels. More important, it confirmed the need to use a submerged tube tunnel because of soil conditions at the site.

A Stage 1 (preliminary) study for the tunnel-island part of the project refined the project geometrics; established the type of sunken tube channel that would be developed for the construction contract documents; and set the basic design criteria for tunnel ventilation, electrical features, island configuration, and other principal design items. The tunnel layout permits a 55- by 1,000-ft channel to be dredged in lieu of the existing 45- by 800-ft channel. The layout and channel configurations are shown in Figure 2.

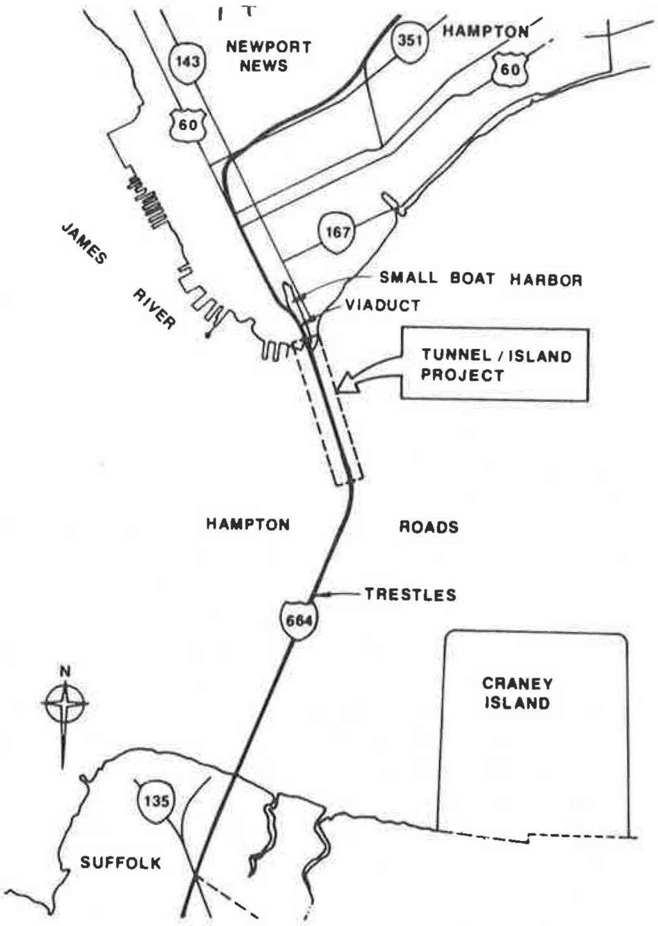


FIGURE 1 Project location plan.

Stage 2 (final) design of the tunnel-islands began in June 1979. Five construction packages were developed:

1. Islands;
2. Ventilation fans;
3. Tunnel (tubes, including finish items);
4. Buildings (and island surface completion); and
5. Electrical systems.

Sverdrup Corporation, 801 North 11th, St. Louis, Mo. 63101.

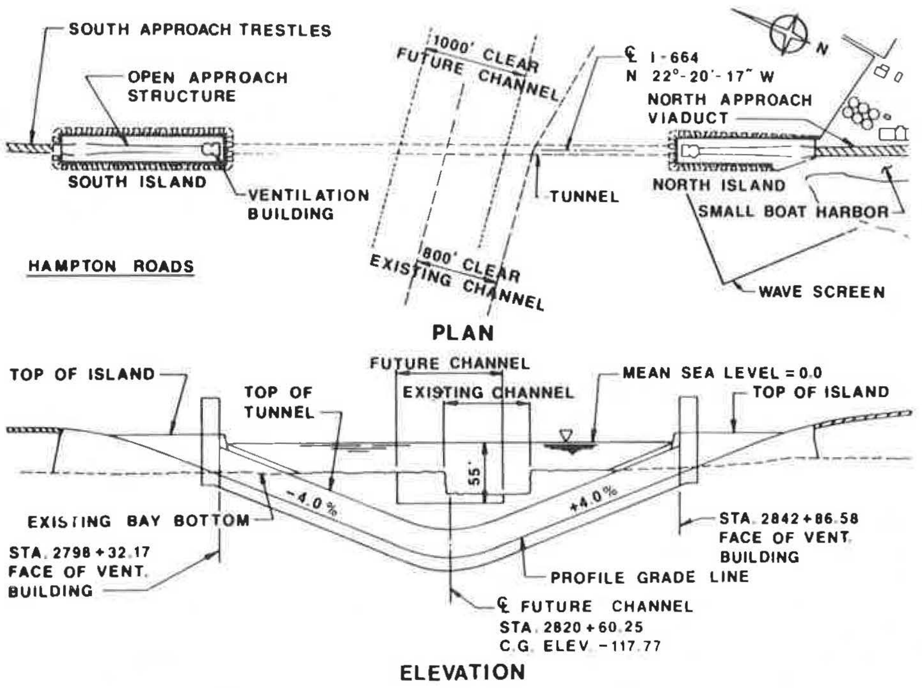


FIGURE 2 Plan and elevation.

