VALLEY CREEK WASTEWATER TREATMENT PLANT REPAIRS

BY PRASAD M. SAMARAJIVA

Valley Creek Wastewater Treatment Plant is an 85 million gal. (320 million L) per day sewage treatment facility. With the pump station in operation, it has 600 million gal. (2.27 billion L) per day peak flow treatment capacity.

The pump station is built in a 100 ft (30.5 m) deep excavation into dolomite bedrock. The footprint of this underground concrete structure is approximately 360 ft (110 m) long and 230 ft (70 m) wide, and it extends out 35 ft (10.7 m) from each side of the substructure's long span. The underground concrete structure has three major functional areas: the wet well, the dry well, and the flume. The wet well, which is continuous through the total depth of the pump station, is the receiving point of influent (raw wastewater). The dry area located in the middle part of the pump station along the long span houses about 20 large pumps and discharge lines. The flume, which runs along the long span of the pump station on the opposite side of the wet well, is supported by 53 ft (16.2 m) tall concrete space frame of columns and beams. The flume is 35 ft (10.7 m) wide and 35 ft (10.7 m) high. In addition, two stairwells, an elevator shaft, and an air shaft are located in the flume area.

The superstructure, which houses the control room, restrooms, loading dock, and storage rooms, is a 55 ft (16.8 m) tall steel and concrete frame structure with concrete masonry unit (CMU) infill walls. Movement of heavy equipment in and out of the pump station is performed by an overhead gantry crane system running along the long axis of the pump station.

Several elements of the underground structure, including the mat slab, failed on April 2, 2005. Damage was visible in numerous structural elements in the form of cracks and spalls. After the failure of the mat slab, groundwater flowed into and partially flooded the pump station, with the water level in the dry well of the station reaching 14 ft (4.3 m) above the base mat. Heavy rains fell in the area days prior to the failure. The groundwater level outside of the pump station 2 days after the failure was approximately 64 ft (19.5 m) above the base of the mat slab.

INVESTIGATION

The forensics engineering team conducted field observations, performed a detailed structural analysis and design review, and conducted geotechnical testing and analysis.

Distress observed in the field investigation can be summarized as follows:

1. A crack in the mat slab 2 in. (51 mm) wide and 100 ft (30.5 m) long in the dry well adjacent to the wall that separates the wet and dry wells;
2. Numerous cracks in the mat slab, flume structure, columns, beams, and walls; and
3. Heaving of the mat slab.

The engineer implemented a finite element analytical model of the entire underground structure. The detailed failure analysis concluded the following:

1. The structural failure of the mat slab was caused by groundwater uplift pressure on the mat slab;
2. The underground perimeter walls of the structure were not designed to withstand the groundwater pressure present at the time of failure;
3. The structure as a whole did not have sufficient capacity to resist uplift forces under hydrostatic pressure if the groundwater elevation was close to the surface; and
4. The strength of the structure was inadequate to resist the lateral earth pressures even without the presence of groundwater.

REPAIR OPTIONS AND CRITERIA

All repair options had to address four structural issues:

1. Repairing the damaged beams and columns under the flume;
2. Grouting or injection of cracks in the mat slab to reduce infiltration of groundwater if no dewatering system is installed;
3. Restraining or strengthening of the perimeter walls to resist lateral loads due to earth pressure and groundwater; and
4. Anchoring the mat slab to reduce buoyancy of the structure or installing a permanent dewatering system.

