Expedited Design and Construction of the Burlington Northern Seattle International Gateway

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On July 1, 1985, Burlington Northern (BN) Railroad Company completed construction of a new container-handling facility at Seattle, Washington. The new facility, dubbed the Seattle International Gateway, had been built in just 6 months, to meet market demands for double-stack railroad equipment and potential growth in the Pacific Northwest. This feat could not have been accomplished without extensive planning, the innovative use of equipment, and the personal commitment of everyone involved. Planning and scheduling began before the project reached the drawing boards and continued throughout the course of construction. Design engineers and construction contractors scheduled their work using the critical path method and continually updated their schedules as conditions changed. Modern, high-production equipment was used to expedite both the design and the construction. Equipment included electronic survey instrumentation, a new device to measure subgrade strength, and high-production concrete batch plants and finishing machines. The end result was an efficient, low-cost, container-handling facility, located within 1 mi of the Port of Seattle and BN's main-line railroad, which offers substantial savings to shippers using stack train service to Chicago and has made the Port of Seattle more competitive in international markets.

On December 15, 1984, the management of Burlington Northern (BN) Railroad Company committed to the construction of a new container-handling facility at Seattle, Washington. This decision was market driven to take advantage of double-stack equipment technology and growth potential in the Pacific Northwest. Market analyses pointed to an immediate need for such a facility and led to the establishment of a July 1, 1985, completion date, allowing only 6 months for design and construction. This paper is a discussion of the engineering studies that led to that commitment and the expedited design and construction of the new facility.

The site chosen for the new facility was on a portion of the Stacy Street switching yard, located between 0.5 and 1.5 mi from Port of Seattle container terminals and within 1 mi of BN's east-west main-line railroad. Early studies of available sites in Seattle pointed to the Stacy Street site for its strategic location and the amount of property available for development. The yard itself is, in essence, two yards with a split lead through the middle as shown in Figure 1. A switching study showed that one of the yards could be removed without adversely affecting switching productivity. This opened up 29 acres for development of the new facility. In addition there are another 32 acres available for future development if the remaining yard is ever removed. As shown in Figure 2, the 29-acre site is situated so that new trackage can be added to allow simultaneous loading and unloading of two trains or as many as 400 containers.

Preliminary layouts showed that about 17 mi of

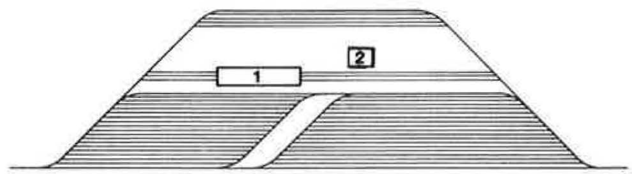
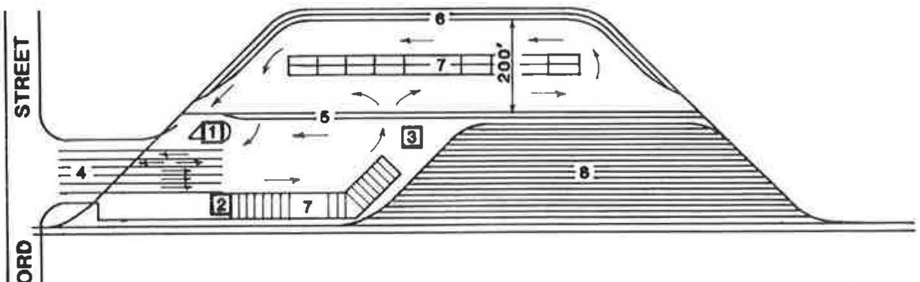


FIGURE 1 Former Stacy Street Yard.

trackage, 84 turnouts, a track scale, and 10 buildings would have to be removed before construction of the new facility. Five miles of new track, 11 turnouts, and 6 new buildings were planned for the new facility. A preliminary cost estimate of $10.6 million was developed using unit cost data from recent intermodal projects in the Seattle region and historic track and building construction costs. Unit costs used for grading, drainage, paving, and utility work were factored from unit costs for actual construction on similar facilities based on the acreage under development.

To expedite the project a tentative design schedule was established in late November and field surveys, using BN forces, were started. This design approach has proven effective on past projects. It provides time to better define the scope of the project, postpones a large financial commitment to a design contract, and allows time to choose the best design consultant for the job. A key part of the entire project was the selection of the designer. Of prime importance was the selection of a firm that understood BN's needs and would look at economic alternatives, deliver on schedule, and produce a clear, concise set of plans and specifications.

