not have an appreciation of the need for curing. Consequently, joint surface rattling problems arise. The U.S. Army Corps of Engineers is experimenting with straight-on curing compounds. Their procedure is to continuously and thoroughly saturate the RCC for the first 24 hours. After that they apply two full strength applications of the curing compound. This seems to work well in keeping a good moist surface that continues to gain strength and durability. This is being considered as a standard procedure for RCC.

To achieve the desired performance of RCC, the density has to be proper. At least 96 percent density should be reached.

RCC is rapidly becoming accepted as the third major method of paving, competing with conventional concrete and with asphalt. It has the potential to become the dominant method of paving, since it provides the quality of conventional concrete, typically at a lower first cost than asphalt.

USE OF UNREINFORCED PORTLAND CEMENT CONCRETE PAVEMENT AT THE BURLINGTON NORTHERN SEATTLE INTERNATIONAL GATEWAY

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In December 1984, Burlington Northern Railroad (BN) decided to build a new container handling facility at Seattle, Washington. The project was begun in response to a growing intermodal market in the Pacific Northwest and the advent of new double stack equipment technology. The new facility is called the "Seattle International Gateway" (SIG; see Figure 1). This paper discusses the design, construction and performance of the Portland Cement Concrete Pavement used at SIG.

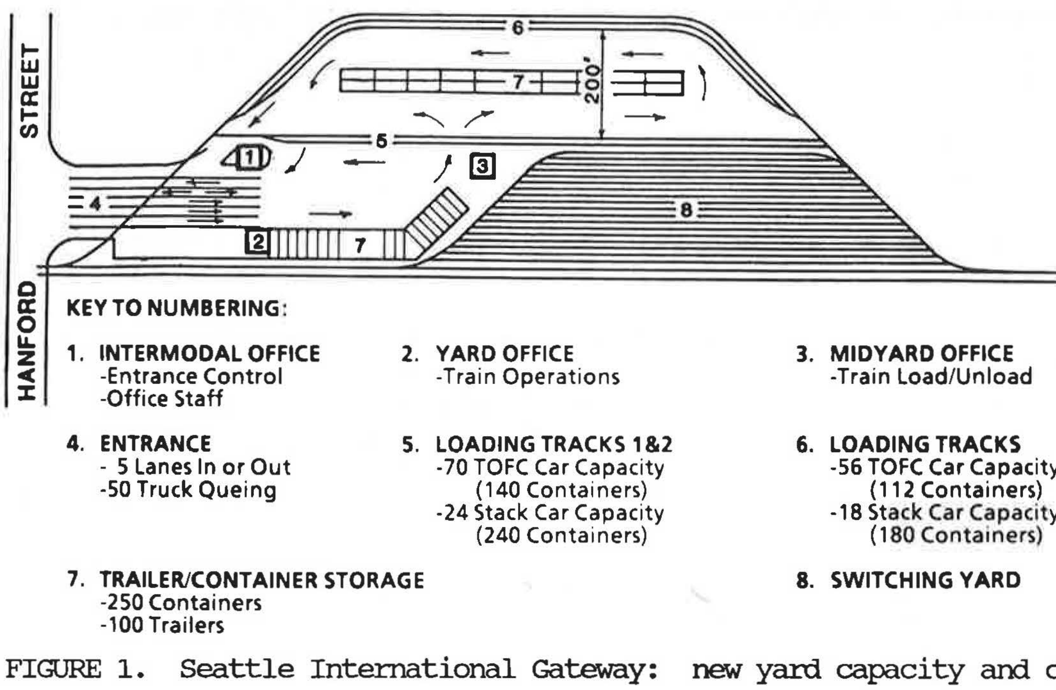

FIGURE 1. Seattle International Gateway: new yard capacity and operation

Until construction of SIG, Seattle had only one intermodal facility which was BN's South Seattle yard. This complex was constructed in the early 1970's to handle trailer on flat car (TOFC) business. In the early 1980's the terminal was expanded to handle container on flat car (COFC) business. The South Seattle yard served Port of Seattle container terminals and industrial warehouses in the Kent Valley. It is located about 10 miles south of the Port and 5 miles north of most warehouses.