The packaging was based on several factors, including previous experience of VDH&T and the designers with contractor interface problems, contract dollar amounts and contractor bonding requirements, and the uniqueness or specialty features of the various design and construction items.

As of this writing, all designs are complete except for the electrical systems package. For several reasons, the design project, which was essentially complete in 1982, was put on hold at that time. The electronic industry's state of the art has been experiencing considerable change. Thus it was decided that the completion of the electrical systems should be accomplished at a time closer to construction to allow inclusion of the most up-to-date systems.

In July 1985 the island construction contract was advertised. In September 1985 Tyger/Pensacola, a joint venture, started work on the island construction that was to have been complete by July 1987. The tunnel contract was awarded to Morrison-Knudsen/Interbeton in September 1986. The ventilation fan contract was to have been advertised by February 1987 and the buildings contract in January 1988.

PERMITS

As described later, the island and tunnel contracts involve a considerable amount of dredging and the placement of large quantities of hydraulic fill. The disposal of unsuitable (for hydraulic fill purposes) material was taken care of by gaining Corps of Engineers approval to use the Craney Island disposal site (Figure 1).

Borrow for hydraulic fill has come from two sources, "upland" sites and dredging the Thimble Shoal Channel just east of the Chesapeake Bay Bridge-Tunnel (about 20 mi east of the I-664 site).

LEVELS

An extensive geotechnical study was performed during the various project stages. Subsurface investigation, used for both the island and the tunnel designs, revealed that settlement and slope stability were the major design concerns for the man-made islands. Basically, the islands are built of hydraulic granular fill confined within and protected by stone dikes. The stability of these structures is essential because they support not only the island-based roadway and building facilities but also the end tubes of the tunnel.

The subsurface investigation included soil borings, a geophysical survey that used seismic reflection and seismic refraction measurements, and laboratory testing of Shelby tube and Osterberg piston samples. The results indicated that there is a layer of muck soil of variable depth on the bay bottom underlain by various layers of sand and silty clay, silty clay and clayey silt, and sand and silty sand. Laboratory consolidation tests, Atterberg limits, void ratios, and natural moisture contents were used to evaluate the compressibility of the substrata.

As a result of the conclusions of the study, complete removal of the muck soils by dredging was specified. This was necessary to reduce settlement, enhance stability, and reduce construction time. The sand and silty sand substrata are not cause for concern. However, the layers containing clay are more compressible and will require time for the settlements to stabilize. Settlements of as much as 3 ft are anticipated. To speed settlement, a 12-ft island surcharge was specified. This reduced the time between completion of the islands and placement of the first tube by about 10 months.

The island geometrics, armor protection, and a seawall around the island perimeter are based on design criteria that used the hindcasting method to predict wave heights. Thus the islands and other facilities are protected from wave forces similar to those of past hurricanes and other storms that have struck the site. About 1.6 million cubic yards of fill and 840,000 tons of armor stone are required for the construction of the two islands (Figure 3).

TUNNEL

As stated earlier, the subsurface conditions at the site required the use of a sunken tube tunnel. There are several different names for this type of tunnel construction: immersed tube, submerged tube, sunken tube, and trench. Regardless of the name, they all are based on the same concept. A trench is dredged to a specific geometric shape, a foundation course or system is placed in the trench, and prefabricated tube segments are floated to the trench and lowered onto the foundation. The tube sections have bulkheads at each end. As the segments are mated, the bulkheads are removed to allow access between the in-place segments. Finishing and other operations proceed in these units while the remaining segments are being placed.

Sunken tube tunnels have been used in the United States for 90 years. A good general description of the various alternates and methods of constructing them can be found in *Civil Engineering Practice* (*3*).

The I-664 tunnel is only the fourth sunken tube highway tunnel in the United States with twin bores. The last such tunnel constructed was the recently completed Ft. McHenry Tunnel in Baltimore. That tunnel included a pair of twin-bore tunnel sections. The design of that tunnel and of the I-664 tunnel proceeded almost simultaneously.

The width of the double-bore tunnels makes the proper mating of the adjoining segments difficult. Things learned during construction on the Ft. McHenry Tunnel have been incorporated in the I-664 contract documents.

VDH&T uses the high sidewalk system in their tunnels. This concept was also used in the Chesapeake Bay tunnels and elsewhere. The premise behind the high sidewalk is that it allows patrolmen to be more visible to motorists and to see vehicles more easily. The high sidewalk does, however, require that tube geometrics for circular-bore tunnels be somewhat larger. This results in a slightly higher cost because buoyancy is a principal design feature for this type of construction.

