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An Examination Of The Clinical Efficiency Of Three Indexes Of Functional Hearing Loss

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STABILIZATION PROCESSES OF EXISTING ADOBE STRUCTURES
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STABILIZATION PROCESSES OF EXISTING ADOBE STRUCTURES

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THESIS

Submitted in Partial Fulfillment of the
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ABSTRACT OF THESIS

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ABSTRACT

This thesis discusses the deterioration of existing adobe structures and the solutions available to retard deterioration.

1. The thesis presents information necessary for analyzing the existing structure.
2. The thesis discusses the causes of deterioration in order to stabilize against it.
3. It discusses and illustrates the various forms and visible signs of deterioration.
4. Finally, the thesis shows the reader various solutions that may be implemented to resolve and halt further deterioration of the adobe structure.

TABLE OF CONTENTS

Page

Introduction....................................1

Section I. Stabilization Processes of Existing Adobe Structures........................8

Understanding Deterioration......................8

Moisture Deterioration..........................8

Surface.....................................9

Subsurface..................................9

Capillary Action............................9

Carbonic Acid...............................13

Soluble Salts...............................13

Temperature Deterioration.......................15

Contraction and Expansion...................15

Sliding Effect..............................15

Combination Moisture and Temperature Deterioration..................................18

Plant Caused Deterioration......................20

Section II. Forms of Deterioration and Visible Signs........................24

Efflorescence...................................24

Spalling..24

Coving Action...................................24

Slumping..27

Section III. Deterioration Related to Foundations.30

Foundation Types................................30

Page

Moisture Seepage....................................32

Settlement..35

Freeze-Thaw Action..................................39

Section IV. Solutions for Deterioration.............41

Classification......................................41

Physical..41

Non-physical....................................41

Solutions for Major Deterioration...................42

Patchwork.......................................43

Reconstruction of Walls.........................46

Solutions for Foundation Settlement.................53

Perimeter Trench...........,....................53

Drain Trench....................................54

Underpinning Foundation.........................55

Excavation......................................56

Rebar Placement.................................58

Concrete Work...................................59

Solutions for Minor Deterioration...................60

Classification..................................60

Chemical Solutions..............................60

Method of Application...........................60

Latent Side Effects.............................61

Appendix A. Chemical Solutions......................69

Appendix B. Testing.................................85

Bibliography..87

LIST OF ILLUSTRATIONS

Page

Eventual Dissolving of Joint Through Capillary Action....13

Redistribution of Salts....14

Sliding Effect....16

Wall Section Showing Points of Failure....16

Plant Caused Deterioration....21

Coving Action....27

Adobe Foundation....30

Stone Slab Foundation....31

Field Stone Foundation....31

On Grade Foundation....32

Moisture Seepage....33

Adobe Foundation Deterioration....34

No Foundation....35

Normal Situation....36

Settlement....37

Wall Section Showing Points of Failure....38

Freeze-Thaw Action....39

Minor Damage....43

Patchwork Solution....44

Removal of Damaged Adobes....44

Wall Preparation....45

Page

Rebuilding..45

Load Bearing Wall.................................46

Possible Collapse.................................47

Relieve Load Above Section........................47

Cut Away Eroded Adobes............................48

Rebuilt Section...................................49

Erosion at Corner of Two Walls....................50

Side View of Eroded Corner........................51

Stair Step Removal of Adobes......................52

Rebuilt Corner....................................52

Perimeter Trench..................................53

Latent Side Effect of Trench......................54

Trench Excavation.................................55

Trench Construction...............................56

Excavation Section................................57

Sectional View....................................57

Rebar Placement...................................59

Sectional View of Treated Surface Showing
Various Depths of Penetration.....................63

Formation of Gap Between Adobe and Treated
Surface...64

Sectional View Showing Moisture Seepage...........65

Capping Solution..................................66

Erosion of Cap....................................68

LIST OF PHOTOS

Page

Surface Run-Off (Furrowing)..............................10

Erosion..11

Erosion of Adobe Wall at Top.........................12

Failure Around Window Opening........................17

Surface Covering Detachment..........................19

Efflorescence, Spalling..............................25

Coving Action..28

Pecos Monument Surface Treatment.....................67

INTRODUCTION

This thesis evolved through various stages over a period of four years. The first stage dealt with a photographic documentation of the art and architecture of the old churches of New Mexico. As this documentation progressed, it became apparent that many of the churches were evidencing varying degrees of deterioration. Further investigation revealed that the archdiocese had lost some irreplaceable historic properties due to natural deterioration. Further substantial loss was attributed to ill-advised attempts at restoration or stabilization of the properties. Church fathers mentioned that they lacked information on stabilization or restoration of adobe structures.

So, the second stage in the evolution of this thesis developed a "bible" for preservation, stabilization, and restoration of old churches. About a year and a half later, the author observed the obvious. Not only the churches were deteriorating, but many adobe houses built at different time periods were also deteriorating. Therefore, the author expanded the thesis to discuss all available techniques and methods for stabilizing adobe--be it a barn or cathedral.

The author found a lack of information available on stabilization of adobe. After extensive research and interviewing the author discovered that no single definitive source existed for information on stabilization of adobe. Most information on adobe stabilization was available only through those persons who have spent a lifetime experimenting with preservation. Therefore, while all available publications on the subject were read, this thesis is basically derived from personal interviews and field observations.

SECTION 1
STABILIZATION PROCESSES OF EXISTING ADOBE STRUCTURES

Although many adobe structures have been lost due to natural deterioration, substantial loss must be attributed to illadvised steps towards restoring or stabilizing them. This thesis treats various types and causes of deterioration and develops an approach for noticing and deducing existing structures to establish the form and source of deterioration. It surveys various solutions for stabilizing an adobe structure that have been tried in order to help the user choose the most appropriate one. This thesis also provides a useful resource of solutions for anyone contemplating adobe stabilization.

Information about an existing structure needs to be gathered to gain a clear understanding of what the structure is experiencing. Noting that a building is deteriorating is not sufficient; it is also necessary to understand why this process occurs. This data will be environmental and geological, as well as how to analyze an existing structure.

Environmental data, when compiled, will provide one part of the information needed to explain what the structure is undergoing. This data deals with two factors, moisture and temperature change. If the adobe structure is deteriorating from moisture, it is necessary to know the source as well as the form of moisture. Atmospherically moisture comes as rain, snow or humidity. Subterranean moisture is due to runoff or ground water. These sources of moisture need to be determined.

Adobe masonry can be affected either by lack of or by too much moisture. For example, if at one time humidity was plentiful in the air and ground around the structure but dropped as time passed, the adobe which had been used to the presence of humidity would dry out and shrink, thereby experiencing efflorescense or spalling.

Extreme temperature change can have an effect on an adobe structure. An example would be a heavy snow fall followed by a quick freeze. Sudden change of temperature (thermal shock) causes rapid expansion and contraction of the adobe masonry and surface covering. Such movement can cause cracking or chipping, thereby exposing the adobe masonry to further deterioration.

Geological information will yield facts dealing with site conditions that might have an impact on the foundation or masonry system of the structure. This information deals with subterranean drainage of water, shifting of the ground and surface drainage which might be the cause of the deterioration.

For example, a structure may have been inadvertantly located on a major catch basin for water, or the site's geological conditions might change so that surface and subterranean waters now drain to the location of the structure. This might cause both settlement of the foundation and coving of masonry walls.

An important part of gathering data is the analysis of the existing structure. To gain insight into present conditions there are three steps or alternatives to this process. One is a "walk-through" of the structure noting visually conditions inside and outside. This visual survey of the structure should indicate stress points or inherent structural defects, and points of settlement which might be causing the deterioration of the structure, especially cracks. Secondly, it is important to determine whether cracks inside correspond to those outside. And finally, a visual survey also reveals points of moisture collection or effects of moisture presence. This general get acquainted process with the structure reveals areas where detailed investigation and testing should be conducted to further define the cause of deterioration.

Steps two and three involve two forms of testing which can be performed on a structure. Step two involves nondestructive testing which is defined as those which do not alter the existing structure. These tests may be in the form of ultraviolet photography which show possible points of soluble salt or moisture concentrations. Information dealing with the humidity content of a wall inside and outside are measured, as well as temperature changes. This method of testing can reveal whether or not the structure is experiencing efflorescence, spalling, coving action or possible slumping. It may also lead to the actual determination of the deterioration or narrow the search as to the cause.

The third test is sometimes considered destructive in the nature. This testing involves the removal of coverings to explore and expose the probable situation or cause of the disintegration. By removing the exterior covering the amount or stage of deterioration of the adobe masonry can be seen. Destructive tests are in the form of core samplings of various structural materials, to reveal the extent of moisture action. Stripping away of coverings to get at the structural skeleton for study and in some cases dismantling of the structure are also sometimes called for. It should be noted that once destroyed the covering can never be exactly duplicated. Usually this manner of testing is a last resort, but in most problems dealing with deterioration this method is the only way to understand the situation precisely.

If dealing with a historical structure the complete picture must be looked at, not only present conditions. A historical survey will yield information about the structure's experience, which might be one of the sources of deterioration. For example, a structural failure might be due to a poorly designed addition, or an exterior wall might have been removed, leaving an interior wall to perform inadequately as the exterior support.

All of the above information is needed in order to narrow down the possible cause of deterioration and to start corrective procedures. If one intuitively assumes the cause and type of deterioration, and simply picks out a remedy, chances are it will not resolve the problem but in the end cause further damage. Generally stabilization projects are a time-consuming undertaking. Of course, most people contemplating stabilization do not have a great deal of time to conduct intensive testing, nor do they wish to spend much time in analyzing the structure. For these people the following part of the thesis will show the common signs and forms of deterioration with an explanation that most owners of adobe structures can use.