Field surveys were used to develop topographic maps and utility and location maps of existing tracks and buildings. For this survey a baseline was established and bench marks set in areas that would not be disturbed by the new construction. Elevations were taken across the site on 50- x 100-ft grids using electronic survey equipment. Locations and elevations of buildings, tracks, and utilities were taken during this survey. The boundaries of the survey extended well beyond the limits of new construction, which saved time as design work moved beyond original project limits.



1. INTERMODAL OFFICE
   - -ENTRANCE CONTROL
   - -OFFICE STAFF
2. YARD OFFICE
   - -TRAIN OPERATIONS
3. MIDYARD OFFICE
   - -TRAIN LOAD/UNLOAD
4. ENTRANCE
   - -5 LANES IN OR OUT
   - -50 TRUCK QUEUING
5. LOADING TRACKS 1 & 2
   - -70 STANDARD CAR CAPACITY (140 CONTAINERS)
   - -24 DOUBLE STACK CAR CAPACITY (240 CONTAINERS)
6. LOADING TRACKS 3 & 4
   - -56 STANDARD CAR CAPACITY (112 CONTAINERS)
   - -18 DOUBLE STACK CAR CAPACITY (180 CONTAINERS)
7. TRAILER/CONTAINER STORAGE
   - -250 CONTAINERS
   - -100 TRAILERS
8. SWITCHING YARD

FIGURE 2 Seattle International Gateway.

Electronic survey equipment, used to speed up the collection of field data, was essential to the timing of the overall project. This equipment usually consists of an electronic measuring device (EMD) mounted on a theodolite, which projects a laser beam of light from the EMD to a prism at the point to be surveyed and reflects the beam back to the EMD. This equipment provided the operator with a digital readout of the horizontal and vertical angles between the EMD and the prism as well as the horizontal and vertical distances. This allowed the rapid collection of data with a small crew, so that remaining crew members could be used to convert field data to drawings in the office.

A BN architect cataloged the number and condition of buildings on site, made recommendations for relocation of current operations during construction, and identified the size and number of new buildings needed for the intermodal facility. A two-story concrete block yard office, housing electronic car verification equipment, was located in the center of the proposed intermodal yard. Nearby was a metal-framed 90- x 250-ft car repair shed with six small buildings along one side. The small self-framed metal buildings were recommended for reuse, either for the new facility or elsewhere on BN property. The yard office and six of the smaller buildings were occupied by BN personnel and the remaining facilities were vacant.

The architectural survey showed that three new buildings were needed off site for maintenance forces who would be displaced because of the new construction. Also, a new yard office and two new buildings for intermodal operations would be required on site. After floor plans were drawn for the new buildings, it was decided to use parts of the existing self-framed metal buildings for the three off-site maintenance buildings and temporarily relocate the people in these buildings during construction. Because the electronic equipment in the yard office would be too costly to move into temporary quarters during construction, the yard office could not be demolished until the new yard office was built.

Requests were sent to several prominent geotechnical firms for proposals to investigate soil conditions on site and to provide design recommendations for pavements and structural foundations. To expedite the selection of a firm, solicitations only allowed 2 weeks for review and return of the completed proposal. On the basis of their understanding of the project and the method they proposed to collect field data, Dames & Moore was selected.

Dames & Moore was requested to determine subgrade strengths, to calculate pavement thicknesses for various paving materials, and to make recommendations for preparing the subgrade before paving. For design purposes it was assumed that overhead lift devices would operate on paved runways along each pair of loading tracks, a side lift device and tractor-trailer combinations would operate anywhere within the facility, but most movement would be concentrated near the loading tracks. The overhead and side lift devices exert wheel loads of 80,000 lb with tire pressures of 90 lb per square inch. Design of and materials used for paving must provide adequate strength for this load. A durable low-maintenance pavement with a 20-year design life was desired.

Subgrade investigations were started on November 27, 1984. Ultimately 180 points were analyzed. An easily portable falling weight deflectometer (FWD) mounted on a trailer allowed the rapid collection of data on subgrade strengths. A preliminary geotechnical report was completed in only 3 weeks. The final report was completed 3 weeks later, on January 7, 1985.

The Dames & Moore study showed that soils across the site were generally weak, consisting of loose mixtures of gravel, fine sands, and local areas of wood chips. The groundwater table was at an average depth of 5 ft below natural ground. As requested, Dames & Moore also identified areas where the weakest soils might lead to problems during construction so plans could be made accordingly.

