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REPORT ON MASONRY DISTRESS

FIRE STATION, NAPOLEON, OHIO

In accordance with your order of January 4, 1985, our firm has researched the cracking of masonry walls on the above structure.

We have studied the construction plans and specs prepared by Wayne A. Wolford, Architect, and obtained shop drawings of the precast systems for our study.

At the jobsite, we observed the location and width of the cracks in detail. We also, had S. A. Storer & Sons remove two concrete blocks to study the method of wall bonding. They also, cut into the double tee bearing and verified the existence of neoprene bearing pads. Bowser-Morner Inc. supervised the excavation of two test pits to study the "fill" beneath the foundation. They studied the patterns and sizes of the cracks, and observed the condition of the rip-rapped river bank. Mr. J. Richard Hoppenjans, P.E., Chief District Engineer, has submitted his report (attached).

In the office, we calculated total load and dead load soil pressures, as well as wind stresses in the masonry. We also, studied the block wall as an independent bearing wall structure (without the composite brick).

In our analysis of the structure, we found many items to report to the City. Our proposal had mentioned six possible causes to investigate. Our study found the following:

1. PRECAST SYSTEM: In all causes studied, only the expansion and/or rotation of the double-tee roof system was exonerated. It bears on neoprene pads and shows no distress at the bearings anywhere.

2. MASONRY BONDING: The City's metal detector found that joint reinforcing is located at alternate courses. (This spacing, which was specified, is considered better than average). The Architect specified "extra heavy deformed wall reinforcing of a truss-type", and with weights per thousand lineal feet of 187#/8", 207#/12", and 212#/13". These weights correspond with normal weight (NOT extra heavy) for two-wire truss type reinforcement. The wall has normal weight (#9 ga.), two-wire truss type in the eight inch wyth of the 13" cavity wall

weighing 187#/mlf. in lieu of 212#/mlf. Then corrugated brick strap ties, 7/8 x 26 ga. were used to tie the brick wythe thru the insulation to the block. The one corrugated strap tie, exposed by Storer, was rusted through, so there is little or no attachment of the brick to the block. In 1974, the 1959 Ohio Building Code required cavity walls to be bonded with "3/16 inch diameter metal rods, bent into a rectangular shape for hollow masonry units with cells laid vertical". " There shall be one tie for not more than 4½ square feet". In other words, the walls were not constructed in accordance with plans, specs, or The Ohio Bldg. Code. Despite substantial deviation from "Code" provisions, the Apparatus Room wall is within allowable stresses, for bearing, and bending, due to roof load eccentricity and wind.

3. FOUNDATION SOIL PRESSURES: This problem is discussed on Page 5 of Bowser-Morner's report (attached). The calculated dead load soil pressures vary from 624 psf. to 3015 psf. Total load soil pressures range from 624 psf. to 4320 psf. This extreme variation, coupled with the narrowness of the fill area beneath the footings probably had some contribution to the cracking of the walls.

4. FOUNDATION HORIZONTAL MOVEMENT: This segment of the total distress is discussed in the Bowser-Morner report on Page 3. Mr. Hoppenjans and I both found movement in the rear wall of nearly an inch. Obviously, if a large earth movement occured, the Fire Station would have collapsed, but a movement of one inch would certainly contribute to the cracking in some of the walls.. The rip-rap repair to the slope probably arrested the bank movement problem.

5. MASONRY DIMENSIONAL CHANGES: For some unknown reason, the Architect did not require control joints, to control shrinkage, as normally specified in masonry buildings. This shrinkage is computed as 0.033 per cent of length of wall. With wall reinforcing in alternate courses, usual standards would require joints at a minimum of three times the wall height of 14'-5" (or 43' ±), in the Apparatus Room (and 50' in the 2 story building), although a twenty-four foot spacing is more common.

"Technical Notes No. 21, Brick Masonry Cavity Walls", by the Brick Institute of America (attached in part), emphasizes the need for control joints in the block, and expansion joints in the brick. The brick expansion joints are recommended in each exterior corner where walls exceed fifty feet in length. Expansion due to temperature changes is normally 0.30 inches per 100 feet, and from moisture changes is 0.24 inches/100 ft..