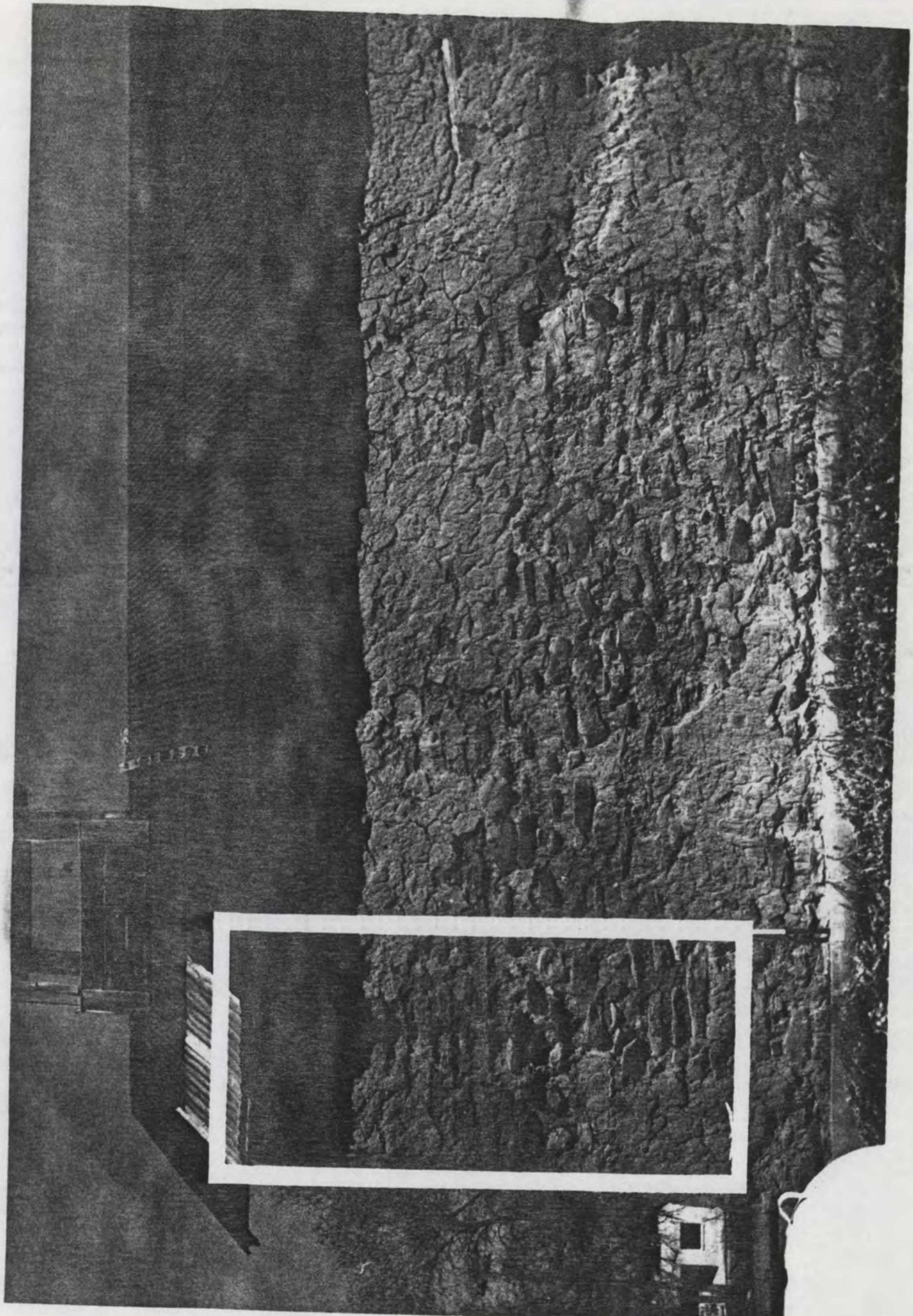
UNDERSTANDING DETERIORATION

The causes of deterioration must be understood in order to stabilize against it. These causes are moisture and temperature changes. Adobe is exposed to surface and sub-surface deterioration. A major cause of surface deterioration is the precipitation of moisture (rain and snow). There are more than two sides to the matter to investigate on this point. One side deals with moisture already present in the surface covering. When more moisture is added through capillary action or water which is absorbed, the surface covering is no longer as rigid as before. The surface's ability to withstand outside forces can thus be weakened until it is unable to support its own weight. Additional moisture can cause the surface covering to become pliable and eventually slide off, exposing the adobe masonry. A cement covering will always separate from the adobe masonry and eventually fall off from its own weight.

The other aspect is the lack of moisture present. This lack of moisture can maintain the rigidity of the surface covering and the bond between it and the adobe brick. The introduction of moisture into the surface covering, and/or the brick, or both, will weaken the bond between the two. Damage occurs as the moisture begins to evaporate from the adobe masonry and covering. Visible signs are the same as efflorescence or spalling. In the case of cement coverings, large sections may separate from the adobe masonry taking part of the masonry with it. This exposes the adobe to weathering. If the surface covering is adobe or non-cement, the covering might transform into mud flowing downward.

Still another problem of surface coverings is the wearing away process by water from rain or melting snow running down the outside. As the water runs down along the surface, small particles are removed. Over a period of years, or months, depending upon the amount of surface runoff, eventually the adobe bricks will be exposed to possible weathering (Reference Photo 1-1). A more serious aspect of surface runoff is the furrowing or channeling of water. When water channeled on a certain area of a structure, the surface covering is eroded away. This can be compared to an arroyo eroding, only here it is on a vertical plane (Reference Photo 1-2 and 1-3).

Subsurface deterioration of adobe masonry is totally different than surface deterioration in that there is a chemical reaction to the presence of moisture. Moisture present in the ground will seep upward trying to escape. This moisture will tend to seep through denser materials (compacted soils, adase bricks, etc.) more than less denser materials (soft clays, gravel, etc.). This process is known as capillary action (capillary in the way plant cells draw water upward). Once the wall has been exposed to capillary action, moisture can move easily throughout the wall (Reference Figure 1-1). The sudden introduction of moisture can weaken the wall, causing it to collapse.



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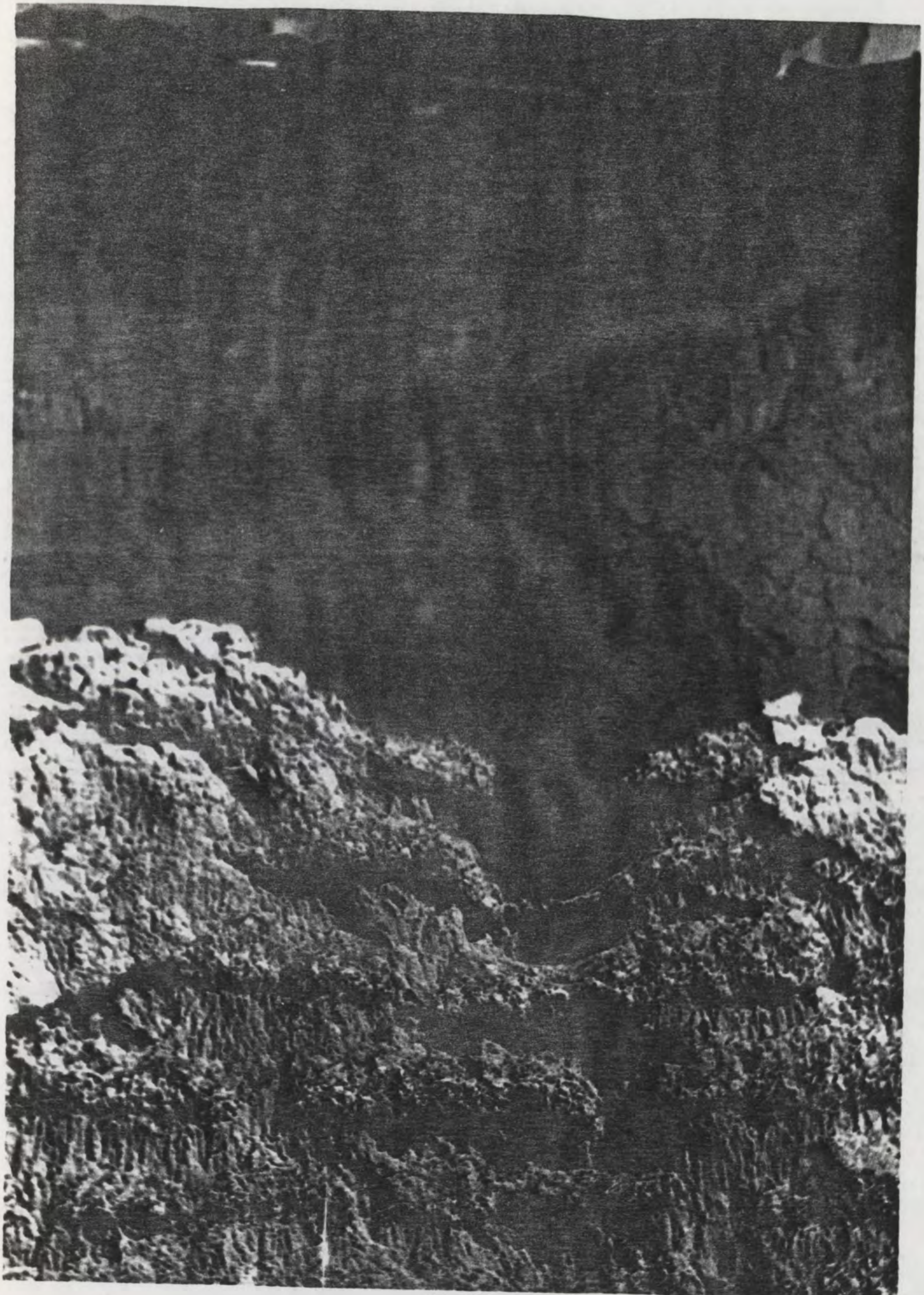

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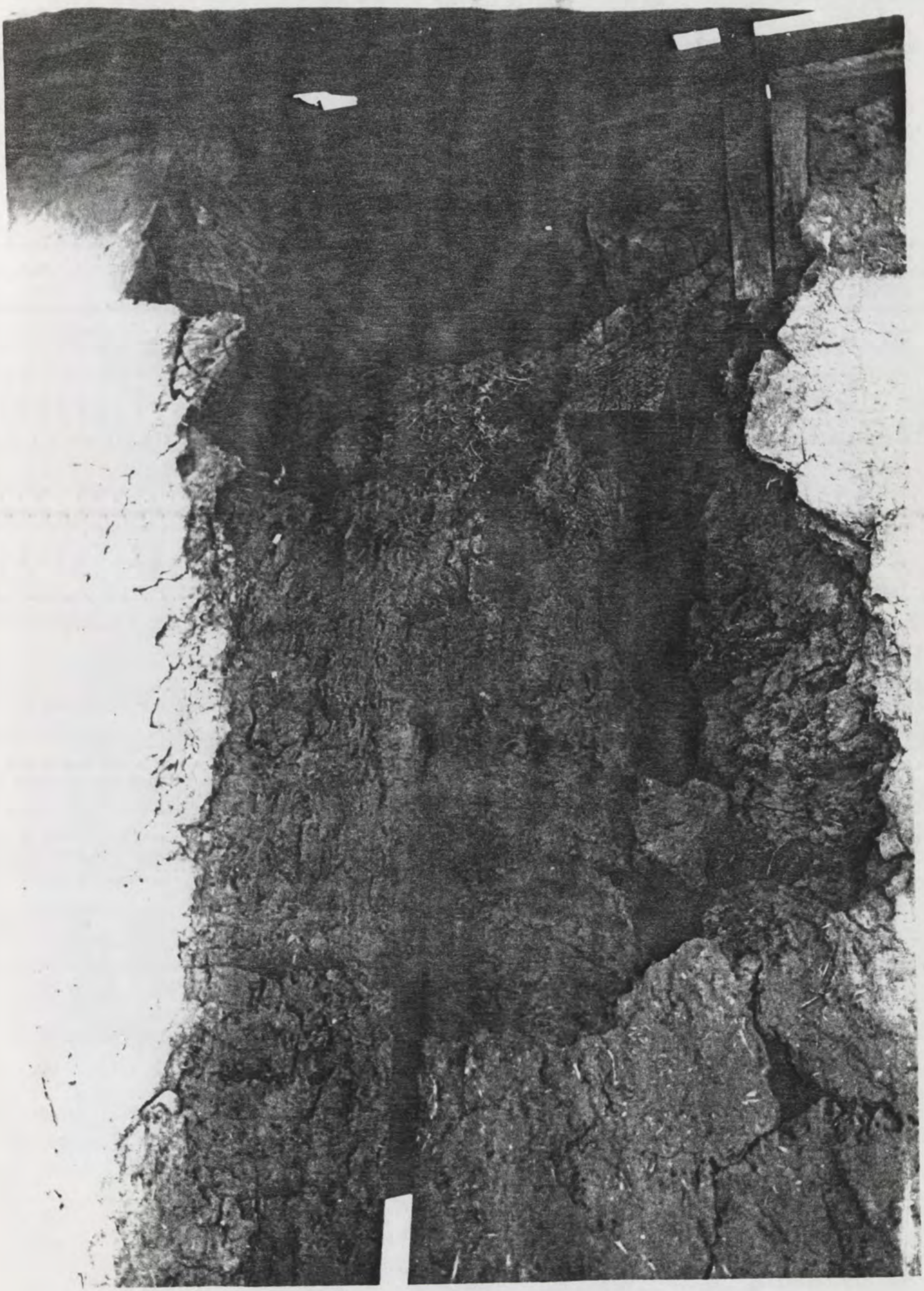