In Stage 1 various types of tunnel cross sections were studied and compared. Four groups were developed, each representing a particular method of constructing prefabricated tunnel tubes. Group I included the single-steel-shell type of tube structure, (Figure 4). A steel shell, supported by transverse and longitudinal stiffeners, forms the outer surface of a concrete structure. The shell waterproofs the concrete and, in addition, provides exterior concrete reinforcement. A coal-tar epoxy coating protects the outer steel surface. Steel trusses are placed within the interior wall sections to help resist forces from launching and concreting. Normally, the steel shell is built and launched from shipbuilding ways. After it is launched, the segment is towed to an outfitting site where concrete is placed in stages through hatches in the top of the steel plate. As the concrete is placed, the tube sinks until it has only a small freeboard when the interior concreting is completed. The segment is then floated to the site and sunk by placing ballast in bins attached to the top of the tube.

The Group II concepts included the circular-steel-shell type of construction, (Figure 4). This is the most common type of design in the United States. Tunnels in this group consist of two steel tubes supported by longitudinal stiffeners and connected at intervals by steel diaphragms. Concrete placed inside the steel shell forms the duck and roadway cavities and also provides structural strength in the in-service, backfilled position. Concrete is placed outside the circular shell plate to ballast the structure. The circular tube shape is inherently suited to supporting forces from launching and concreting. Except for the method of placing ballast, this group of tunnels is essentially the same as Group I: both are built on ways,

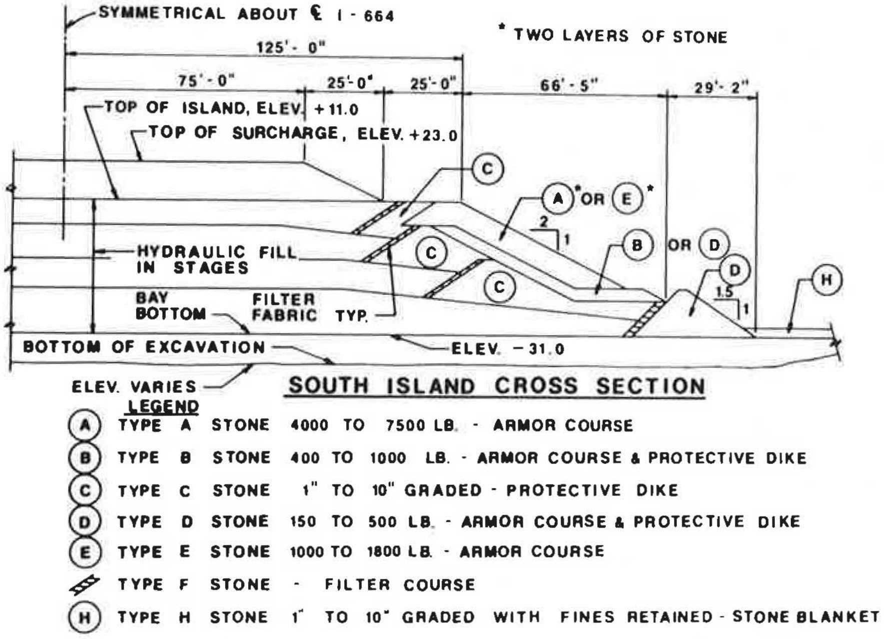
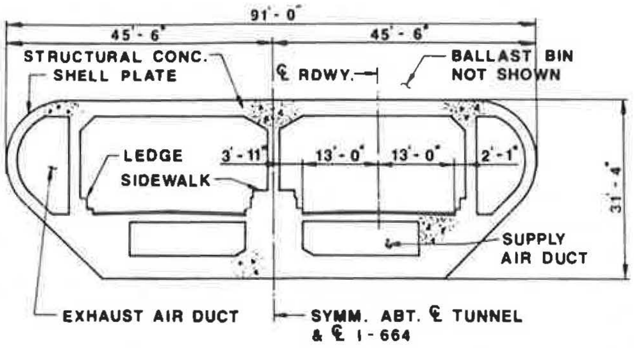
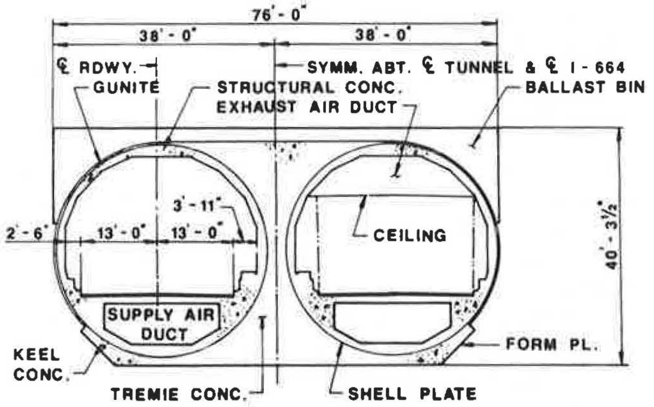


FIGURE 3 South Island cross section.



