PDHonline Course C672 (2 PDH)

Concrete Repair Methods

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CONCRETE REPAIR METHODS

1.0 INTRODUCTION

Undoubtedly, concrete is the undisputed king of the construction materials. It can be molded to unlimited form possibilities, its mix can be adjusted and manipulated to a myriad of formulations to achieve many weights, strengths, densities, textures and colors.

Concrete is quite superior to the other competing materials because of its better qualities and attributes, such as:

a. with the proper mix design, adequate and competent handling, it can develop a compressive strength in excess of 10,000 pounds per square inch (PSI),

b. its high fire resistance,

c. its termite resistance, and

d. its excellent durability.

Few materials have been so discussed, debated, challenged, disputed, experimented with and tested as concrete has been. Of course, it has its limitations and shortcomings also, and yet, some of those same disadvantages are the ones which have helped to make it great. For instance, true that it is a heavy material, but in case of an extreme hurricane or tornado you would feel fortunate if all that sheer weight is on your side.

Most people are aware of the fact that concrete is a rough and tough material that can do the job and could, when properly maintained, last for several hundred years while providing the service it has been designed and made for. However, few know that it can be cut, reshaped, improved, modified, patched up, added on and repaired to start a new job under a revised scope and specifications.

In this course we will examine all those repair techniques that can be used to modify, correct, improve, reinforce, restore and expand concrete structures. Some of those repair methods are of common knowledge to many while some other ones are less common and perhaps more innovative and challenging to the regular engineering practitioner.

First, we will cover the common neglectful reasons for concrete premature decay and how it can get affected by certain chemicals and compounds. As we examine the most common mechanism of deterioration which starts with microscopic hairline cracking that gets exacerbated by temperature changes, thus creating an access path to humidity which eventually reaches the reinforcing bars, which in turn swell and consequently trigger spalling of the concrete coverage. We will see how such decay affects integrity, strength and durability of the material. After the initial decay, if not arrested on time, destruction could be a certain prospect. Second, we will examine the available repair procedures and methodologies, and thirdly, we will describe actual case histories of successfully executed structural and/or cosmetic repairs.

2.0 CONCRETE KNOWN ENEMIES

In spite of concrete being the best construction material ever known, it is not without its formidable enemies. They are: curing shrinkage, temperature changes, creep, poor handling practices, corrosion, carbonation, chlorides, tension stresses, under design and fatigue.

CURING SHRINKAGE

The early loss of water can cause fresh concrete to shrink, thus creating tensile stresses within the freshly deposited concrete mix. If such stresses develop before concrete has attained the adequate strength, surface cracking will start to form and propagate.

Surface cracking may sometimes occur through the concrete surface within the first thirty minutes while concrete is still in the plastic stage. Considering the fact that shrinkage cracks are most common during hot-weather concreting, or when the circumstances would favor rapid moisture evaporation from the concrete surface. In those circumstances is when the proper curing practices, as described below, have an important role to prevent the occurrence of such detrimental shrinkage. Once shrinkage cracks are formed, they will get exacerbated by temperature differentials, and from there on, they will continue to worsen with the consequential detriment to concrete quality.

TEMPERATURE CHANGES

Concrete expands as temperature increases and contracts as temperature falls. The *thermal coefficient* is a measurement of that expansion and contraction. Such coefficient is affected by many factors such as, aggregate type and size, quality of mix, humidity, material age and water-cement ratio. Of all those, aggregate type and size have the greatest effect on the coefficient's value.

As a valid average for all unreinforced concretes, a thermal coefficient of 5.5 millionths per degree Fahrenheit is sufficiently accurate to calculate thermal expansions and contractions.

Since the thermal coefficient for steel is about 6.5 millionths per degree, then the thermal coefficient for reinforced concrete has been assumed as 6.0 millionths per degree Fahrenheit, which is the average between the two materials, concrete and steel.

Summarizing, the thermal coefficient of linear expansion (ε) is the variation in length, per unit of length, for a change in temperature of one degree. Peculiarly, the thermal coefficient does not change dimensionally by the geometric rules. That is why the coefficient of surface expansion is just two times the linear coefficient, and the coefficient of volumetric expansion is three times the linear coefficient.

Given the following values:

(ε) = thermal coefficient of linear expansion
t = thermal differential (change in temperature in degrees)
l = length of subject material (in feet)
E = modulus of elasticity
Δl = length increment
Δf = axial stress increment

Then, the reinforced concrete thermal coefficient of linear expansion for a temperature change of 100°F is:

$$\varepsilon = 0.0006$$

And, the length increment caused by the same thermal differential is:

$$\Delta l = 0.0006tl$$

In the same manner, the increment in axial stress would be:

$$\Delta f = 0.0006Et$$

CREEP

The American Society for Testing and Materials (ASTM) has given us their official definition of *creep* which is "a time dependent deformation which continues after the application of a load that is maintained constantly acting on the solid material".

There are in fact two stages of deformation, the *immediate* deformation that takes place when a load is applied to a given structure, and the *long-term* deformation that takes place with time. The formulas commonly used by engineers to calculate deflections only give them the immediate (short term) deformation. On the other hand, that long term deformation mentioned above is in fact what ASTM defines a "creep".

Creep is dependent upon the following factors:

a. the magnitude of the load and therefore the stress caused by it,

b. the age and strength of concrete at the time of load application,

c. the length of time the load remains in place,

d. the size of aggregate used in the concrete mix, and

e. the reinforcement ratio.

As a reasonable simplification, some design engineers after determining the short-term (or immediate) deflection, they take an equal amount and assign it to the long-term deflection, or creep.

HANDLING PRACTICES

We have herein designated as “handling practices” to the entire process taking place from the batching plant through and until the concrete is deposited and cured in its final destination at the site.

To produce concrete of uniform and predictable quality, the aggregates have to be measured by weight and mixed thoroughly until such mix is of uniform appearance and has fully complied with the requirements of ASTM Specification C94.

The most common method of transportation from the batching plant to the site is by truck mixer. Transportation time should be closely recorded and monitored in such a way that overheated concrete could be detected and not be allowed in the pouring process.

Before concreting takes place, forms shall be inspected for adequacy. Sawdust, nails and regular fabrication debris shall be completely removed and the forms carefully moistened before depositing the fresh concrete. Since the water/cement ratio is of great importance, the contractor shall refrain from adding water to the concrete mix other than what is called for by the plant engineer in his mix design.

The most common method for concrete compaction and most likely the best available, is controlled vibration. Vibrators not only will produce the right consolidation and density, but also will turn stiff and dry mixes into more workable and better flowing pours.

Screeding is the common method used to bring the top concrete surface to the proper even grade or elevation. Screeds should be moved across with a sawing motion towards the far end. There should always be a concrete surplus against the advancing face of the screed to avoid low spots on the finished concrete surface.

The final step in the finishing process is normally done by either hand floating or by using trowelling machines, depending on the approved specifications.

After all pouring, screeding and finishing steps have taken place, then comes an important and significant process which may have an important role in the final product, that is the curing process. There are several proven curing methods depending on location, height above ground, climate and resources. In a nut shell they are: water ponding, sprinkling, wet burlap, plastic sheathing and curing sealers, or a combination of two or more of them. They are mostly covered by the ASTM Specifications C171 and C440.

Proper curing is important because rapid and excessive water evaporation can significantly affect the hydration process and trigger the unwanted material shrinkage that we have referred to above.

CORROSION

Since its pH ranges from 12 to 13 when first poured, concrete is a material with a high alkalinity. Consequently, the embedded reinforcing steel is well protected by a passive oxide layer promoted by the initial rush of alkalinity produced by the hydration of the concrete around it.

While the alkaline environment is normally effective for a long period of time after pouring, its continuing effect is dependent on the hermetic tightness of the concrete cover over the reinforcing steel. However, possible defects in depth, porosity and permeability of the concrete cover may put the embedded steel in jeopardy.

Corrosion of steel is an electromechanical process that requires an electrolyte to take place. In our case, moisture serves as an electrolyte when the concrete coverage fails to provide the necessary protection, especially due to excessive porosity coupled with a decrease in the pH level. Figure 2.1 provides a visual representation of how variations in the pH level can protect against or allow the start of the corrosion process.

The typical steel corrosion byproducts are iron oxides and hydroxides, commonly known as “rust”. When rust develops it swells from 8 to even 12 times its original volume. The forces created by such a formidable expansion cannot be resisted by the concrete cover and the relief comes in the form of spalling.

CARBONATION

As alkalinity decreases, air moisture allows atmospheric carbon dioxide to react with the calcium hydroxide in the concrete giving way to calcium carbonate. As the permeability increases so does the speed of moisture penetration.

