SUBSIDENCE RESISTANT REPAIR OF A BLOCK BASEMENT

by

J. W. Mahar, Ph.D.[1], G. G. Marino, Ph.D., P.E.[2], E. Murphy[3] and J. Farnetti[4]

Abstract: A one story house was damaged by mine subsidence movement. The house is located in a small subsidence sag and is experiencing differential settlement and compressive ground strains. Instead of waiting for the ground movements to eventually stop, The Illinois Mine Subsidence Insurance Fund developed a permanent repair scheme that was implemented at the same time damaging mine subsidence movement was affecting the structure. This repair provided a significant structural resistance against the anticipated residual mine subsidence movement and was aesthetically acceptable to the homeowners. The repair consisted of epoxying vertical and horizontal steel straps and then applying a cover coat of fiber-cement on the unreinforced concrete block basement walls. The repair scheme was relatively untried, but had been successfully researched. This paper provides information on the mine subsidence movement/damage, the design concepts of steel strap/fiber-cement repair, construction details, performance and costs. Other applications of the use of the steel strap repair method are also discussed for releveling of a building and/or correcting subsidence damage to structures located in the tension zone.

Additional Key Words: Mine Subsidence, Permanent Masonry Wall Repairs, Compression Damage, Repair Techniques and Costs

Introduction

One of the major problems with mine subsidence-damaged structures is the time required before permanent repairs can be made without risk of future damage. Level line survey data and structural behavior observations collected in Illinois have revealed that damaging mine subsidence movements continue for periods of 5 to 20 years after the initial failure at mine level. In most cases the owner must wait until cessation of mine subsidence movement before permanent repairs can be made. There are many cases where foundations and/or interiors of structures have been repaired prematurely and where damage has developed subsequent to the repairs. In order to overcome this problem, the Illinois Mine Subsidence Insurance Fund established a laboratory and field investigation program to test repair procedures that could be implemented during the late stages of mine subsidence and still survive the mine movement.

History of Mine Subsidence

The case study is a one-story, wood-frame structure above a full basement and floor slab located in Streator, Illinois. Mine subsidenec movement began in September 1994. The structure is above a room and pillar mine that was abandoned in 1892. The mine workings are located at a depth of approximately 91 ft below the ground surface. The seam height is 5 ft and rock overburden is approximately 46 ft thick. Prior to repair the rate of mine subsidence movement was 0.005 ft/month and ongoing damage was noted in the structure.

Original Structure And Mine Subsidence Damage

The original structure had a brick shelf wall basement on the north, west and south walls (shelf 46 in. high and 23 in. wide) (Fig. 1.). A short section of the north and south sides as well as the east side had vertical concrete block walls (9-block high). The mine subsidence damage in the home was primarily compression (inward movement) on the basement walls. All of the walls showed a typical compression damage pattern. Horizontal moment cracks formed along the tops of the shelf walls and 2 ft below the top of the east block wall. The cracks were open 1/16 to 7/16 in. and were offset 3/8 to 2-5/8 in. Inward movement ranged between 0.6 to 7.3 in. Diagonal cracks were present in the corners. A summary of the basement wall damage is given in Table 1. A substantial portion of the compression damage predated the mine subsidence movement and was caused by earth pressures and hydrostatic loads in the plastic soils behind the walls.

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[1] President, Geotechnical Consultants, Inc., Savoy, IL.

[2] President, Marino Engineering Associates, Inc., Urbana, IL

[3] General Manager, Illinois Mine Subsidence Insurance Fund, Chicago, IL

[4] Claims Manager, Illinois Mine Subsidence Insurance Fund, Chicago, IL

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Cracks and construction joint separations were present in the basement floor slab. The cracks/separations were typically oriented north-south and east-west and openings ranged from hairline to 3/16 in. wide.

Some mine subsidence-induced damage was present in the superstructure. The damage pattern was consistent with typical compression cases in which there is no positive connection between the foundation walls and the superstructure. The area of greatest deformation was located on the south side of the dwelling. Hairline cracks were present in some of the ceilings and above window frames. Interior door frames were racked 1/16 to 5/16 in./2 ft with no preferred orientation.

Between 22 May 1995 and 5 January 1996 the north and west basement walls showed additional inward wall movement of 0.1 to 0.2 in. The inward movement corresponded with mine subsidence displacements in the range of 0.18 to 0.45 in.

The overall tilt in the residence measured along a common mortar joint (CMJ), and common siding and soffit lines measured during three site visits are summarized in Table 2.