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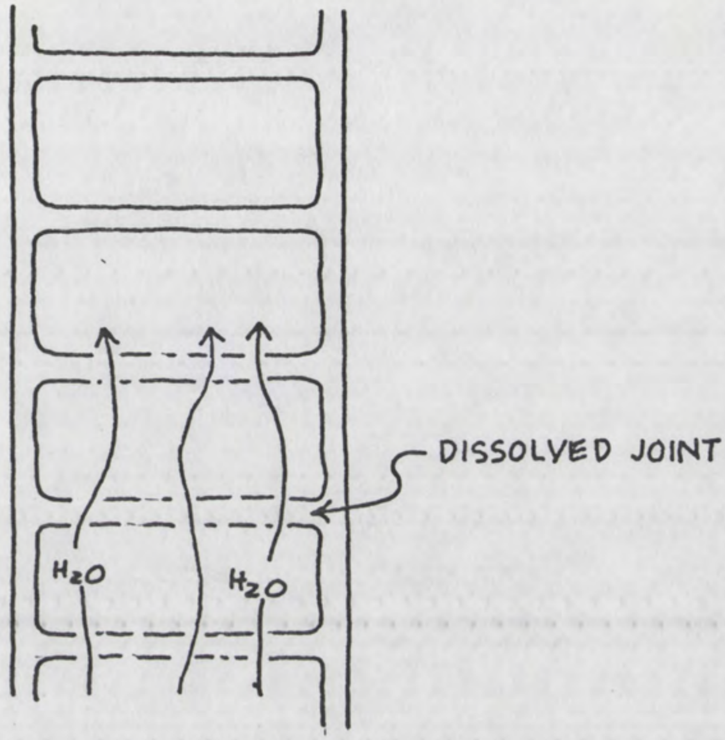


Figure 1-1. Eventual dissolving of joint through capillary action.

There are two results from capillary action which cause wall deterioration. The first occurs as moisture travels through certain humus soils. As moisture enters the soil a chemical reaction occurs forming a weak carbonic acid. This acid is them carried into the adobe masonry and dissolves the bonding crystals of the clays. This action can lead to crumbling of the masonry and other forms of deterioration such as efflorescence and spalling.

The other cause of wall deterioration from capillary action is soluble salts. Earth used to make adobes usually contains some soluble salts. These salts can be compared to ordinary table salt. When added to a glass of water the salt dissolves. When the water evaporates, the salt once again appears in a crystalized form.

Salts present in adobe masonry dissolve in the same manner. Continual capillary action generally works from the ground upward through the inside to the outside of the wall. Damage results when the moisture reaches the outer surface and begins to evaporate. This causes the salts to crystalize. As this process of redistributing soluble salts continues, the surface layer and the adobe masonry will become unstable and start to crumble (Reference Figure 1-2).

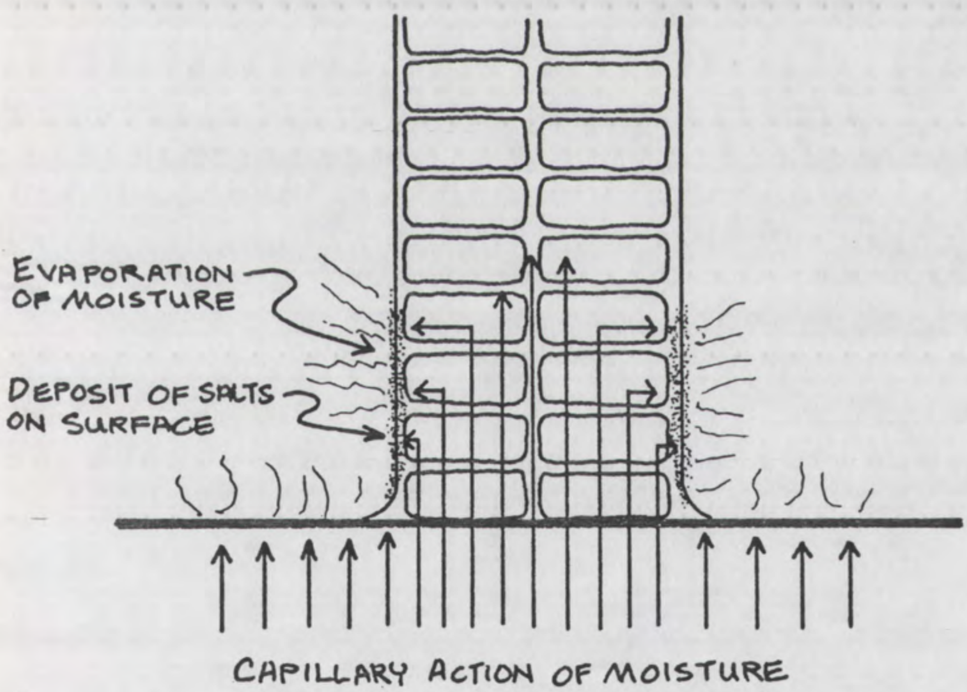


Figure 1-2. Redistribution of Salts

These two actions caused by moisture rising through the adobe masonry usually have a damaging effect ranging from minor to major. One major effect is efflorescence, in which the outer surface of the adobe wall will begin to change into a powder as the water evaporates outward, depositing the salts on the outside. Another is spalling, where the adobe breaks off in chips, scales, or fragments in the process of drying. Spalling generally follows after a wall has undergone the effects of efflorescence. As moisture increases, so does the degree of deterioration of the adobe masonry. A sign of this increase is coving action which is the eroding away of adobe masonry at the outside lower portion of the structure. Coving action occurs as the result of prolonged spalling. Slumping is another action from increased moisture in which the adobe masonry loses its rigidity and becomes mud.

The second cause of deterioration is temperature. Every material can withstand certain amounts of temperature change before failing. The failure of the material is due to the heating of the material, making it expand, and the cooling of the material, causing it to contract. This process causes the material to crack and crumble from the pressure of expansion and contraction over a period of time.

Because the surface covering of most adobes is rigid when undergoing the contraction and expansion, the covering will move (slide) as a solid mass. This sliding effect occurs during the most radical temperature changes during the winter months. Certain surfaces of the structure are exposed to the heat from the sun, while others are not (Reference Figure 1-3). As one surface is being heated, during the winter months, it is expanding and moving in one direction, generally outward. The surface that is not exposed to any form of heat is cold

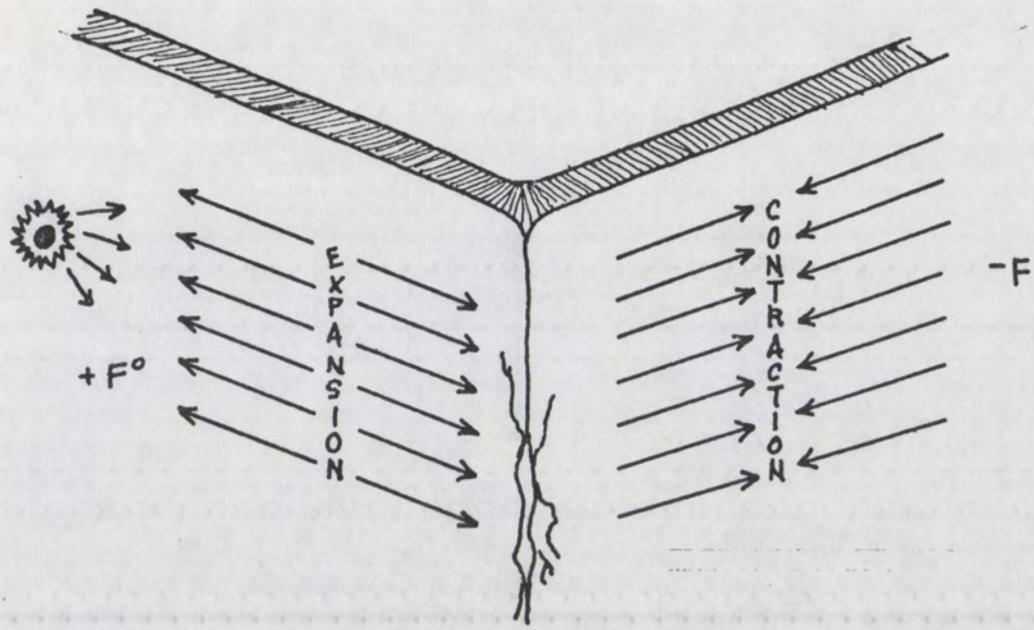


Figure 1-3. Sliding Effect

and will contract inward. The result is a sliding effect of the surfaces away from each other. So, wherever the two wall planes meet or change, there will be some general cracking (Reference Figure 1-4).

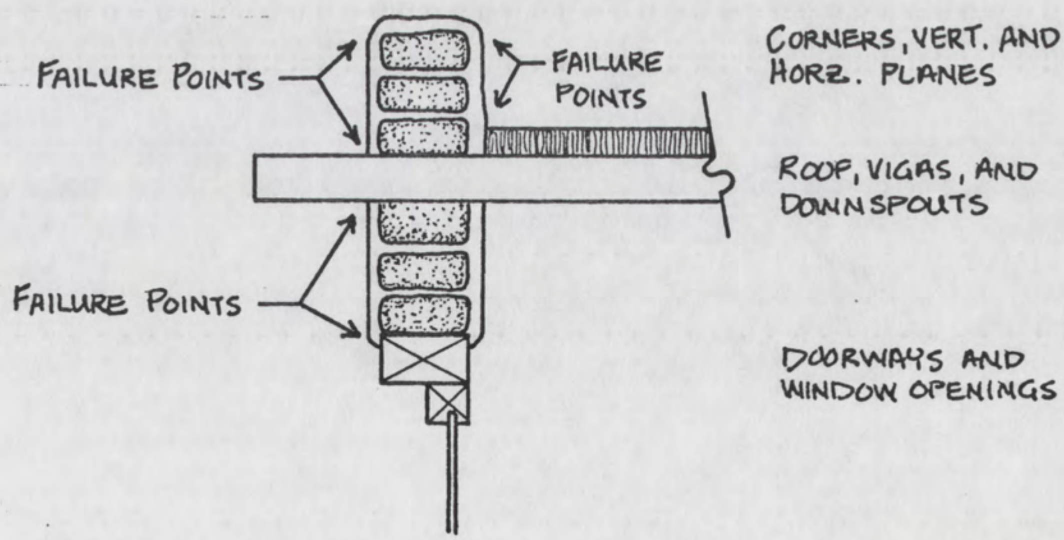
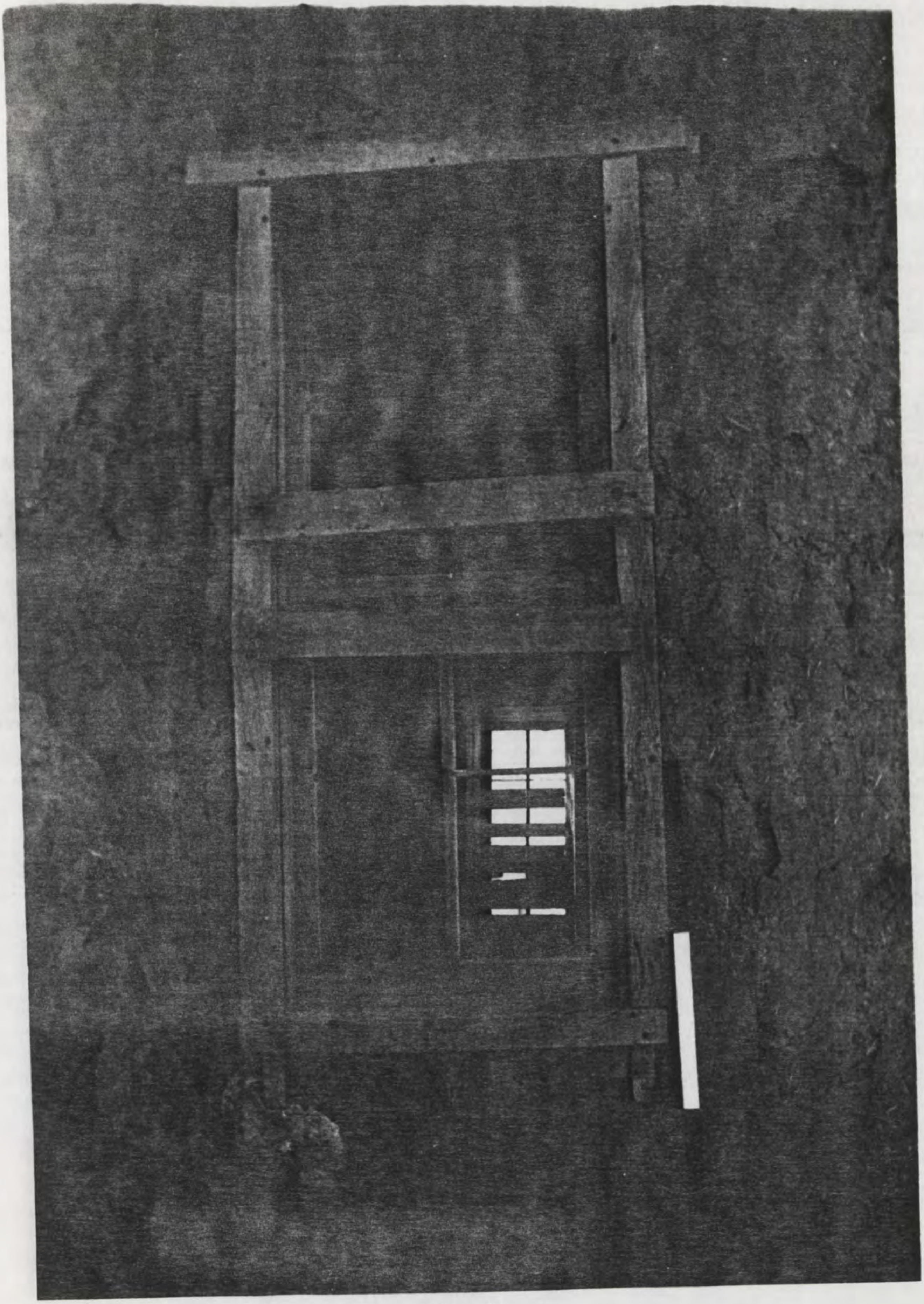