Flaws in the concrete cover, such as: hairline cracks, honeycombs, bugholes, debris, dirt, contaminants, etc., provide the favorable paths for carbonation penetration. Once the reinforcing steel enters in contact with carbonation, it is no longer protected and decay and deterioration start their course.

CHLORIDES

When chlorides are present in concrete, whether by inclusion or penetration, the potential for steel corrosion is greatly enhanced.

Chlorides can be directly present in the concrete mix as part of wrong admixtures, contaminated mixing water, combined with other contaminants, through indirect exposure of the building structure to deicing chemicals or from the ambient air in marine locations.

Normally the pH of fresh concrete (12-13) is enough protection against chlorides, but as the pH begins to drop down, say to 10 to 10.5 levels, the chlorides will unleash their relentless attack against the reinforcing steel.

TENSION STRESSES

The tension strength of unreinforced concrete is very low, in fact it is just about 7 to 10% of its compression capacity, and therefore, structural design standards generally are inclined to recommend to the design engineer to use a zero value.

The factor which most affects the durability of concrete flat work is the fact that is done without reinforcement and worse yet, placed on poorly compacted ground. Clayed soils subject to frequent and considerable amount of volumetric changes, such as those encountered in most areas in the states of Georgia, Tennessee and North Carolina, will sponsor a large incidence of cracking in unreinforced concrete which, if left unchecked, in a few years after pouring it will be in shambles, uneven and ready to be replaced.

UNDERDESIGN

Although under-design is not a flaw of the material but negligence or incompetence on part of the design engineer, it reflects on concrete performance. A poorly designed structure would likely develop cracks which could eventually mark the beginning of a fast decay, unsightly condition and even the eventual danger of collapse.

Obviously, the solution to the under-design malady is to commission the work to design engineers with the proper knowledge and demonstrated abilities and experience. Unfortunately, the public does not know the difference and is commonly guided by ill advisers or faulty advertisement. They should rather refer their inquiries to their local chapter of the pertinent engineering society.

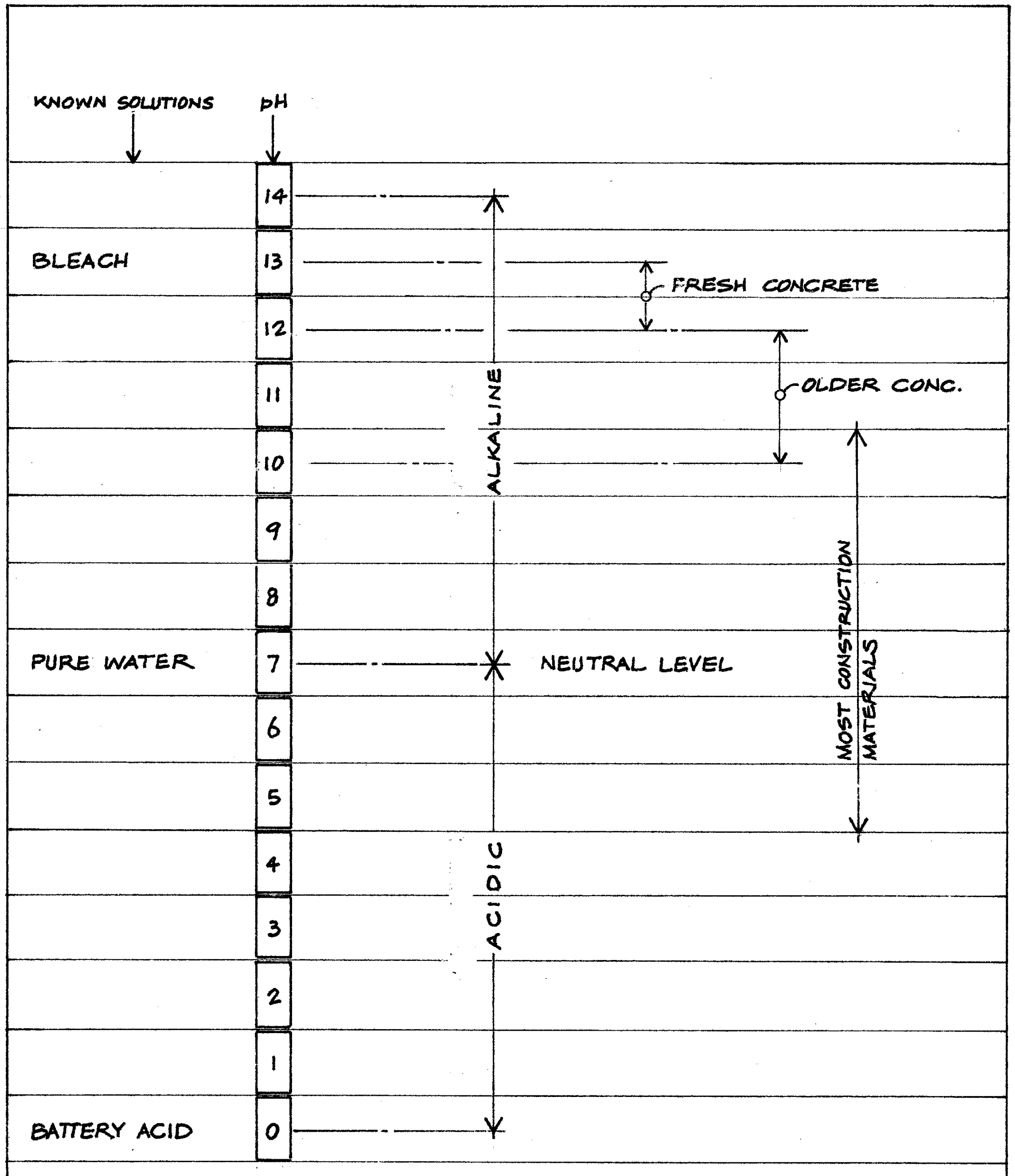
FATIGUE

Although not discussed as often as it should, the design engineer needs to have it in mind. Fatigue caused by repetitive vehicular loads could become an area of concern in bridge and parking garage design. In the same manner, repetitive lateral loads should also be a concern in the design of tall buildings.

The general consensus and common engineering practice prescribes that any structure subject to repetitive loads shall endure the fatigue generated by a given minimum number of stress cycles.

The minimum number of stress cycles for a combination of wind and dead loads shall be no less than 100,000 cycles for commercial buildings. The same standard shall apply to the combination of moving traffic live loads and dead loads for bridges and parking garages.

It should be noted that the concept of the 100,000 load cycles is the equivalent of an average of about ten cycles every day for a design period of 25 years. For cases with a larger number of cycles or longer design periods, the total allowable number of cycles shall be adjusted accordingly.



pH SCALE

FIGURE 2.1

3.0 IDENTIFICATION OF VISIBLE AND LATENT DAMAGES

As part of the prevention of latent and future damages, it is essential that the probable and actual causes of damage are unequivocally identified.

Most reinforced concrete defects and damages become evident at locations where steel bars have a reduced or substandard coverage and/or the concrete has poor quality. However, the determination of cause usually requires a deeper and more detailed investigation. This is paramount so as to be able to address the causes rather than just treat the symptoms. The extent of the scope of repairs must reach all latent damages to prevent continued deterioration.

The structural engineer in charge of the damage survey crew must have the technical competence, relevant experience and proven quality management skills to identify and document all the visible and latent problems.

He must also have an intimate familiarity with the available materials in the market that are best suitable to successfully complete the scope of repairs. Normally, the desirable remedial treatment must at least satisfy the following basic criteria:

1. Corroded reinforcement needs to be thoroughly cleaned, protected and added on if necessary.

2. An absolute and guaranteed bond shall be created between the repair materials and the original concrete.

3. Selected and specified materials must be physically compatible with the parent reinforced concrete. The ideal repair materials are those with a similar compressive strength, thermal expansion and slightly lower modulus of elasticity.

4. The treatment should offer high resistance to carbon dioxide and chloride ingress.

The damage survey should cover a complete visual examination backed up by sketches, mapping and color photographs illustrating all damage(s). It should also have the results of all testing performed, including but not limited to:

a. Strength of concrete determined with a Schmidt Hammer or similar instrument.

b. Depth of concrete cover and reinforcing location using a cover meter or similar tool.

c. Depth of carbonation zone.

d. Concrete chloride content.

e. Concrete permeability as determined by an absorption test.

4.0 REPAIR METHODOLOGY

After the damage survey is complete and the repair procedures are discussed, diagnosed and agreed upon by the members of the remediation team, the responsible engineer shall prepare the repair plans and details which shall include all steps of the restoration process, including but not limited to: marking and lay-out, cutting procedure, demolition, preparation of steel, preparation of substrate, formwork (if necessary), application of resins, grouts and mortars, application of coatings and sealants.