Changes in dimension of structures are known as "Strains" and relate directly to "Stress" by a ratio known as the "Modulas of Elasticity", and designated by the letter "E" ("E" for concrete masonry is approximately 1,500,000 psi. and 2,000,000 psi. for brick masonry).

We can multiply the dimensional changes by "E" and find the stress imposed on the wall. These dimensional changes and resulting stresses are as follows, for the eighty-six foot north/south walls:

A. Shrinkage of Block:
-.0005 x 86' x 12"/ft.= -.516" x 1,500,000 psi. = -774,000 lb./in.

B. Expansion of Brick from Temperature and Moisture:
Expansion of 50^{o}F. = .0000036 x 50^{o} x 86' x 12 = +0.1858"
Moisture Expansion = .0002 x 86' x 12"/ft. = +0.2064"

2,000,000 x +0.3922"
= +784,400 lb./in.

C. Horizontal Movements of Rear Wall (apparently from bank slippage) Caused Stress in N/S Walls:

Measured +0.5 inch x 1,500,000 = + 75,000 lb./in.

Since these do not occur simultaneously, they should not necessarily be added.

In other words, all of these dimensional changes have caused stresses to crack the walls. To arrest any future movement, we would recommend the following:

1. The front and back walls be tied at the foundation, so they cannot move apart.

2. Brick expansion joints should be cut in the outside corners.

3. Some of the wall cracks should be converted to sawn control joints, others should be grouted with epoxy to repair the walls.

4. The rip-rap should be monitered so any future movement is reported at once.

5. Some rebonding of the masonry wythes should be done in areas of high stress, or potential of movement.

At this time, we would not recommend any foundation work to attack the varying soil pressure problem. Any differential settlement should have ended by now.

We wish to thank the City for the opportunity to report on this problem.

Respectfully submitted:

Robert M. O'Shea

Robert M. O'Shea, P.E.

BOWSER-MORNER, INC.

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TOLEDO DISTRICT: 122 S. St. Clair St. • P.O. Box 838 • Toledo, OH 43696 • 419/255-8200

LABORATORY REPORT

Report to: Mr. Robert O'Shea
914 N. Summit Street
Toledo, Ohio 43604

Date: April 10, 1985
Laboratory No.: 39080
Authorization:

Report No. T-25140

Report on: Investigation of Cracking
Napoleon Fire Station
Napoleon, Ohio

The following report summarizes the results of our work done at the above referenced site in Napoleon, Ohio. Authorization to proceed with the necessary work was given in a letter from Mr. Robert O'Shea dated December 28, 1984. All work was to proceed in accordance with the verbal agreement between Mr. O'Shea and Mr. Hoppenjans of Bowser-Morner, Inc.

The purpose of this work was to examine the fire station in Napoleon, Ohio, to perform on site testing, and to review documentation concerning the construction of the building in order to provide an opinion as to the cause of cracking which the building is experiencing. The building in question is the existing Napoleon fire station which is located west of the existing city office building and adjacent to and south of State Route 424 in Napoleon, Ohio. The building consists of a large apparatus room approximately 110 feet long by 66 feet wide, and living and office quarters for the firemen which is a two-story attached structure approximately 30 feet by 90 feet. The construction is brick and block masonry with slab-on-grade with precast concrete roof and floor systems. The building was constructed in approximately 1976. We have reviewed the original construction drawings and specifications as provided to us by the City of Napoleon and a report concerning the cracking problem which was issued in September, 1984 by Jording and Associates.

Bowser-Morner, Inc. made site visits to the fire station on January 15, 1985 and March 29, 1985. During the January 15, 1985 visit by Mr. Richard Hoppenjans, the interior and exterior of the structure was visually examined in some detail and the performance of the building was discussed with the Fire Chief. On March 29, 1985, Mr. Gary Neutzling, a geotechnical engineer with the Toledo office of Bowser-Morner, Inc., supervised the excavation of two test pits at the rear of the apparatus room from the exterior of the building. Field notes from these two test pits are attached with this report. The purpose of the test pits was to determine the nature of the soil profile in the immediate vicinity of the footing at the rear of the appartus room. As can be seen from the attached field notes, it appears that the contractor when constructing the building excavated old fill materials to depths in excess of 8 to 9 feet and backfilled the excavations with a relatively clean silty sand. This is in substantial accordance with the specifications that required the removal of all old fill prior to the construction of the foundations. It should be noted, however, that the excavation at trench No. 1 indicates that the width of the sand fill does not extend 5 feet beyond the building lines as specified in the construction documents. The sand fill appeared to be reasonably dense at the time it was excavated. Numerous photographs were taken of the test pit and of cracking which was noted in the building in the two site visits.