The geotechnical consultant provided design recommendations for asphalt concrete (AC) pavement, portland cement concrete (PCC), and a relatively new paving concept called roller-compacted concrete (RCC). They presented a number of alternative pavement sections for each paving material and loading case (Table 1). In addition to pavement sections, they also provided references to appropriate standard specifications for the quality of all paving and subgrade materials and provided recommendations for treatment of contraction and construction joints in rigid pavements.

TABLE 1 Pavement Sections

	Rigid Pavements		AC Pavement	
Alternative	Crane Ways	Yard Area	Yard Area	Entrance
1	19-in. PCC 12-in. GB	17-in. PCC 12-in. GB	4-in. AC 10-in. CRB 30-in. GSB	8-in. AC 12-in. GB
2	19-in. RCC 12-in. GB	17-in. RCC 12-in. GB	7-in. AC 8-in. CRB 20-in. GSB	
3	14-in. PCC 10-in. CTB	12.5-in. PCC 10-in. CTB	10-in. AC 6-in. CRB 10-in. GSB	

Note: PCC = portland cement concrete, RCC = roller-compacted concrete, AC = asphalt concrete, GB = gravel base, CTB = cement-treated base, CRB = crushed rock base, and GSB = gravel subbase.

Grading operations were to begin in February 1985. This raised serious concerns about unpredictable Seattle weather delaying the project due to the weak, moisture sensitive subgrades on the site. To ensure proper compaction of the subgrade, Dames & Moore recommended proof rolling before placing the granular base and removing unsuitable materials from areas that would not compact. They also recommended use of a granular base course to provide a stable working surface during wet weather.

By late December enough survey and soils data had been collected to allow the solicitation of proposals from design consultants. The proposals requested complete design of the facility from grading and utilities to buildings and traffic flow patterns. The designer would provide complete contract drawings and specifications and would secure as many building permits as possible before construction. Proposals also included a separate item to provide all construction inspection services that would not be accepted until completion of design work.

The firm of Duffy, Lawver and Kumpf, (DL&K) Inc., was chosen for design engineering. They were currently working on another BN trailer-on-flatcar terminal project, which gave them the background they would need for the Seattle project. They also showed a thorough understanding of the railroad in general and paving projects in particular. This contract was awarded before completion of field surveys and soils investigations, allowing collection of additional data required by the designer while field crews were still mobilized.

DL&K provided a preliminary design schedule using the critical path method (CPM). As requested, this schedule covered the time between the start of design and award of a construction contract. The timing of building permits and construction schedules was estimated to establish a date for completion of design and commencement of construction. However, the schedule would have to be flexible to allow for changes as the design progressed and additional information was collected.

During preparation of the preliminary schedule, the design and permit process was started to avoid any delay to the general contractor when that contract was awarded. The items that could be designed easily included construction of a new yard office, installation of a storm sewer discharge, and demolition of the car repair shed.

On completion of this preliminary schedule, a meeting was arranged with the city of Seattle, Department of Construction and Land Use. Lead personnel in each agency, through which permits would be reviewed, attended. This meeting resulted in an understanding of how the permit process would work, the number of permits required, and the amount of time needed for city reviews. The entire project could have been seriously delayed without this meeting and the cooperation afforded by the city.

Following this meeting, DL&K formulated a final design schedule, an abridged version of which is shown in Figure 3. The schedule started with four activities on parallel critical paths shown in Figure 3 as dark heavy lines. Time constraints did not allow float time in any of the major activities. The most float time, shown as a light dashed line, in any subactivity was 5 days. However, the time estimated by the city to secure building permits was thought to be overstated and, if so, could result in some additional float time.

Completion of the new yard office was critical to finishing the project on time. An old yard office stood in the way of new track work, paving, and yard lighting. However, electronic equipment was located in that building and temporary relocation was too costly; therefore, completion of the new building was needed early in the project.

The design and construction of the new yard office were scheduled for completion on May 3, 1985, using railroad construction crews; however, city permits could not be issued until all plans and specifications were approved by the city. These delays were eliminated by specifying a standard "off-the-shelf," preengineered metal building that conformed with city building code requirements. Meanwhile, foundation plans and architectural details based on this standard building were worked out by DL&K.