The following pages cover some of the standard proven procedures and methods used in the repair and restoration of damaged structures.

WALL RESTORATION

Figure 4.1 pictorially describes the recommended general procedure to repair damages sustained by reinforced concrete walls. The numbers on the pictures match those steps described below.

Step #1
After the damage survey is complete, the affected areas contained in said survey shall be marked in a clearly identifiable manner for the repair crews to accomplish their job.

Step #2
Sawcut the perimeter of the damaged area as beforehand marked up by the damage surveyor. This cut shall be done by using a penetration stop to limit the depth of cut to no less than ½ in. or more than ¾ in., so to avoid cutting through the wall reinforcing bars.

Step #3
Hand chisel damaged concrete to the required depth or use a chipping hammer when convenient. For larger areas demolition can be done by using a high pressure water jet. Although such method uses large amounts of water, in addition to being a speedy operation it can also maintain an effective dust control which is convenient to have in populated areas.

Step #4
When reinforcing bars are rust damaged by one-third of less in diameter, the depth of cut can be limited to the damaged area of steel, however,

Step #5
When the damage caused by rust exceeds one-third of the diameter, the cut shall be extended so to expose a depth equal to one-quarter of an inch passed the furthest point of the reinforcement layer. On that event, the damaged reinforcing steel shall be

replaced by new steel and the splice length used shall meet ACI requirements.

Step #6
After all the concrete cutting has been completed and inspected, all exposed steel shall be cleaned free of rust and debris by using a wire brush or by a blast of pressurized air. After cleaning, apply two coats of an approved rust inhibitor and bonding agent.

Step #7
Fill in and pack tight the entire pocket with the grout specified on the repair drawings.

Step #8
After the pocket has been grouted and screeded to the approved finishing standards or to the approval of the resident inspector, whichever applies. Protect the area with a layer of wet burlap, which is to remain in place for the entire curing period.

Step #9
Level the new surface with an approved waterproofing compound. When the patch is fully cured, apply one coat of a commercial epoxy sealer.

SLAB ON GROUND RESTORATION

It is quite common to find cracked ground slabs in the majority of the residential and commercial buildings around us. On one end, design engineers do not dedicate enough time to properly detail ground slabs on their drawings, and on the other end the contractors treat them as incidental “flat work” and more often than not, the preparations are made very haphazardly.

The majority of those cracks we often see could easily be averted if proper attention would be paid by all of those involved. First, soil compaction under concrete slabs is of paramount importance. If the soil under a slab is not compacted to at least 95% of its maximum density, the soil will surely settle and the slab will irremediably crack, it is that simple. Second, crack control joints need to be provided adequately. There are three types of crack control joints: *expansion, contraction and shrinkage joints* and they all should be clearly indicated as part of the construction drawings.

There is one more consideration to be taken into account when it comes to soil characteristics. If the soil directly under the slab happens to be a clayey soil or any other one of the clay family of soils, the chances are high that the slab placed on it will be eternally cracked. Clayey soils are known to experience radical volumetric changes depending on their humidity content. Should that be the case, the engineer would be better off by recommending the removal of the clayey material for a thickness equal to twelve times the thickness (12t) of the proposed concrete slab and have it replaced with a pad of clean sand deposited in layers of twelve inches and compacted to 95% of their maximum density.

Premolded joint fillers shall be provided against walls and columns to allow for the inevitable temperature movements in the slab, otherwise ugly cracks will form in those areas. An expansion/contraction joint pattern is advisable for any large ground slab area. Panels should be limited to some 20′ x 20′ (400 sq. ft.) and pouring should be made following a checkerboard pattern to allow for early concrete shrinkage.

Do not depend on polypropylene fibers (fibrous reinforcement), they are not a replacement for properly designed and placed steel reinforcement. Use it for what it is, a distant secondary resource against temperature and shrinkage stresses.

That stigma often mentioned by some engineers which goes: "cracks belong in concrete" is far from being so. A properly designed concrete structure with adequate provisions for expansion and contraction does not need to crack. In cold climates, exposed concrete members need to be either protected or water-tighten in such a way that humidity and water droplets do not soak-in the concrete pores and get frozen in the winter with the logical results of cracking and spalling.

Figure 4.2 shows what it can be done to rescue a slab damaged by a settled soil base, as a solution to keep a building functioning, as well as being a substitute for demolition and replacement with the resulting consequences of higher cost, delays and interruptions.

The methodology shown is known as *slab jacking* or *mud jacking.* The idea is to inject a pressurized cementitious grout under the failed slab to restore its original position and provide the needed support.

As the grout is pumped into a drilled hole through the existing slab and into the air pocket underneath, it creates an upward pressure on the bottom of the pocket as the grout flows under the slab and forces it back to position.

There are three grout formulations that have been found adequate and have been tried successfully in the past, they are:

Grout Design #1
Four parts of clean fine sand and one part of Portland cement and clean water.

Grout Design #2
Five parts of *caliche* (generic term for ground limestone), one part of Portland cement and one part of water.

When no air pockets are found, but just loose soil is detected under the slab, a soil process known as *permeation* is recommended. Permeation consists of pressure injected grout into the soil itself, which increases density and therefore compressive capacity. The grout formulation for such process is given below:

Grout Design #3
This is a chemical grout composed of four ingredients: sodium silicate as the base material; a reactant gel; calcium chloride as an accelerator; and clean water. This should be kept in mind when handling calcium chloride. Such chemical should be kept away

from and never allowed to enter in contact with the reinforcing steel.

Figure 4.3 depicts a cosmetic solution to provide the last touch to the cracks in the case described above, or on the other hand, to generically solve the case of any ground slab or road pavement slab for that matter, which could have cracked due to temperature differentials or overloading.

The following are the repair procedural steps applicable to a condition similar to that depicted on Figure 4.3:

Step #1
Pressure clean the entire slab under the repair program.

Step #2
Rout floor cracks following a straight polygonal line pattern similar to that shown on the lower figure. The resulting groove should have a maximum of ½ in. wide by ½ in. deep and should contain the crack within its width.

Step #3
Air blast the repair area clean and free of dust and debris.

Step #4
Fill in the polygonal groove with the specified joint sealant or approved similar.

Step #5
After the sealant has been allowed to cure to manufacturer specifications, apply sealer according to the approved drawings.

Often times after a concrete slab repair and restoration has come to completion and its appearance is no longer a matter of concern, then old blemishes and stains on the concrete surface become a centerpiece in everybody's attention. If so is the case with your job at hand, we have included a brief guide of how to remove new and old stains as part of Appendix A at the end of this course.

SUSPENDED CONCRETE SLAB RESTORATION

In this section we will cover the three most common damage conditions found in suspended structural slabs and their corresponding repair procedures.

Figure 4.4 depicts a slab with an upper surface damage that has not gone through the entire depth. The procedure described ahead applies to a maximum damage depth of up to half the slab thickness (½t).

Step #1
Sawcut perimeter of the delaminated or cracked concrete area to a maximum depth of ½ in.

Step #2
Remove deteriorated concrete to a sound substrate. Use a 35 lb. hammer to the bottom of top reinforcement. Then use the 15 lb. hammer to clean up around and detail the reinforcing bars. If the reinforcement has not been yet damaged by rust and is still tightly bonded to the concrete, then, undercutting the bars is not necessary.

Step #3
When the demolition is complete and has reached the intended sound substrate, sandblast the area clean.

Step #4
Re-examine all reinforcing bars. Replace those with a section loss greater than 25% and provide splices for the new bars to conform to ACI requirements.

Step #5
Coat all exposed bars with an approved epoxy rust inhibitor.

Step #6
Soak patch area and blow dry it, then apply a coat of bonding agent and fill in the patch with the approved grout or concrete. If shrinkage is a serious concern, add polyfibers to the mix.

Step #7
Cover the patch area with wet burlap and allow it to cure for 48 hours before sealer is applied to the patch.

Figure 4.5 depicts a repair procedure applied to damage taken place on the underside of the concrete slab and which does not exceed one-half of the slab thickness.

Step #1
Sawcut ½ in. deep following the outer perimeter of the damaged area and continue with chipping hammers to a depth reaching the sound substrate. Allow ¾ in. minimum clearance beyond all reinforcing bars.

Step #2
Once demolition is complete, sandblast substrate free of debris, loose particles or degraded material.

Step #3
Carefully examine all reinforcing steel and replace bars with a sustained section loss greater than 25%. Provide splices in conformance with ACI requirements.

Step #4
Install forms and shoring as recommended by the responsible engineer.

