Chapter 9 Remedial Measures

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. [Note that the cause of the problem is always the source or changes in the soil moisture which causes the swelling and/or shrinking of the soil supporting the foundation] 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. [Since the cause of damaging foundation movement is always a soil moisture issue, it is essential that changes in the soil moisture be minimized. No remedial procedure likely to be effective unless this is done.] 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. [The statement that the amount of damage that requires repair is key; if the damage impairs the usefulness and safety of the structure, foundation repair would normally be recommended; but optional foundation repair might be recommended if the owner was not happy or accepting of the performance of the foundation.]

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. [This is a little ambiguous but it seems to mean that since most damage is cosmetic, repairing the cosmetic damage is usually more economical than underpinning the foundation, assuming there has been no structural damage; i.e., no damage to the load carrying capacity of the frame structure,.] At early signs of distress, remedial action to minimize future distortion should be undertaken and should be given a greater priority than the cosmetic re- pairs 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 deter- mine 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. [It is virtually impossible that any remedial measure or repair will make the house like new; any remedial measures that are undertaken should be undertaken with the understanding that they may not work and would thus be a waste of time and money.]

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 Condition:. 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 deter- mined. 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. [While the information listed would be valuable to have, the reality is that in a real estate transaction, very little of this information is likely to be available. This makes it all the more important that the engineer you retain be experienced and have good engineering judgment.]

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. [Notice that level surveys are only considered reliable enough to be used to determine the trend of foundation distortion or movement when prior survey records and reliable benchmarks are available. These conditions are extremely rare in a real estate transaction. A single elevation survey is, at best, a very approximate indicator of the levelness of a foundation surface. It is not a reliable indicator of how much distortion the foundation has experienced or the trend of any foundation movement.] 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 deep-rooted 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. [This is an extremely important point; we agree strongly that the majority of slab-on-ground foundations that have caused some degree of distress are not damaged to the extent that foundation repairs are warranted much less required. For this reason alone any statement that foundation repair is required as opposed to being an option should be regarded with a degree of skepticism.] 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. [Foundation repairs are not likely to be effective over time if the cause of the soil movement is not identified and removed. Removing the cause of the soil movement almost always involves drainage improvements and a program to mitigate soil moisture changes adjacent to the perimeter of the slab-on-ground foundation.]

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.

a. 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. [This last point is frequently misunderstood; the fundamental question is not whether there is a visible crack in the slab; the fundamental question is what kind of damage and how much the foundation distortion is causing to the house.]

(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.

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 watertight utility connections.
Moisture stabilization (maintenance of constant moisture whether at high or low levels)	Remove natural swelling soil and recompact with impervious, non- swelling 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; pro- vide 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.
Reinforced and stiffened slab-on-grade adjustments	Mudjack using a cement grout; underpin with spread footings or shafts to jack up the edge of the foundation