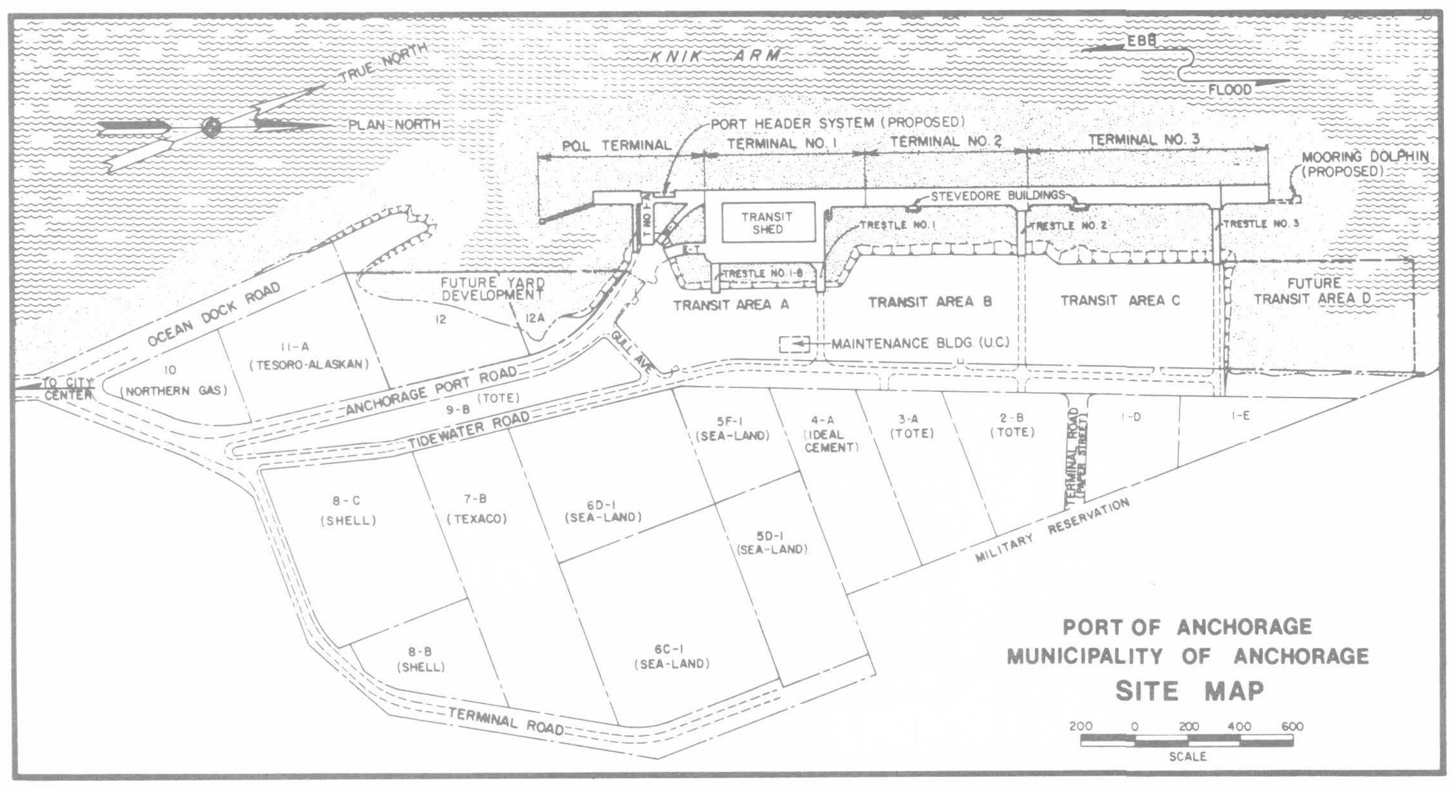

Figure 1. The Port of Anchorage opened for business in 1960 after building Terminal No. 1. Since then the Port has grown through nearly a dozen expansions. It is an excellent example of phased development following guidelines of a thorough master plan.

ward from each pile along the full length of the tidal zone until they look like giant "popsicles." Eventually, the ice cylinders join, forming a lattice-work of ice ribs between piles. Finally, the holes in the lattice are plugged. Growth rates for the ice cylinders have been measured at over 1 in. (25 mm) per day. Density is low due to air entrainment so the ice under the wharf weighs less than a solid block of ice. Even so, ice loads nearly double the demand for support placed on each pile and ultimately the subsurface strata.