GROUP I, CONCEPT 1



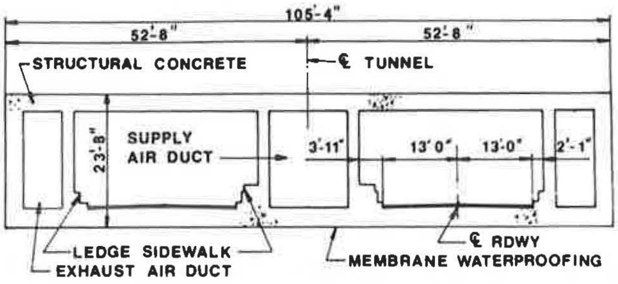
GROUP II, CONCEPT 5

FIGURE 4 Groups I and II cross sections.

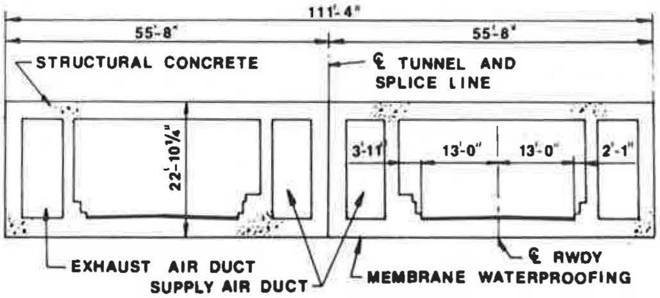
launched, and towed to the site. Because many tunnels have been built using this system, contractors are familiar with general fabrication and placement methods.

Group III comprised concepts that use a casting basin for tunnel segment fabrication. An area large enough to accommodate at least one-half of the required tunnel segments is selected along a shoreline to serve as the casting basin. The size requirement is an economic consideration. The area also has to be deep enough to float the completed segments. The area is encompassed by a cofferdam and dewatered. Cut-off walls and a well-point system are installed. Then the reinforced concrete tunnel segments are fabricated in the basin (Figure 5). Posttensioning is often used to improve watertightness of the segments. A waterproofing membrane is placed on the exterior concrete faces. When the segments are completed, the casting basin is flooded and the segments are floated to the site. The segments are lowered into the trench by placing gravel in ballast pockets attached to the top of the segments.

There are several advantages to this type of construction, but a major disadvantage is the casting basin. A large area (15 to 30 acres was considered for I-664) is required. It was anticipated that the most convenient sites (for I-664) would have been in wetlands. The activities at the basin were thought likely to cause environmental changes. Because other construction methods were available, the use of a Group III proposal would have been considered only if economics indicated that environmental mitigation efforts should be pursued.



GROUP III, CONCEPT 7



GROUP IV, CONCEPT 9

FIGURE 5 Groups III and IV cross sections.

The Group IV concepts were similar to those of Group III. However, this group would have used one of the islands as the casting basin to eliminate the environmental problem just discussed. As it turned out, construction on the island itself became quite complex. Furthermore, because of the size of the islands and ventilation buildings, the width of the tunnel segment was limited. Thus, for some concepts, the section would have had to have been built in two parts (Figure 5) and then joined after floating. Also, only one segment at a time could be constructed. Last, the completion of the ventilation building would have had to wait until the last segment was completed. This would have extended the overall construction schedule.

Consideration was given to the many advantages and disadvantages of each group of concepts. The determining factor in selecting a Group II concept, a circular-steel-shell section, was cost. This concept was almost 10 percent less expensive than those in any of the other groups.

This concept was then developed into final design and the contract documents were completed. Some of the tunnel design criteria follow.

1. Cover: Ten-foot minimum within the shipping channel (protection against anchor drag). Beyond the channel, the minimum cover is 5 ft.
2. Overdredging: There is a 3-ft allowance.
3. Tube placement tolerances are as follows:

	Inboard End	*Outboard End*
Horizontal alignment	±½ in.	±1 in.
Vertical alignment	±½ in.	±1½ in.
Maximum differential of vertical measurement tilt	±½ in.	±½ in.

4. Water elevation: Mean sea level equals Elevation 0.0. Maximum storm conditions, extreme high at Elevation +8, extreme low at Elevation –4.