The tilt was not consistent between the structural elements and was not compatible with the pattern of basement wall damage (greatest damage along the north wall). Moreover the tilt predated the recent mine subsidence movement.

Permanent Foundation Repair Scheme

In January 1997, the monitoring points on and around the structure were undergoing downward movement at a rate of 0.001 to 0.003 ft/month. At that time the structure should not have been repaired using conventional block wall foundations. However, it was decided that permanent repairs could be made if the original basement walls were replaced and reinforced to carry the residual mine subsidence compression loads.

The permanent repair of the basement walls consisted of removal of the original brick shelf walls and a section of the block wall, replacement with 8-in. concrete blocks, and strap retrofit/ fiber-cement support of all basement walls. The east wall was saved and the joint connections along the north and south walls were inclined in order to properly interface the concrete blocks. The floor joists and sill plates were cribbed and supported on wood beams and columns while the brick walls were torn down and replaced. The perimeter area adjacent to the home was excavated to a depth of approximately 5 ft deep in order to construct the block walls and footings.

The basic concept and testing of the strap retrofit system was developed at the University of Illinois under a research contract with the Illinois Mine Subsidence Insurance Fund (Marino, 1992). The retrofit system was first tested in the laboratory and then later field tested. The field tests consisted of repairing subsidence-damaged test foundations with steel straps covered with fiber-cement mortar and then monitoring the behavior of the repaired foundation during additional subsidence from longwall mining (Marino, 1997). The load-deformation characteristics of retrofitted block masonry under 3-point loading is shown in Fig. 2 . The reinforcement characteristics for each test beam are given in Table 3. The retrofit beam strength is largely dependent on the amount of reinforcement. The test results and study of the construction methods provided the basic background data for designing and repairing the structure in Streator.

The strap retrofit system consisted of 3/16-in. thick by 4-in. wide vertical steel straps spaced 4 ft apart horizontally (Figs. 3 and 4). One line of horizontal straps was placed at the approximate lower third point above the floor. The straps were butt welded to form a continuous reinforcement system. Both sets of straps were then bonded to the concrete block by injecting an epoxy mixture (EvaPox #1) into the 7/32 in. diameter port holes drilled through the straps. The epoxy was contained behind the straps by applying a 1/4-in. wide sealer (Sinmast #6) along the edges of the straps (Fig.5). Cracks in the concrete blocks were filled prior to mounting the straps on the wall. Key items in proper placement of the retrofit strap system are grinding the surface of the strap, preparing the concrete block surface (removed paint where needed and scarified the surface of the blocks) and completely filling the space between the strap and the wall (Fig.6). Checks of the space between the straps and the blocks were made after the steel was mounted on the wall. The gap between the wall and the straps was specified to range between 1/16 and 1/8 in. and adjustments were made using the strap mounting bolts. Care was taken to properly mix the two-part epoxy components and to inject continuously behind the wall. The epoxy was injected in a systematic manner starting at the floor end of the vertical straps and progressing upward from the initial injection port (Fig. 7). The vertical straps were injected first and then the horizontal straps finished. Seal failures were noted when the epoxy began to set up in the tube and increased pressure was needed to inject the more viscous fluid where a few failures occurred, additional sealant was applied over the leak area and a fresh batch of epoxy was mixed and injected behind the strap. The temperature of the basement was maintained above 40°F. The top of the wall was anchored to the floor joists using steel gusset plates.

Differential settlement related to mine subsidence movement caused water to pond near the southeast corner of the basement. The original block walls became wet and had to be dried prior to injecting the epoxy behind the straps. The area around the basement was built up and a sump installed to prevent water seepage into the basement (Fig. 8). The sump was later tied into a perimeter drain that was placed in the open cut portion of the basement walls.

The straps as well as the wall were then covered with a ½- in. thick fiber-cement layer (Quikwall Bonding Adhesive). The layer was placed in two 1/4-in. thick lifts and the walls were finished to a smooth surface (Fig. 9). Application of the layers was started in one lower corner and progressed outward and upward to cover the wall. The initial layer was approximately 1/4-in. thick over the block walls and 1/8-in. thick on the surface of the steel straps. The surface of the initial fiber-cement layer was scarified prior to placing the second lift. The fiber-cement layer were wetted periodically to assist proper hydration. A professional plasterer applied the fiber-cement layers to the wall.