As discussed in Mr. Jording's report, there are numerous possibilities for the causes of the cracking which the new fire station is experiencing. Two of these causes which relate to soils and foundations would be the movement of the adjacent slope overlooking the Maumee River which would cause horizontal and vertical strains in the building, and differential foundation settlement. There is no way to know for sure how much horizontal movement has occurred in the slope overlooking the Maumee River. Apparently, the slope has been repaired and partially protected since the building was constructed. Apparently this was done because people were observing that the slope was physically moving towards the river. A large patio at the rear of the living quarters of the fire station has apparently moved towards the river approximately 1/2 to 1.0 inch. In addition, it appears that the back wall of the apparatus room has moved away from the floor slab by at least 1/2 inch. One other area where horizontal movement seems apparent was in the southeast corner of the apparatus room where a large compressor sits on a concrete block foundation which rests upon the floor slab. Careful examination of this area indicates that the appartus room wall has moved away from the block foundation. As best as could be determined from the visual examination, it appears that these movements were essentially horizontal. The building, therefore, does offer some evidence of horizontal movement which could account for some amount of cracking and deformation in the structure.

It has been our experience with slopes that overlook the Maumee River that they can stand safely for long periods of time with very steep slopes on the order of 1 horizontal to 1 vertical. It is essential, however, that the toe of these slopes be protected from erosion. If left unprotected, large earth movements are likely to occur. This particular slope is composed of natural soil materials and large quantities of fill (more than 10 feet near the top of slope). The fill material is completely random and it is impossible to predict its performance, however, it has been successfully standing in this area for some time and is therefore likely to do so in the future. Furthermore, the test pits which were excavated indicated dry soil conditions. The lack of water in this slope could easily account for the stability which it is exhibiting.

The amount of horizontal and/or vertical movement that is associated with slope instability is normally very large. Little factual information is available on the creep movements which might occur in the otherwise stable soil material outside the zone of influence of an actual slope failure. Normally, once one of these slopes starts to fail large movements on the order of 10 to 20 feet occur at the top of the slope. We have some doubts, therefore, whether or not the cracking which is occcurring in the building is totally related to slope movements. The horizontal movement of the slab behind the building might be explained in terms of frost action versus actual slope movement. The separation between the floor slab and foundation in the apparatus room could be explained by the wall tilting outward from these two structures. In any case, it is our belief that the movements which have occurred in the horizontal direction are relatively small and limited to date. Furthermore, it is hard to understand how these types of movements would be able to cause cracking in the entire length of the east wall of the appartus room and in the front of the building in the living quarters.

The other soil related possible cause of cracking is differential settlement of the foundations. The original specifications for the building required that the contractor remove all old fill and replace it with compacted sand. It is our belief that if this was done properly that foundation settlement problems would have been precluded based upon the available information. Our test pit at trench No. 1 and our shallow pit at location No. 2, indicates that fill sand was in fact placed beneath the foundation walls in the appartus room. Our only reservation is that the fill sand apparently stops relatively quickly once outside the building lines. This means that loads which are carried by the sand fill may be transmitted laterally into the old fill and might have allowed some additional settlement to occur depending on the condition of the old fill at any location. On the other hand, the sand fill appeared to be relatively tight and on balance it is likely that the sand fill is adequately carrying the design loads. It is our understanding that the actual soil pressures are on the order of 1-1/2 to 2-1/2 kips per square foot. This is a relatively light load for a compacted sand backfill. Therefore, it is our opinion that if our test pit is representative of the entire construction area, then excessive differential settlements are probably not occurring. This conclusion is consistent with our observations of the cracking in the building which does not indicate significant vertical movements across the cracks.