5. Buoyancy: Sinking ballast factor of safety to be at least 1.10; after joint dewatering and bulkhead removal, factor of safety to be at least 1.02; completed tube (in-service) factor of safety to be at least 1.25.

6. Roadway vertical clearance: 16 ft 6 in. minimum.

7. Launching and outfitting stresses shall not exceed 133 percent of the normal unit stresses in the AASHTO code. Tubes shall be investigated for side- and end-launching.

There are several features of the design that bear review.

Tunnel Configuration and Alignment and Project Details

The alignment and cross section as presented in the contract plans are shown in Figures 2 and 6. The cross section includes twin bores, each with a 26-ft-wide roadway, a high sidewalk, a ledge, an exhaust air duct above the roadway, and a supply air duct below. Exhaust air ports are located in the ceiling; supply air flues leave the supply duct and open into the roadway cavity in the sidewalk and ledge faces.

The walls of the roadway cavity will be covered with special ceramic tile. Originally, and as presented for bids, the ceiling was a series of suspended porcelain-enamel, concrete-filled panels. The roadway lighting was to have been fluorescent fixtures hung on the tunnel walls as shown in Figure 6. However, as discussed elsewhere in this paper, recent decisions about the construction and operational cost of fluorescent lights versus other lighting methods have caused a restudy of lighting types and their location. If a different lighting system is used, the lights will be ceiling mounted. Thus the new study will also include a reevaluation of the ceiling system.

There are 15 tube segments, each almost 298 ft long. The horizontal length of the tunnel is 4,454 ft measured face-to-face of the ventilation buildings. The overall length of the tunnel, portal-to-portal, is 4,782 ft. The tunnel segments will include more than 18,000 tons of structural steel.

Support and Placement of Tunnel Tubes

The geotechnical investigation indicated that no special precautionary measures were needed to support the tunnel segments. Thus two common methods of support were developed and were shown on the contract documents as contractor bid options. One was a screeded-gravel foundation. A 2-ft layer of gravel is placed in the bottom of the trench by clam shell or tremie tube to prevent segregation of the material. The gravel is then screeded to the proper elevation by a heavy beam, template, or drag. The second method presented was a pumped-sand foundation. In this method, the tubes are placed in the trench on a temporary support at each corner of the segment. For this project, a prefabricated concrete pad was used. Jacks were incorporated into the system to make alignment adjustments. A sand slurry would then be pumped under the tubes, and the tube load would be transferred to the sand foundation by gradually releasing the jacks. Different methods of placing the sand slurry have been used on other projects. No particular method was specified for the I-664 project. (Morrison-Knudsen/Interbeton chose the screeded-gravel option.)

Typical Tube Joints

The contract documents call for a rubber gasket sealing system at typical tube joints. This system requires the gaskets to be compressed to properly seal the joint. This is achieved by first having divers align the just-lowered segment with the adjoining elements using a series of jacks. Final compression is then

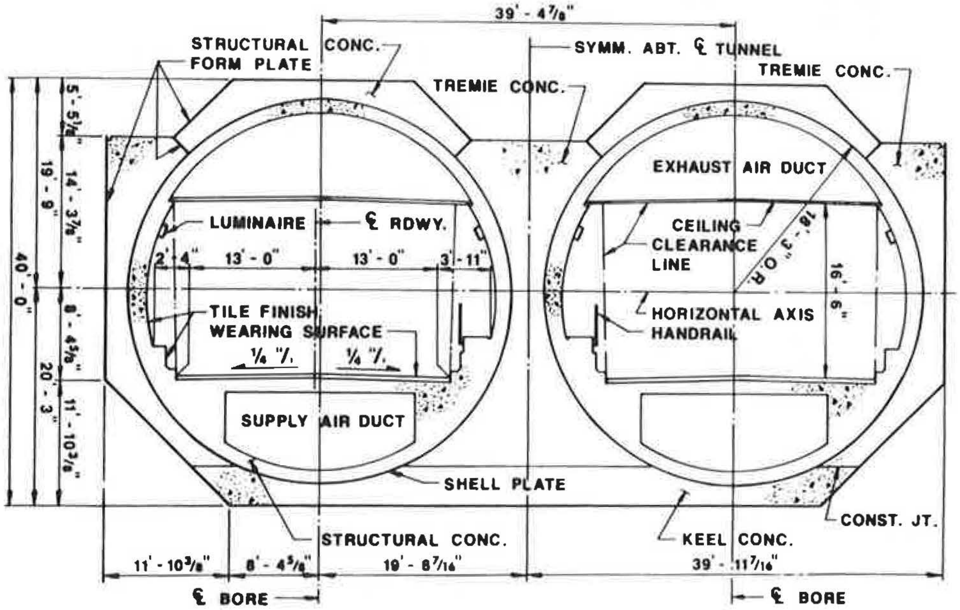


FIGURE 6 Typical cross section.

achieved by dewatering the joint area. This activates a hydrostatic force on the free tube bulkhead. The resulting pressure moves the free tube and compresses the gasket. The jacks help hold the alignment during the process.