Figure 1-4. Wall Section Showing Points of Failure



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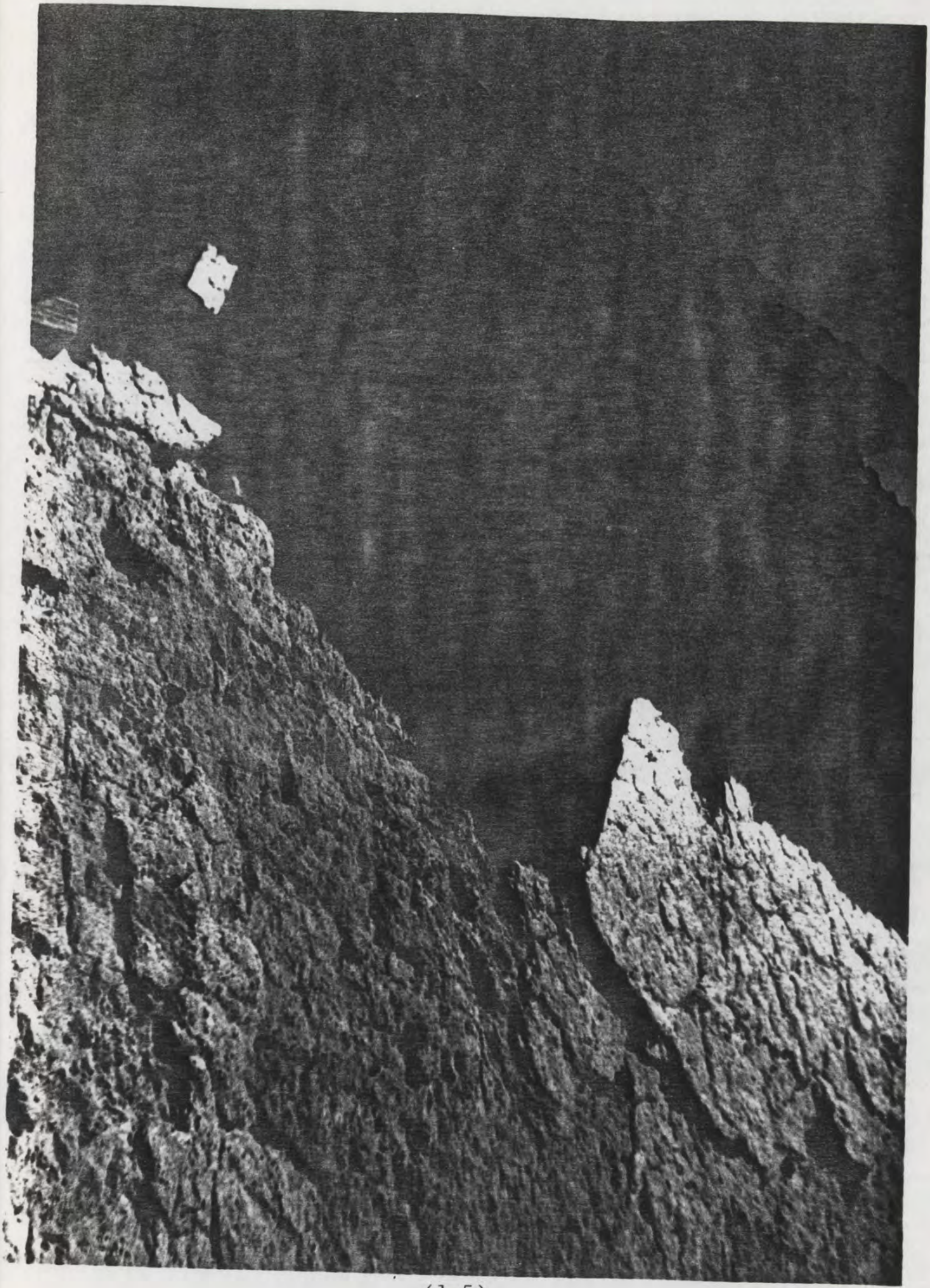
Results from sliding action can be quite damaging to the adobe masonry. In most cases, the covering is keyed onto the adobe masonry. As the covering expands and contracts, it will carry parts of the masonry with it. This is considered a grinding effect or wearing away of the bond between the surface covering and the adobe masonry. When the covering falls off, it will take parts of the adobe wall with it, thus exposing the wall to possible deterioration (Reference Photo 1-5).

Another damaging result is the separation of the covering from the masonry, which in the case of a cement covering, remains intact. The separation causes the formation of a space between the two materials. This can cause the condensation of moisture, especially where there are large amounts of moisture present in the air and extreme heat. When the covering slides or separates from the masonry, hairline and major cracks can develop. A result besides the condensation of water, is the channelizing of water down the inside of the covering and into contact with the adobe masonry.

This water, if held in contact with the adobe masonry, and not exposed to drying out action of the air, may cause slow disintegration of both covering and adobe masonry. The degree of disintegration may vary from efflorescence and spalling to possible coving action or slumping, depending upon the amount of moisture.

Combine moisture with the environmental factor of temperature change and one has an even more serious condition of deterioration to deal with. When small amounts of moisture



(1-5)

are present in the covering, the effects of temperature change with regard to expansion and contraction is greater. Moisture occupies a certain amount of space between the particles of the surface covering, adobe masonry, and the space between the two materials. When the surface covering undergoes a contracting or expanding force, the space between the particles absorbs the movement. However, with moisture present in the spaces there is no relief, especially if the moisture has taken on the form of a solid (ice) due to freezing. This causes the covering to crack or chip off due to the pressure exerted during periods of contracting.

When the temperature increases, the particles comprising the materials move apart, creating a larger space in between. If there is a large amount of moisture present, this movement allows more space for additional moisture to occupy. So, when the material undergoes a decreasing temperature change, thus contracting again, there is no space for it to be absorbed. Eventually, as this process continues, the bond between the particles of the surface covering will fail. The covering to the adobe masonry will sooner or later fail as the covering crumbles or flakes off.

Other factors causing wall deterioration are minor, but should be noted. These minor effects are plants, animals and insects. Plants can cause various kinds of damage. For example, as ivy climbs up an adobe wall, the aerial root will penetrate the slightest pore or crack to gain a foothold. As the aerial root enlarges, it also tends to enlarge the pore or crack

(Reference Figure 1-5). As this process continues, there will be further cracking and crumbling of the surface covering. Large pieces may fall off, exposing the adobe masonry to possible deterioration. Moisture can then seep in causing further damage.

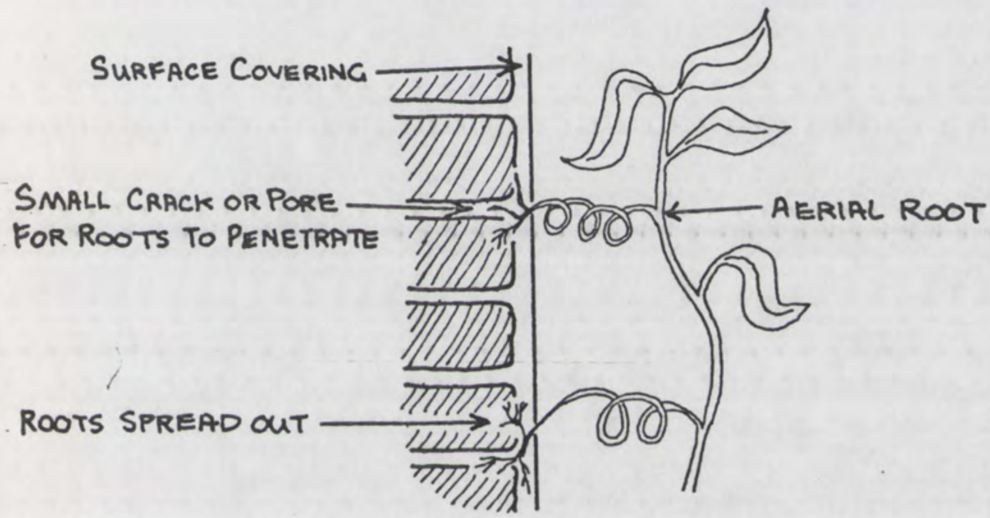


Figure 1-5. Plant Caused Deterioration

Even the presence of a garden next to an adobe wall can cause damage. Under normal conditions moisture in the ground at the base of the structure evaporates into the air, and the base dries out when exposed to the sun. Plants next to the structure tend to shade the wall from the sun and inhibit the moisture from evaporating. Also, the moisture in the ground is retained by the plant's root system, and the moisture level increases when the plants are watered (Reference Figure 1-8). Damage occurs when moisture is not allowed to evaporate from the ground and lower portion of the structure. Damage can be in the form of soluble salts being deposited on the surface causing possible efflorescence of spalling, a minor damage, to more serious damage such as coving action.