To further simplify the building design process, modular buildings were requested for use as combination office and lunch room facilities at the entrance to the yard and at midyard. The buildings were two-story structures with upper stories consisting of glass walled towers, from which trucks entering the facility would be controlled. The lower story would be used for office, lunch, and locker room facilities. The selected modular buildings are preapproved by the Washington State Department of Labor and Industries Factory Assembled Structures Section. This approval eliminated the need to secure city permits.

In most paving projects storm drainage is installed before other construction. The downstream end or outfall to the storm drainage system is installed first, thus providing an outlet for storm water as the system is built. Field surveys had located a 96-in.-diameter Municipality of Metropolitan Seattle (METRO) combination storm and sanitary

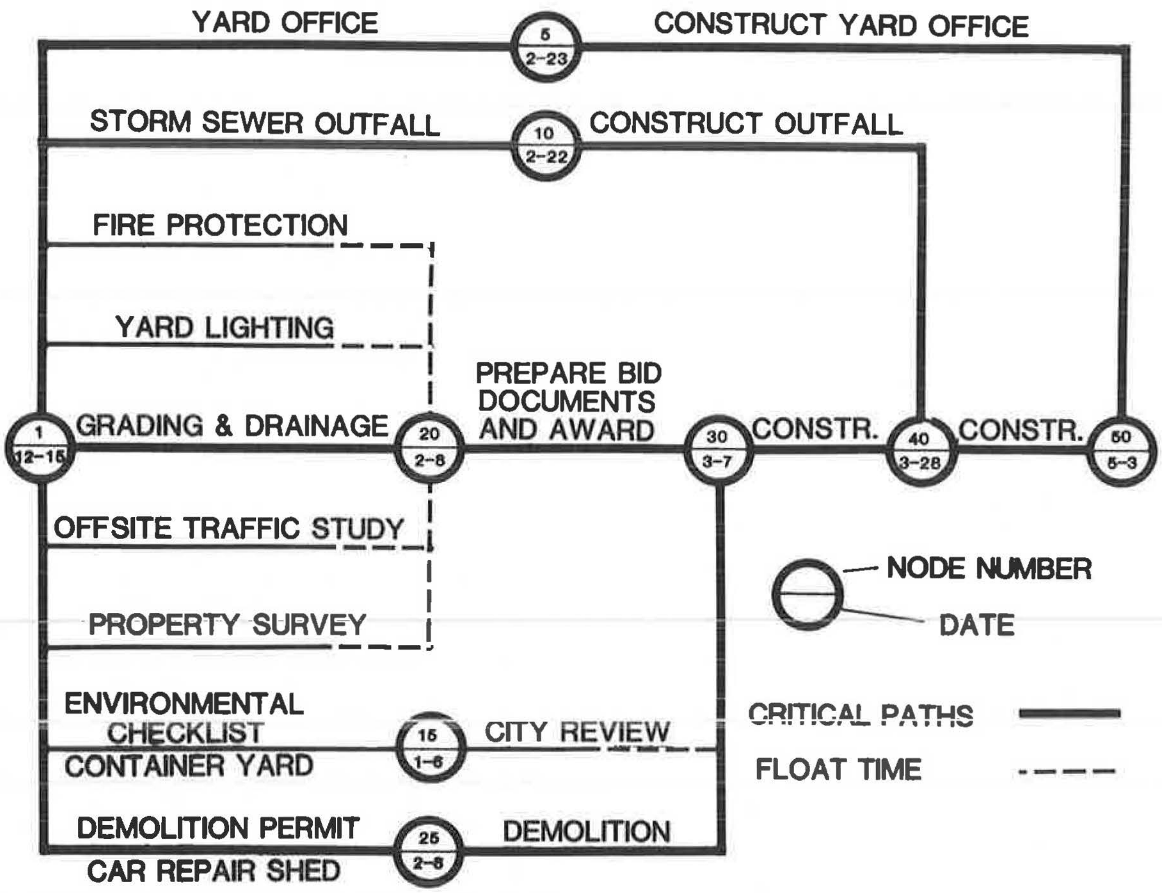


FIGURE 3 Abridged diagram of DL&K CPM design schedule.

sewer for use in the new storm system. In discussions with METRO it was learned that additional storm water could not be added to the present system because it would cause sanitary sewage in the system to overflow into Puget Sound. Therefore, a new outfall was designed running 240 ft under two city streets and six railroad tracks.

The outfall design was completed 4 weeks before completion of the overall design. Construction bids for the outfall were solicited as a separate contract in advance of the main contract. To ensure that this work would not delay the main contract, specifications were written with a rigid completion date of March 28, 1985.