The adhesive strength of ice on various construction materials is high and considerable moments and forces have to be resisted by structures subject to icing. A solid ice sheet 9.5 in. (240 mm) thick over a large area would have to form for the uplift to equal the structural resistance according to tests of ice collapse loads made in Canada. Fortunately, the tides disallow thick unbroken ice sheets.

For the Port of Anchorage the worst case of uplift pressures comes at high tide when the entire mass of ice encasing all the piles is submerged. The buoyant force must be resisted by the weight of the structure. The question then becomes what buoyant force to use in designing the structural components.

For downdrag the lighter weight of air entrained ice was used as based on measured densities. Such light ice creates a greater uplift when submerged. However, most of the honeycomb space tends to fill with water and an uplift closer to that produced by the weight of solid ice develops.

There are, however, other factors also working against uplift. No one pile must resist the buoyant force independently. All of the piles work together since they are tied securely together by the deck. There is also a substantial live load on portions of the deck although it is not considered in the design for resisting uplift. Many piles have bearing collars attached, which can resist a large uplift force. The other piles are friction piles which work almost as efficiently in resisting uplift as they do in supporting downward loads.

Early in the design process bubbler systems were looked at to determine if they would keep the ice from building up under and around the dock. The first application of a salt water bubbler system at Thule Air Base on the west coast of Greenland had reported some success.

Bubblers were ruled out because:

- The ice accumulating on the piles froze after the water receded putting it out of reach of a bubbler.
- The tidal flow and ebb at Anchorage is swift enough to disrupt the bubble plume since bubblers are only effective in water flowing at less than 3 ft/sec (0.9 m/s).

Acutally the ice buildup, if not too great, is an asset. It effectively absorbs impacts from ice flows. When pack ice forms against the wharf the pull of the tides form shear lines parallel to the structure and the pack ice actually becomes a protective buffer. It has also been found that ice forms an excellent fendering system.

Design Considerations: Ice Floe

Ice formation in the salt water normally begins by the middle of November and continues well into March. However, the ice season has been known to last from mid-October to mid-May. "Breakup," which normally occurs in March, is aided by increasing hours of sunshine, rising air temperatures, and fresh water runoff. The tides never allow a solid ice sheet between banks of Knik Arm at Anchorage. The rapid rise and fall in water level tends to continuously break up the ice.

The broken ice sheets form ice floes which move with the water currents. Although the outgoing tides may be extreme and swift, they do not flush much of the floe ice out of Knik Arm. The ice floes tend to simply move back and forth within the estuary. Thus, structures within the waterway must resist impact loads and sustained pressures created by the moving ice floes. Often they will impinge against the structure at velocities of up to 5 knots (2.6 m/s).

Figure 2. Steel piles resist the ravages of ice and cold climate much better than concrete piles. These concrete piles, shown as a comparison, were exposed a year. Each cycle of the tides becomes a freeze — thaw cycle in the tidal zone when air temperatures are below freezing. These scoured and spalled areas result from a combination of frost action, falling ice, and floe ice impacts.

Design values of ice strength for impact loading were taken as follows:

Compressive strength	400 psi (2.8 MPa)
Flexural strength	200 psi (1.4 MPa)
Shear strength	120 psi (827 kPa)

An unpublished study indicates floes moving at speeds higher than a certain critical velocity, which lies between 3.4 and 3.9 ft/sec (1.0 – 1.2 m/s), exert smaller sustained pressures than slower moving ice floes. The maximum compressive strength of the ice is reached instantaneously at higher velocities and the structure cuts into the ice sheet. Until the sheet slows, shear strength will regulate the pressure exerted. Full compressive strength will be reached and sustained by floes moving at less than the critical velocity.

Design Considerations: Earthquake

Ice buildups also affect the structure's response to earthquakes. It can either help or harm. The design used withstood the March 1964 earthquake with only minor damage. That earthquake measured 8.4 on the Richter scale and the entire Anchorage area subsided approximately 2.7 ft. (0.82 m).

