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Masonry investigation of the Nott Memorial

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Abstract

The Nott Memorial is a unique, 16-sided building constructed between 1858 and 1876 on the campus of Union College in Schenectady, N.Y., USA. It is listed on the National Register of Historical Structures.

On June 17, 1989, 2 m^2 of facing stone fell from the building. This paper discusses the investigation and analysis of the masonry problems and the evaluation of the facing stone and mortar. These problems include a) deteriorated mortar and facing stones, b) lack of bond between facing stones and backup, c) excessive stresses, and d) inherent weaknesses in the walls.

1 Construction

The exterior walls are masonry bearing walls. A cast-iron interior framework supports the floor joists, the roof, and the dome. At each corner, a chimney was built integrally with the wall.

The 16 exterior walls, each approximately 5.2 m, rise 16.2 m to the eave of the roof. The wall thickness varies from 1.2 m at the basement and 0.6 m at the roof. See Figures 1 and 2.

The facing stones are primarily of a local bluestone (Schenectady Wacki). Ohio sandstone is used to trim the openings. Polished granite forms window pillars at the first floor. The bluestone is dressed on the face and averages 130 mm in depth; the backs are very irregular. The sandstone is uniform and dressed to form arches, sills, and belt courses.

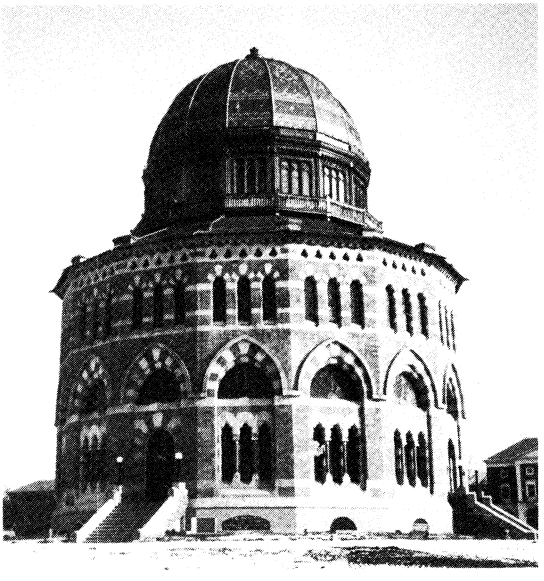


Figure 1: Nott Memorial (1995)

The backup is a rubble core of small pieces of bluestone and mortar with many voids and an inside wythe of bluestone. The walls are bonded with mortar; there is little interlocking of the face stones to the backup. Photographs of the original construction, [1], indicate that the masonry was built from scaffolding positioned within the building.

2 Problems

Until the facing stones fell, the condition of the masonry walls had not been fully evaluated. Previous repairs included repointing cracks and deteriorated joints with a thin layer of cement mortar. The failure occurred at a corner between the window arches at the second floor adjacent to a chimney. The bottom of the failure was below the projecting arch belt course.

3 Inspection

Following the failure, exterior observations were made of the masonry. Interior finishes covered the walls; only partial observations were possible. Subsequent removals exposed the interior face of the exterior wall for inspection.

