CHAPTER 9

REMEDIAL PROCEDURES

9-1. Basic considerations

Remedial work for damaged structures is usually difficult to determine because the cause of the problem (e.g., location of source or loss of soil moisture, and swelling or settling/shrinking soil) may not be readily apparent, A plan to fix the problem is often difficult to execute, and the work may have to be repeated because of failure to isolate the cause of the moisture changes in the foundation soil, An effective remedial procedure may not be found until several attempts have been made to eliminate the differential movement. Requirements for minimizing moisture changes (chap. 7) are therefore essential. The foundation should have sufficient capacity to maintain all distortion within tolerable limits acceptable to the superstructure. This distortion occurs from differential heave for the most severe climates and changes in the field environment.

a. Specialized effort. Investigation and repair are therefore specialized procedures that usually require much expertise and experience. Cost of repair work can easily exceed the original cost of the foundation. The amount of damage that requires repair also depends on the attitudes of the owner and occupants to tolerate distortion as well as damage that actually impairs the usefulness and safety of the structure.

b. Minimization of repairs. Most damage from effects of swelling soil tends to be cosmetic rather than structural, and repairs are usually more economical than rebuilding as long as the structure remains sound. At-early signs of distress, remedial action to minimize future distortion should be undertaken and should be given a greater priority than the cosmetic repairs as this action will minimize maintenance work over the long term. Maintenance expenses and frequency of repairs tend to be greatest in lightly loaded structures and residences about 3 to 4 years following the original construction. Overall maintenance can be minimized by taking remedial action to minimize future distortion before extensive repairs are required (e.g., breaking out and replacing sections of walls).

c. *Examples of remedial procedures.* The choice of remedial measures is influenced by the results of site and soil investigations as well as by the type of original construction. Table 9-1 illustrates common remedial measures that can be taken. Only one remedial procedure should be attempted at a time so as to determine its effect on the structure. The structure should be allowed to adjust, following completion of remedial measures, for at least a year before cosmetic work is done. The structure is seldom rebuilt to its original condition, and in some instances, remedial measures have not been successful.

9-2. Evaluation of information

All existing information on the foundation soils and design of the foundation and superstructure should be studied before proceeding with new soil investigations.

a. Foundation conditions. The initial soil moisture at time of construction, types of soil, soil swell potentials, depth to groundwater, type of foundation and superstructure, and drainage system should be determined. The current soil moisture profile should also be determined. Details of the foundation, such as actual bearing pressures, size and length of footings, and slab and shaft reinforcing, should also be collected. Drilling logs made during construction of shaft foundations may be used to establish soil and groundwater conditions and details of shaft foundations. Actual construction should be checked against the plans to identify any variances.

b. Damages. The types and locations of damage, as well as the time movements first became noticeable, should be determined, Most cracks caused by differential heave are wider at the top than at the bottom. Nearly all lateral separation results from differential heave. Diagonal cracks can indicate footing or drilled shaft movement, or lateral thrust from the doming pattern of heaving concrete slabs. Fractures in slabs-on-grade a few feet from and parallel with the perimeter walls also indicate heaving of underlying soils. Level surveys can be used to determine the trend of movement when prior survey records and reliable benchmarks are available. Excavations may be necessary to study damage to deep foundations, such as cracks in shafts from uplift forces.

c. Sources of moisture. The source of soil moisture that led to the differential heave should be determined to evaluate the cause of damage. Location of deeprooted vegetation, such as shrubs and trees, location and frequency of watering, inadequate slopes and pending, seepage into foundation soil from surface or perched water, and defects in drain, water, and sewer lines can make important changes in soil moisture and can lead to differential heave.

9-3. Stiffened slab foundations

Most slab foundations that experience some distress are not damaged sufficiently to warrant repairs. Damage is often localized by settlement or heave of one side of the slab. The cause of the soil movement, whether settlement or heave, should first be determined and then corrected.

a. Stabilization of soil moisture. Drainage improvements and a program to control soil moisture at the perimeter of the slab are recommended (chap 7) for all damaged slab foundations.

b. Remedial procedures. Remedial work on slabs depends on the type of movement, Repair of a settled area requires raising of that area, while repair of a heaved area often requires raising the entire unheaved portion of the slab up to the level of the heaved portion. Repair costs are consequently usually greater for heaving than settling cases.