Tube Closure and Tube-to-Ventilation Building Joint

The first three tubes adjoining each island will be placed before the remaining segments. This will allow work to proceed simultaneously on both the tunnel and the building contracts. The ventilation building foundation will be constructed within a cofferdam. The end tube details at the ventilation building joint were developed to allow the building contractor to "tie in" to the tube. This permits him to complete his cofferdam, dewater, and construct the building-tube joint in the dry. The joint details allow differential settlement between the massive building structure and the tube. To prevent movement of the first three tube segments placed, they will be backfilled before the cofferdam is dewatered.

Placing tubes from both ends results in the last tube being placed between two earlier tubes. Obviously, the compressed gasket joint system used at the typical joints can be achieved at only one end in this situation. The tremie-concrete collar joint method will be used on the last or closure joint. This joint system was used on many older tunnels that were built before the rubber gasket system was developed.

TUNNEL VENTILATION

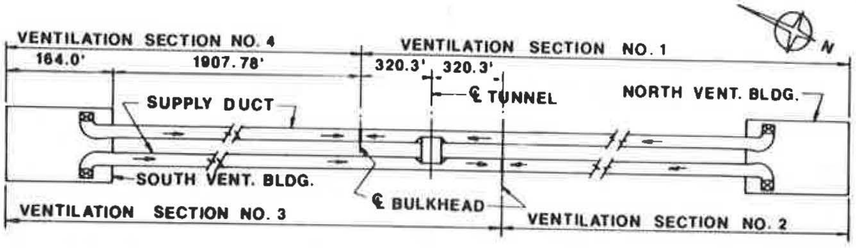
The tunnel ventilation system will be fully transverse (i.e., it will include both supply and exhaust air fans). A ventilation building housing fans, fan drives, louvers, exhaust vents, and other equipment is located at each end of the tunnel. Each tunnel bore will have two ventilation systems, each served from the ventilation building nearest the section (Figure 7). Each ventilation system will have a supply and an exhaust duct system. The facility will have a total of 24 fans (12 exhaust and 12 supply).

The fans will be centrifugal, double inlet, and double width with bearings mounted on separate outside pedestals. The bearings are specified to be of the spherical roller type. The fans will be driven by a three-speed drive made up of two motors and two HTD belt drives. Each fan will be connected to a single-speed motor through the first drive. This single-speed motor will have shaft extensions on both ends. The shaft connection not connected to the first drive will be connected through the second drive to a smaller two-speed motor.

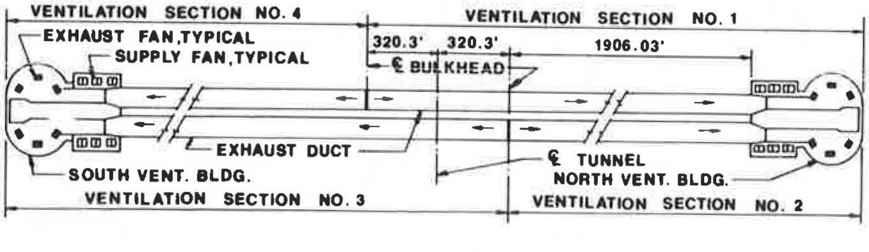
The "ducted fan" concept (i.e., all three fans for a ventilation system will be located in one fan room) will be used. For proper operation, metal duct work will connect the fan inlets with one of the building's concrete exhaust shafts that, in turn, connects to the tube exhaust duct. The metal duct becomes a partition that isolates the fan from the rest of the fan room. Vitiated air is exhausted by the fan through a metal vent connected to the building ceiling. A turret or nozzle on the roof dissipates the air well above the operations part of the building and avoids contaminating the fresh air intakes.

The three supply fans per section are located in a chamber that has louvers in the exterior building walls. Outside air will be pulled into the room. The louvers will not be weatherproof. Rainwater will enter during high-speed fan operations and extreme weather conditions. All fan room chambers, exhaust and supply, have floor drains to clear rainwater from the chamber.

The fan motors will be equipped with antifriction bearings. The synchronous speed ratings are 1,200 rpm maximum for the large motor and 1,800 rpm maximum for the small motor. The fans can be started from rest on any of the three speeds, and each motor is designed to be started a maximum of four times per hour. By varying the number of fans operating at a time (one, two, or three) and the motor speed (low, medium, or



PLAN - BELOW ROADWAY



PLAN - ABOVE ROADWAY CEILING

FIGURE 7 Tunnel ventilation systems.

high), a wide range of air flow can be provided. This allows efficient and functional operations. Each fan has a damper. The purpose of the damper is to isolate a nonoperating fan from the remainder of the system, thereby eliminating a backdraft through the nonoperating fan and permitting the operating fans to function properly.