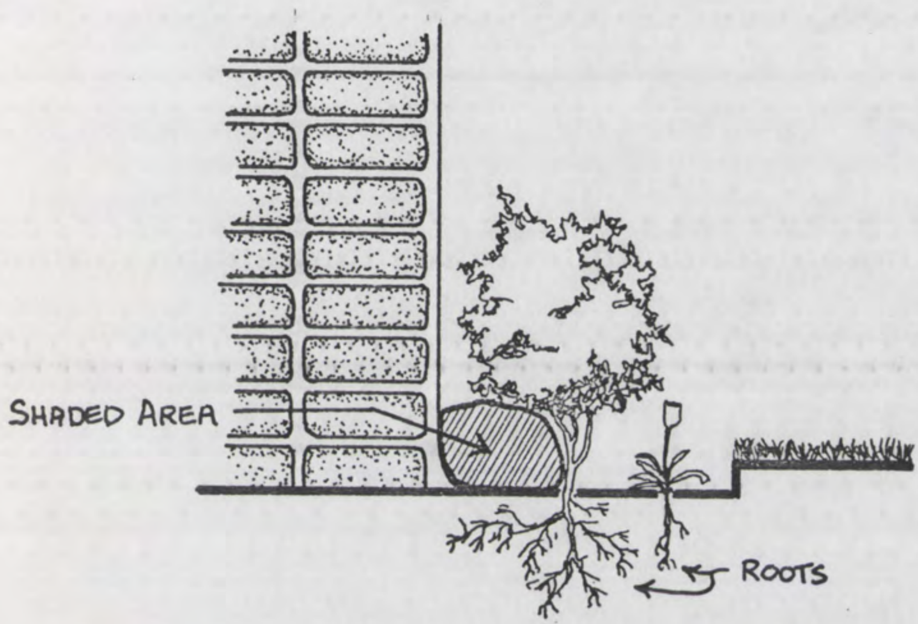


Figure 1-8. Plants Causing Deterioration

Shrubs or thorny bushes planted next to an adobe structure cause some damage to the surface covering. If the wind blows the plant against the surface, the movement causes the limbs to rub the surface and remove small particles of the covering. As this process continues, the surface covering will wear down and become susceptible to moisture deterioration.

Animals and insects can cause some damage to adobe surface coverings and masonry. This damage is likely to occur around the base of the structure. Some insects will burrow into the covering at ground level if the covering has been softened by moisture and separated from the masonry. The space between the covering and masonry is humid and a perfect place for insects to breed. Animals seeking an insect for food will dig after it, causing further damage to the covering and adobe masonry. This allows for more moisture to enter and cause possible damage to the masonry and surface covering.

SECTION II
FORMS OF DETERIORATION AND VISIBLE SIGNS

The first noticeable stage of deterioration due to soluble salts is efflorescence, which can be noticed when one brushes the wall surface with a hand. Usually if the wall has been undergoing efflorescence, small amounts of crumbs or a fine powder will form on the surface and then dust off. Since the outer layer of the adobe has been reduced to a powder form, it can be easily removed by wind or rain. This exposes the surface covering to further deterioration (Reference Photo 1-6). Unless resolved, this form of erosion will eventually remove the surface covering and expose the adobe masonry to the same effects.

After the adobe has been undergoing the effects of efflorescence, the next stage of deterioration to occur will be a spalling action. It is caused by the same process that produces efflorescence. Small fragments of the adobe will chip or break off, exposing the next layer to deterioration (Reference Photo 1-7). Spalling erodes up to several centimeters of the material, unlike efflorescence, where only the surface erodes. During this erosion process large areas of the adobe masonry crack and flake off, and larger areas are exposed to further moisture and wind erosion.

Coving action is an eroding or eating away of the lower outside portion of the adobe masonry. Coving action occurs

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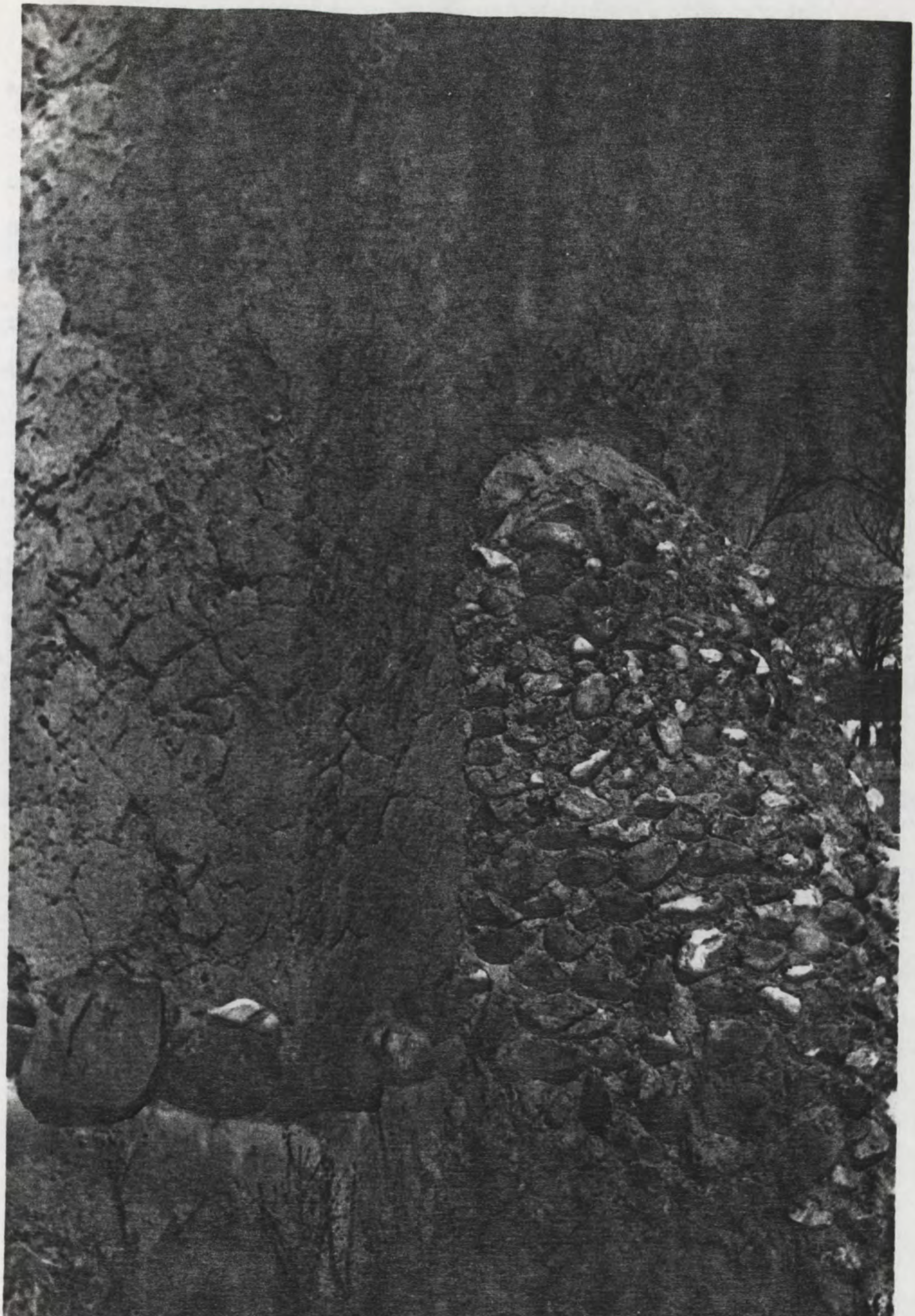


(1-7)

as the result of prolonged spalling. Coving starts on the outside of the wall and works inward. This process is an undermining action of the masonry wall. Coving could be considered as a magnified spalling process with the pieces that fall off larger and concentrated at the base rather than over the entire area (Reference Figure 1-9), (Reference photo 1-8). Coving action can weaken the base of the wall

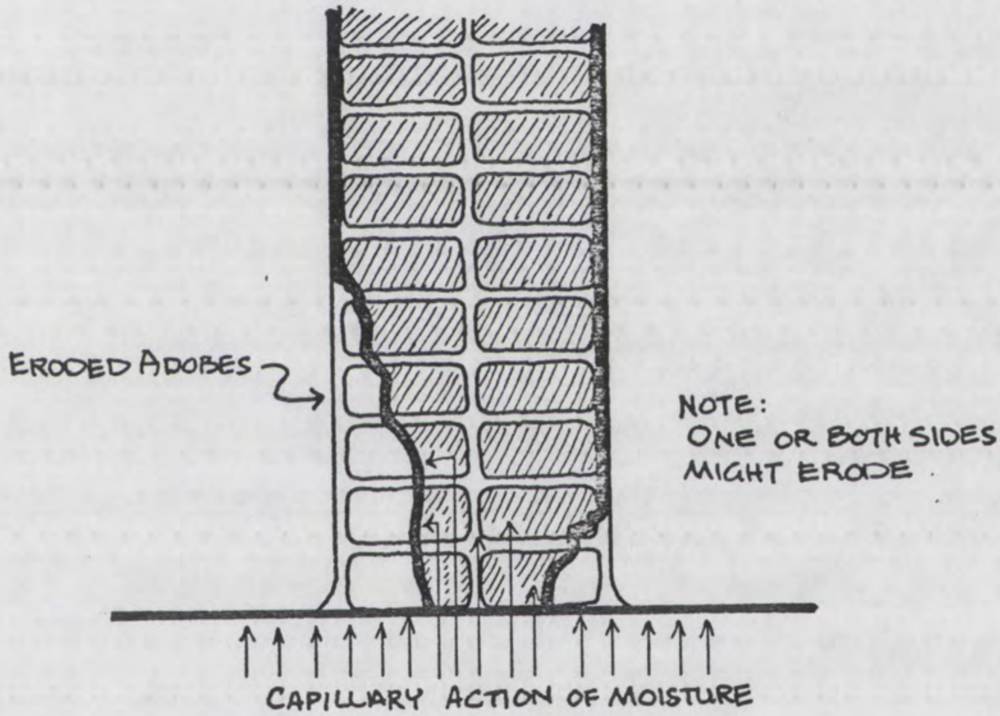


Figure 1-9. Coving Action

on the outside to a point of collapse. Unless the wall is allowed to dry out, further deterioration of the structure is likely to occur.

There is some difficulty in knowing if an adobe wall is about to slump. In most cases, the adobe masonry has been covered with a rigid cement plaster. Cement plaster does not usually allow for the evaporation of moisture adequately from

(1-8)

the wall, in most cases, which adds to the problem of the adobe becoming unstabile. The signs resemble those of efflorescence or any other form of moisture-related actions, except coving action, in that there is a distinct water mark or a surface area which shows as a continually damp spot on the outside. The only sure way to know if the adobe masonry is stabile or about to slump would be to remove the covering. There have been cases where the wall looked stabile until the covering was removed, but then the once firm adobe could be scooped out by the handfulls.

Slumping takes place at various points along the base of the wall. There is no set time period for this action. Slumping can result in a matter of months or years, depending upon the source and amount of moisture. The result is very damaging in that once a portion of the wall slumps, the remaining portion can more easily collapse at that point.

SECTION III
DETERIORATION RELATED TO FOUNDATION FAILURE

Many different types of foundations support adobe structures. Historically "foundations for the walls, whether adobe or stone, are prepared with a minimum of effort. The usual practice is to dig a trench, no wider than the intended wall, and fill it with courses of adobes, or stone slabs, or field stones (Reference Figures 1-10, 1-11, 1-12, 1-13). The wall may also foot directly upon the ground, without foundations."[1] (Reference Figure 1-12).