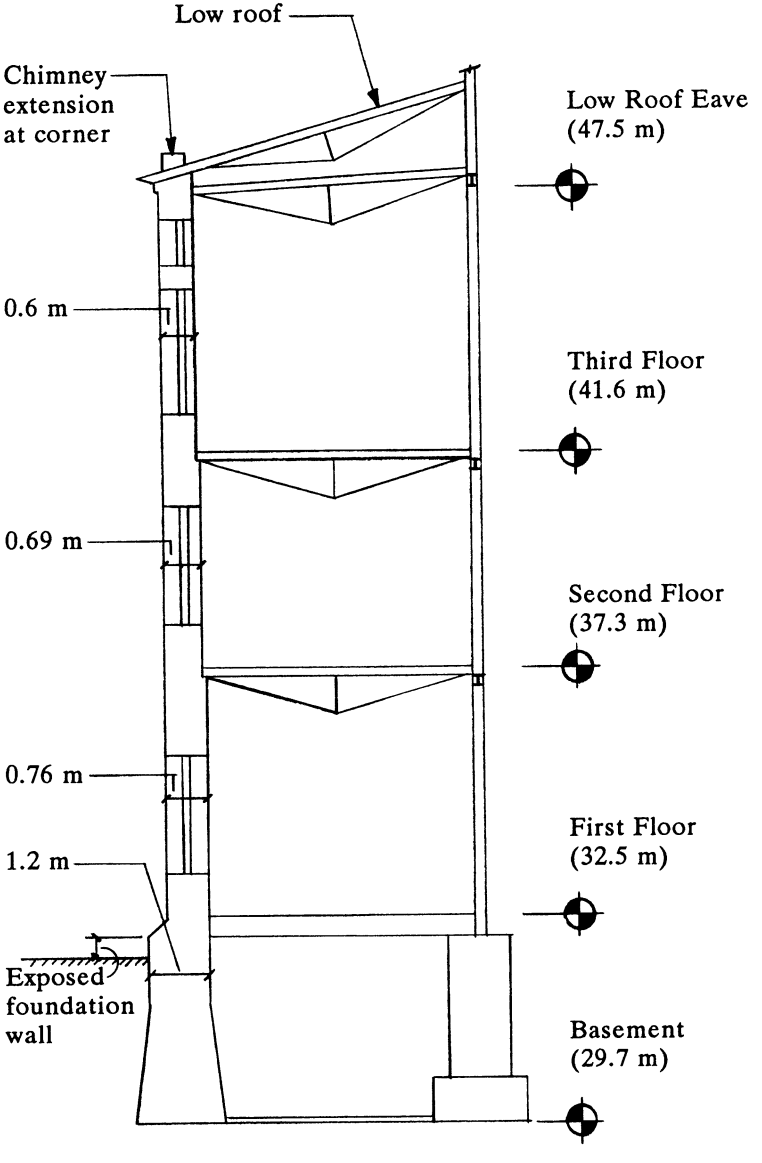


Figure 2: Section through Exterior Wall

Foundation Wall

The exposed foundation stones and mortar was in generally good condition. Sometime after the building was constructed, a cement plaster was added for aesthetic purposes. The plaster was essentially deteriorated and delaminated as determined by "sounding" the wall. The condition of the mortar between the stones was very soft and easily removed. The mortar joints between the stones are generally 3 mm to 6 mm wide. Some mortar joints are non-existent; the stones bear upon each other. The stones are severely deteriorated (faces are delaminated and some stones are cracked). An earlier report, e.g. Mendel [1], states that the stones used in the foundation were unsuitable for the upper portions of the building.

Building Walls

Moisture readings were taken, [3], at exterior locations at approximately 25 mm incremental depths. The readings revealed that the mortar was relatively dry through the face stones. The mortar was weak and was sometimes non-existent behind the facing stones.

Several samples of original mortar were taken from the building during this phase and examined with a stereoscope. In addition, the samples were chemically analyzed for constituent materials.

The mortar contained cement, lime, and sand. The sand-to-cement/lime ratio varied between 1 to 1 per Ryan-Biggs [3] to 1 to 2 per Notter [4]. The report of 1973 [1] states that the cement used in the mortar was "Kingston Cement," a natural cement.

The mortar samples were generally severely deteriorated from freeze-thaw cycles. In general, the mortar could be easily scraped and removed to the full depth of the facing stone. In most wall areas, the mortar is cracked; and in some areas, the mortar was completely missing from between the stones. In some areas, the mortar joints could be probed 150 to 400 mm without encountering any additional mortar or backup.

Three generations of repointing mortar were distinguishable by their colors. They were not well bonded and could easily be removed intact in several locations. Most repointings were only 6 mm deep and were made with a relatively hard portland cement mortar.

As stated, the exterior facing stones are constructed of granite, sandstone, and bluestone 125 to 150 mm thick.

The granite is only used as pillars in the first-floor windows. There was no significant problem with the granite.

The sandstone is used for the other decorative treatments. It too was in generally good condition except at isolated spots.

The majority of the facing stone is bluestone which is a sedimentary stone commonly called "shale". It has clearly defined bedding layers. Figure 3 shows the three possible orientations; all three were used in this building. The most serious deterioration occurred with the bedding planes vertical and parallel to the exterior face; spalling of the surface occurred. The other two bedding orientations showed deterioration at the edges of the stones along the bedding plane.