Step #5
Drill a strategic port hole through the forms and pump the specified grout mix into the repair pocket. When dealing with large repair pockets it is helpful to have a second hole on the opposite end to let the air out and visually make sure that the grout has traveled all the way through the pocket. At the end of the pumping effort, remember to plug up all drilled holes.

Step #6
After the specified curing time has passed, remove all formwork and apply a coat of the sealing compound.

Figure 4.6 covers the case of concrete damage extending through the entire depth of the slab. The key numbers below correspond with the steps below as well as the featured numbers shown on the figure.

Step #1
Sawcut along perimeter and remove deteriorated concrete. Use a 35 lb hammer for the bulk demolition and 15 lb hammer to clean up reinforcement and finish the excavated pocket.

Step #2
Sandblast substrate clean and free of loose material.

Step #3
Replace all reinforcing bars with a section loss of 25% or larger. Apply a coat of epoxy rust inhibitor.

Step #4
Reinforcing bars with a section loss less than 25% shall be wire-brushed down to the bright metal. Apply a coat of epoxy rust inhibitor.

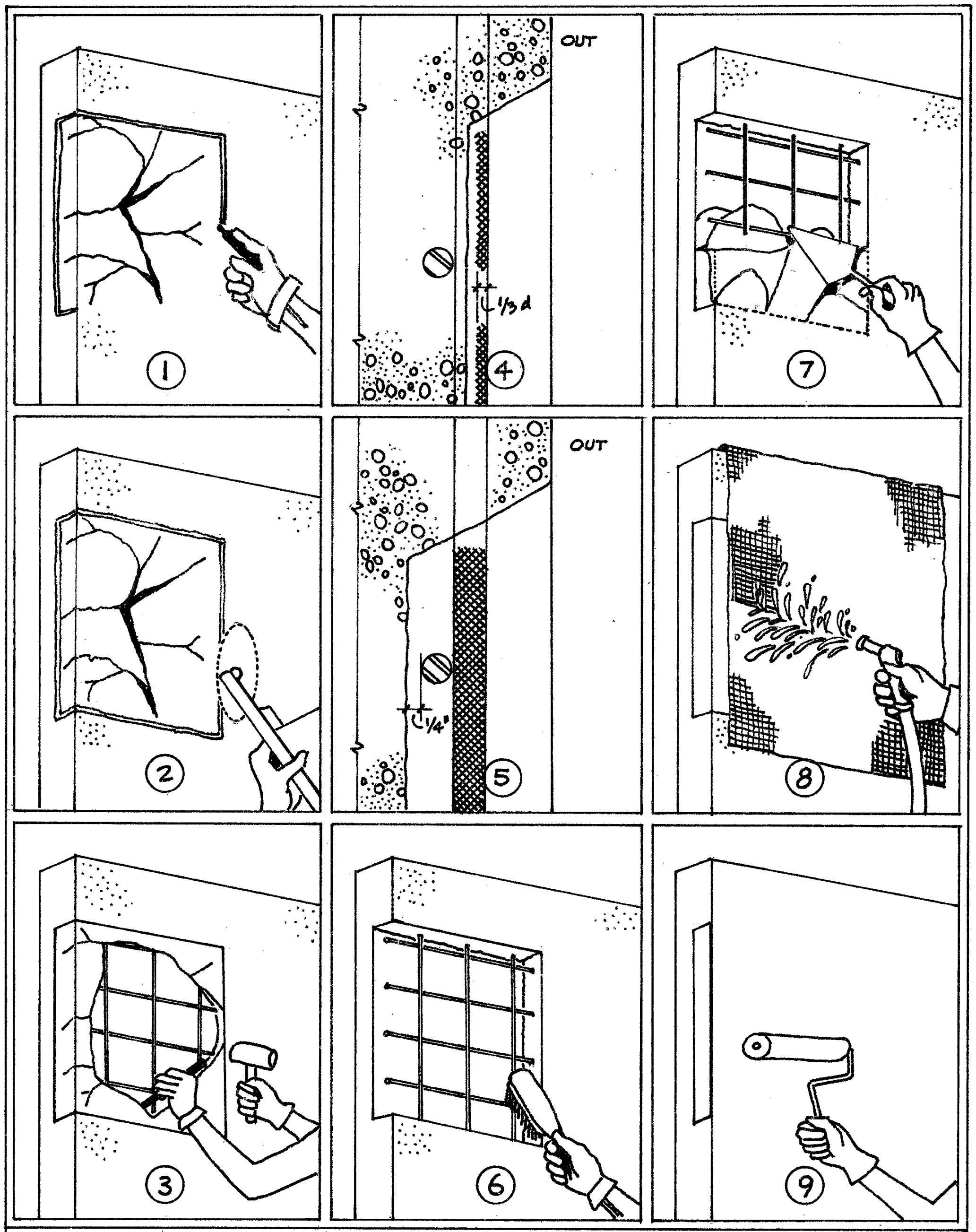
Step #5
Install forms and shoring as specified by the responsible engineer.

Step #6
Proceed with the concreting. Apply wet burlap and allow the poured area to cure. At the end of the curing period, apply the approved sealing compound.

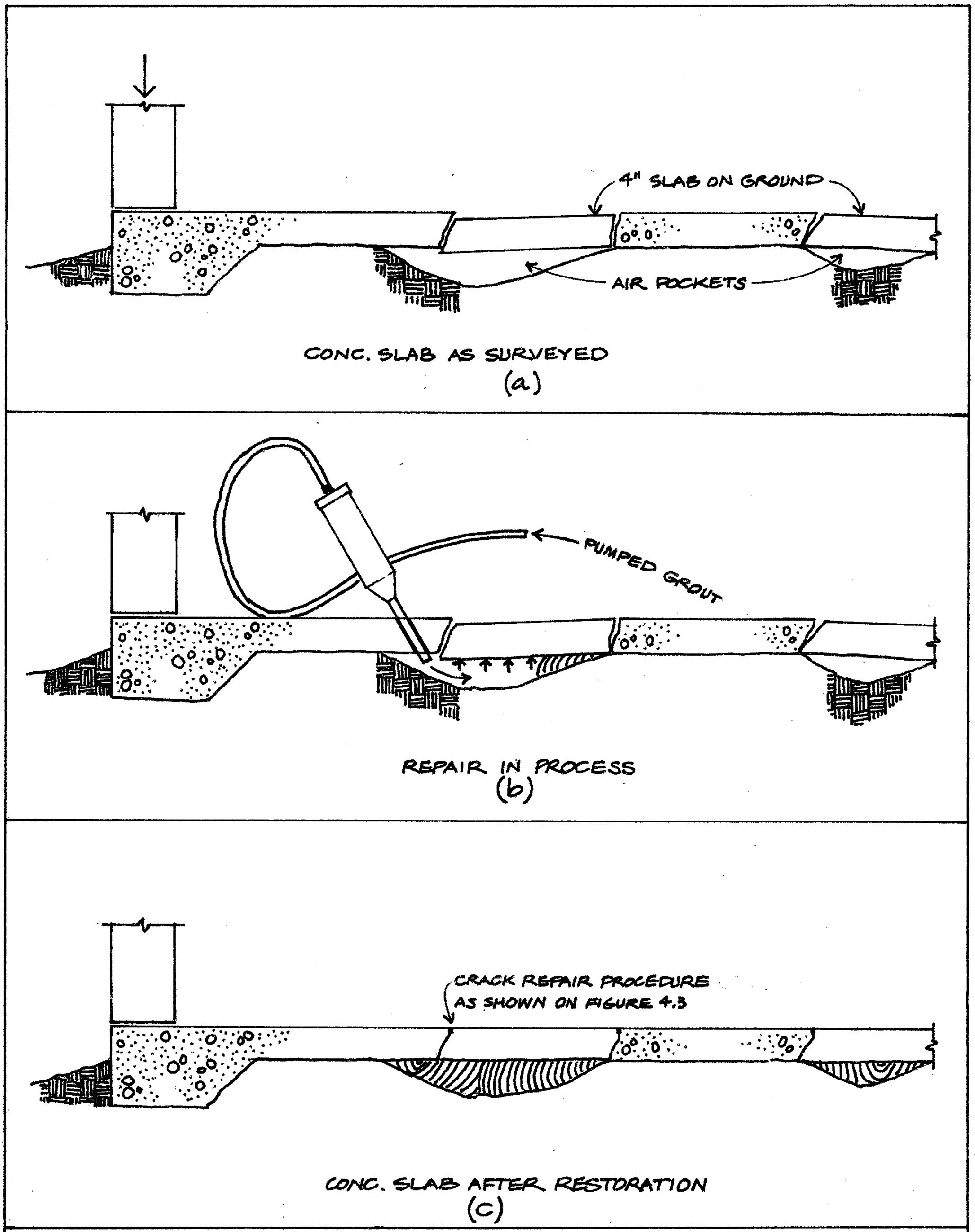
Before we get out from this area of study regarding the repair of suspended slabs, it is worth noticing the importance of adequate shoring while performing this type of work. Shoring must be well conceived, distributed, spaced and calculated in such a way that the structure under repairs is assisted with the proper temporary supports needed, so to avoid mishaps or calamities as the one we have described in our course titled “Basics On Forensic Engineering, Part IV”.