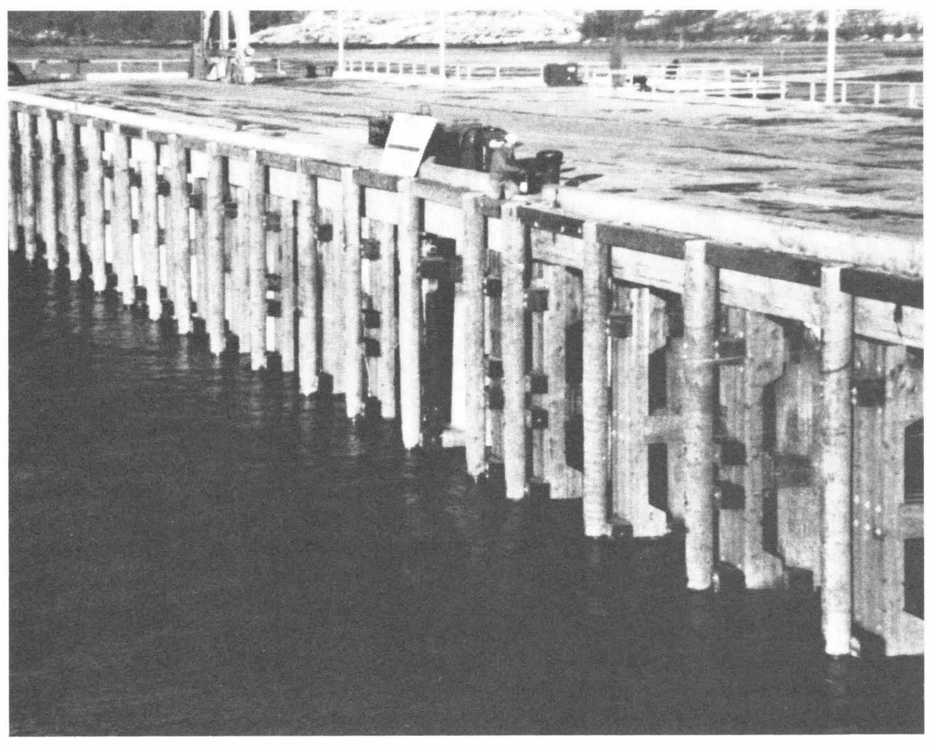

Figure 3. The Port can normally only count on being ice free for six or seven months each year. This fender system is rigid enough to withstand ice loads and smooth enough to allow ships to ride extreme tidal ranges.

The resistance to horizontal earthquake forces is offered by the piles — the battered (inclined) piles, as well as the vertical piles. When considering the wharf free of ice with dead load plus 50% live load, the horizontal force was found to be resisted 25% by the verticals and 75% by the A-frames.

Encasing all of the piles in an ice block results in a corresponding increase in earthquake force. However, because of its massive envelopment and the joining of many piles together, it also has some beneficial effects by providing lateral support to individual piles acting as columns and stiffening the vertical piles against lateral deflection.

In the case of the Port of Anchorage a 20 ft. (6.1 m) thick encasement of ice would stiffen the structure considerably. This is particularly true on the shoreward side where the water is shallow and the ice would extend down to the mudline. The ice would "fix" the piles and change their deflection profile. With this fixity it was found that the proportions for pile types resisting deflection are 60% for the verticals and 40% for the A-frames: that is, the verticals take a greater share than the A-frames.

An evaluation was also made where a coating of ice around each pile was assumed, which adds to the weight and hence the earthquake force, without the beneficial effect of fixity. Such an analysis was used for all areas of the wharf and in all cases it was found that the design is within safe limits.

Design Considerations: Corrosion

In 1957 when the initial port facilities were designed, corrosion of steel piles in Cook Inlet was estimated at 60 mils (1.6 mm) over 20 years. All of the piles were armed with this extra thickness of steel. A monitoring system was established so that additional corrosion protection systems could be added when the extra metal allowance was depleted. Recent inspections indicated corrosion problems of another kind.

Figure 4. During a typical winter ice begins coating the steel piles by the middle of November. Twenty days later the piles will be encased by about a 1-ft. (0.3m) thickness of ice. Ice cakes 6 – 30 ft. (1.8-9.1m) long will be ramming into the wharf.

Figure 5. After another twenty days ribs of ice will be spanning the 10 ft. (3m) between piles, forming an open lattice within the pile grid.

Although there are many reasons for corrosion it only occurs in two significant ways. First is the normal surface oxidation, rust. This is often caused by differential aeration, a condition created by variation in oxygen concentrations. Second is electrolysis which requires an electrolyte or moist conductor. Water, and particularly salt water, is an excellent electrolyte. Basically, there is a common denominator: electro-chemical corrosion cannot proceed in the absence of water.

According to tests conducted by U.S. Steel in other areas, steel corrosion typically shows two peaks in the ocean environment: one in the splash zone and the other just below low tide. The splash zone corrodes by cyclic wetting and drying action. The other peak seems to be in a low oxygen area that sacrifices itself to the tidal area as the water level drops.

For practical purposes there is no significant corrosion of the piles above elevation 5.0 ft. (1.5 m) at the Port of Anchorage. Since the splash zone extends well above that level this lack of corrosion seems inconsistent with corrosion patterns experienced elsewhere. This is due in part to the fact that the lower limit of consistent ice encasement also falls at about 5 ft. (1.5 m). We feel that the ice acts as a coating in the splash zone for about six months each year which eliminates the factors contributing to corrosion. The extreme tidal range of 42 ft. (12.8m) is also beneficial since a widely distributed splash zone results.