Demolition permits were required for all buildings on the site. The yard office and the car repair shed were too large for BN crews to demolish; therefore, a contractor was used. Because the yard office would remain until the work under the main contract was started, its demolition was included in that contract. However, because the 90- x 250-ft car repair shed occupied the new track site, it was removed under a separate contract to avoid any delays to the main contract.

Plans were then made to remove the remaining eight buildings with BN crews, as soon as demolition permits were issued. Demolition permits were obtained well in advance of major construction, allowing crews time to complete demolition before award of the main contract.

Dames & Moore's soils report was reviewed with DL&K to select a pavement design section from proposed alternatives. The use of cement-treated base was ruled out as not cost-effective. Asphalt concrete pavement could not be used in yard areas because trailer dolly wheels and stacked containers would cause the pavement to fail. It was decided to use AC pavement only in the entryway, on parking lots, and over the four loading tracks.

It was not known if roller-compacted concrete pavement would prove more economical than PCC pavement in yard areas and for craneways. Design was provided for both and included as alternate bid items in the contract documents. Concern was expressed that RCC pavements are relatively new and, as such, somewhat risky to construct. Inspection of several RCC pavements throughout the Pacific Northwest and Canada showed that construction methods and equipment are still experimental and that service life is unknown. On the other hand, a rigid specification was written to ensure an acceptable end product. This would drive up the cost of RCC, but it might still compete with PCC.

PCC pavement has the advantage of being placed as a fluid, which can allow abrupt changes in pavement depths. RCC has the disadvantage of being placed using conventional asphalt paving equipment because it cannot attain compaction requirements behind the paving train with abrupt changes in pavement depth.

A pavement section is shown in Figure 4. Pavement depth throughout the yard is 17 in. of concrete over a 12-in. gravel base. The concrete depth was increased to 19 in. for overhead crane runways and to 24 in. at the edges of concrete slabs, as recommended by Dames & Moore. Pavement sections for RCC and PCC materials were made identical although PCC pavement could have been thinner in some places.

All necessary city permits were obtained before completion of the contract documents on February 21, 1985. Documents were then mailed to the various bid-

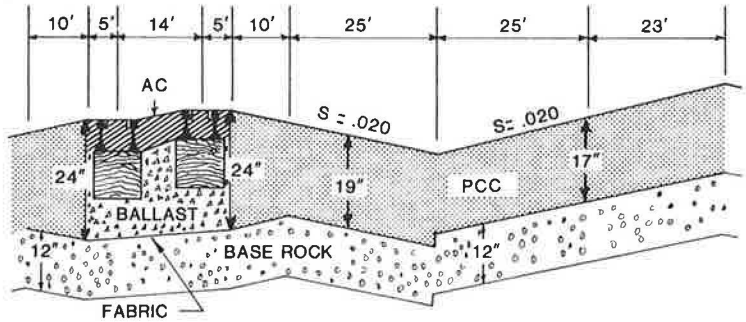


FIGURE 4 Cross section through pavement showing 1/2 width between loading tracks.

ders with a March 7, 1985, bid opening date. The design was completed in only 37 calendar days, which included the Christmas and New Year's holidays. During this time, a great deal of time and effort was spent securing permits. For example, hand carrying documents through agencies greatly expedited the permit process.

Before design work started, BN crews began removing 17 mi of trackage and 84 switches. Removals were begun on December 15, 1984, and all rail, ties, and other track materials were removed from the site by February 5, 1985, a total of 34 working days. To maintain access to industry track and ongoing locomotive maintenance operations, some 2,000 ft of new trackage and 5 new turnouts were constructed. Also, new track materials were received and stockpiled awaiting the completion of subgrade construction by the general contractor.

As yard construction progressed, BN personnel laid 5 mi of new track using continuously welded rail (CWR) in one-quarter-mile lengths, constructed 28 switches, and placed more than 1,000 ft of rubber-surfaced grade crossings. This work was closely coordinated with that of the general contractor who was preparing subgrades, constructing drain lines, moving equipment through the site, and placing concrete paving. At times there were as many as 150 people working on the site, but interference was kept to a minimum.

At this time BN building crews were demolishing structures on site and earmarking parts for reuse in three new buildings being erected three blocks away for maintenance personnel displaced by the new yard project. Work on the three maintenance buildings was started before the yard office because city permits for the yard office were not issued until March 7, 1985. When the permits were issued, yard office construction began.