After the basement walls were rebuilt and before the retrofit system was installed, a drain tile in gravel bedding protected with geotextile fabric was installed in the open excavation (Fig.10). An asphalt mastic compound was applied to waterproof the basement exterior (Fig.10). At the end of the project, the open excavation was backfilled with on site and imported silty clay without systematic compaction. The soil was placed wet of optimum to minimize potential swell pressures while the fiber-cement was curing. The fill was crowned to allow for some ground settlement adjacent to the wall. Topsoil was used in the final lift.

The final step was to repair the first floor rooms. Cracks were sealed and rooms repainted. Some adjustments were made to interior door frames and windows.

First-time Costs

The total cost for the strap retrofit system alone was approximately $20,000.

The cost breakdown for the entire 136 lineal feet of 72 in. high basement walls is summarized as follows:

Steel Straps and Preparation	$	1,885.00
Labor: clean, install and weld straps		3,187.24
Strap Mounting Materials (bits etc)		354.00
Strap Sealer: Sinmast #6 Bonder		638.96
Strap/Block Epoxy: #4 Eva-Pox Bonder		2,850.00
Fiber-Cement: Quikwall Bonding Agent		494.40
Labor: Strap Sealer		1,607.20
Labor: Strap/Block Epoxy		1,352.00
Labor: Fiber-Cement Layer		3,520.80
Steel Gusset Plates		207.67
Labor: Steel Gusset Plates		194.00
Subtotal	$	16,291.27
Overhead and profit (21%)		3,421.17
TOTAL COST	$	19,712.44

The costs do not include rebuilding the basement walls or repairing the first floor interior. It should be noted that this project was the first time the strap retrofit system was used for repair of an actual mine subsidence damaged structure by a contractor having limited experience with epoxy injection work.

Post Construction Performance of Repaired Walls

After completion of the basement and first floor repairs, monitoring points were placed on and around the structure to measure residual mine subsidence movement and to evaluate the performance of the repaired walls. Four settlement points were driven to refusal at a depth of 12 ft and 7 pins were installed on a common mortar joint to monitor the movements. Elevations were tied to benchmarks well outside the area of movement.

The follow up survey revealed that differential movement at 1/16 to 1/8 in occurred in the structure between 25 June and 2 December 1997. No visual damage was detected in any portion of the repaired basement walls or in the first floor rooms during the site inspections.

Application of Strap Retrofit System to Other Mine Subsidence Damaged Structures

The epoxy-steel strap system has several subsidence repair applications. The retrofit can be practically applied to both concrete and masonry foundations experiencing tensile or compressive ground movement. Depending on the direction in which the straps are installed the retrofitted wall can resist compressive ground strains, tensile ground strains, and sagging as well as hogging ground movement (in other words Abending@ of the ground). A field test was also performed to determine if the straps could be used to level a foundation. Leveling was successfully accomplished in two tilted foundation walls which were 8 to 9-in out of level (Marino, 1997). In these cases the straps provide two uses: releveling and retrofitting of the foundation walls.

Literature Cited

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TABLE 1 SUMMARY OF BASEMENT WALL DAMAGE PRIOR TO MINE SUBSIDENCE REPAIR

WALL	MOMENT[1] CRACK	SHEAR[2] OFFSET	DIAGONAL[3] CRACKS	INWARD WALL MOVEMENT
NORTH	open: 5/32 offset: 2-5/8	none	HL to 1/4 0 to 3/4	7.3
SOUTH	open: 9/32 offset: 3/8	none	1/16 0 to 3/16	2.5
EAST	open: 1/16	none	1/32	0.6
WEST	open: 7/16 offset: 7/16	none	HL-1/8 0 to 3/8	1.5

[1] - all measurements in inches
[2] - at the base of the wall
[3] - top line represents open distance and bottom line is offset

TABLE 2 OVERALL TILT IN THE STRUCTURE

	22 MAY 1995	22 AUG 1995	5 JAN 1996
CMJ	3.9 in. W to E	3.9 in. W to E	3.9 in. W to E
SIDING	1.5 in. N to S	1.4 in. N to S	1.3 in. N to S
SOFFIT	2.5 in. E to W	2.5 in. SE to NW	1.4 in. E to W

TABLE 3 STRAP DIMENSIONS AND CROSS SECTION STEEL PROPERTIES. (MARINO AND GAMBLE, 1993)

SPECIMEN	STRAP SIZE	A_S (in^2)	ρ
Beam No. 1	1/4"x 14"	3.50	.0290
Beam No. 2	3/16"x 4"	0.75	.0063
Beam No. 3	`1/8"x 6"	0.75	.0063
Beam No. 4	3/16"x 7"	1.31	.0205