Port of Seattle shippers using South Seattle became concerned over increasing rail costs mainly influenced by high drayage costs. In response, a new site was found within one mile of the Port of Seattle which BN made available for a new intermodal yard. Along with yard construction BN acquired new double stack rail cars, state of the art container handling equipment and installed a computerized system for routing containers from dock side to destination. The new intermodal yard is located on a portion of BN's Stacy Street switching yard. The yard has direct rail access to BN's transcontinental and north/south mainlines. In addition, the site provides truck access to Interstate Highways 5 and 90 within one mile of the front gate.

Preliminary surveys showed that the Stacy Street site had the proper dimensions to accommodate loading and switching of intermodal trains. The figure shows the preliminary track layout and operating plan. Site geometry allowed construction of trackage for simultaneous loading of two double stack trains or the equivalent of 400 container loads. The entrance to the site provides necessary queuing space for up to 50 trucks.

In order to meet market demands, BN made plans to complete the new facility as soon as possible. Demolition work was scheduled to start in February 1984 and construction was to begin in March. Based on an ambitious construction schedule, a completion date of July 1, 1985 was established. The decision to start construction in February was made in spite of winter rains common in the Seattle area. Although the schedule did not account for weather delays, construction plans and techniques were designed to minimize such delays.

Pavement Design

Geotechnical studies were performed included using a Falling Weight Deflectometer (FWD) to determine California Bearing Ratio (CBR) and modulus of subgrade reaction (k) values throughout the yard area. Based on these findings and loading conditions from the heaviest types of equipment proposed for use, thickness and other design considerations were determined for asphalt and concrete pavements. Finally, subgrade preparation required prior to placement of the pavement structure was recommended.

Surficial soils across the site were generally weak, consisting of loose mixtures of gravel, fine sands and local areas of wood chips. Underlying the surficial soils was fine, clean sand. The water table was found at an average depth of five feet below natural ground. Areas where the weakest soils might lead to problems during construction were identified so that plans could be made to prevent related delays.

A portable FWD mounted on a trailer was used to collect data on subgrade strengths at 180 points across the site. Based on this data and a statistical analysis of CBR and k-values, the geotechnical consultant developed design parameters for CBR = 5 and for k = 100 pounds per cubic inch (pci). The design CBR value was taken as the 90th percentile value and the k-value as the mean value. These design values were used to develop pavement and base course thicknesses for each alternative.

For design purposes it was assumed that loaded overhead lift devices would operate on paved runways along each pair of loading tracks. It was further assumed that a loaded side lift device and tractor-trailer combinations would operate anywhere within the facility, but most movement would be concentrated near the loading tracks. Wheel loads for fully loaded conditions on both the gantry crane and the piggy packer are about 80,000 pounds, with tire pressures of about 90 pounds per square inch (psi). It was assumed that truck-trailer combinations have two tandem axles of 34,000 pounds each and a single steering axle of 12,000 pounds.

The gantry crane was assumed to be the design vehicle for the runways, the piggy packer for the yard proper and trucks for the facility entrance. Loading conditions for the gantry crane were assumed to be low volume, channelized, and for the piggy packer low volume, unchannelized. For design of the truck lane at the facility entrance, an average daily traffic (ADT) of 175 fully loaded trucks per day was assumed. A durable low-maintenance pavement with a 20-year design life was desired.

Design recommendations were provided for asphalt concrete (AC), Portland Cement Concrete (PCC) and Roller Compacted Concrete (RCC) pavements. A number of alternative pavement sections for each paving material and loading case, were presented, as shown in Table 1. Alternatives for AC pavement are shown as information only since this paper is limited to discussion of rigid pavements.

TABLE 1. PAVEMENT SECTIONS

	Rigid Pavements		AC Pavements	
Alternative	Crane Ways	Yard Areas	Yard Areas	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, GSB = Gravel Subbase

A 12-inch thick Granular Base (GB) was recommended for use under rigid pavements in Alternatives 1 and 2. Use of a 12-inch GB in lieu of placing a rigid pavement directly on the subgrade, allows an increase in the design k-value resulting in a thinner rigid pavement section. In addition, the base will minimize pumping and rocking of the slabs and provide a more stable construction surface in the event of wet weather. In general, the granular base was recommended because it would result in lower maintenance of the pavement section throughout its design life.