This recommended reading deals with the partial collapse of a flat slab in a parking garage located in the City of Gaithersburg, Maryland. In the case in question, the builder was held ultimately responsible due to his negligence in providing the proper shoring while the repairs were taking place. Again, we strongly recommend its reading to all design engineers and builders, especially those whom one time or another may get directly or indirectly involved in projects of that nature.

Concrete is indeed a very resilient and forgiving material, however, none of us want to be connected with cases where its ultimate limits are put to a test unnecessarily. A few more shoring jacks is a little price to pay so to avoid the high cost of clean-up, repairs, investigation, legal fees, penalties and delays thereafter, as well as the embarrassment and due repairs to one's reputation.



RECOMMENDED STEPS FOR WALL RESTORATION
FIGURE 4.1

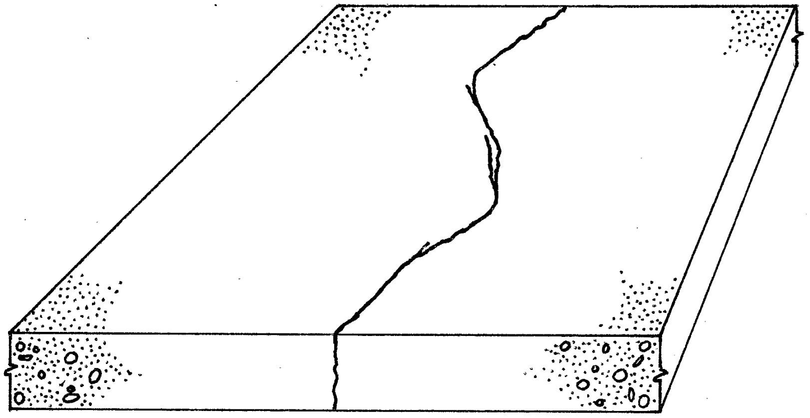


CONC. SLAB AS SURVEYED
(a)

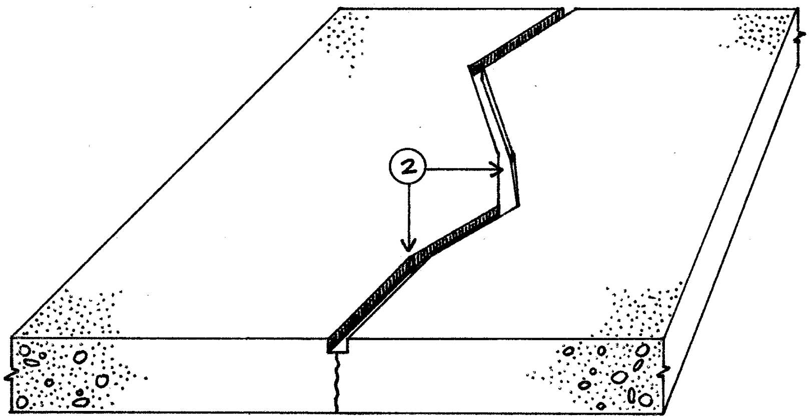
REPAIR IN PROCESS
(b)

CONC. SLAB AFTER RESTORATION
(c)

RESTORATION BY SLABJACKING
FIGURE 4.2

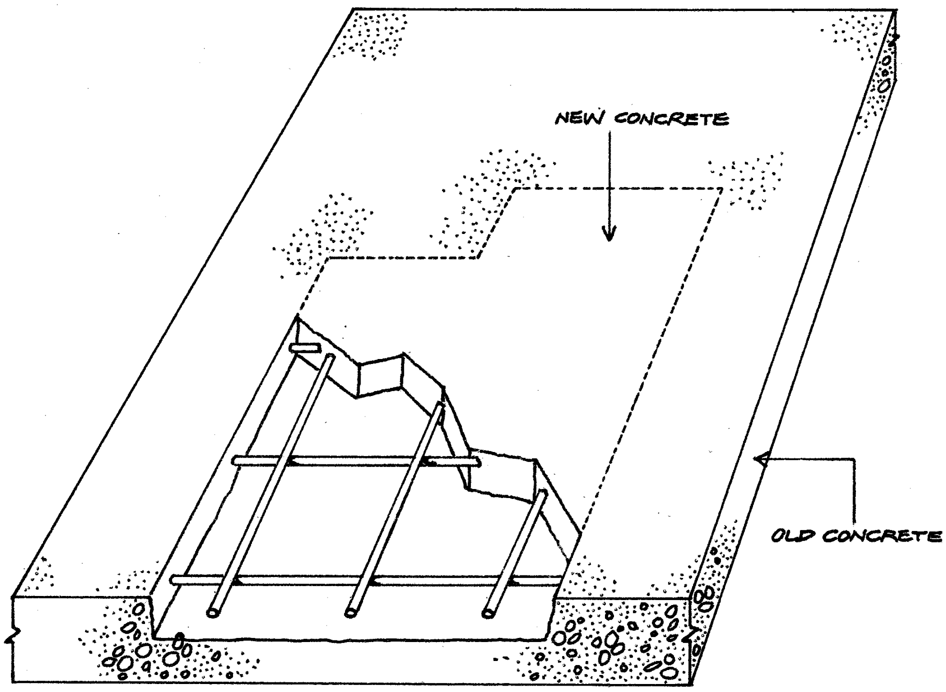


CRACKED SLAB AS SHOWN ON DAMAGE SURVEY.



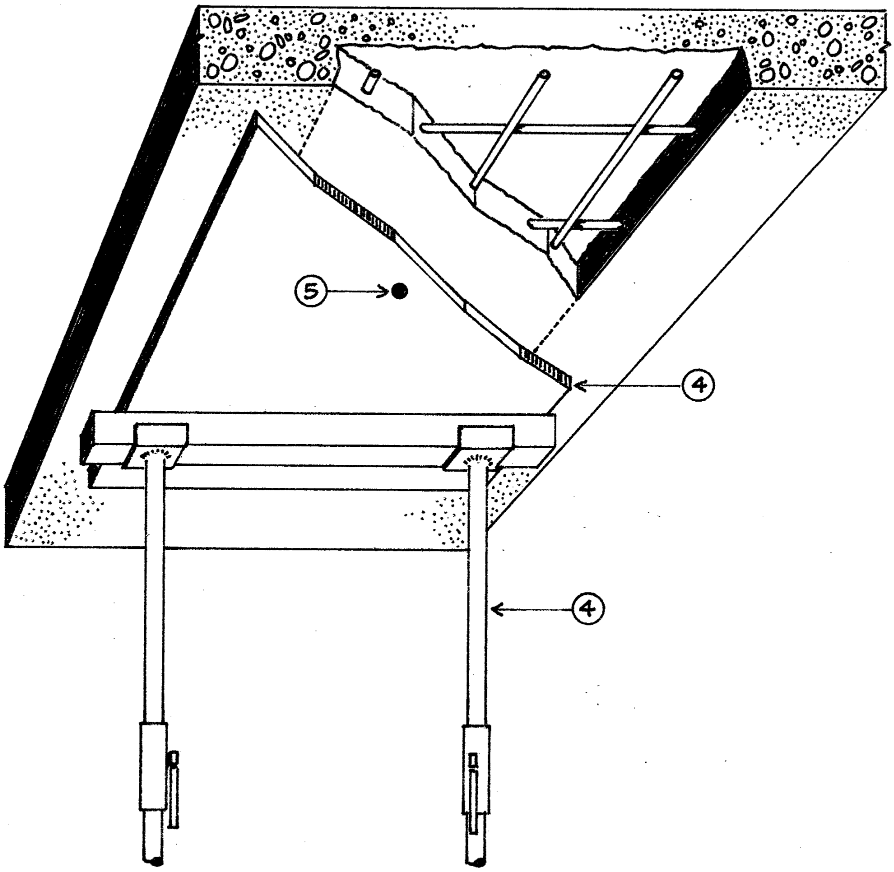
CONCRETE SLAB AFTER ROUTING IS COMPLETE.