ρ = reinforcement ratio=A_S / bd
b= beam width
d= beam depth

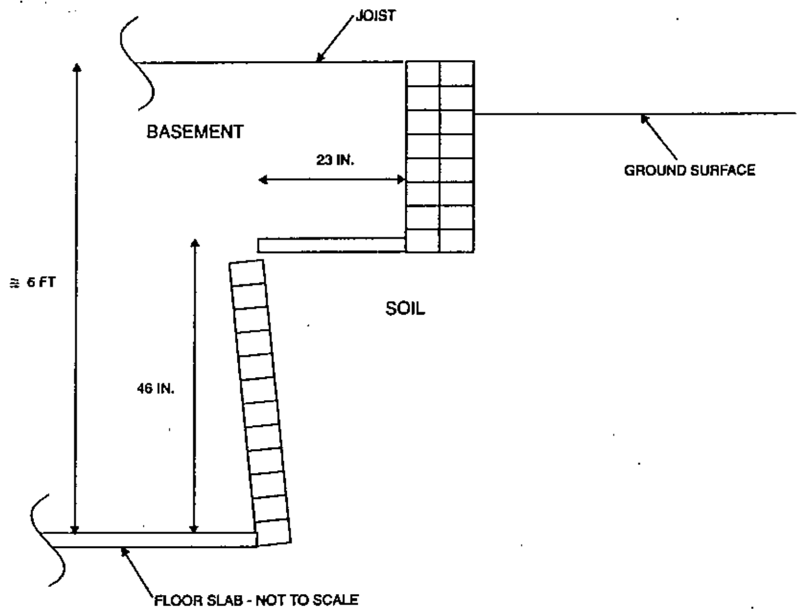
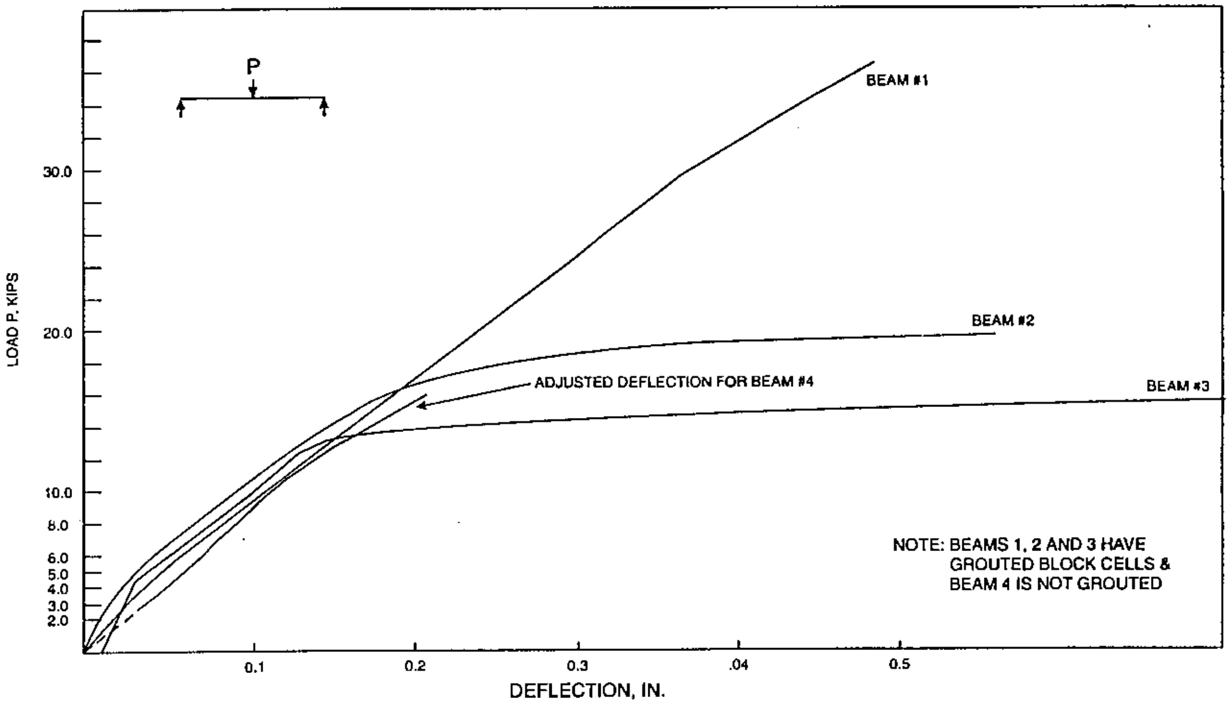


