

Saskatoon City Hospital Repairs

Saskatoon, SK, Canada
Submitted by Walter P Moore

Saskatoon City Hospital, in the province of Saskatchewan, Canada, is comprised of four patient levels with interstitial mechanical levels. This project involved the evaluation, repair, and strengthening of a cast-in-place, post-tensioned, waffle-slab structural framing system. Work was conducted in an interstitial space over an active emergency room with strict measures in place for noise, vibration, and infection control. These constraints presented many challenges in the repair of the structure.

The owner engaged a design consultant to conduct a comprehensive condition assessment of the building's waffle-slab system and develop a future course of action for repair. The assessment identified a variety of issues that impacted the structural capacity of the floor framing. These included:

- Widespread cracking in the waffle-slab pan, beams, and ribs;
- Cracking in the waffle-slab drop panels;
- Slab shear deficiencies; and
- Column punching shear deficiencies.

BACKGROUND

Saskatoon City Hospital is comprised of several patient care wings. The building structure consists of cast-in-place concrete waffle slabs with a two-way, unbonded, post-tensioned system and conven-

tionally reinforced columns. The location of the repair project was an active emergency room wing with an interstitial mechanical floor directly above, which was suspended by metal hangers from a roof-level waffle system. The interstitial space contains numerous pieces of mechanical equipment and piping to supply emergency room activities.

This project focused on the investigation and repair for cracking distress in the waffle-slab system above the emergency room wing. Once the nature and extent of the cracking distress to the structure was indentified, the design consultant was engaged to prepare construction documents to address the noted deficiencies in the waffle-slab system. A local contractor specializing in concrete repair and carbon fiber-reinforced polymer (CFRP) applications was selected through a bid and qualification process.

STRUCTURAL EVALUATION

Based on a review of the post-tensioning stressing plan, the post-tensioned waffle-slab system was stressed in phases during initial construction. From a subsequent review of stressing calculations, it was determined that portions of the waffle-slab system could have cracked during initial stressing due to high post-tensioning forces. During the investigation of the building, cracking consistent with this post-tensioning stressing



Exterior view of Saskatoon City Hospital

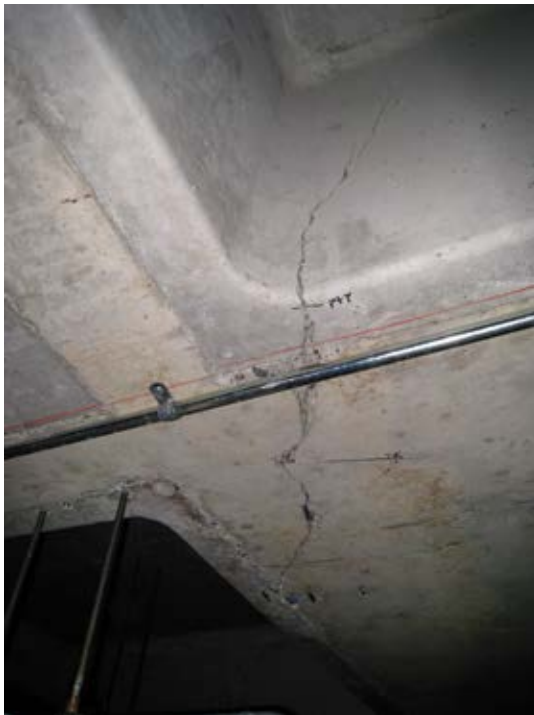


Mechanical equipment located in work area

2012 Award of Excellence

behavior was identified in the waffle-slab pan, joists, ribs, and drop panels at the roof level over the interstitial mechanical space. This cracking adversely affected the capacity of the waffle-slab structural system, thus creating a life-safety concern over the ability of the slab to carry the loads that were present. Emergency shoring was installed throughout the facility to establish the necessary infection control measurements.

Although cracking was visibly apparent at the surface of the various waffle-slab components, the depth of cracking and condition of the post-tensioning reinforcement was unknown. Crack mapping was conducted to establish patterns and typical occurrences of cracking. Nondestructive testing established the crack depths, the profile of the post-tensioning tendons, and locations of other reinforcement. The investigation showed cracking predominantly along the column gridlines and around



Typical cracking in waffle slab



Infection containment system in work area

through slab drop panels. Cracking was found to be full-depth at portions of the waffle slab and the crack widths were found to vary with seasonal temperature exposure at the roof level.