Other details that complete the tunnel ventilation system are items such as stainless steel turning vanes, shotcrete-formed curved shafts, and blank-off panels that permit the supply and exhaust air flow to be adjusted.

Under normal operations, the east tunnel bore carries northbound traffic and the west bore carries southbound traffic. The ventilation system has been designed for this mode of operation. It also has been designed for two-way traffic in either bore. The total facility has been designed to accommodate a closure of either bore as a result of extreme maintenance requirements or a catastrophic situation such as a trestle closure. The parameters of the ventilation system follow.

1. Ventilation rates: under design conditions, carbon monoxide (CO) concentration rates are not to exceed 125 parts per million.
2. Design conditions:
   a. The worst possible condition of 10-mph traffic with a traffic flow of 1,500 vehicles per hour per lane.
   b. A traffic mix of 91 percent passenger cars and 9 percent trucks.
   c. Anticipated CO output from vehicles as measured by the Environmental Protection Agency's 1976 tests.
   d. Tunnel roadway grades (4.0 percent maximum).
   e. The higher ventilation amount of the two operating conditions:
      (1) Two lanes of one-way traffic or
      (2) Two lanes of two-way traffic.
   f. Design minimum ventilation rate of 100 ft^3/min per lane foot.
   g. All three fans within a ventilation system shall operate for 100 percent ventilation requirements.

BUILDINGS AND OPEN APPROACHES

The ventilation buildings were primarily developed to be functional. They contain the tunnel ventilation fans and the primary facility mechanical and electrical equipment. In addition, the north ventilation building houses the facility control center, communication room, and main facility offices.

The design of the building also sought to keep the building compact. Although this is probably the basic consideration in the design of most conventional buildings, it is even more important in this case. First, the building area required can affect the size of the island because there are specific requirements for features such as truck turning movements at the tunnel end of the building, parking areas, and sight visibility and traffic movements between the end of the open approach and the end of the island. Second, buoyancy is a design consideration. The more compact the building area is below sea level, the less is the effect of buoyancy on design and construction. Last, the below-grade building size determines the magnitude of island excavation and the cofferdam and dewatering system that is required to build the below-grade part of the structure.

In the I-664 building design the functional requirements were achieved by using procedures that maintained compactness and, in addition, presented a structure with distinctive architectural treatments. One unique detail that was used to minimize the below-grade foundation area was the cantilevering of the second and higher floors. This permitted automobile parking under the cantilevered floors. This, in turn, helped keep the size of the island down. The use of a brown-tone, rough-textured surface on all exposed concrete allowed the I-664 project to avoid the stark appearance of some other facilities' ventilation buildings. The same concrete treatment was used on the open approach structures. The premium for this aesthetic treatment is minuscule in comparison with the overall cost of the project.

The lowest level of the building contains the portal pump rooms. These rooms house the mechanical equipment and ancillary systems that collect drainage from the open approach roadways and from the tunnel low-point pump room. The portal pump system then sends the runoff overboard into the bay via an underground drainage system that terminates in an outfall headwall located within the island armor layer.

The second lowest level in the ventilation building is the roadway level that serves as part of the tunnel and connects the tubes with the open approach structure.

The open approach structure has walls 38 ft high and footings as much as 11 ft thick. This thickness is required to resist buoyancy because the roadway elevation at the building interface is almost 23 ft below sea level. A safety barrier separates the two-way traffic within the approach structure.

The problem of the "black hole" effect of tunnel portals (on a bright day) was particularly important on this project. The north portal will appear as a black hole to southbound drivers because the midday sun will, during all seasons, be to the south and in their eyes. Sun screens have proven to be of minimal benefit in this situation. A flaring transition, in the form of a sweeping curve, will be used from the building wall to the tunnel ceiling to diffuse the bright natural exterior light into the less bright artificial light of the tunnel (Figure 8). The colored, textured concrete finish will also lessen the black hole effect. Tunnel lighting will follow transition zone procedures normally used to reduce the impact of changes in light. Also, throughout the lighting transition zone, the roadway slab will be portland cement concrete instead of the normal asphaltic concrete used elsewhere in the tunnel and on the open approaches. The lighter concrete color will help reduce the outside-inside lighting contrast—at least for a while.