A 10-inch thick Cement Treated Base (CTB) under rigid pavements was included in Alternative 3. CTB allows the maximum reduction in pavement thickness. In addition, it provides uniform, strong support to the rigid pavement and prevents subgrade from pumping and slab rocking. The process for placing CTB is not unlike that used for a granular base except cement must be mixed with subgrade materials prior to compaction. A danger in using CTB is the possibility of reflective cracking into the rigid pavement caused by inconsistencies in the CTB. After reviewing this alternative, CTB was ruled out for economic reasons.

Besides alternative pavement designs, references to appropriate material and construction specifications along with recommendations for subgrade preparation and treatment of contraction and construction joints were provided. It was recommended that all joints not be more than 25 feet on center. Expansion joints were not necessary except at fixed structures such as buildings and light standards where 3/4 to 1-1/2 inch wide expansion joints were recommended.

Due to concerns about wet weather, proof rolling the existing subgrade was recommended. The proof rolling would identify areas exhibiting pumping or heaving which could not be compacted. Subgrade materials in these areas could either be removed and replaced with sand and gravel fill or allowed to dry out before rolling. This would insure against failure of the subgrade between the placement of gravel base and construction of the pavement even during significant wet spells.

From the proposed alternatives, it was decided to use AC pavement only in the entry way, on parking lots and over the four loading tracks. The use of cement treated base was ruled out as not cost effective. Asphalt concrete pavement could not be used in yard areas since trailer dolly wheels and stacked containers would fail the pavement.

It was not known if roller compacted concrete pavement would prove more economical than PCC pavement in yard areas and for crane ways. Design was provided for both and included as alternate bid items in the contract documents. Even though specifications for RCC were strict, concern was expressed that such 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 were still experimental and that service life is unknown.

A pavement section suitable to both PCC and RCC construction was selected. Cross sections of the pavement design loadings by equipment type and by width of the pavement are shown in Figures 2 and 3. Pavement depth in the yard is

17 inches of concrete over a 12-inch gravel base. The concrete depth was increased to 19 inches for overhead crane runways and to 24 inches at the edges of concrete slabs.

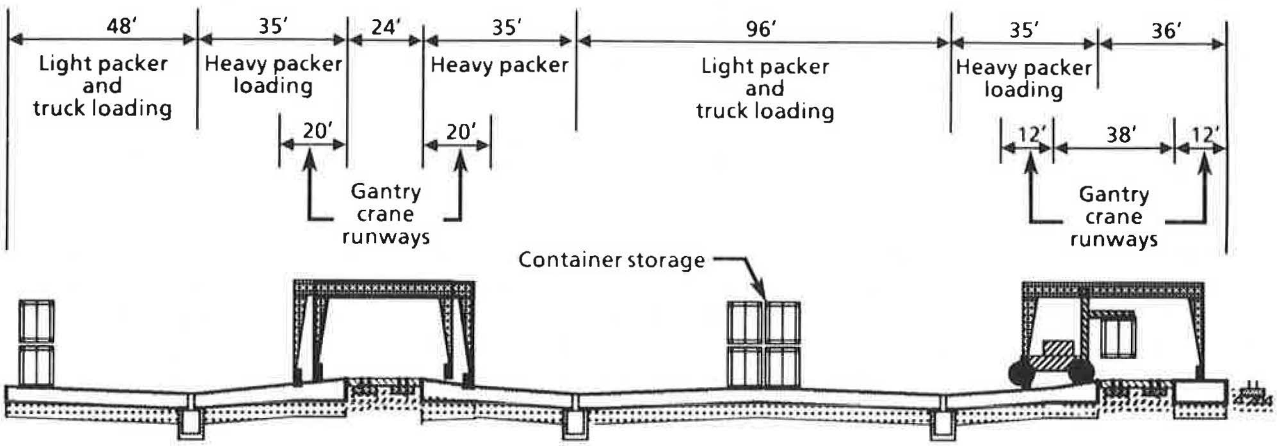

FIGURE 2. Cross section showing design loadings (not to scale).