BN building, electrical, and communications crews completed work on the 2,300-ft^2 yard office, including installation of all utilities and electronic equipment on May 3, 1985, as scheduled. These crews then completed work on the two modular buildings in the new yard before returning to complete the three maintenance buildings. They erected a total of 8,100 ft^2 of new buildings and demolished 8,000 ft^2 of existing buildings in just 6 months.

A contract for installation of the new storm drainage outfall was awarded on February 22, 1985, with a definite completion date of March 28, 1985. The outfall, a 36-in.-diameter concrete pipe, was placed inside a 240-ft-long 54-in.-diameter steel casing. The drain was connected to a 90-in.-diameter city of Seattle storm drain to Puget Sound. The casing was installed by jacking and boring under city streets and railroad tracks at an elevation about 10 ft below grade. However, the task was complicated by groundwater, which was found only 4 ft below ground. Two dewatering wells, placed before the jacking and receiving pits were excavated, proved inadequate to handle the amount of groundwater encountered. Three additional wells were installed before the groundwater table was low enough to continue boring operations. As a result, this work was completed 9 days beyond the completion date, which was a nuisance, but did not delay completion of the facility.

A general construction contract was awarded on March 7, 1985, to Sea Con Construction Co., who was the low bidder on the PCC pavement alternative. The low bid for RCC pavement was below that of PCC, but not enough in BN's opinion to warrant risking acceptance of RCC. The difference between the lowest and highest bids was only 4.8 percent, which indicated that prices were quite competitive and that the plans were well prepared and the specifications well written. The various bid items and quantities are given in Table 2, but, because bids were not publicly opened, it is not possible to list bid prices.

Along with the bid, the contractor submitted a critical path method (CPM) construction schedule, which is schematically shown in Figure 5. (The actual schedule is too complex to reproduce here.) Activities on the critical path are batch plant site preparation, delivery of the high-production batch plant from overseas, and main-line production of PCC paving at a rate of 1,500 yd^3 per day. The schedule, based on 5 working days per week, did not allow for delays due to inclement weather or equipment failures. However, weekend work compensated for delays.

The contractor had a well-organized project team. The project manager was a company owner. His general superintendent in charge of field activities reported to him. Separate positions were established for purchasing, project engineering, weather consultation, and maintenance and procurement. These people all reported directly to the project manager.

The contractor held weekly meetings with the project team (i.e., subcontractors, city inspectors, BN consultants, and BN construction superintendents) to review the progress of each activity on the critical path and discuss a plan of attack for work during the ensuing week. Every 2 weeks, the contractor provided a bar chart showing activities to be accomplished in the upcoming 2-week period.

The day after the contract was awarded, the contractor moved in his survey crews to set rough grading control. BN survey crews had provided the contractor with basic field control, which included centerline stakes for new tracks and off-site bench

TABLE 2 Contract Bid Quantities

Item	Description	Quantity	Item	Description	Quantity
1	Base rock	84,000 tons	11	12-in.-diameter RCP	1,855 LF
2	Asphalt concrete	10,800 tons	12	15-in.-diameter RCP	760 LF
3	Unreinforced PCC	48,400 CY	13	18-in.-diameter RCP	690 LF
4	Reinforced PCC	450 CY	14	24-in.-diameter RCP	2,555 LF
5	AC curbing	3,000 LF	15	36-in.-diameter RCP	165 LF
6	Paint striping	12,000 LF	16	4-in.-diameter PVC pipe	1,080 LF
7	Catch basins	89 Ea	17	8-in.-diameter water pipe	3,075 LF
8	Manholes	34 Ea	18	6-in.-diameter water pipe	1,700 LF
9	6-in.-diameter RCP	1,080 LF	19	100-ft light towers	16 Ea
10	8-in.-diameter RCP	4,195 LF	20	Miscellaneous electrical	Lump sum

Note: CY = cubic yards, Ea = each, RCP = reinforced concrete pipe, LF = lineal feet, and PVC = polyvinyl chloride pipe.