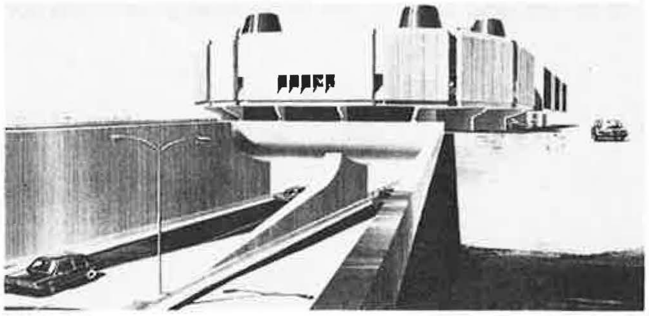


FIGURE 8 Portal treatment.

ELECTRICAL SYSTEM

Two 13,800-volt feeders, each capable of handling the entire bridge-tunnel facility, will be brought from switching stations in Newport News. The feeders will be connected to two independent power sources supplied by the local power company. The feeders will lead to switchgear units in the north ventilation building's switchgear room. From there power will be distributed to the various electrical and mechanical systems of the facility. The reason for having two independent power sources is obvious. Power outages for a facility such as I-664 can cause real problems. Although emergency generators can be installed (as they will be at I-664) to provide certain tunnel-oriented essential services, it is not feasible to provide units sized to drive all facility systems necessary for normal operations, such as the computer-controlled traffic control system, all tunnel lighting (about one of three lights on the sidewalk side of each bore is powered by the generator), television surveillance system, and other facility power and lighting systems. Lengthy power outages have caused other facilities to develop unique operating procedures in an attempt to maintain user safety.

As mentioned earlier, the original contract documents specified the use of what has been a conventional tunnel lighting system (i.e., beyond the transition zone, two continuous rows of fluorescent luminaires, one located on each side wall). The economic benefits, both for construction and operations, presented by sodium lighting units have led various agencies, including VDH&T, to consider the use of these systems in tunnels. Recently, the Washington State Department of Transportation, in cooperation with the FHWA, let a contract that uses high-pressure sodium luminaires installed in the tunnel ceiling. This was done after the system was tested in an existing tunnel. On the basis of economic projections for the Washington project, and estimates for I-664, VDH&T has authorized a study that will compare fluorescent and high- and low-pressure sodium lighting systems.

MECHANICAL SYSTEM

Most of the mechanical design elements for the I-664 project are routine for tunnel facilities. Special consideration was given to the open approach and tunnel drainage. There have been some problems in other facilities in keeping the tunnel drainage system clean. The I-664 tunnel design tried to alleviate the problems by providing drains that were easier to clean. Time will tell if these efforts are successful.

Water supply for the facility will be achieved by bringing a 10-in. line from a meter vault in Newport News to the north island. It will be underwater within the small-boat harbor. This avoids the freeze problem that would be presented if the line were attached to the superstructure of the approach viaduct.

The water supply line will provide domestic water to the complete facility. It will also provide fire protection water to hydrants on each island and to hydrants within each tunnel bore. The tunnel hydrants will be located in niches in the sidewalk-side tunnel wall and will be spaced about 300 ft apart. A recirculation line will be provided at each hydrant to prevent freezing.

Fire protection is divided into two basic areas, ventilation buildings and tunnel. The fuel loading in the buildings is minimal. Therefore the buildings will have only fire extinguishers as required by code. A halon sprinkler system will be provided in the central control center to protect the computer and other electronic systems.

Several fire-fighting procedures will be used in the tunnel. These include use of the exhaust fans to remove smoke and heat, stopping supply air fans when appropriate, use of portable fire extinguishers stored in niches in the tunnel, island-stationed emergency vehicles that contain appropriate fire-fighting equipment, and response of the Newport News Fire Department to all vehicle and structural fires. A standpipe, which will allow the fire department to pump sea water from the harbor if the domestic water supply is insufficient, is located on each island.

ACKNOWLEDGMENTS

The tunnel and island portion of the I-664 crossing of Hampton Roads has been discussed. Obviously, the complete facility will extend well beyond these limits. The final design of the associated construction packages that interfaced with the tunnel was performed by VDH&T or other consultants. Their efforts and cooperation are acknowledged. The project was and will continue to be a challenge. When completed, nearly 20 years after the initial VDH&T efforts, it should serve well the citizens of and the visitors to the Tidewater area.

REFERENCES

1. *Corridor Location Study*. McGaughy, Marshall & McMillan–Sverdrup & Parcel, joint venture, St. Louis, Mo. 1972.
2. *Environmental Impact Study*. McGaughy, Marshall & McMillan–Sverdrup & Parcel, joint venture, St. Louis, Mo., 1975.
3. T. E. Kuesel. Immersed Tube Tunnels. *Civil Engineering Practice*, Journal of the Boston Society of Civil Engineers Section, ASCE, Vol. 1, No. 1, Spring 1986, pp. 57–78.