Based on the owners' input, five conceptual repair schemes depicted in Fig. 1 were developed with approximate construction costs. After evaluating the associated risk, construction issues, and cost and life expectancy of the pump station, the owner chose a combination of Options C and D. This included strengthening the structure to resist

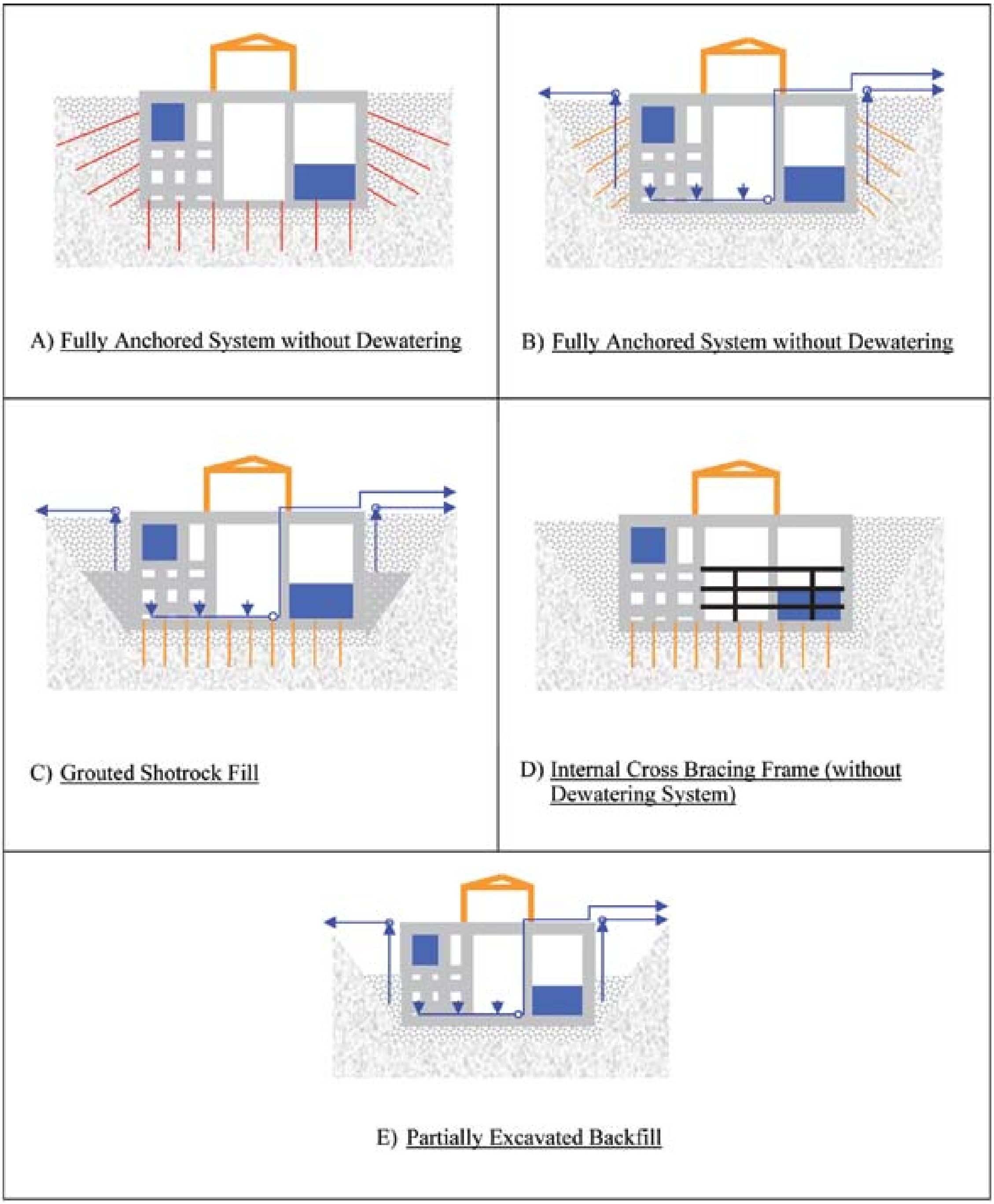

Fig. 1: Considered repair options

the hydrostatic lateral pressure due to groundwater and yet put in place a dewatering system to maintain the groundwater levels below a chosen threshold.