FIG. 1 CROSS SECTION OF SHELF WALL



NOTE: BEAMS 1, 2 AND 3 HAVE GROUTED BLOCK CELLS & BEAM 4 IS NOT GROUTED

FIG. 2 LOAD-DEFLECTION PLOTS FOR STEEL STRAP REINFORCED BLOCK MASONRY BEAMS (MARINO AND GAMBLE, 1993)

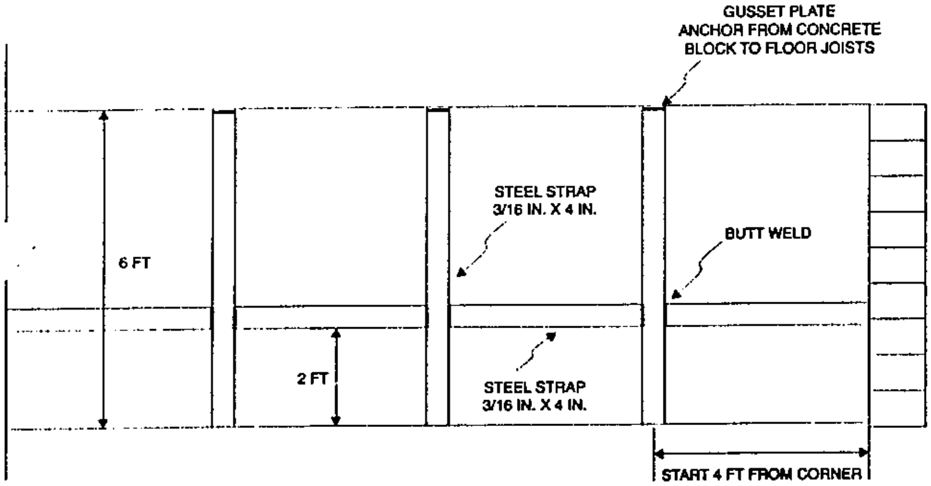