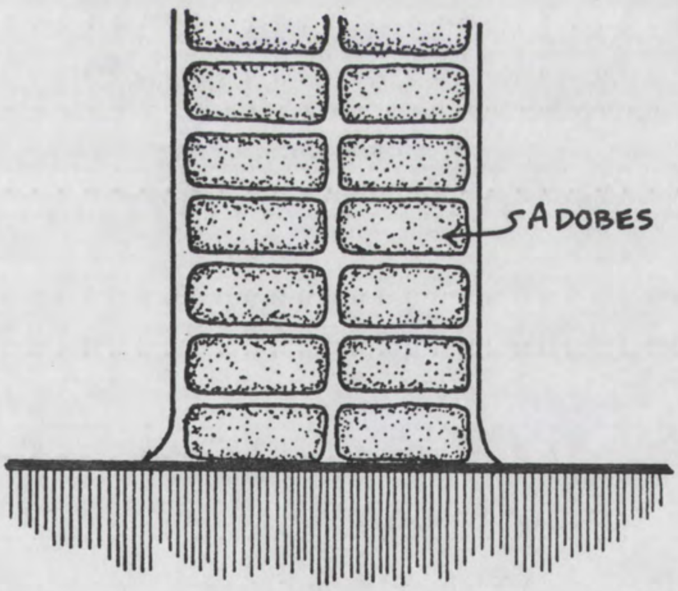


Figure 1-10. On Grade Foundation

[1] The Religious Architecture of New Mexico, George Kubler, The Taylor Museum of the Colorado Springs Fine Arts Center, copywriter 1940, p 39.

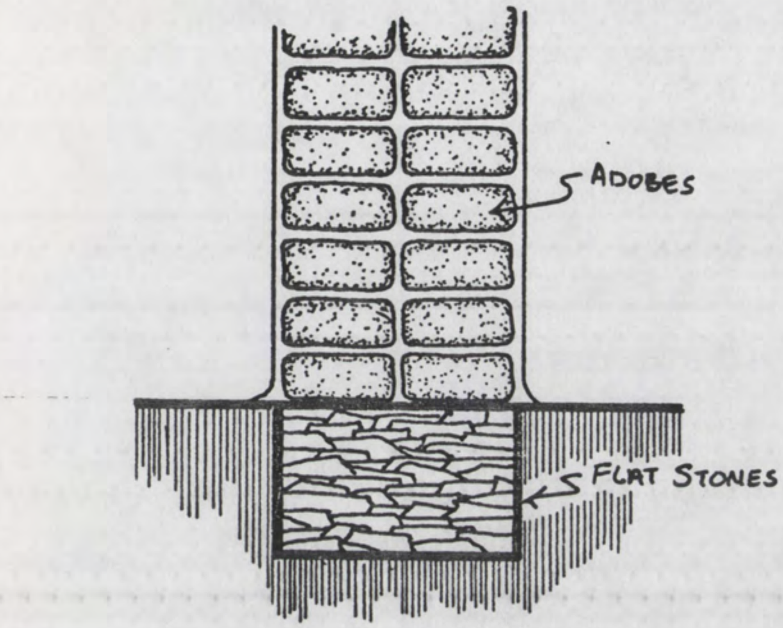


Figure 1-11. Stone Slab Foundation

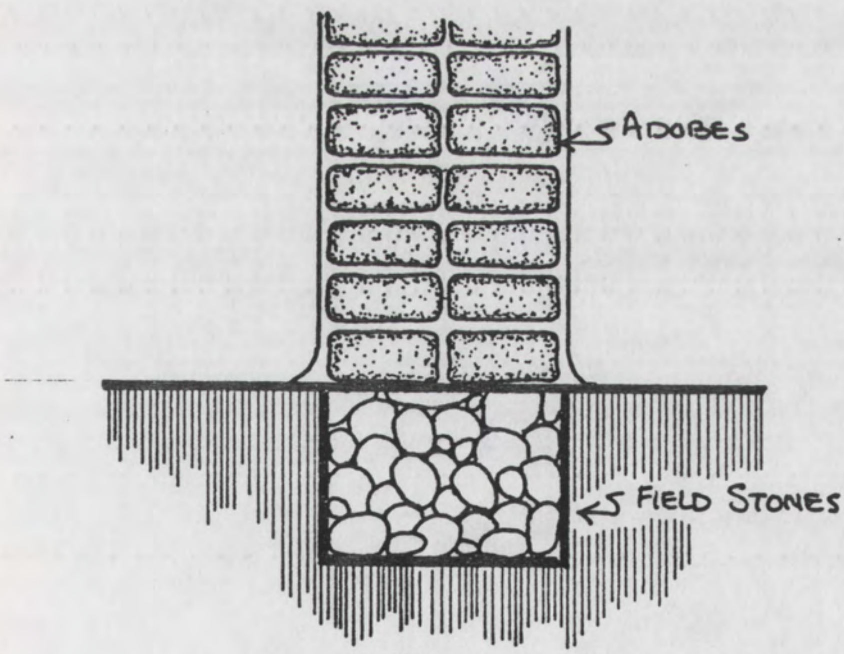


Figure 1-12. Field Stone Foundation

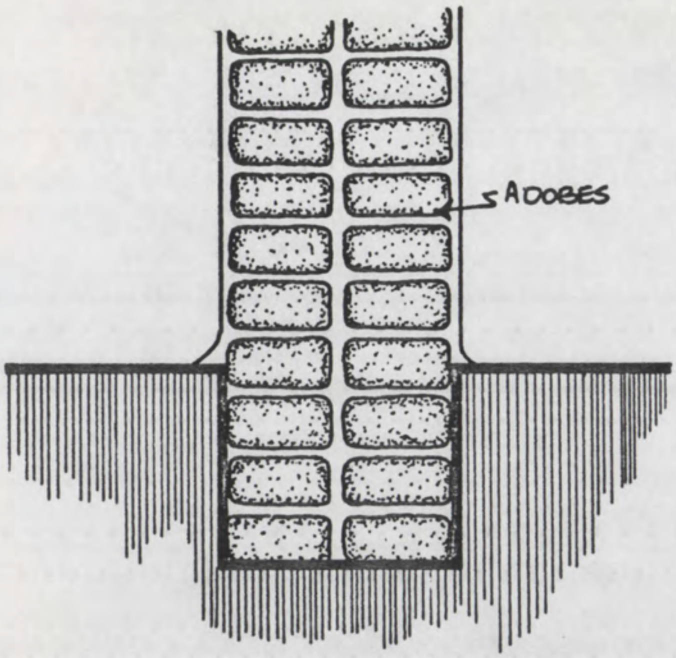


Figure 1-13. Adobe Foundation

Modern foundations consist of a concrete footing with concrete blocks, capped with a tar to form a moisture barrier, forming the stem wall for the support of the adobe masonry (Reference Figure 1-14).

Foundations are affected by moisture and temperature change which can cause deterioration of adobe masonry. Structural failure of foundations is most often caused by moisture. The earlier types of foundations are more susceptible to moisture than modern foundations because of the manner of construction.

The stone slab or field stone foundation is affected by moisture seeping upward from hydrostatic pressure, between the stones and into contact with the adobe masonry (Reference Figure 1-15). After moisture has come into contact with the

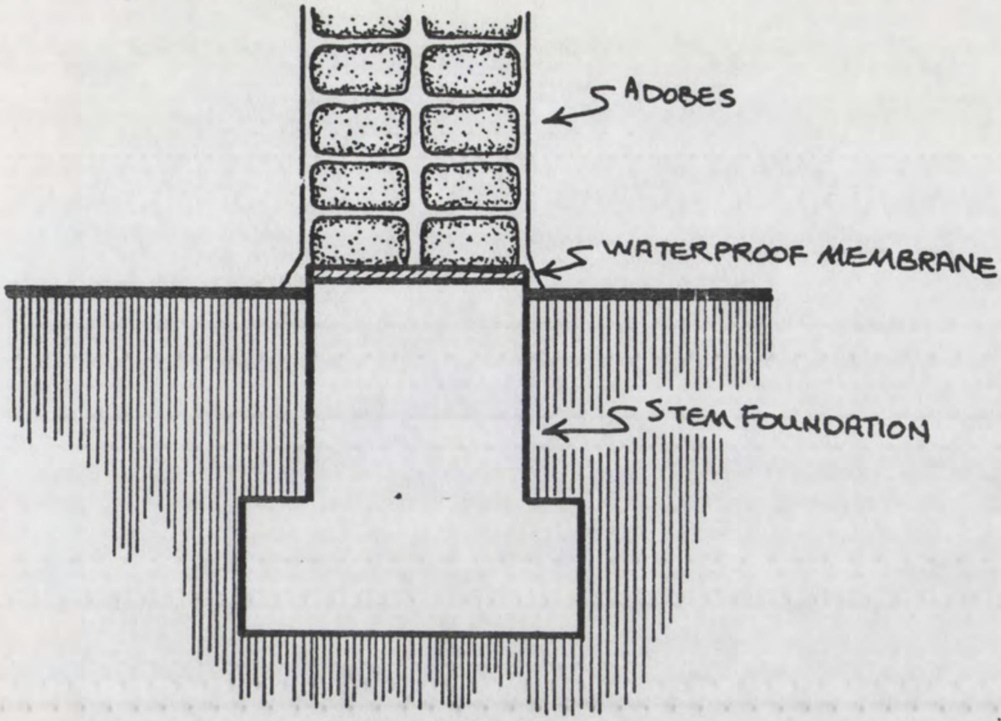


Figure 1-14. Block Stem Foundation

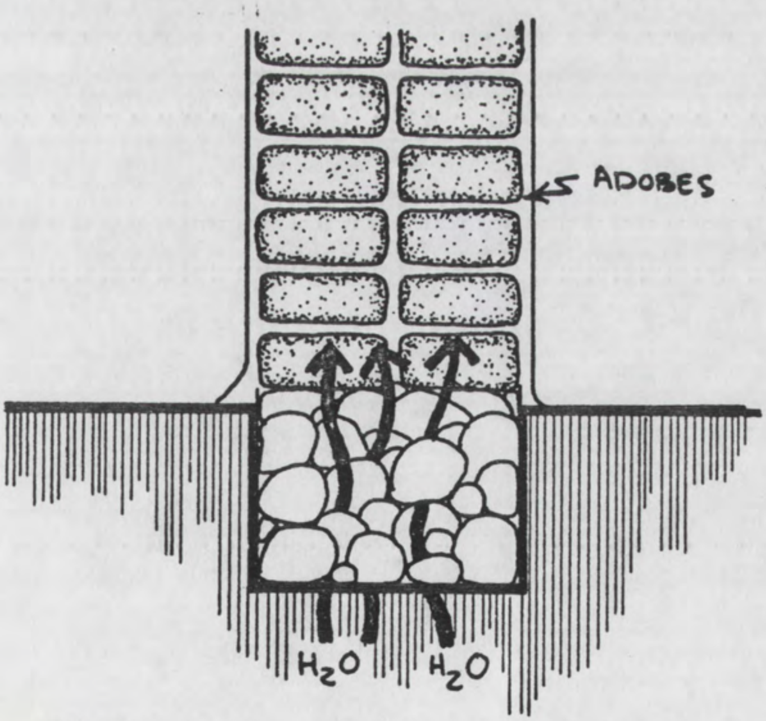


Figure 1-15. Moisture Seepage

adobe, capillary action will start, and the adobe will start to deteriorate. The deterioration may be in the form of spalling, coving action or slumping.

Adobe foundations are affected in somewhat the same fashion as stone by seeping moisture, but the resistance to the moisture is less (Reference Figure 1-15). This is because the foundation and walls are of the same material.