A Port of Anchorage field survey undertaken by The Hinchman Company of Detroit, Michigan, last year indicated three other things: 1) stray current electrolysis is not present and is not the cause of any observed corrosion; 2) general metal loss is occurring at and below the mean lower low water line at a rate that has, to date, not seriously weakened the wharf, but has consumed most of the original corrosion allowance of 60 mils (1.6 mm) of steel on older piles in the area of elevations -2 to +3; and 3)

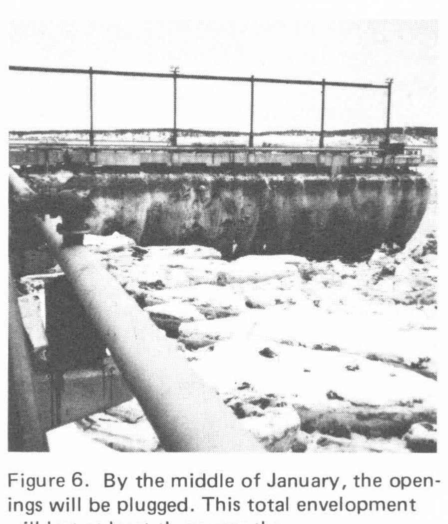

Figure 6. By the middle of January, the openings will be plugged. This total envelopment will last at least three months.

selective corrosion of possibly considerable significance from a structural point of view is occurring on some but not all welds in the vicinity of the mean lower low water line.

Exclusive of the selective corrosion of the welds, this general corrosion is progressing at a rate of approximately 3 to 4 mils (0.08 – 0.10 mm) per year as predicted in 1957.

The first indications of a potential corrosion problem were detected in May 1976. A routine inspection performed during an extreme low tide located a circumferential break in a pipe pile weld. The break had occurred at a field welded splice located several feet below the mean lower low water line.

Unfortunately, the very limited area of the welds make detection extremely difficult other than by visual means. Divers, however, cannot visually inspect the welds since the waters contain a high proportion of glacial silts.

In our opinion, the cause of the selective attack of the weld metal is a low level of electrochemical potential difference of the weld metal with respect to the parent metal making up the bulk of the piles. Such differences in potential result from slight variations in chemical composition of the metal, heat effects from the welding operation, and internal stresses in the metal resulting from the welding process.

Corrosion engineers at U.S. Steel Corp. suggest that corrosion in the heat-affected zone can be controlled to some extent by decreasing the cooling rate after welding. One method is to use a high-heat-input weld.

Under conditions present at the Port of Anchorage with large masses of ice during the winter season, we would not expect any type of protective coating to last more than one or two seasons. In our opinion, application of cathodic protection represents the most reasonable approach to preventing further selective corrosive attack of weld metal on the existing wharf structure.

As a result of the corrosion protection studies, certain changes have been made to pile design.

- All future piling will include the application of cathodic protection at the time of construction.
- Every attempt will be made during construction of new piling to minimize field welds or splices in the zone between elevation +5.0 and the mud line.

All work for the Port of Anchorage is handled by Tippetts-Abbett-McCarthy-Stratton operating in the State of Alaska as a professional corporation with offices in Anchorage (within the Port facilities). Austin Brant is the Executive Vice President of the Corporation. Philip Perdichizzi is also a Vice President and is in charge of all the work handled by the Anchorage, Alaska and Seattle, Washington offices. They and Tetsu Yasuda, as Project Engineer, have been involved in the phased development at the Port of Anchorage.

The Port of Anchorage moved 130,425 tons of freight in October to move the total all-cargo move for the year to just over 1.7 million tons. The October total was 27,126.2 in petroleum products and 103,298.8 tons of general cargo. The freight figure was broken down to include 132 tons of local, 509.3 tons of foreign and 129,783.7 tons of domestic freight. The petroleum figure was the entire movement as inbound domestic for a total of 195.715 barrels of crude and products. The port indicated total general cargo year-to-date stands at 945,755 while total petroleum move year-to-date was pegged at 762,-309.1 tons.