In conclusion, it is our opinion that some horizontal movements have occurred in the building probably due to slope instability along the Maumee River. Based upon the available evidence it appears that the foundation construction was proper and that excessive differential settlement is not the likely cause of the problems in the building. If there are any questions, or we can be of any further service please contact us.

STATE OF OHIO
J. RICHARD HOPPENJANS
36850
REGISTERED
PROFESSIONAL ENGINEER

Respectfully submitted,

BOWSER-MORNER, INC.

J. Richard Hoppenjans

J. Richard Hoppenjans, P.E.
Chief District Engineer

JRH/sav
Attachments
3-Client

BOWSER MORNER

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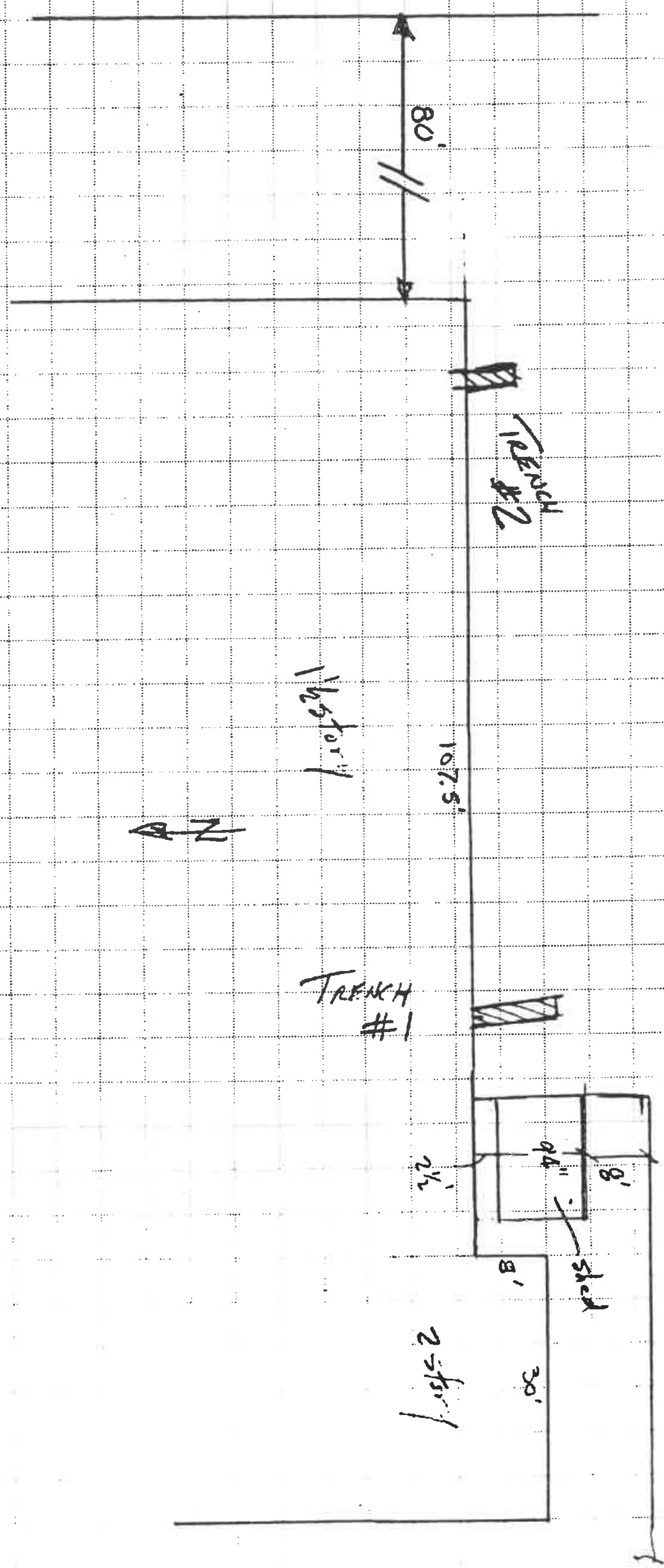
(419) 255-8200

JOB [illegible]
SHEET NO. ______ OF ______
CALCULATED BY JRA DATE 4-9-85
CHECKED BY ______ DATE ______
SCALE 1" = 20'