FIG. 3 GENERAL STRAP RETROFIT LAYOUT FOR SUPPORT OF BLOCK BASEMENT WALLS - STREATOR, ILLINOIS

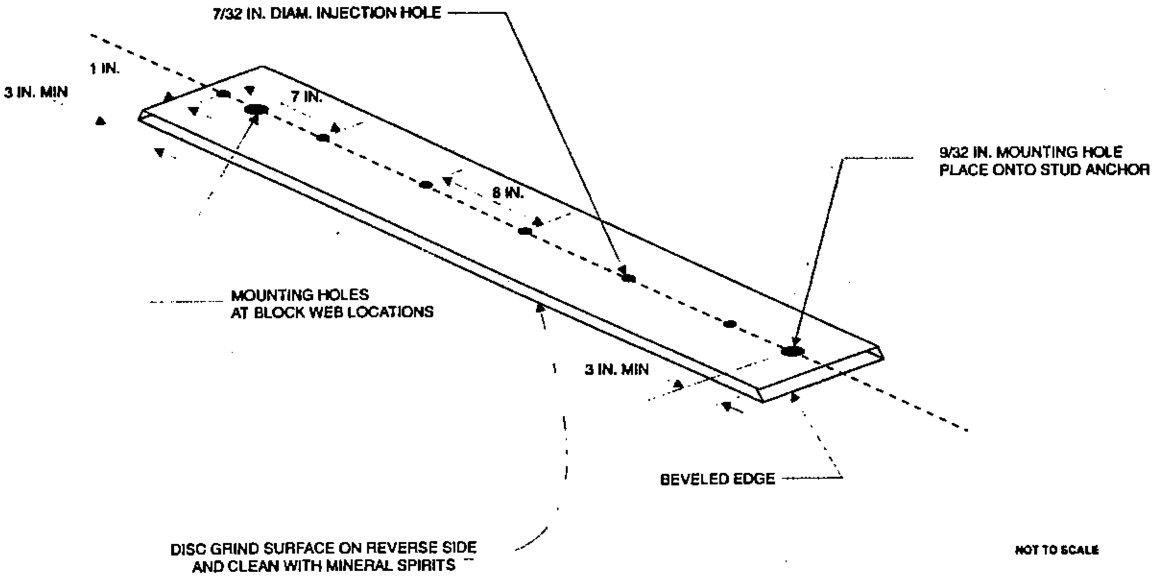


FIG. 4 STRAP PREPARATION

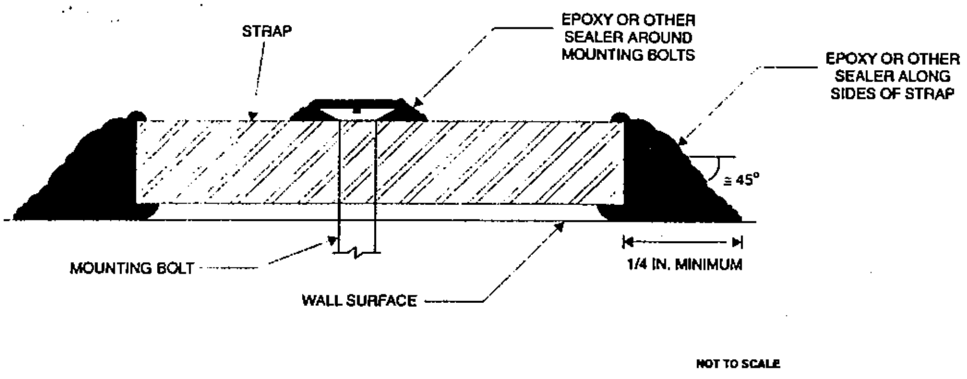


FIG. 5 STRAP SEALING METHOD

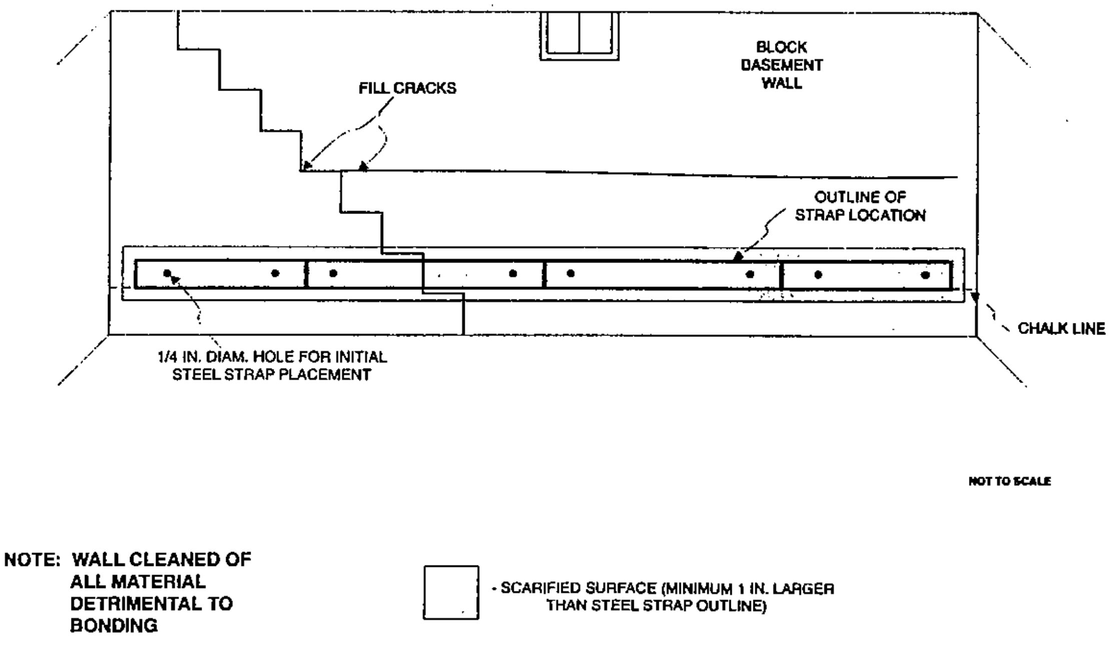