ENGINEERING AND CONSTRUCTION CHALLENGES OF THE REPAIRS

Given the challenging nature of the project, the engineer consulted the facility's original general contractor and a subcontractor to develop a better understanding of challenges associated with the proposed repair options. The presence of the structural frames inside and large shot rock fill in the basin outside led the subcontractor to recognize that installation of rock anchors of the perimeter walls would be highly cost prohibitive. Therefore, Options A and B were abandoned. The geotechnical engineer found that complete grouting of the shot rock fill would be virtually impossible; therefore, Option C was also dismissed. The partially excavated backfill Option E would limit accessibility to the pump station. In addition, the buried lines in the proposed excavation area would hamper sewage transfer operations. Also, the owner wanted to limit the repair work only within the pump station.

As a result, repairs were limited to Option D or a derivative of this option. Even though the impact

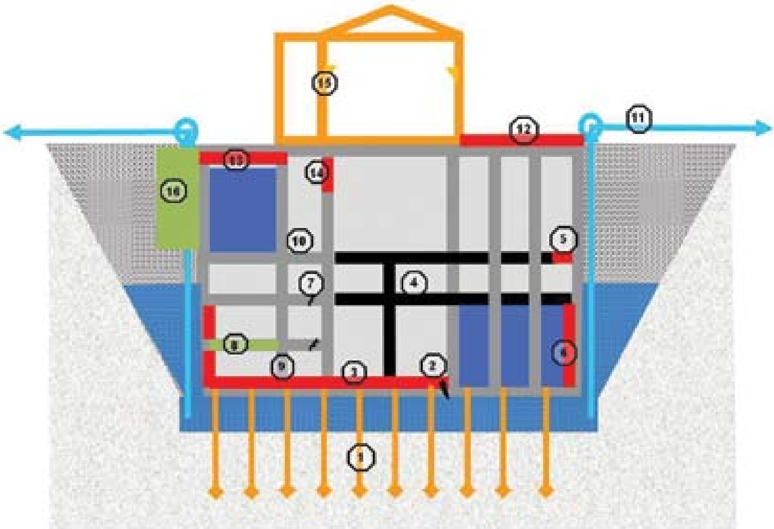

Fig. 2: Various items of repair

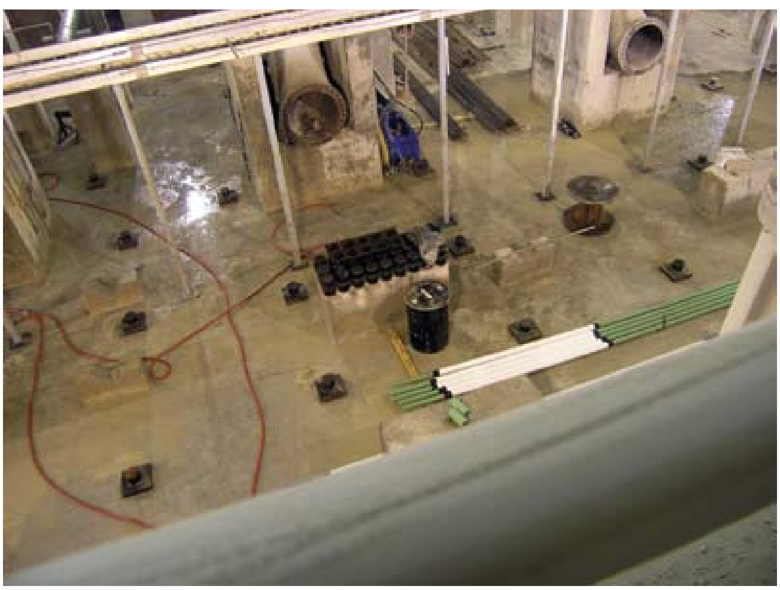

Fig. 3: Installed rock anchors

Fig. 4: Urethane crack injection in progress

of wall strengthening on the sewage retention capacity in Option D appeared to be insignificant, the introduction of an internal bracing system would severely hamper the pump station maintenance operations. For example, it would be virtually impossible to remove and replace the pumps if transverse braces were installed at every current frame location. Furthermore, installing transverse braces at the lowest level of beams would limit maneuvering space for internal operations of the pump station.