STRUCTURE REPAIR

Based on the findings of the slab crack investigation, repairs were undertaken to strengthen the waffle-slab system over the emergency room. Due to the potential contamination from performing concrete repairs within the interstitial mechanical space, strict infection control containment measures were implemented to control dust and other airborne contaminants. Work areas were cordoned off with plastic containment and zipper access and sterilized shoring was installed throughout the emergency room to support the interstitial space during the repairs.

Concrete repair work began with epoxy injection of waffle-slab cracks. Due to heightened dust control concerns, the surface seals that were installed were left in place (with a neat appearance) after injection. Approximately 1500 ft (457 m) of cracks were injected during this phase.

The CFRP reinforcement was then installed to strengthen the cracked and structurally deficient waffle-slab joists and ribs. Concrete surface preparation was undertaken by applying HEPA filter vacuum attachments to concrete removal equipment to minimize dust. Imperfections in the waffle slab were smoothed with epoxy repair mortars prior to the CFRP application. CFRP U-wraps were installed to strengthen the waffle slab for shear near the columns using one or two plies, depending on the strengthening requirements. Cautionary stickers were placed on the CFRP applications to prevent damage from possible future equipment hanger installations. Approximately 100 waffle-slab joists were wrapped with approximately 3000 ft² (280 m²) of CFRP material.

The final concrete repair work involved the installation of concrete column collars to strengthen the waffle slabs for punching shear deficiencies. While carefully complying with infection control requirements, the contractor roughened the concrete surface of the columns and installed reinforcing steel for the collar installation. The contractor fabricated steel forms to facilitate the placement of the repair material and used a self-consolidating concrete mixture to minimize vibrations. The interface between the concrete collars and slab soffit was then filled with dry-pack grout for uniform bearing with the waffle slab. A total of six column-to-waffle-slab joints were strengthened for punching shear.

WORK PHASING

The interstitial space contained numerous pieces of mechanical equipment and piping that interfered

with the locations of structural repair. The project team and facility managers worked closely to develop work phasing plans and coordinate construction activities during the repair work that included extensive movement of the mechanical equipment.

Work above an active hospital emergency room required other special considerations. Concrete demolition and repair work had to be conducted in a manner that would minimize noise and vibration impact on intensive care facilities. Strict infection control measures were put in place to ensure that dust was minimized, and low volatile organic compound (VOC) materials were specified to reduce odor and noxious off-gassing.

QUALITY CONTROL

Throughout the project, quality control was maintained by defining and adhering to a rigorous site inspection and testing protocol. The engineer provided routine site visits throughout the project to verify quantities and monitor the quality of repairs. The engineer also conducted periodic bond testing of the CFRP installation to ensure proper adhesion, and acoustic sounding and infrared thermography were used to detect voids in the CFRP installation. In addition, CFRP witness panels were created for laboratory testing to confirm the specified design parameters of the CFRP material.

TECHNICAL INNOVATIONS

This repair project featured several technical innovations for work adjacent to occupied spaces. First, customized infection control measures were introduced to contain and mitigate dust exposure during concrete repair. These measures were provided by the owner and were frequently reconfigured to accommodate mechanical equipment and piping interference in the various work areas. Second, externally bonded carbon-fiber reinforcement was used for structural strengthening of waffle-slab components to minimize the repair footprint.

SUCCESSFUL REPAIR

Saskatoon City Hospital represents a vital piece of infrastructure for Saskatchewan. Taking this into consideration, the design team conducted the evaluation and repair of the hospital with a heightened awareness for public safety and structural repair solutions with minimal impact on the health-care facility.

Some of the unique project features were:

- Use of nondestructive tools for investigation;
- Repairs to restore the structural integrity of the building;
- Strengthening using CFRP with minimal footprint;
- Use of self-consolidating concrete for column repairs to minimize the impact of concrete repair material placement;



Carbon-fiber reinforcing of beam section



Formwork and reinforcement for column strengthening

- Use of low-VOC materials;
- Development of infection control measurements to minimize dust; and
- Continual communication between the owner, engineer, and contractor.

Saskatoon City Hospital

OWNER

Saskatoon Health Region
Saskatoon, SK, Canada

PROJECT ENGINEER/DESIGNER

Walter P Moore
Houston, TX

REPAIR CONTRACTOR

Vector Construction, Ltd.
Saskatoon, SK, Canada