Seattle Journal of Commerce 12-8-78

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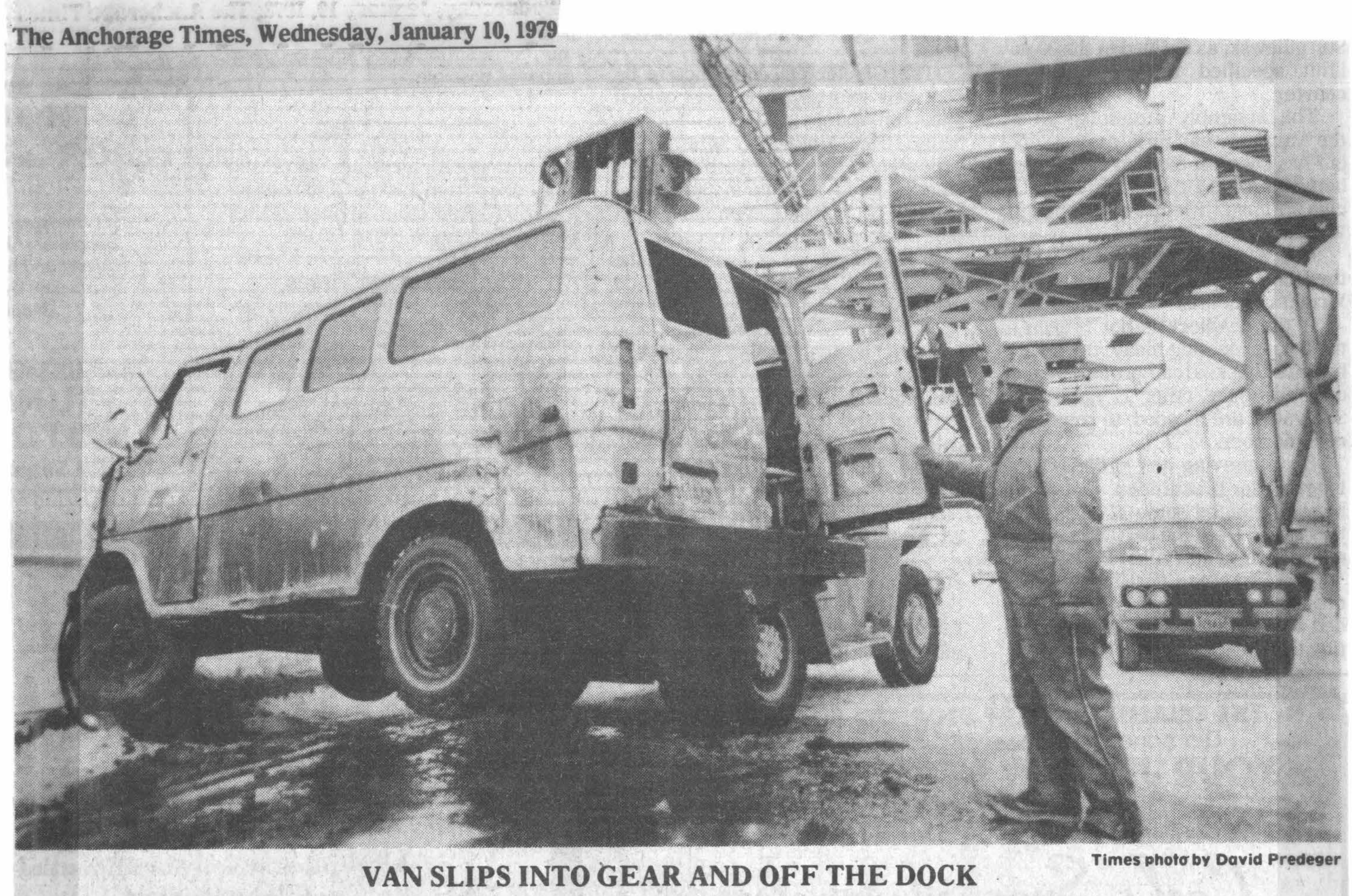
Anchorage port moves 2 million

The Port of Anchorage moved more than 2 million tons of cargo last year, according to the port's monthly tonnage summary.

During December, 71,402 tons of general cargo passed through the port, bringing the year-end figures to just over 1.9 million tons.

Total petroleum products handled during the month of December totaled 97,679.6 tons (704,759 barrels), bringing the year-end total tc 977,599.5 tons (7.05 million barrels).

The Anchorage Times, Wednesday, January 10, 1979



Times photo by David Predeger

VAN SLIPS INTO GEAR AND OFF THE DOCK

Workers at the Port of Anchorage hoist a van that was recovered Tuesday afternoon from 63 feet of water in Cook Inlet. The unoccupied van acidentally went over the edge of the dock at Terminal 2 after the driver parked it but left it running. The gear slipped into drive and the car went into the icy water. The van was owned by Sea Star Stevedore Co. and was removed from the sea bottom because it was in the path of a ship due in later that day. Port officials say it is the first time they know of that a vehicle has gone over the edge of a dock here.

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