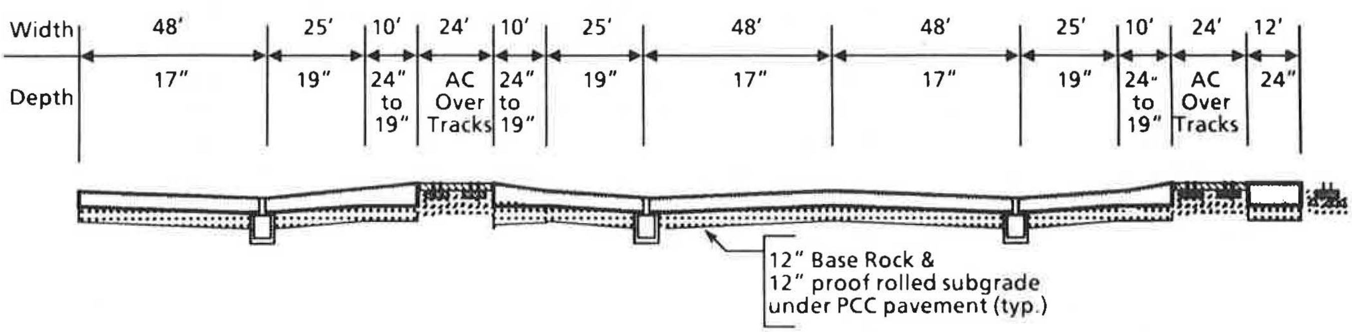

FIGURE 3. Cross section through width of PCC pavement (not to scale).

Although pavement sections are identical, it should be noted that PCC pavement could have been made thinner in some places. PCC pavement has the advantage of being placed as a fluid and can allow abrupt changes in pavement depths. RCC has a disadvantage being placed using conventional asphalt paving equipment since it cannot attain compaction requirements behind the paving train with abrupt changes in pavement depth.

Pavement Construction

A general construction contract was awarded on March 7, 1985 for 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 contractor moved survey crews onto the site and immediately started planning storm drain construction. Installation of the 3.25 miles of storm drain was an important factor in completing the project. Not only did grading and paving operations hinge on storm drain completion, runoff from winter rains had to be removed from the site as quickly as possible.

In conjunction with storm drainage, the contractor began regrading the site and proof rolling the subgrade. Specifications called for proof rolling both disturbed and undisturbed subgrade materials to a minimum compaction of 98% of maximum density at a depth of 12 inches as measured by the modified proctor ASTM D 1557-70 method C. All subgrade materials which did not meet this compaction requirement were either removed or tilled and allowed to dry, before being recompacted.

Plans called for a 12-inch thick gravel base course under all PCC pavements. The base course was compacted to 98% of maximum density as measured by the above proctor method. Base course and AC pavements were constructed in accordance with a 1984 Standard Specification for "Road Bridge and Municipal Construction", Public Works Association, Washington Chapter.

A minimum concrete compressive strength of 4,000 pounds per square inch at the end of 28 days of curing was required. Following is the approved concrete mix design with volumes shown per cubic yard of concrete produced:

Cement (Type II)	460 Lbs.
Fine Aggregate	1,560 Lbs.
Course Aggregate	1,980 Lbs.
Total Water	25.0 Gal.
Admixtures:	
Water Retention Agent	
Air Entrainment Agent	

PCC pavement was constructed in accordance with "Standard Specifications for Municipal Public Works Construction", 1975 edition, by Washington Public Works Association as amended by "City of Seattle Supplement to Standard Specifications for Municipal Public Works Construction" dated 1976.

Contraction joints were spaced 25 feet on center. Transverse contraction joints within 100 feet of a free edge of the pavement were doweled with smooth steel dowels 1-3/4 inches in diameter by 22 inches long spaced 18 inches on center. All other contraction joints were saw cut 1/4-inches wide while the concrete was still green and later routed to 3/4-inch widths. These joints were filled with a backer rod and cold applied joint sealant. An AASHO premolded joint filler type M213 was placed between the pavement and adjacent structures such as light tower foundations and drainage structures. All construction joints were keyed using a tapered 4-inch by 2-inch nominal key way.

During construction a great deal of emphasis was placed on quality control. A total of 670 compaction tests were taken on the subgrade and gravel base. During paving operations, 586 concrete cylinders were tested. The testing required the full time services of a man from a testing laboratory.

Figures 4-6 show the on-site batch plant, the smoothing of the pavement at the SIG yard and the operational truck entrance.