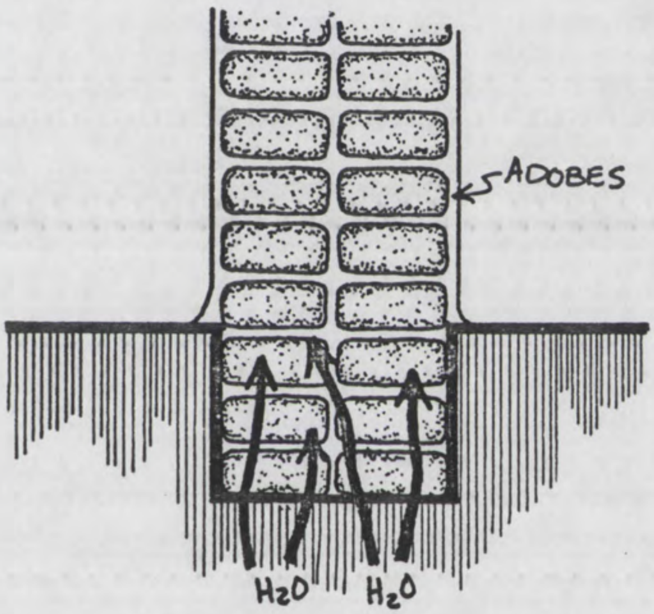


Figure 1-16. Adobe Foundation Deterioration

When there is no foundation supporting the adobe masonry, chances of moisture affecting the adobe masonry is greater. Foundations usually prevent moisture from coming into contact with the masonry besides supporting the masonry. Moisture from the ground being drawn upward by capillary action will cause a fusing or dissolving of the masonry into the ground as the moisture level rises and falls (Reference Figure 1-16).

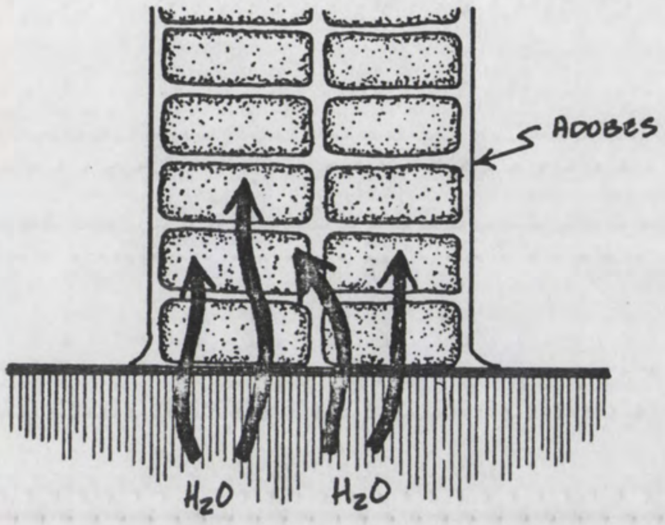


Figure 1-17. No Foundation

This lack of foundation support by having the adobe masonry placed right on the ground can lead to problems such as spalling of the masonry, coving action, or possible slumping. Also, as the adobe dissolves into the ground, the walls will begin to settle. This settlement will cause cracking of the masonry, thus allowing for moisture to enter and cause further damage to the adobe masonry.

The modern block stem foundation system is less likely to allow moisture to come into contact with the adobe from the ground. However, the modern foundation is affected by moisture causing settlement which can cause deterioration of the adobe. In a normal situation the downward force of the structure's weight is resisted by the ground (Reference

Figure 1-18). As long as the ground can resist, the force of the structure will remain stabile.

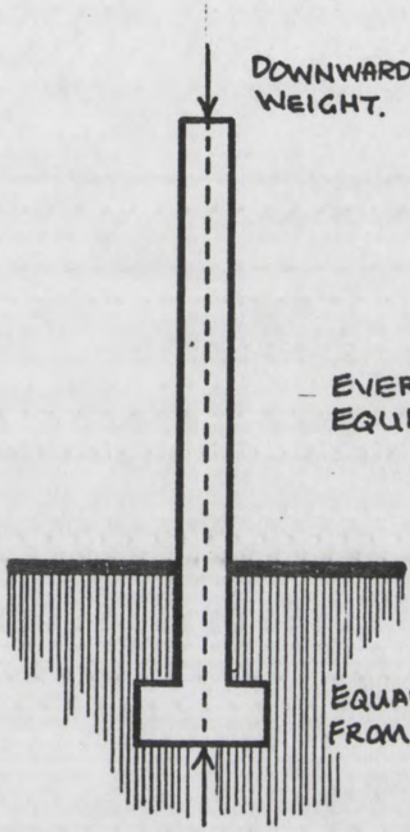


Figure 1-18. Normal Situation

Over a period of time sufficient amounts of water can weaken the ground which supports the structure by rendering it unstabile or pliable, so that it can no longer resist the weight of the structure. In this situation, the building's weight will displace or force the soil away and the structure will begin to sink until it encounters firmer soil for support. This situation is known as "settling" or "settlement" (Reference Figure 1-19), and usually takes a period of years to occur, unless the situation is very extreme.

Such settlement may vary from one point to the next, thus causing unequal settlement. The visible effects of settlement can be the sloping of floors. The most common indication of settlement is the floor remaining level and the walls settling, causing the floor to be higher than the doorway (Reference Figure 1-20), or sagging of windows (Reference Photo 1-8).

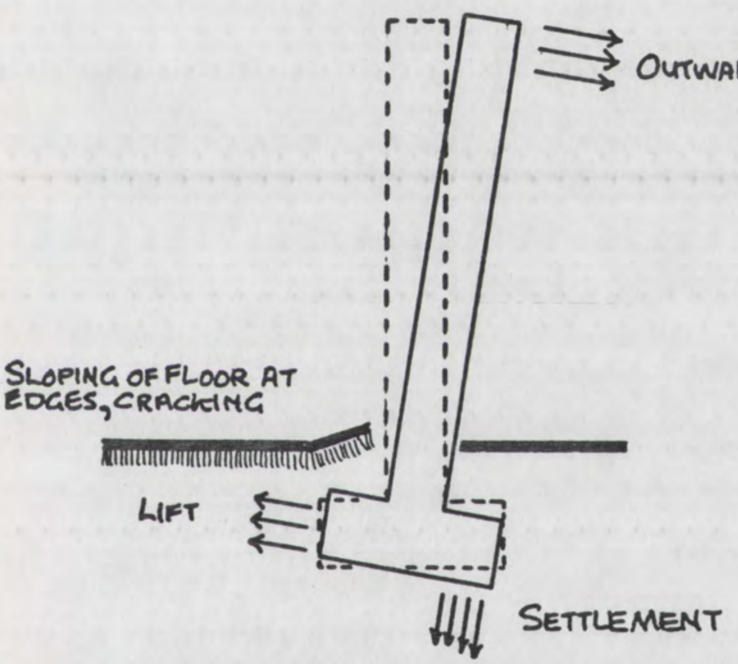


Figure 1-19. Settlement

Cracking due to settlement around windows, doors and corners is a possible indication of possible settlement. In extreme cases irregular settlement can end in the collapse of the structure. Furthermore, the cracks can allow moisture to seep in and start deteriorating the adobe masonry. (Reference Figure 1-21).

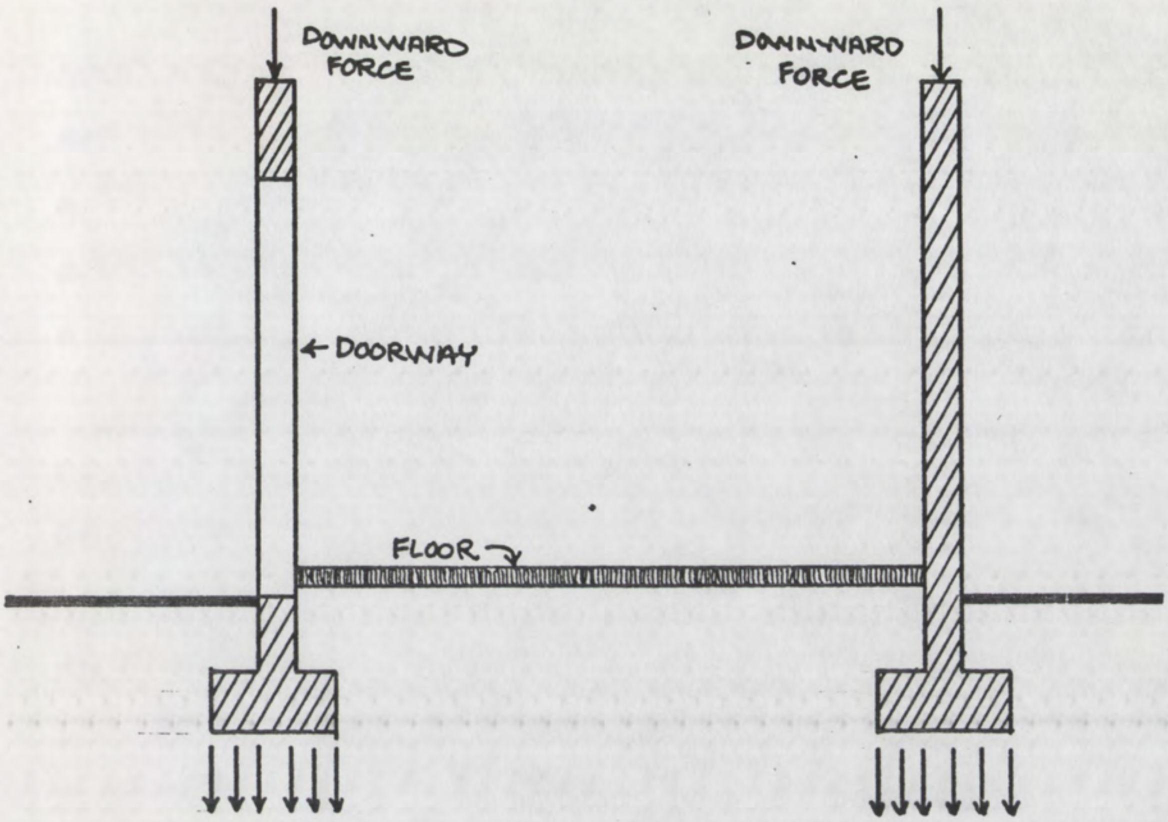


Figure 1-20. Settlement

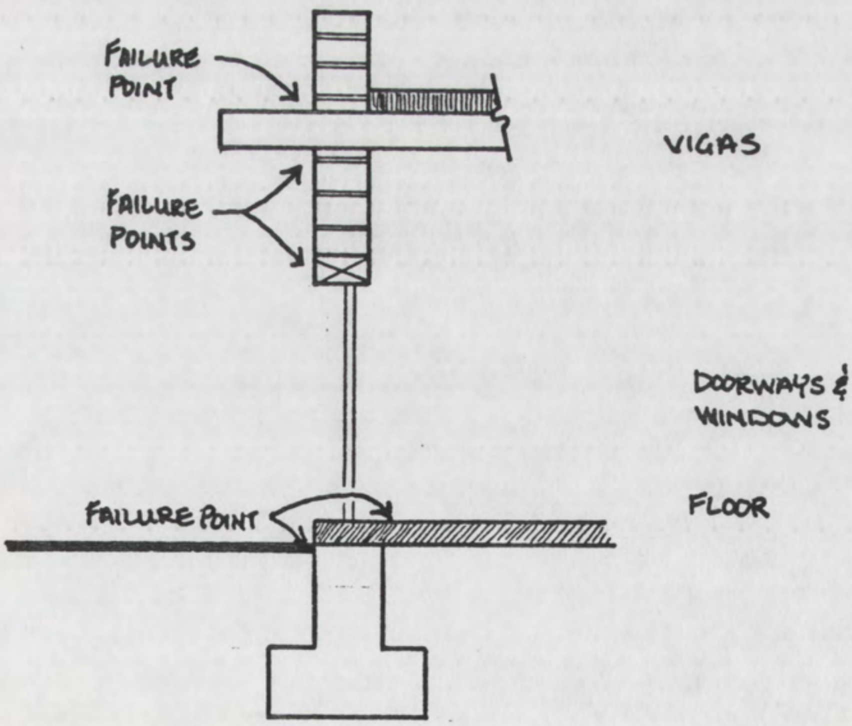


Figure 1-21. Wall Section Showing Points of Failure

Besides moisture causing the foundation to settle, when combined with temperature change, another form of foundation and wall failure results. This form of failure is caused by a freeze-thaw action of the ground. Moisture present in the ground if frozen will lift the wall, and in the spring it will drop back down (Reference Figure 1-22).