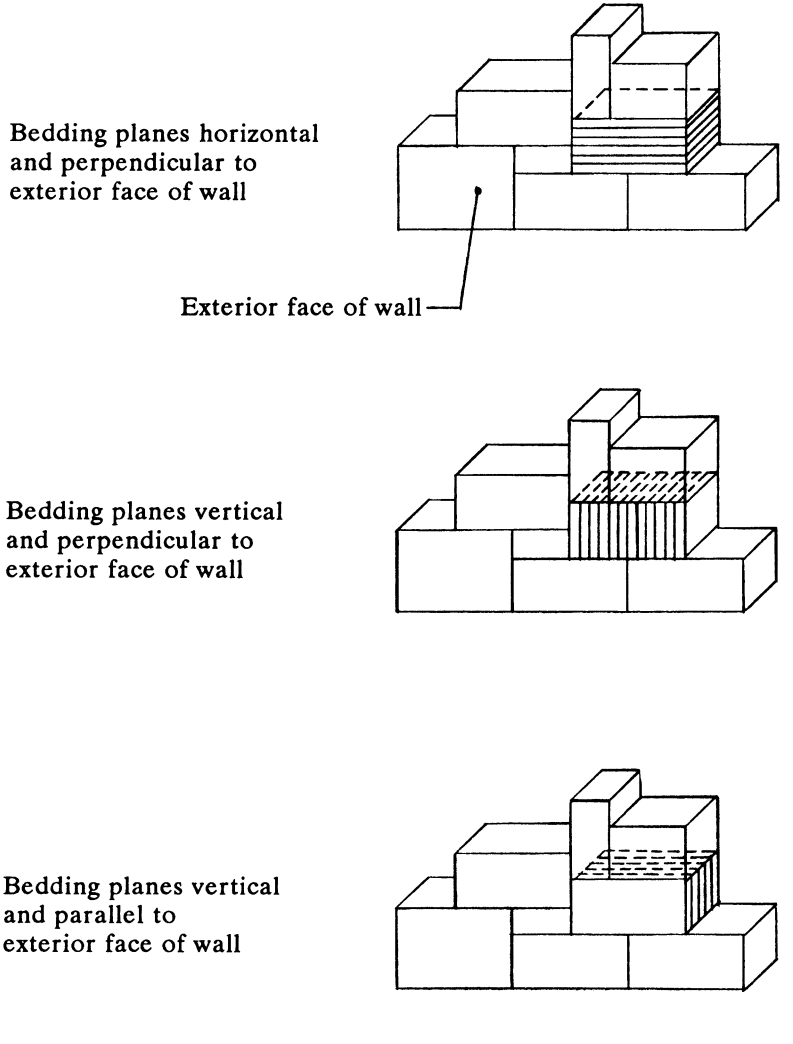


Figure 3: Bedding Plane Orientations

Many of the bluestones were sounded. Many with bedding planes vertical and parallel to the wall sounded "hollow" indicating the stone was delaminated and spalling.

Most of the cracking occurred between the arched openings of the second floor. In addition, several arches were discovered to be moved outward from the backup. Three arches were stabilized temporarily using cables and blocking.

All of the stones were dirty and partially covered with ivy.

During a previous repair, sealants were installed around windows and in the joints of the belt courses. These have since failed.

Removals were made at three locations and the failure area. No signs of distress immediately adjacent to the failure were found.

The stones which fell seemed to separate rather cleanly from the rest of the wall. This is a result of the inherent weakness caused by the integral chimney. A crack extended above the failure and seemed to follow the chimney. From our inspection of the other walls, this crack probably existed prior to the failure. It appears the failure began at the lower portion of the arches adjacent to the chimney cavity.

The removals indicated there were voids behind the facing stones, and the mortar in the backup was dry and could be easily removed. No header stone nor anchorage was observed between the facing stone and the backup. Core drilling the back-up indicated there were voids in the backup also. Due to the deteriorated condition of some stones, they were damaged during the removals.