Based on those restrictions and the owner's operational requirements, the engineer limited the transverse bracing locations to every other frame and above the first beam level. As a result, the walls needed to be strengthened together with the installation of the transverse braces.

After considering all the associated issues and the owner's desire to have the pump station operational even during a failure of the groundwater pumping system, the repairs pictured in Fig. 2 were designed and are described as follows:

ANCHORING THE MAT SLAB USING ROCK ANCHORS (NO. 1)

Nearly 700 rock anchors were installed (refer to Fig. 3) on 9 x 9 ft (2.7 x 2.7 m) grid in the dry well and 9 x 12 ft (2.7 x 3.7 m) grid in the wet well. Finite element analysis was used to ensure effectiveness of the anchors when they were repositioned beyond the allowable 2 ft (0.61 m) tolerance.

MAT SLAB MAJOR CRACK INJECTION (NO. 2)

The major crack in the mat slab was injected to its full depth using hydrophilic polyurethane grout (refer to Fig. 4). The presence of many fractures in the area made it difficult to seal all the cracks. Injection could be stabilized only after several attempts to bridge the gap.

INSTALLING A HOUSEKEEPING TOPPING SLAB OVERLAY FOR THE BASE MAT (NO. 3)

An 18 in. (460 mm) housekeeping topping slab was placed over the existing mat slab by sandwiching a drainage mat in between. The purpose of the drainage mat was to ensure free dissipation of groundwater seeping through numerous cracks in the base mat.

TRANSVERSE BRACING (NO. 4)

New 36 x 36 in. (910 x 910 mm) transverse bracing struts (refer to Fig. 5) were designed to match the existing beams. Concrete was chosen for the wet well section and galvanized hollow structural steel square sections were chosen in the dry areas. The complexity of precise positioning of the bracing struts was met by the contractor.

WALER BEAM IN WET WELL (NO. 5)

A new 96 x 60 in. (2440 x 1520 mm) high-strength concrete waler beam (refer to Fig. 6) was attached to the concrete wall with epoxy-grouted galvanized dowels. For accessibility reasons, the locations of construction joints, stirrups assembly, and lap splicing were customized so the contractor could conduct other repair tasks simultaneously in the level below.

WALL STRENGTHENING (NO. 6)

Existing 72 in. (1830 mm) thick perimeter walls were thickened over a 35 in. (890 mm) height above the mat slab with thickness varying from 72 in. (1830 mm) at the bottom to 24 in. (610 mm) at the top of the thickened section using high-strength concrete (refer to Fig. 7). Epoxy-grouted galvanized steel dowels were used to ensure composite action between the existing wall and the new wall.

INJECT CRACKED BEAMS, COLUMNS, AND WALLS TO REESTABLISH AGGREGATE INTERLOCK (NO. 7)

Numerous small cracks in the structure were epoxy-injected to ensure aggregate interlock.

RECASTING HEAVILY DAMAGED CONCRETE BEAMS (NO. 8)

Heavily damaged concrete beams were demolished and recast to their original sizes. The reinforcement, however, was redesigned in the beams to function as struts.

EXTERNALLY BONDED TIES FOR COLUMNS AND STRUTS (NO. 9)

New externally bonded steel plates designed to function as ties that were found to be insufficient in the existing members were used together with epoxy anchors to restrain unconfined longitudinal reinforcement (refer to Fig. 8).

REPAIR CONCRETE SPALL (NO. 10)

Concrete spalls throughout the structure were repaired using standard repair methods.

A PERMANENT DEWATERING SYSTEM (NO. 11)

Based on a groundwater study, a new programmable four-pump dewatering system was installed.