COSMETIC REPAIR METHOD FOR CONC. SLAB CRACKS.
FIGURE 4.3



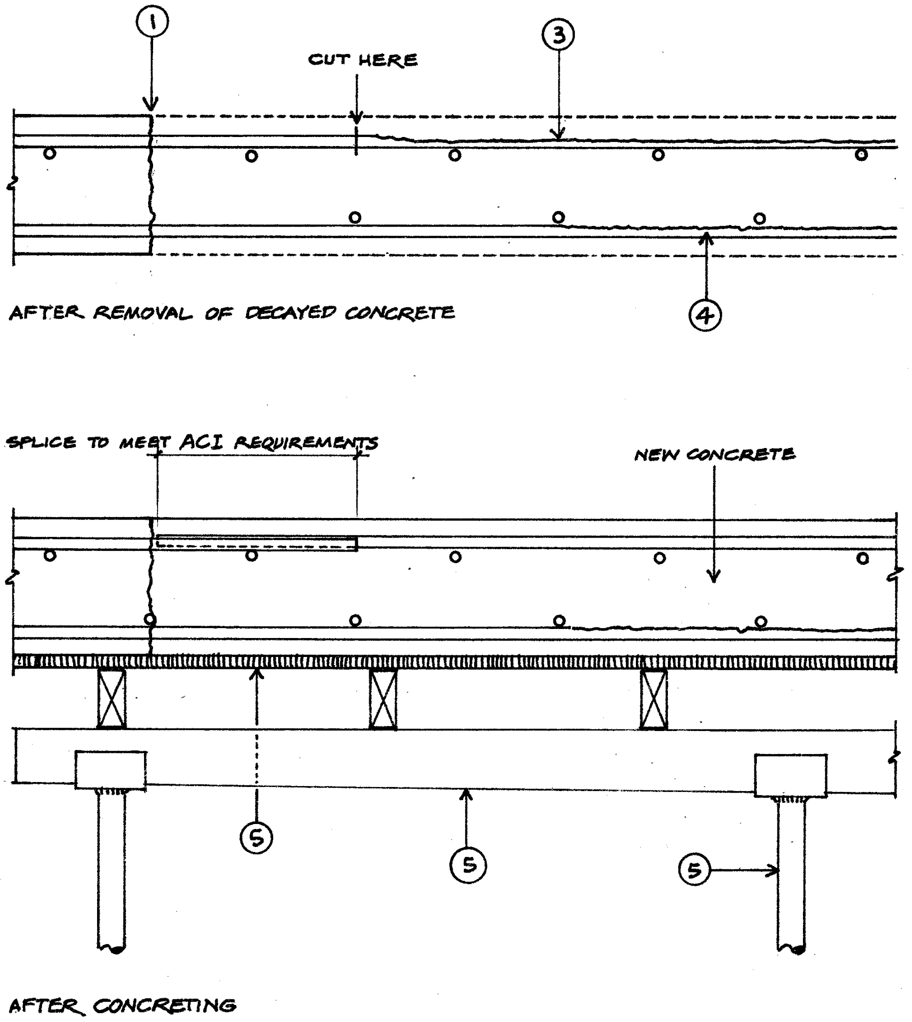
DEPENDING ON LOCATION AND EXTENSION OF PATCH, SHORING MAY BE NECESSARY. FOLLOW ENGINEER'S RECOMMENDATIONS.

TYPICAL SLAB REPAIR METHOD
DAMAGE ON THE UPPER HALF OF SLAB
FIGURE 4.4



TYPICAL SLAB REPAIR METHOD
DAMAGE ON THE LOWER HALF OF SLAB

FIGURE 4.5



TYPICAL SLAB REPAIR METHOD
DAMAGE THROUGH SLAB DEPTH

FIGURE 4.6

5.0 TWO CASE HISTORIES

In no other sector of the construction industry concrete gets so neglected and abused than in the single family housing business. In order to enhance their profits and fit into that fiercely competitive business, builders cut corners in many areas. One of them is looking for ways not to have to use reinforcing bars to save the time, as well as the cost of labor and material.

While all engineers know (or perhaps we need to say "should know") that concrete has little tension capacity. In fact, without adequate reinforcement concrete lacks the high qualities that we have always given it credit for. It is commonly seen in the construction sites, ground slabs, footings and walls provided with the least amount of reinforcement (if any) the builders can get away with.

That condition added to the fact that the soil base is poorly compacted, if any, open the doors for the profusion of unsightly cracks in almost every house around the block. That not only brings down the quality of house construction, but gives the material an undeserved bad name.

It is for this reason that we have selected as our first example, a single family house we were retained to helping solve its woes.

Case History #1

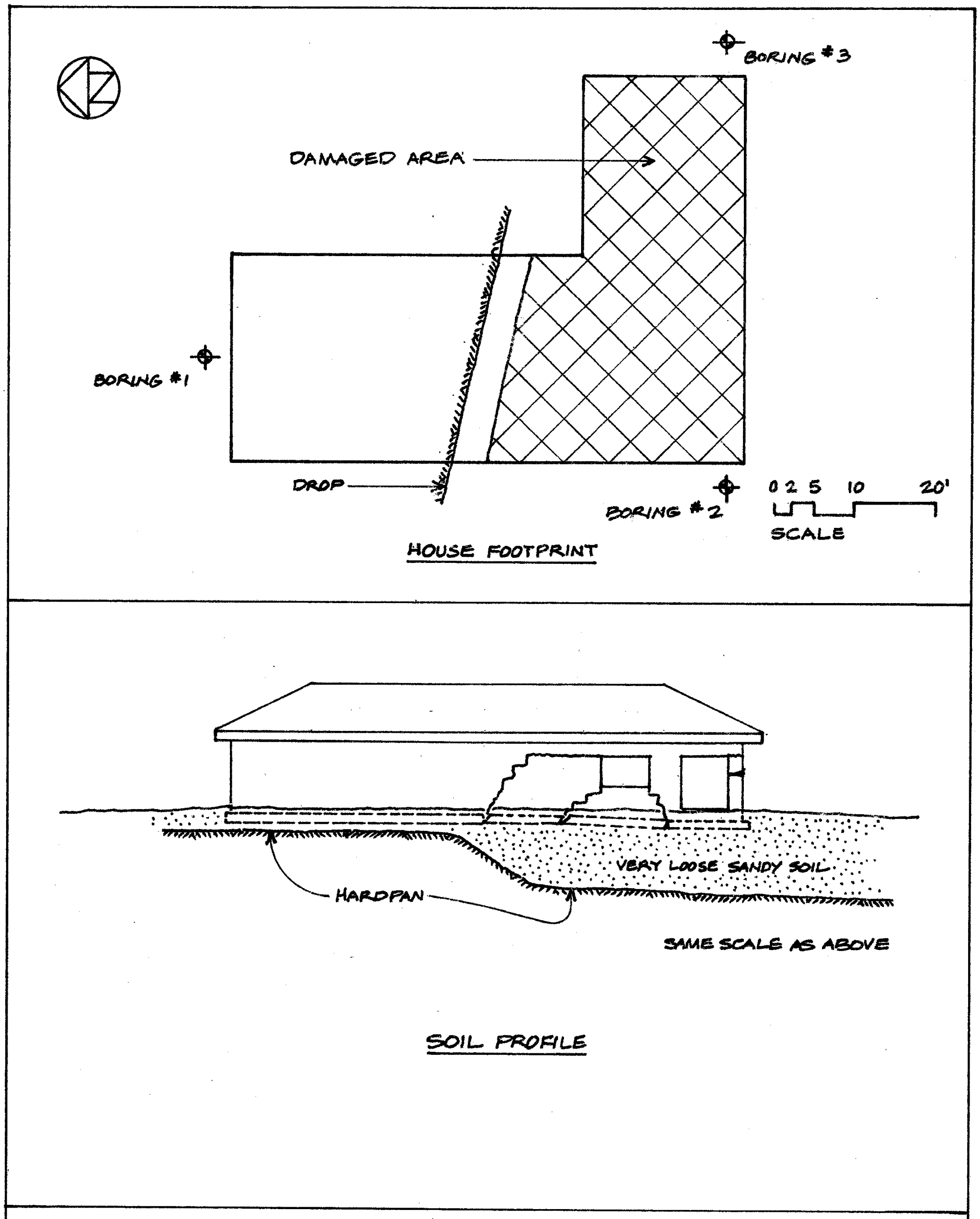
The year was 1986 and the house in question was located on the 6th hundred block of N.W. Second Terrace in the City of Deerfield Beach, Florida. At such time, the Deerfield Beach Building Department was threatening to issue an order of condemnation and demolition.