FIG. 6 WALL PREPARATION FOR RETROFIT STRAP BONDING TO BLOCK WALL

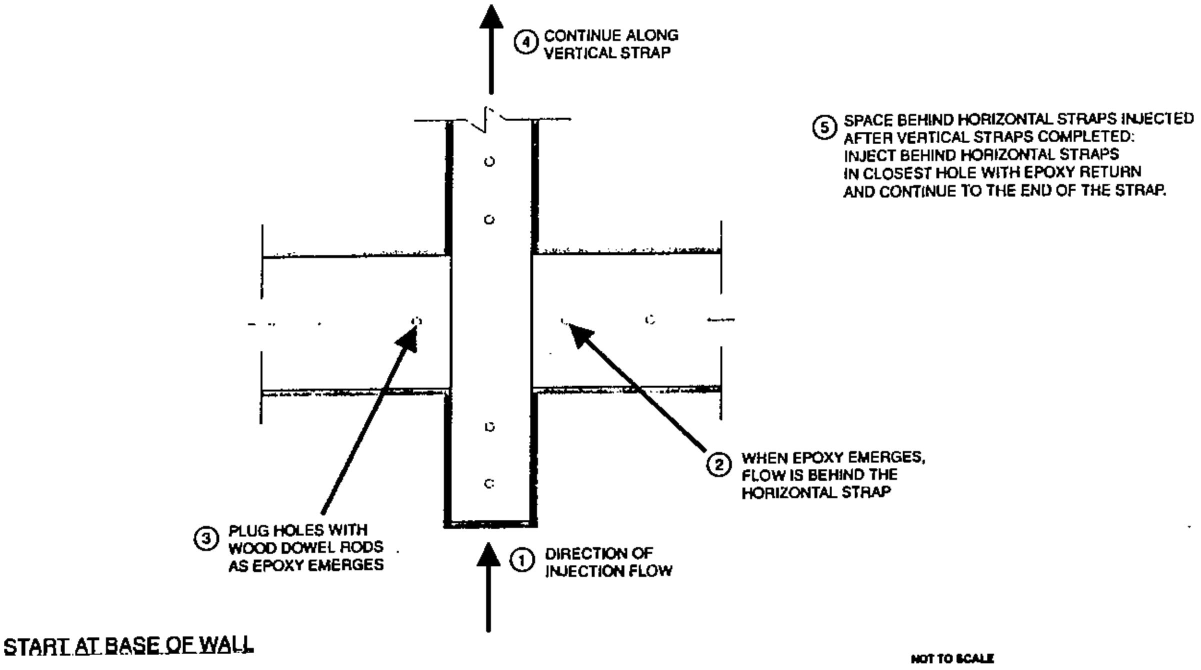


FIG. 7 ILLUSTRATION OF EPOXY INJECTION PROCEDURES

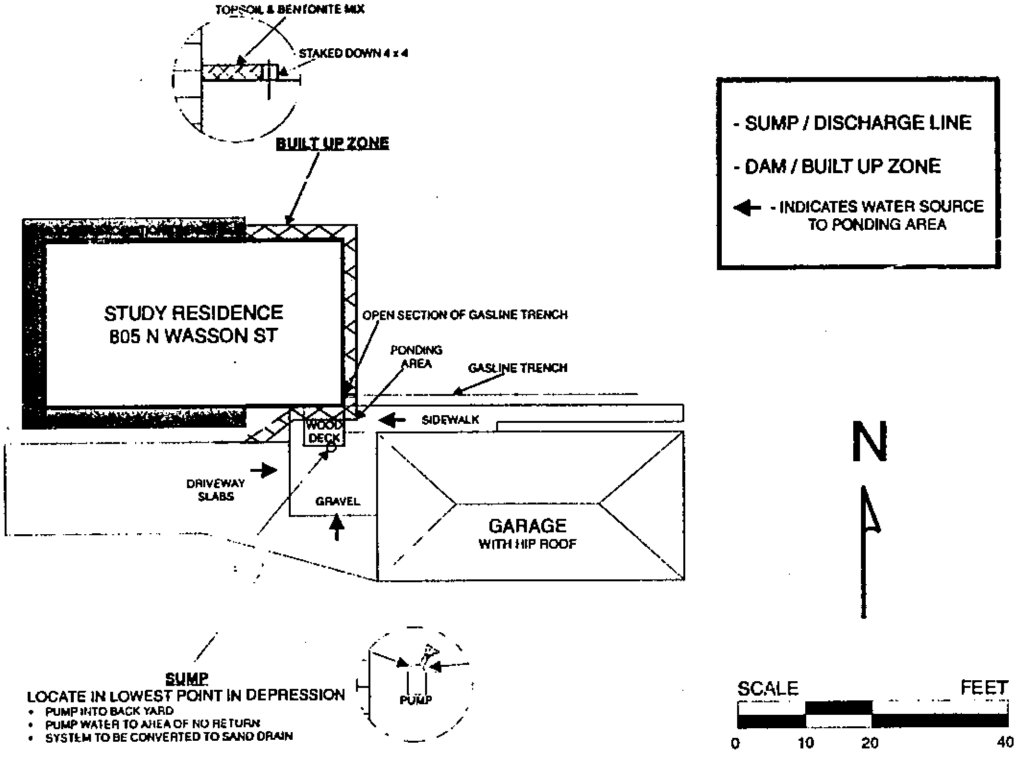
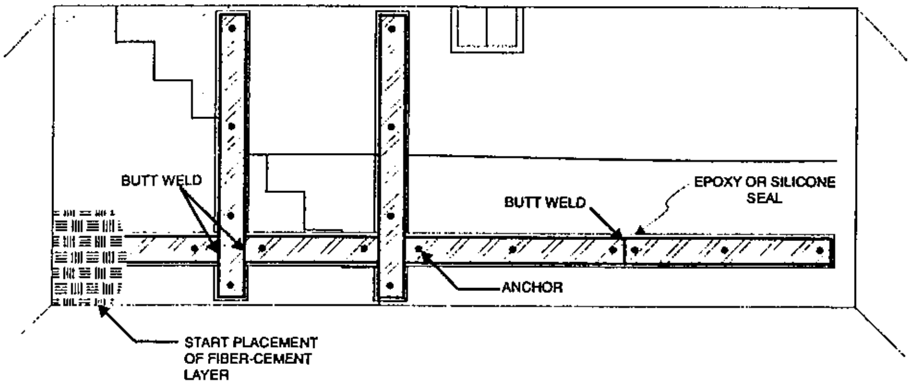