Interior observations yielded some interesting data. The corner chimney vents were modified during a previous renovation which further weakened the corner. Some separation between interior stairs and the exterior wall had occurred at two corners. Subsequent investigations, e.g. Notter [4], indicated there was no clear relationship of interior cracking to exterior cracking nor to wetness in the wall.

4 Analysis

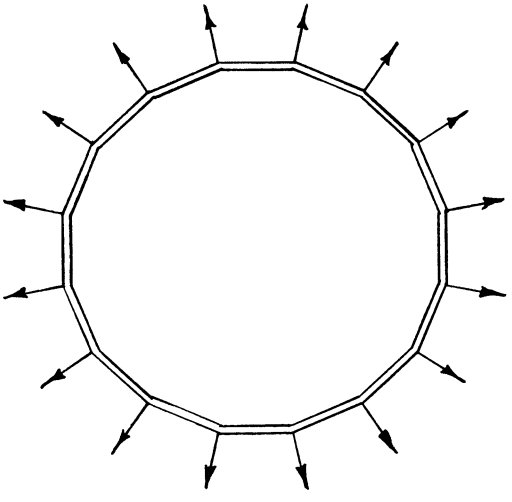
A structural evaluation of the exterior walls was performed at three levels. They were analyzed as bearing walls which support roof and floor loads. However, the dominant load was the weight of the masonry itself. Compressive stresses varied from 180 kPa to 662 kPa. This is consistent with other structures of the time period.

Due to the unique, 16-sided configuration of the building, the arched openings create some unusual stresses. Figure 4 shows the horizontal thrust

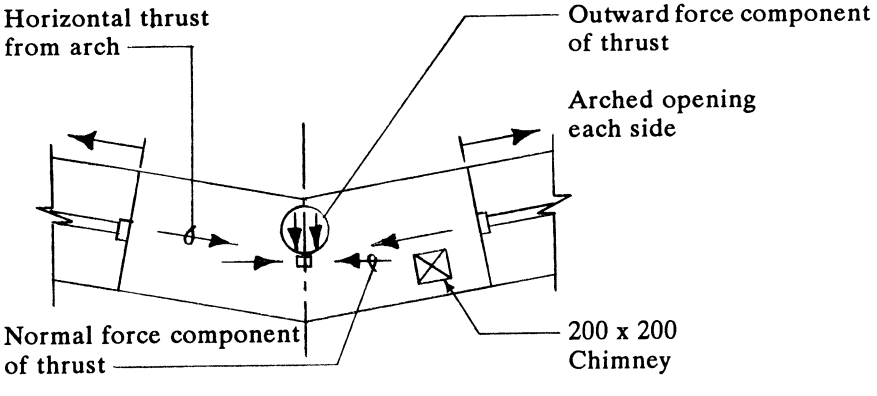
of the arches resolve into normal and outward components. The normal components are offsetting but add to the overall compression of the vertical loads. The total compression increases to approximately 1380 kPa.

The outward component produces a hoop stress, which is taken by the masonry in tension, of approximately 172 kPa.

The highly stressed area is the point where the failure initiated.



Key Plan at Arches



Corner Plan

Figure 4: Horizontal Forces from Arches

5 Assessment

The exposed foundation masonry is in generally fair condition but requires repointing. The parging can be removed or repaired; it appears it was added for aesthetic and waterproofing.

Overall, the exterior mortar is deteriorated and needs to be repointed using a compatible mix.

The facing stones of granite and sandstone are in overall good condition. However, isolated sandstones need crack repairs. The bluestone condition is generally acceptable. Many stones have been damaged by the hard repointing mortar of previous repointing; spalled and cracked stones need to be replaced.

Voids in the backup need to be filled, and the facing stones need to be anchored to the backup. Proposed methods include a) grouting the voids and anchoring the stones mechanically, e.g. Ryan-Biggs [3], and b) filling voids only at areas where stones are removed and replaced and anchoring around openings, e.g. Notter [4].

The major structural problem is the high stresses in the corners which caused the cracking and the spreading of the building. To reduce the stresses, it was necessary to strengthen the 16 corners and redistribute the loads. This entailed filling the chimneys with a reinforced grout and patching the interior openings created during an earlier renovation. In addition, the outward forces from the arches were to be restrained by a reinforced concrete tension ring placed along the interior of the building and anchored to the reinforced corners.

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