The basic structure with a 1950 vintage consisted of unreinforced exterior masonry walls on isolated (stem) footings and the roof was solved by using the typical wood trusses with plywood sheathing. The southern part of said house showed some soil settlements resulting in severe cracks along the South wall which had settled more than two (2) inches below its original level, as well as deep cracks through the floor slab which also had settled along with the wall.

Three (3) Standard Penetration Test (SPT) borings were drilled down as shown on the enclosed Figure 5.1. Those borings told the story with no room left for doubt, the problem was caused by differential settlements, the house was sitting on the border of a soil profile where the hard pan underneath had taken a plunge from 2 ft. deep at the North end of the house to 20 ft at the South end. On top of that hard pan there was a mass of very loose gray sand where the house was sitting on.

Boring #1 showed at 2 ft. deep a blow count on the sampler of 40 blows per foot of penetration, while Borings #2 and #3, at the same depth, showed a blow count of 5 blows per foot.

We used the most obvious solution at hand by jacking up the South wall back to position by using the very effective method of bracketed helical piers, while the floor slab was satisfactorily repaired by applying the method we have already described in the enclosed Figure 4.2.



CASE HISTORY #1
FIGURE 5.1

Notes from the author:

1. Figures 6.1, 6.2 and 6.3 apply to Case History #2 below and can be found at the end of that section.

2. The text of Chapter 6.0 has been deleted with no detrimental consequences to the narrative.

Case History #2

Sometime in October 1991 we were called to South Florida to examine a country club free standing stairway showing alarming cracks across the landing. The witnesses' story went like this: "During a holiday while celebrating an activity typical of those which normally take place in those facilities, a group of unsupervised adolescents decided to take advantage of the vibration prone structure and jumped repeatedly at the end of the cantilever while enjoying the exciting trampoline effect……"

Seemingly, the jumping went on long enough so as to generate vibratory accelerations near the level of *resonance,* thus developing considerable torsional moments at the center of the landing with shear forces beyond the concrete capacity, as result of such activity, early emerging failure manifested itself with the appearance of transverse cracks as will be seen on the figures ahead.

Figure 6.1 depicts the stairway as it looked immediately after completion. Railings have been omitted in order for the reader to have a better understanding and a simpler view of the scene.

The cracks we observed during our visit were crowded together towards the center of the landing and propagated in both directions, back to the flight steps and towards the end of the landing. See point marked "O" on the enclosed plan view shown on Figure 6.2. Cracks were wider at line CD and the gap gradually decreased to hairline type as they reached line FG.

Because of the asymmetry of the flights as they connected to the landing, the pattern of deflections was similarly asymmetrical also due to the compression on the lower flight. Measured deflections were reasonably comparable to those later calculated in the office. In order to make that determination in the field, we conceived a stair drawing based on the known riser/tread relationship and compared it against the actual field measured structure. The maximum measured deflection was 1.75 in. at point F. The rest of deflections were 1.52 in. at point G, 1.08 at point D and 0.88 in. at point C.

Before leaving the site of the incident, we had points C, D, F and G temporarily supported by using adjustable jacks and the area was barricaded to avoid public use while we did our office work.

After two weeks of analysis and discussion in the office, we came up with a set of repair sketches and recommendations that are basically and pictorially summarized on Figure 6.3 at the end of this section.

The solution consisted of a "T" shaped support built out of 6" x 6" steel tubing anchored to a 4′ x 5′ reinforced concrete footing. Before installation of the steel tubing support, measured deflections were corrected to half their value by adjusting the shoring jacks 0.44 in. at point C and 0.54 in. at point D.

The steel studs were set in drilled pockets and the steel tubing support frame fastened to the four anchor bolts coming out of the concrete foundation. The four (4) steel studs were inserted and set in a two-part epoxy grout mix and allowed to cure for 24 hours. Then expansive grout was packed in at the top and bottom gaps, similarly as it has been shown in Figure 6.3.

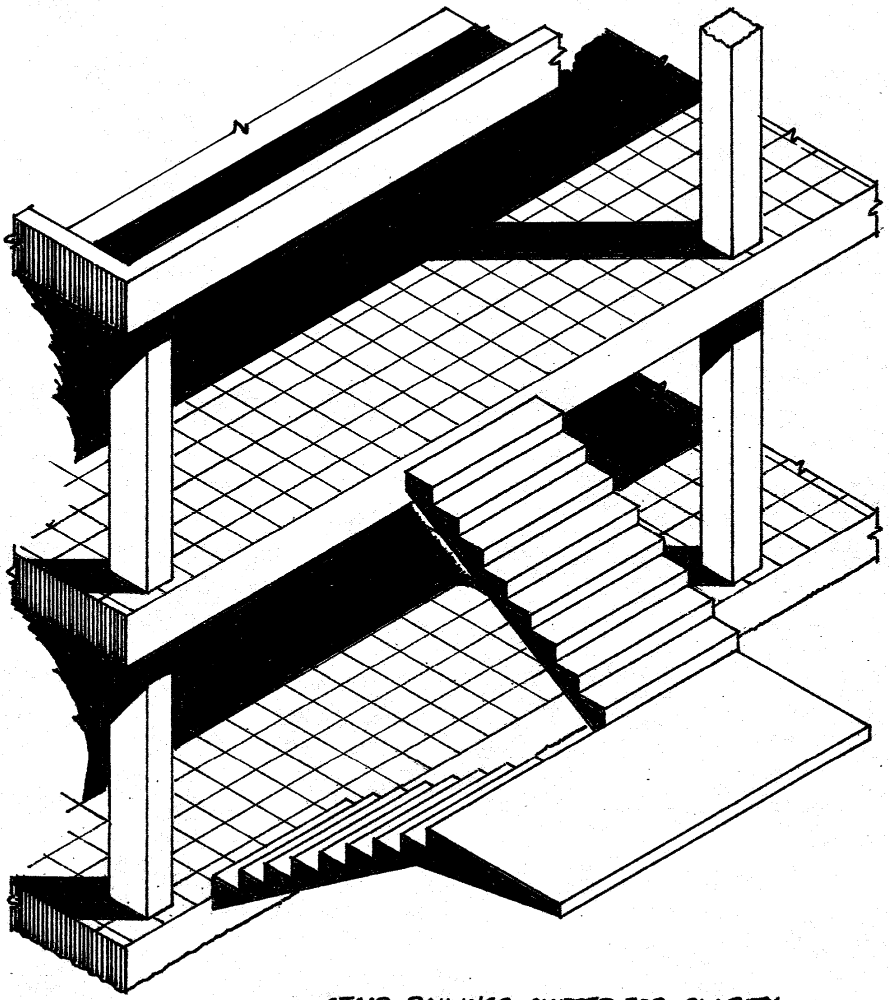
The steel tubing frame was filled in with regular grout, so as to evacuate the air and preclude the possibility of rust from the inside out. Two coats of rust inhibiting paint were applied to the exterior face of all exposed metal parts.

Upon completion of all those described steps, the landing cracks had substantially reduced. The remaining cracks were cosmetically repaired by first sealing them on the surface with fast setting epoxy grout. Then, two ports were drilled at both opposing ends and liquid epoxy compound injected at one of the ports until it flowed out at the far end port.

After curing, all patched-up surfaces were detail chiseled and ground smooth to our field inspector's expectation and satisfaction.

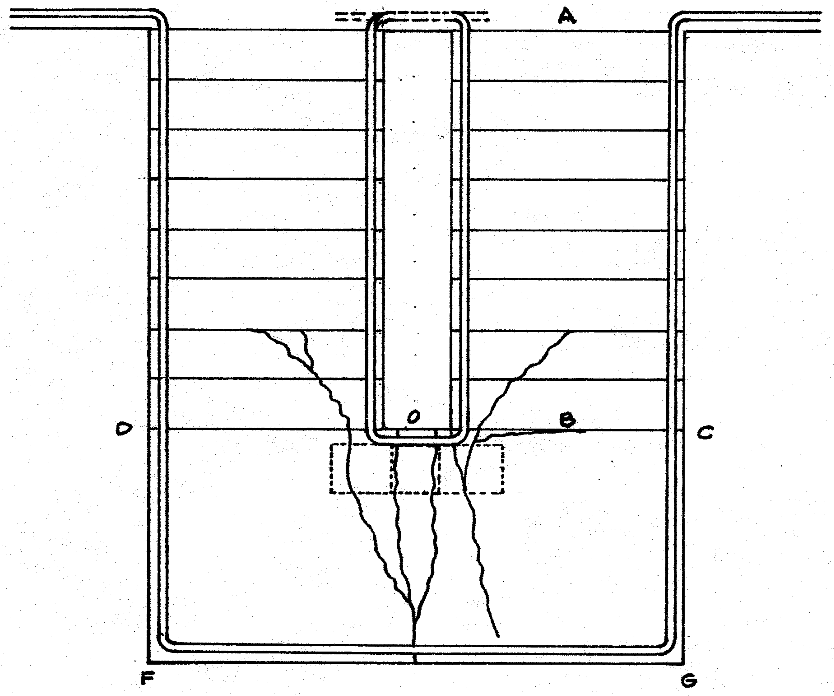
Although the daring characteristics of the original design had been somewhat taken away by our repair scheme, but also gone was the "trampoline bounciness" that so irresistibly had been by attracting such a dangerous game.