(1) Repair of a damaged slab consists of a combination of underpinning and mudjacking using a cement grout. Mudjacking using a cement grout is required simultaneously with underpinning to fill voids during leveling of the slab. Fractured slabs are usually easier to repair than unfractured slabs that have been distorted by differential movement because usually only the fractured portion of the slab requires treatment. The distortion of unfractured slabs can also cause considerable damage to the superstructure and inconvenience to the occupants.

(2) Underpinning and mudjacking are applied simultaneously and usually clockwise around the slab until all parts of the foundation are at the same elevation. If a heaved area is lowered to the same elevation as the rest of the foundation, such as to repair a mushroomed or dome-shaped heave pattern, the slab is first supported before digging out the soil to prevent the slab from creeping down on the work crew during the digging. Attempts at leveling dome-shaped distortion by raising the perimeter may be unsuccessful because mudjacking usually causes the entire slab to rise.

9-4. Drilled shaft foundations

Most damage to structures with shaft foundations consists of fractured slabs-on-grade. The shaft may contribute to the damage caused by migration of moisture down the shaft/soil interface into swelling soil beneath the shaft footing. The fracture pattern of open cracks in the floor slab parallel to and several feet from the wall often shows that the slab had not been free to move near the walls. Damage to drilled shafts is often caused by upward movement of the shaft from swelling soil beneath its base and by uplift forces on the shaft perimeter from adjacent swelling soil.

a. Stabilization of soil moisture. Drainage improvements and a program to control soil moisture around the perimeter of the foundation are recommended (chap 7).

b. Remedial procedures. Repair often requires total removal of the slab and underlying wet soil, replacement with nonswelling soil, and placement of a new slab isolated from the perimeter walls. Repair of drilled shafts consists of cutting down the top of the shaft and releveling the foundation. The tops of the drilled shafts are cut to the elevation of the top of the lowest shaft where possible.

Table 9-1. Remedial Measures

Measure	Description
Drainage	Slope ground surface (positive drainage) from structure; add drains for downspouts and outdoor faucets in areas of poor drainage, and discharge away from foundation soil; provide subdrains if perched water tables or free flow of subsurface water are problems; provide flexible, watertight utility connections.
Moisture stabilization (maintenance of constant moisture whether at high or low levels)	Remove natural swelling soil and recompact with impervious, nonswelling backfill; install vertical and/or horizontal membranes around the perimeter; locate deep-rooted vegetation outside of moisture barriers; avoid automatic sprinkling systems in areas protected with moisture barriers; provide a constant source of moisture if a combination of swelling/shrinking soils is occurring; thoroughly mix 4 to 8 percent lime into soil to reduce potential for swell or pressure-inject line slurry around the perimeter of the structure.
Superstructure adjustments	Free slabs from foundation by cutting along foundation walls; provide slip joints in interior walls and door frames; reinforce masonry and concrete block walls with horizontal and vertical tie bars or reinforced concrete beams; provide fanlights over doors extended to the ceiling.

Table 9-1. Remedial Measures–Continued

Measure	Description
Spread footings and deep foundation adjustments	Decrease footing size; underpin with deep shafts; mudjack using a cement grout; reconstruct void beneath grade beams; eliminate mushrooms at top of shafts; adjust elevation by cutting the top of the shaft or by adding shims; increase footing or shaft spacing to concentrate loading forces and to reduce angular distortion from differential heave between adjacent footings and shafts.
Continuous wall foundation adjustments	Provide voids beneath portions of wall foundation; posttension; reinforce with horizontal and vertical tie bars or reinforced concrete beams.
Reinforced and stiffened slab-on-grade adjustments	Mudjack using a cement grout; underpin with spread footings or shafts to jack up the edge of slabs,