UNFORESEEN CONDITIONS

During construction, some additional structural deficiencies were discovered. The majority of these deficiencies can be attributed to the discovery of the substitution of precast hollow core slab panels for a cast-in-place reinforced concrete slab at the ground level to function as a diaphragm. It was determined that these hollow core slab panels were not designed to act like a diaphragm. As a result, creating new

Fig. 5: Steel strut installation in progress

Fig. 6: Waler beam epoxy doweling in progress

Fig. 7: Wall strengthening in progress

Fig. 8: External compression ties

Fig. 9: Installation of dowels for wet well overlay

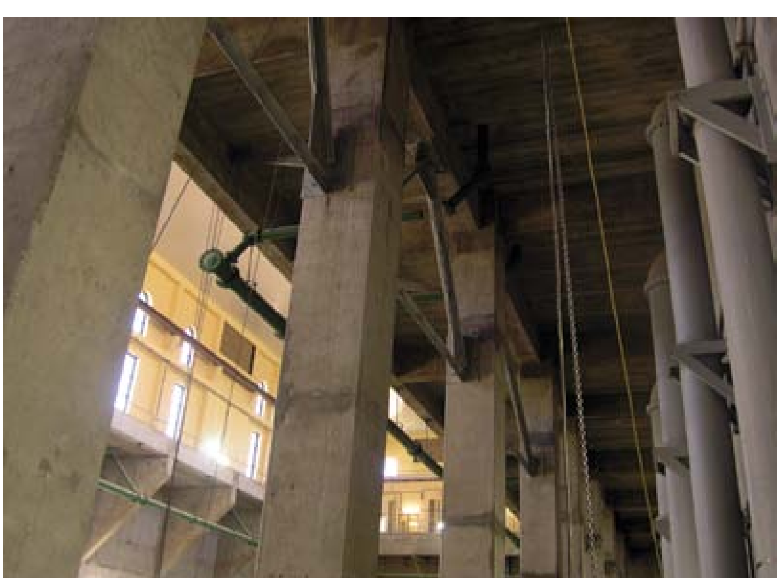

Fig. 10: Steel trusses designed to support crane beams

access hatches for the wet well repairs became impossible without strengthening the diaphragm slab. In addition, the concrete corbels for the bridge crane and the transfer beams under the crane columns were found to be structurally deficient. To correct these deficiencies, the repairs pictured in Fig. 2 were designed and are described as follows:

WET WELL DIAPHRAGM STRENGTHENING (NO. 12)

A new high-strength overlay concrete slab was installed over the wet well top diaphragm (refer to Fig. 9). The thickness of the overlay was limited because installation of shoring was impractical in this deep well to support the existing slab.

CONCRETE BEAMS INSIDE THE FLUME (NO. 13)

Concrete beams measuring 36 x 36 in. (910 x 910 mm) were installed inside the flume under the superstructure. Self-consolidating concrete was poured into the formwork through ports in the existing hollow core planks.

STEEL TRUSSES TO SUPPORT CRANE BEAMS (NO. 14)

Galvanized steel trusses were designed to facilitate field assembly so workers could install them in pieces without the use of a heavy crane (refer to Fig. 10).

CORBEL STRENGTHENING (NO. 15)

Additional reinforcing bars were epoxy-grouted into the crane support corbels to meet the necessary strength requirements.

CLOSURE OF THE STAIRWELL OPENINGS (NO. 16)

The stairwell openings in the middle of the top diaphragm were closed to ensure continuity in diaphragm action. As a result, new stairwell segments were designed to provide access to the stairwells from the exterior.

PUMP STATION RESTORED

After 6 months of investigation and analysis and 5 months of repair design, a plan was accepted by the owner to repair the pump station. These repairs included 700 rock anchors, nearly 25,000 epoxy-grouted dowels, 650 tons (590,000 kg) of steel, and 8000 yd^3 (6100 m^3) of concrete.

Despite the magnitude and challenges of the repairs, the pump station was restored and fully operational to the owners' satisfaction in less than 3 years from the time of failure (refer to Fig. 11). The success of these unusual repairs should be credited to the exceptional teamwork and creative structural solutions by all parties involved and the owners' unwavering commitment to restore the pump station to serve the community.