Field notes
By G. Neutzling
3-29-85



Scale 1" = 20'

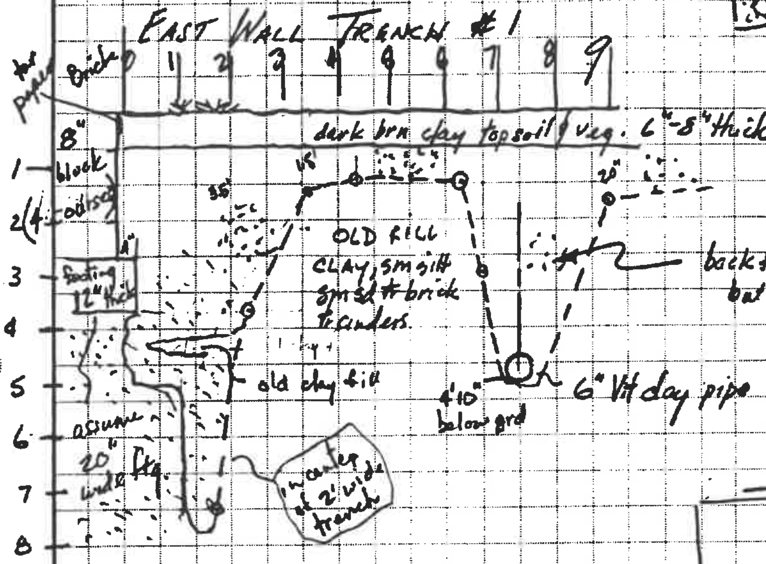
BOWSER-MORNER, INC.
122 So. St. Clair St., P. O. Box 838
TOLEDO, OHIO 43696
(419) 255-8200

JOB 39080
SHEET NO. ______ OF ______
CALCULATED BY JRH DATE 4-9-85
CHECKED BY ______ DATE ______
SCALE ______

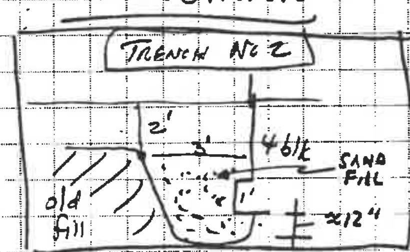
Field Notes By G. Neutzling

[x] Orange fill sd.

EAST WALL TRENCH #1

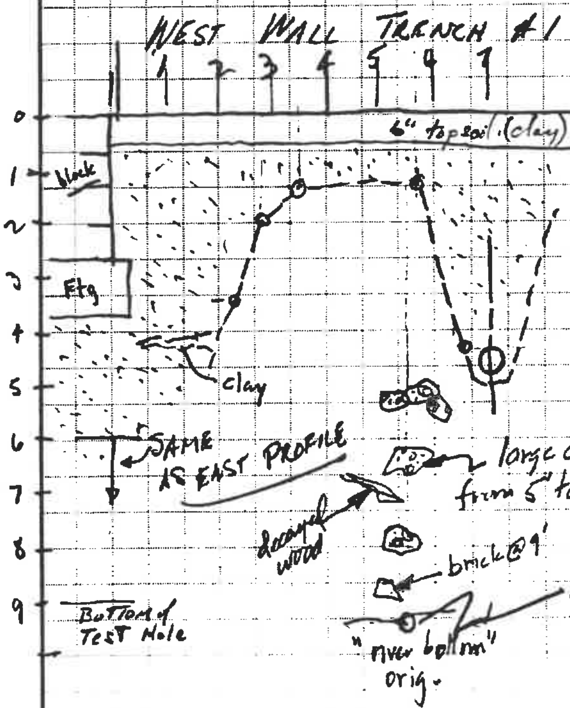


2' wide trench.



Note: Excavation backfilled w/ clean sd to above bottom of ftg. & compt w/ jumping jack. Rest backfilled w/ backhoe & tamped w/ bucket.

WEST WALL TRENCH #1



Piece of conc @ 5.5' below grd

(orig) Slightly org gray Clay sm silt tr sd tr roots tr decayed wood (Sampled in bag)