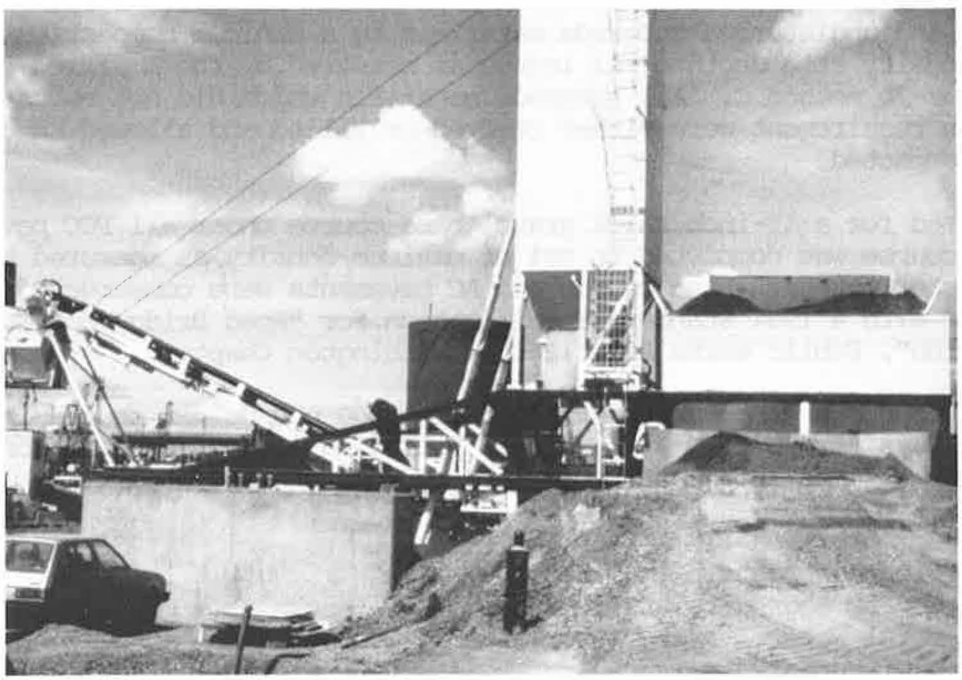

FIGURE 4. On-site batch plant

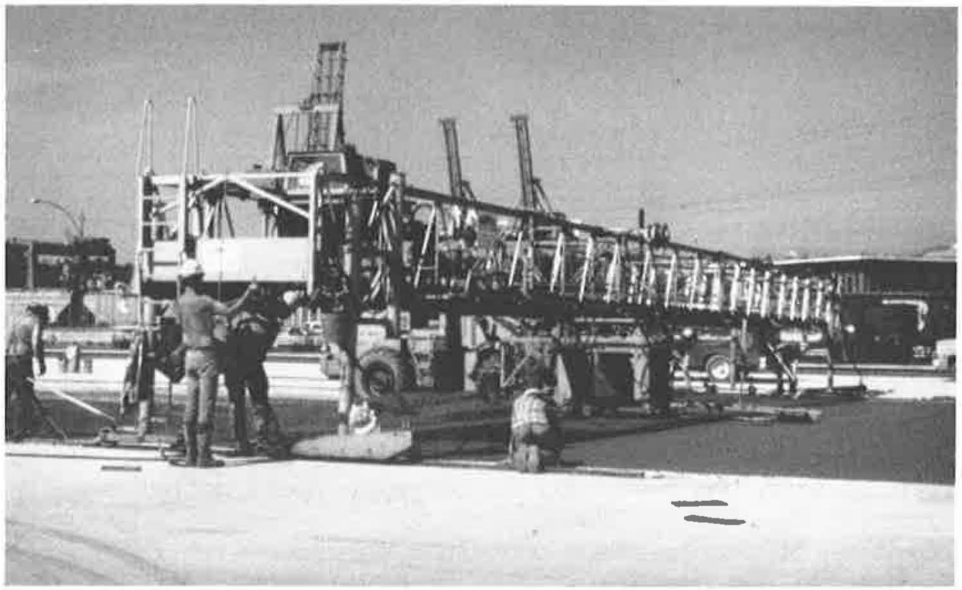

FIGURE 5. Smoothing pavement in SIG Yard

FIGURE 6. Operational truck entrance

Pavement Performance

An inspection of the SIG facility was made in June 1988. At the time of this inspection it is estimated the total number of containers handled since its opening was 540,000. This inspection found no apparent problems with the pavement. There is no undesired cracking, surface spalls, joint degradation or other signs of deterioration.