Placing Dry-Mix Shotcrete Under Extreme Winter Weather Conditions

by Howard Robbins

Temperatures that range from 90 °F to –40 °F (32 °C to –40 °C), nonstop barge traffic, a solid ice pack for months of each year and the passage of time caused substantial damage to a large ore dock in the Upper Peninsula of Michigan. After negotiating with several contractors, the owner selected the Truesdell Corporation to perform the initial stages of repair to the concrete support columns and concrete beams using the dry-mix shotcrete process as the preferred repair method.

The dock itself is approximately 1200 ft (366 m) long and 75 ft (23 m) high from water level to the base of the rails, and 54 ft (16.5 m) wide on the deck. The deck supports four rail lines to accommodate the 400 to 500 rail cars needed to "charge" the dock. External chutes are then lowered from the ore pockets to load each barge with iron ore. The designers used gravity to perform all of the heavy work of loading the vessels. The approach trestle, constructed of steel, leading to the ore dock adds another 575 ft (175 m) to the overall structure. With 100 ore pockets on each side of the structure, the dock was constructed to accommodate the delivery of iron ore for processing. Construction was completed late in the year 1912. The structure comprises wood, metal, and approximately 200 concrete columns encasing the metal structural members. Consistent with construction methods at the turn of the century, the entire structure is built atop 10,000 timber piles sunk 20 ft (6.1 m) into the sandy soil of Lake Superior. Over time, the concrete encasing the steel support columns has deteriorated, cracked, and spalled. Almost every column requires some degree of repair. Due to the nonstop barge traffic (over 300 vessels during the 9-month shipping season), the dock can only shut down for a limited 10-week period each year. This 10-week period falls in the coldest months of winter, when the lake is frozen and ships cannot travel.

Overview of ore dock concrete support columns with barge taking on ore

Remedial work commenced in January of 2004 with scaffolding, lighting, generators, and heating equipment mobilized to the job site. The first challenge was the availability of materials. Due to the remote location of the dock and low ambient temperatures, wet-mix shotcrete was not practical or readily available. It was determined that dry-mix shotcrete would be the most efficient and cost-effective structural material to use. Weather was a major consideration and had a significant impact on the project both logistically and financially. Average ambient temperatures for the duration of the project were 30 °F below zero (–34 °C) with 30 mph (48 km/h) winds, always from the cold north shore of Lake Superior. Additionally, the area gets 200 to 300 in. (5 to 7.2 m) of snow each year. Dealing with these extreme conditions required an elaborate scaffolding system 50 ft (15.2 m) tall, 25 ft (7.6 m) deep that ran the full length of the repair area. The scaffolding was completely tented with reinforced tarping that was able to withstand high wind velocities, followed by double layers of insulated blankets. Temperatures in the enclosed workspace had to be maintained at a minimum of 40 °F (4 °C) both day and night. Multiple propane heaters with 1000 lb propane tanks were used to

keep the area warm for the crew members and also to allow the special cold-weather-mix shotcrete, purchased from King Packaged Materials, to cure per the manufacturer's specifications. Air compressors and air lines placed outside of the tented workspace were subjected to extreme conditions and required regular attention to avoid freezing. To no one's surprise, heating costs represented the single largest cost—roughly 25% of the total cost of repairs

After the workspace was enclosed and weather protected, work began with the demolition of the deteriorated, spalled, and damaged concrete columns and struts. To replace original reinforcing, Truesdell installed structural steel lacing bars and other conventional steel at various locations. Existing reinforcing was the original 93-year-old square steel bars and angle iron. Approximately 40 lineal ft (12 m) of crack repairs were completed at each column using high-pressure epoxy injection. Finally, shotcrete was placed to repair the damaged beams and columns and provide adequate cover over the steel reinforcing. Approximately 10,000 lb (4537 kg) of dry-mix material was placed at each column location.

Using the aforementioned methods and given the very short window of opportunity to work in the extreme cold-weather conditions, performing all of the remaining work will require a 3- to 5-year schedule.

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Close-up of damages to concrete support column and cracked concrete beam

One side of dock showing sequence of columns needing extensive repairs

The effects of 93 years of wear and exposure to the elements