Valley Creek Wastewater Treatment Plant

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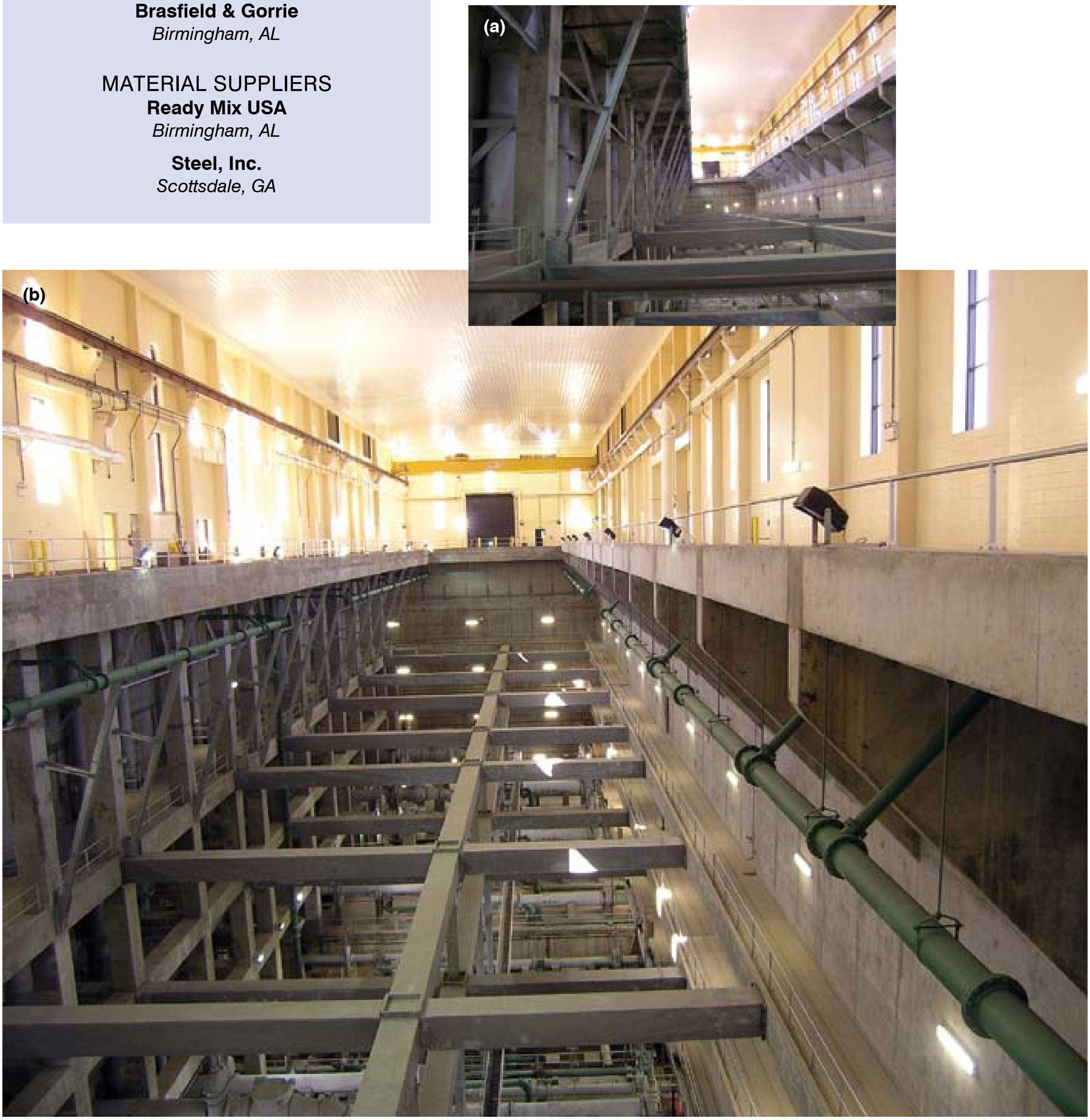

Fig. 11(a and b): Pump station restoration complete