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February 11, 2022

Dan Watson
Director of Facilities
Greenwich Public Schools
290 Greenwich Avenue
Greenwich, CT 06830

Subject: **GREENWICH CENTRAL MIDDLE SCHOOL**
DEFLECTION ON 2ND LEVEL FLOORS

Dear Mr. Watson,

Per your request this is a follow-up letter from our site visit and inspection of 2nd level floors in the original building. The AHJ inspected the condition and requested that DTC provide an opinion on observed deflection.

The 2nd level floors in question are in the east to west wing of the original building connecting with the addition at a sally port. The AHJ observed a consistent deflection in these floors measuring a typical 1-1/2" at mid-section. The deflection tapers to zero on either end in the north to south axis.

DTC was able to study some as-built records and inspected the existing 2nd level floor conditions on several occasions. According to design records the floors in question are 10" cast-in-place structural slabs that clear-span east to west in each of the classrooms in this wing of the original building. The ends of these slabs are supported by structural steel beams and columns framed in the north to south direction. These slabs are not attached to parallel running CMU walls.

Figure 1 - Underside of Structural Slab

Figure 1 is a photo of the underside of the 2nd level slab inspected by the AHJ from the perspective of looking up at the bottom of the slab where the AHJ measured the 1-1/2" deflection. The CMU wall is painted white over what appear to be formerly blue and yellow. The bottom of the structural slab is seen in the upper left corner. The gap between the slab and CMU wall appears black and is packed with an insulation material. There is no physical connection. The slab and wall show no signs of excess stress or failure, such as fractures.

Deflection is normal to all clear spanning structural members including these slabs. Deflection varies with service load conditions such as occupancy and design standards, and is a slight arched shape or bow from end-to-end for a clear spanning structural slab. The existing slabs were designed to

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clear span 30'-0". By contemporary standards[1] the slabs would be designed for a 1-5/16" deflection measured from plumb level where the AHJ observed 1-1/2" deflection measured from plumb level. We do not know what deflection criteria was used at the time the building was designed but a 3/16" variation from contemporary standards can be attributed to any number of factors such as evolving design standards, workmanship, and quality control. DTC's opinion is the observed deflection is the result of evolving design standards and quality control measures at the time the original building was constructed. Observed deflection is not a structural concern. Following is a discussion.

The strength of concrete is achieved by a chemical process activated by the introduction of water to a mixture of sand, aggregate and Portland cement. This process is called "cure" and strength is based on design of the concrete mixture and quality control. Normal strength concrete mixtures are designed to achieve their full strength within a 28-day curing period. 28-days is a predictive time frame unrelated to the calendar. Design strength can be achieved prior to or after a (28) calendar days depending on many factors. The 28-day prediction defines when analytical tests are performed to determine and document actual strength gain in the field.

Temporary shoring and form work used to support the curing of an elevated structural slab must remain stable, plumb level, and in-place throughout the 28-day curing period in order for the slab to retain its designed shape. The shape is typically shown in drawings as plumb level and undeflected. The slab will immediately deflect under its own weight following removal of forms. It will continue to deflect with increased service loads such as work on the slabs and occupancy. The deflection is not permanent in so much as the concrete slab is properly cured prior to applying service loads.

Movement or prematurely removing formwork while an elevated slab is curing deforms a slab's shape. Movement can be the result insufficient cribbing and struts in the framing of form work, assemblies, consolidation of soils, deflection in forms, blowout, premature removal, prematurely working on slabs, or combinations. By observation the slabs were formed with planks. This is indicative of stick-framed timber formwork and does not meet current standards for quality control. Assemblies, struts, and jacks would have been timber and nails. This type of formwork system is prone to relaxation while being initially loaded with concrete and worked. Timber contracts with decreasing moisture content which is the natural consequence of concrete operations. These conditions would be exacerbated with combinations of factors noted above. We expect to see some degree of deformation in the shape of elevated slabs for buildings of this era and formwork.

We do not have a record of the deflection criteria used in the design of the slabs. Today we would design these slabs for 1-5/16" deflection under all service load conditions applying contemporary standards. This is based on the strength of concrete and design[2]. The observed 3/16" variation with contemporary standards is not surprising and not a structural concern by itself. We look for other indications of structural failure or fatigue in the slabs but found none during our field inspections.

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[1] For school buildings, the International Building Code (IBC) is the general standard from which CT Building Code conforms. The IBC was first issued in 1997 and adopted by CT in 2005.

[2] Elevated structural slabs are exposed to stress that include compression, tension, bending and shear stresses. There are other considerations but generally designers use concrete as support for compression, shear, and bonding with reinforcing steel imbedded in the concrete. We use reinforcing steel to support compression, tension, shear, and bending.

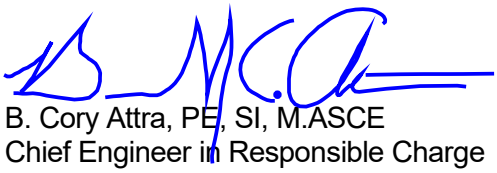
Design standards have evolved and standardized since the design of Greenwich CMS. The design of Greenwich CMS appears based on Allowable Stress Design (ASD) which uses factors of safety that are more conservative compared with contemporary standards. The reason contemporary factors of safety are less conservative is because the quality of workmanship and materials have substantially improved. Our interpretation of as-built records is that the designers took into consideration the quality of workmanship and materials for its era.

For these reasons DTC concludes that the observed deflection is normal, within design tolerances, and not a structural concern.

Please call or email me if you have any questions or need additional information. My cell phone number is (603) 400-5455 and my email is cory.attra@teamdtc.com.

Very truly yours,

DTC, INC.



B. Cory Attra, PE, SI, M.ASCE
Chief Engineer in Responsible Charge

Enclosure 1. Narrative Description of Exigent Repairs
2. Proposed Bridge Locations & Illustration

cc: Bob Hammersley, DTC
Katie Bosnan, DTC