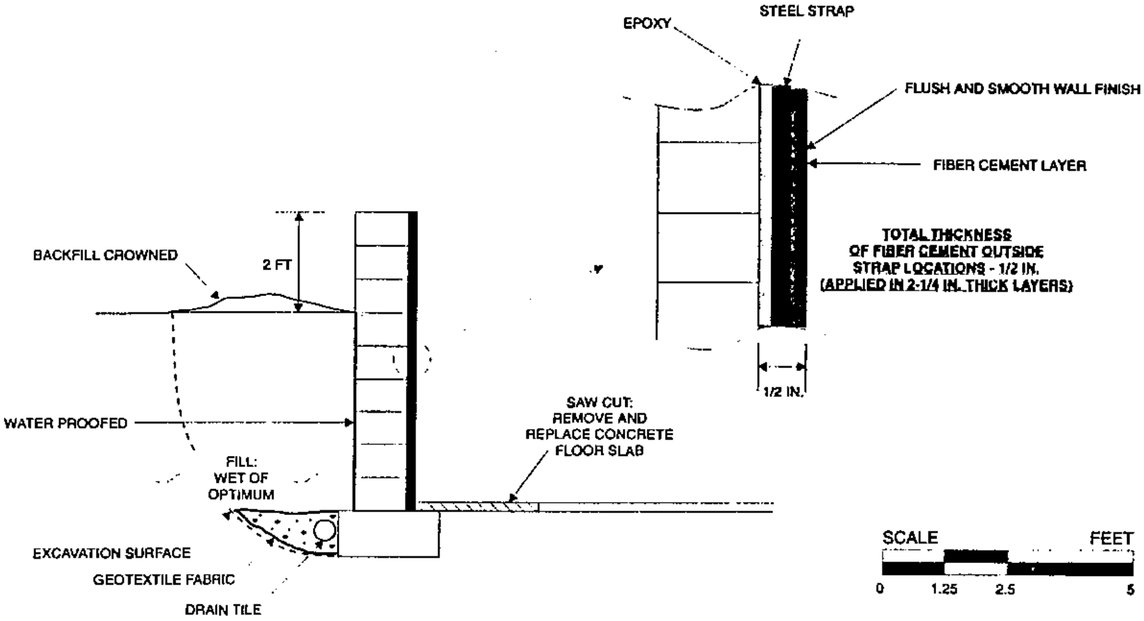
FIG. 8 PLAN MAP SHOWING THE LOCATION OF PONDING AREA AROUND STUDY RESIDENCE - STREATOR, ILLINOIS



NOT TO SCALE

APPLY TO MAXIMUM OF ¼ IN. OVER STRAPS

FIG. 9 APPLICATION OF FIBER-CEMENT LAYER



TOTAL THICKNESS
OF FIBER CEMENT OUTSIDE
STRAP LOCATIONS - 1/2 IN.
(APPLIED IN 2-1/4 IN. THICK LAYERS)

FIG. 10 CROSS SECTION OF RETROFIT STRAP/FIBER-CEMENT REINFORCEMENT