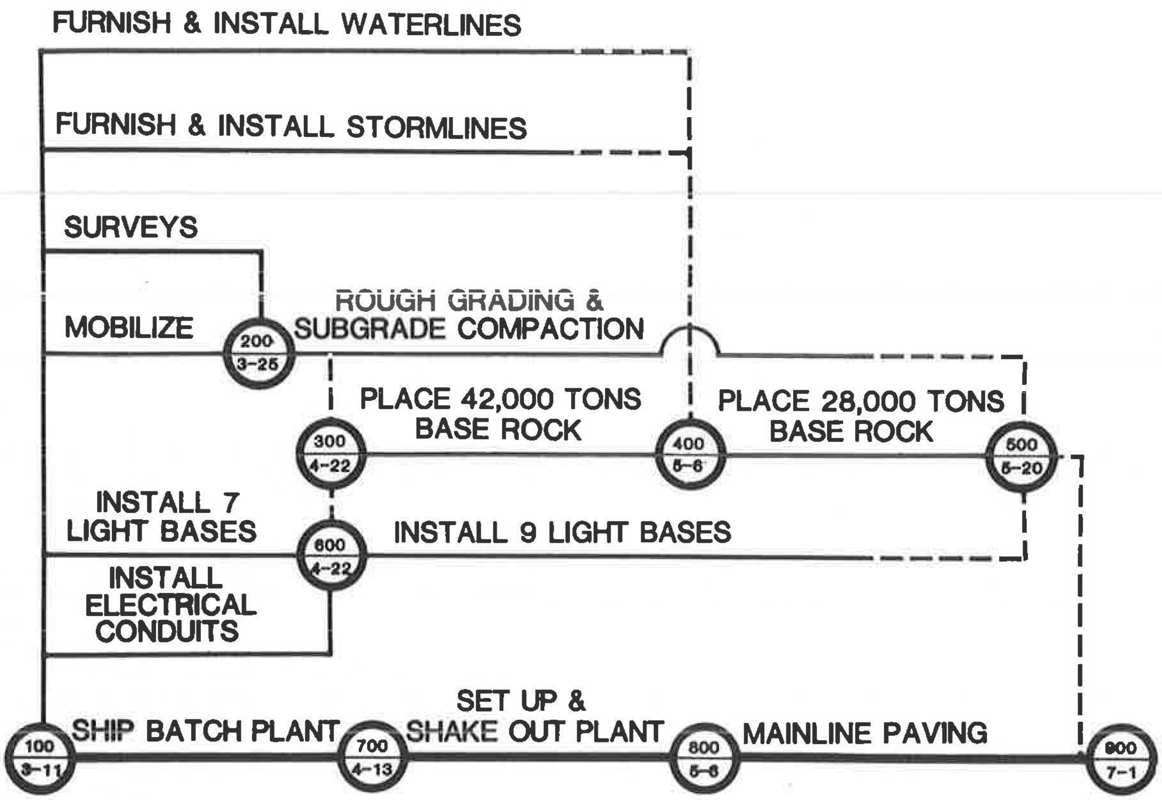


FIGURE 5 Abridged SEA CON CPM construction schedule. This is an oversimplification of a complex diagram and is only used to give the reader an idea of the magnitude and complexity of the project. Refer to Figure 3 for an explanation of symbols.

marks. The contractor's crews used an electronic device to establish grades, one that is commonly used in building construction to set elevations for drop ceilings. This device sprays a burst of laser light away from the instrument, and by placing a receiver anywhere within range of the instrument, it is possible to accurately measure the elevation of a point on the ground. This instrument allowed the contractor to set grade stakes and begin rough grading within the first week of construction.

The project site was not close to supplies of gravel for use in the base course. Moving 525 tons of gravel per hour through city streets posed real problems. The contractor solved the problems by importing gravel on barges to a slip located two blocks from the site. He then moved gravel a short distance on city streets. This movement was made at night, partly to avoid conflicts with daytime traffic and partly to avoid congesting the construction site with gravel trucks. Gravel was spread loosely at night, then rolled to the specified compaction during the day.

Barge displacement was used to measure aggregate weight instead of weighing each of the nine trucks every time they completed their 30-min cycle to the barge. If a conventional scale operation had been used, trucks would have had to be loaded and weighed every 3 min to maintain scheduled cycle times. This would not have been practical.

A two-directional grid system was established for placing and testing base materials. Subgrade compaction tests were made and were found satisfactory before the gravel base was placed. The same plan was applied to compaction of the base course before placement of the concrete pavement. This plan not only assured a quality pavement, it also coordinated grading and inspection activities.