In closing and for those interested, there is considerable more information on this case and related matters and they can be found in the last part of our course titled "Stairs & Stairways" which is presently available from this same source.



STAIR RAILINGS OMITTED FOR CLARITY.

FIGURE 6.1
FREE STANDING STAIRWAY



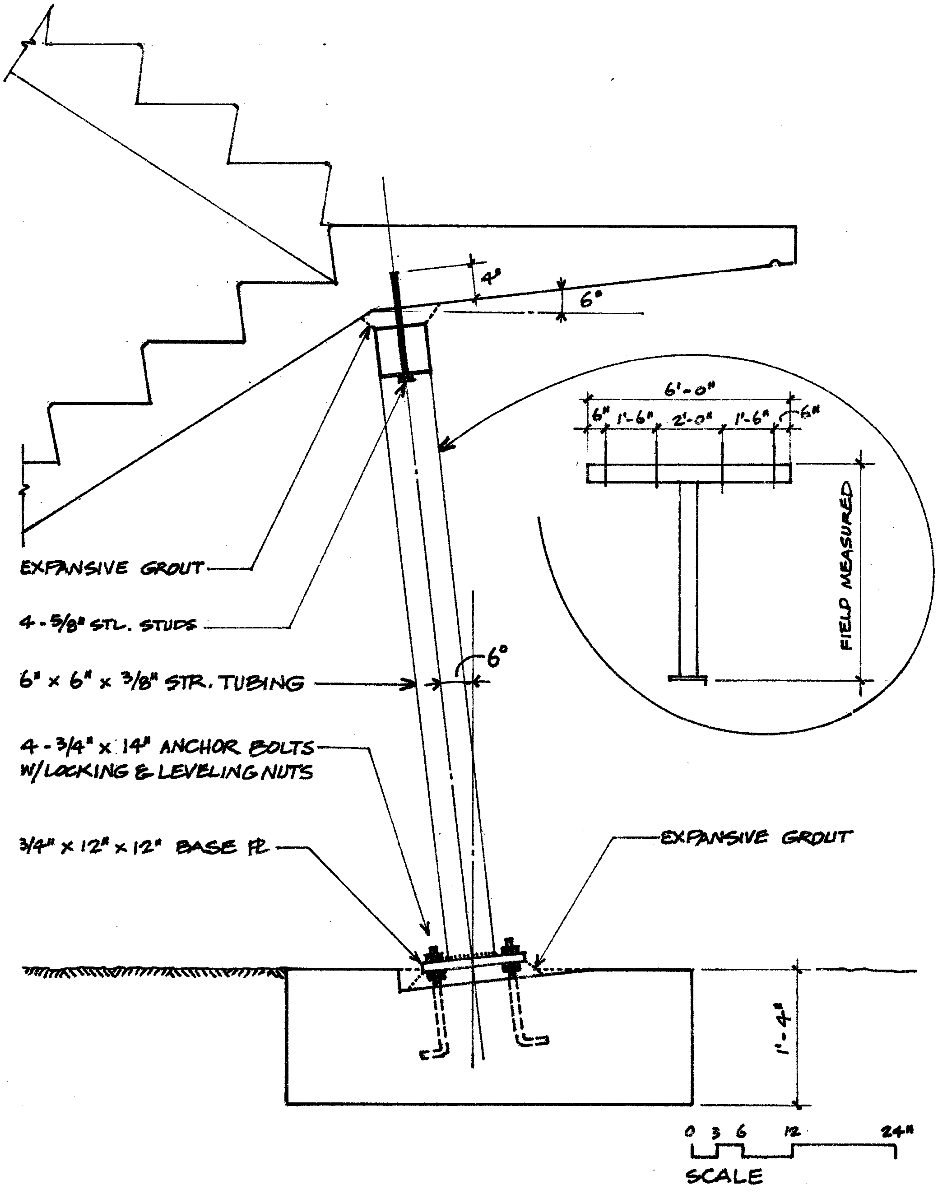
SOUTHEND COUNTRY CLUB
1991

STAIR #4

CRACK PATTERN
3MM. GAP ON LINE CD
HAIRLINE ON LINE FG

PLAN VIEW

FIGURE 6.2
DOCUMENTED CASE #2



STAIR REPAIR DETAIL
FIGURE 6.3

7.0 CONCLUSION

When concrete fails to perform its intended job and purpose, more often than not, its failure is related to one of the following conditions:

a. the structure was designed for the wrong loading conditions or the design engineer failed to consider or evaluate stresses that were beyond the structure's capacity to endure,

b. it was exposed to service conditions or to a corrosive environment without the proper protection,

c. its quality failed due to inadequate aggregates, poor mixing procedures, wrong additives and/or admixtures, extended transportation time, excessive amount of water added at the construction site, lack or absence of consolidation, extreme temperatures, poor curing practices, inadequate formwork or too early stripping.

d. lack of appropriate repairs or timely maintenance.

When all steps are taken according to the known rules and procedures, reinforced concrete is an unmatched material for its exceptional qualities, let alone its adaptability for military defensive purposes, as it is extremely useful in fortifications, bomb shelters and bunkers as it was proven many times over during the Second World War.

If all efforts fail due to unknown reasons or unanticipated conditions, as it may happen in rare occasions in a lifetime when changes, modifications and repairs are necessary, we have provided in this course the means and the ideas of how to successfully solve those problems in an effective and cost effective manner.

The reader may also find the methods covered herein useful in the repair of car parking structures, dilapidated public housing, the restoration and preservation of historic buildings, as well as bridge repairs and maintenance.

END

APPENDIX A

STAIN REMOVAL FROM CONCRETE SURFACES

Whether they are fresh or old, most stains on concrete surfaces can be permanently removed, however, in some cases it requires patience and persistence. If it does not work the first time keep repeating the treatment until the desired results become a reality.

OIL STAINS

Fresh old stains can be prevented if the spot is immediately covered by a thick layer of either *hydrated lime* or *Portland cement*. Let it rest for an hour or longer until the oil is completely absorbed by the dusty coat, then remove and wash it clean.

Since oil can be absorbed by the concrete surface very rapidly or if the stains are old, the following treatment will be necessary:

Mix one pound of *trisodium phosphate,* half pound of *whiting* and dissolve them in one gallon of clean *water.* Stir the mix until it thickens to a paste and apply it to the stain and let it stay on it overnight. Next day remove the dry coating and wash it with clean water.

IRON STAINS

Light iron stains can be removed by soaking it with a solution of one pound of *oxalic acid powder* per gallon of *clean water.* After letting it rest for two hours, scrub it off with a stiff brush.

Dark oil stains on the other hand, can be very stubborn and need a more aggressive treatment. Dissolve one part of *sodium citrate* in 6 parts of *water.* Sprinkle the mix with *hydrosulphite* and add *whiting* until it gets to the consistency of a paste. Apply to the stain and let it stay on for not longer than one hour. Then remove and wash clean.

COPPER STAINS

To treat green copper stains, mix one part of *ammonium chloride* and four parts of *talcum powder,* add *ammonia* and stir to the consistency of a paste. Place over the stained area until it is completely dry, then remove and wash clean. Old stains may required several applications.

ALUMINUM STAINS

White aluminum scabby stains can be removed by scrubbing a 20% solution of *muriatic acid* on the stain until it is gone. Wear thick gloves to protect your hands for that acid is very aggressive.

INK STAINS

The following formula applies particularly to writing blue inks. Prepare a solution of *sodium perborate, whiting* and *hot water*. Mix them to a thick paste consistency and apply a thick layer over the stain and allow it to dry to the touch. Scrape and wash the area until it is clean. Some inks will leave a brown stain behind; if so is the case, treat it again with the same formula used for iron stains.

TOBACCO & URINE STAINS

Dissolve two pounds of *trisodium phosphate* in one gallon of hot *water.* Add twelve ounces of *chlorinated lime* and stir the mix until it turns to a paste. Apply to the stain and leave in place for two hours. When dry to the touch: scrape and wash.

This mixture could be highly corrosive to metal objects and will discolor fabrics. Please take the appropriate precautions.