The contractor had ordered a new, high-volume, concrete batch plant from overseas. Delivery of this plant was delayed about 3 weeks, so the contractor

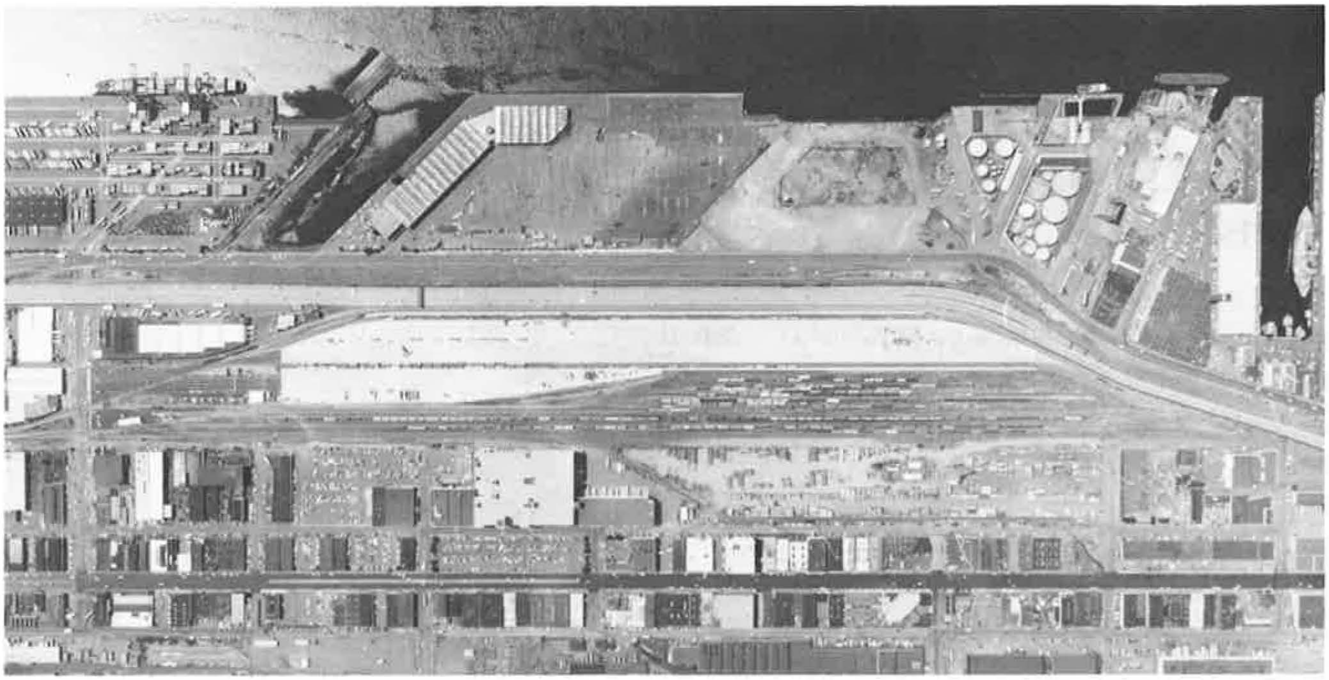


FIGURE 6 Seattle International Gateway. Photo by Christophoto.

set up a conventional dry mix plant and used mix trucks to batch the concrete. The dry mix could not produce the required 1,500 yd^3 of concrete per day and had to be supplemented by Redi-mix concrete brought in from a nearby plant. Dry mix operations were continued during setup and shakedown of the new plant so concrete production was never slowed.

Concrete was brought from the batch plant in end dump trucks and placed on the ground near its final location. It was then moved into its final location by a front end loader, and a Bidwell finishing machine was used to screed, tamp, vibrate, and finish the pavement. The finishing machine was operated on top of steel forms at widths of up to 75 ft. The machinery could be raised 5 ft above finished grade to clear obstacles such as shafts on light tower bases. This feature virtually eliminated the need to hand work the concrete. After the pavement had cured overnight, contraction joints were installed with concrete saws. The joints were later routed to specified widths before fillers and seals were added.

From the beginning inclement weather was a concern. A weather consultant was hired to provide the contractor with an accurate forecast at least 12 hr in advance of any work that would be adversely affected by weather conditions. This service helped save time during construction, but the biggest help was that Seattle rainfall was 10.7 in. below historic annual rainfalls throughout the duration of construction.

The new facility was opened for business on July 1, 1985, just 6 months after the decision to build. It has already made the Port of Seattle more competitive in international shipping and BN in intranational transportation. The Seattle International Gateway (Figure 6) now operates stack train service to Chicago three times a week, offering a substantial savings to shippers over conventional truck or trailer-on-flatcar services.