If this movement of the foundation upward and downward continues for long periods of time, eventually the walls will become unstabile from the pressure exerted. Minor and major cracking of the walls and of the foundation will occur. The result is moisture seeping in and possibly causing deterioration in the form ranging from efflorescence to coving action. This freeze-thaw action is one of the major causes of wall failure.

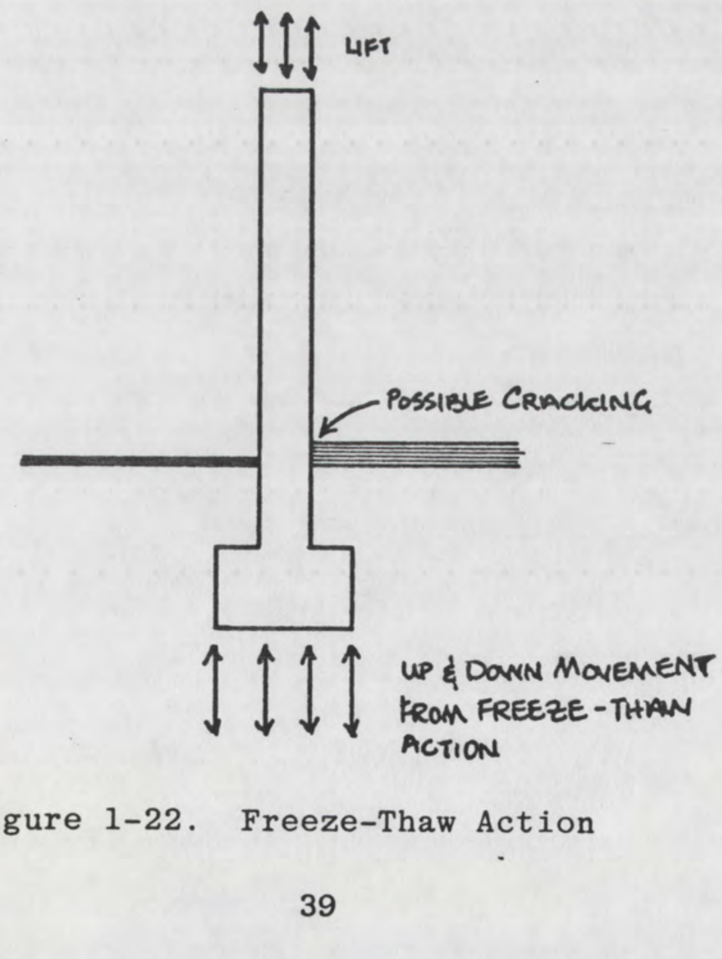
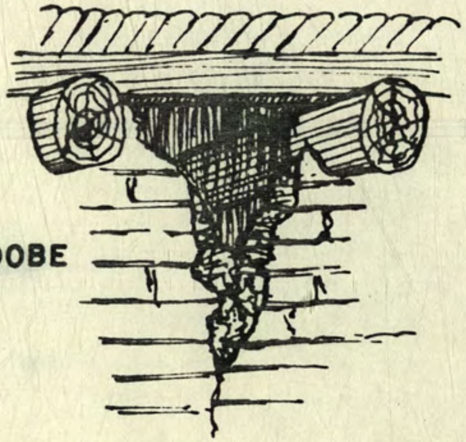
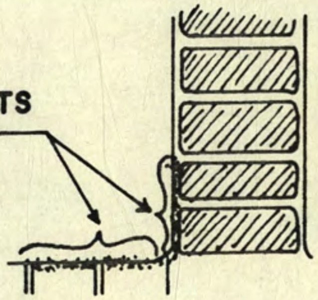


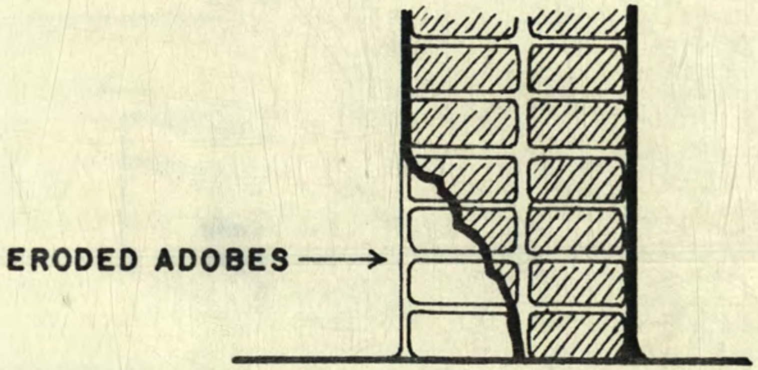
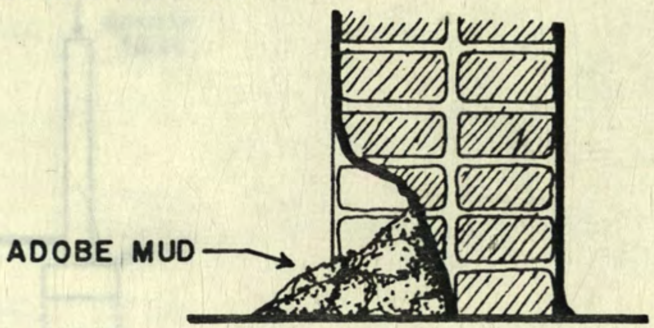
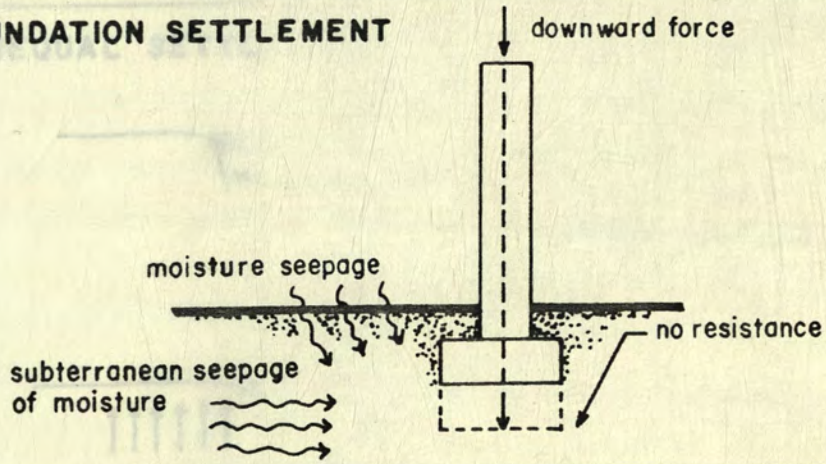
Figure 1-22. Freeze-Thaw Action

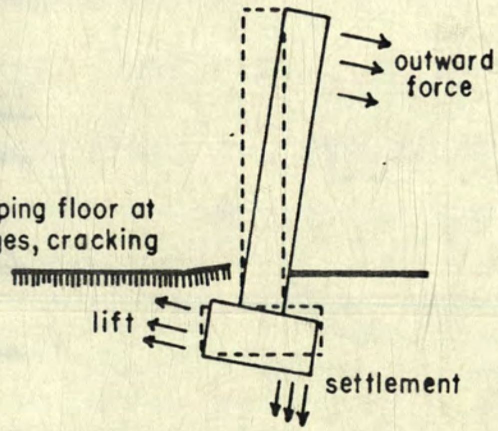
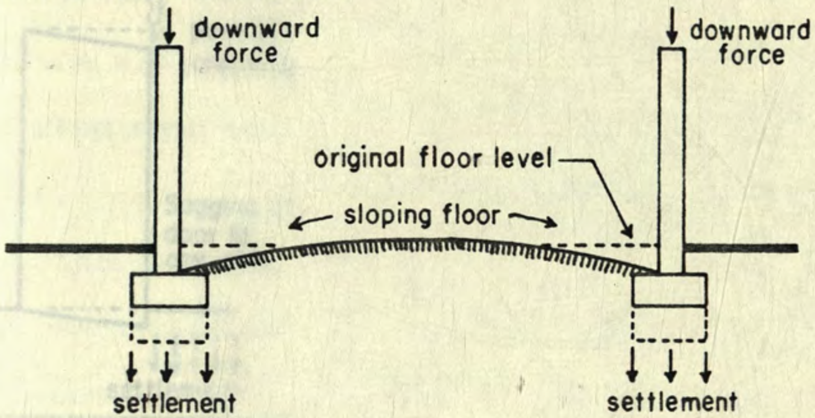
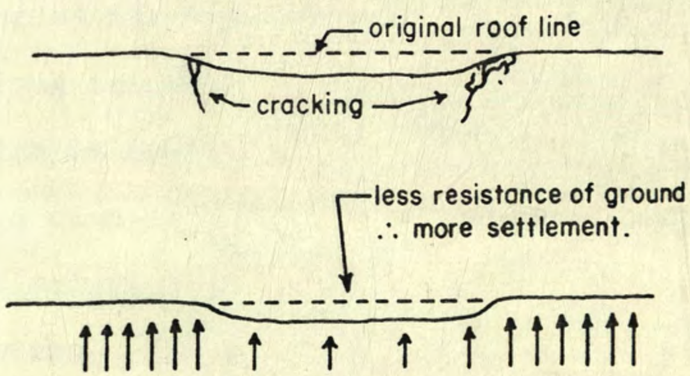
Thus far I have dealt with one aspect of adobe deterioration the effects of moisture-related disturbances. There are many more aspects of deterioration of adobe, but moisture-related forms are by far the most common and most difficult to resolve. In the following chapter I shall offer various solutions for stabilizing the adobe structure against deterioration.

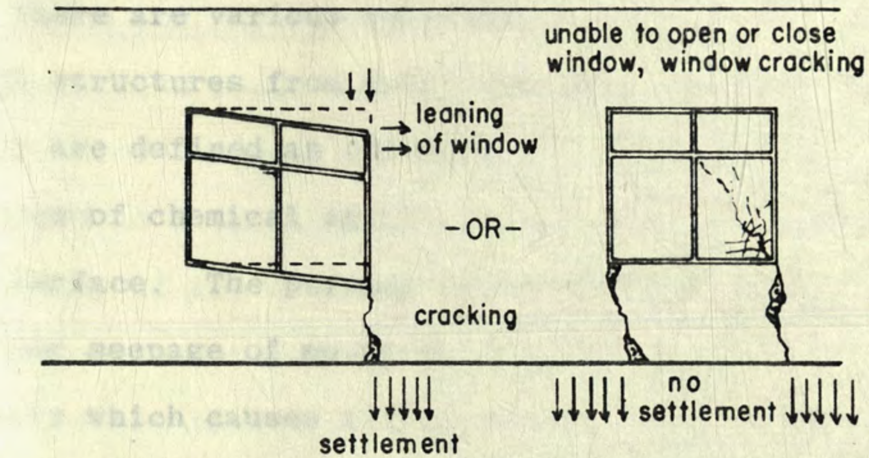
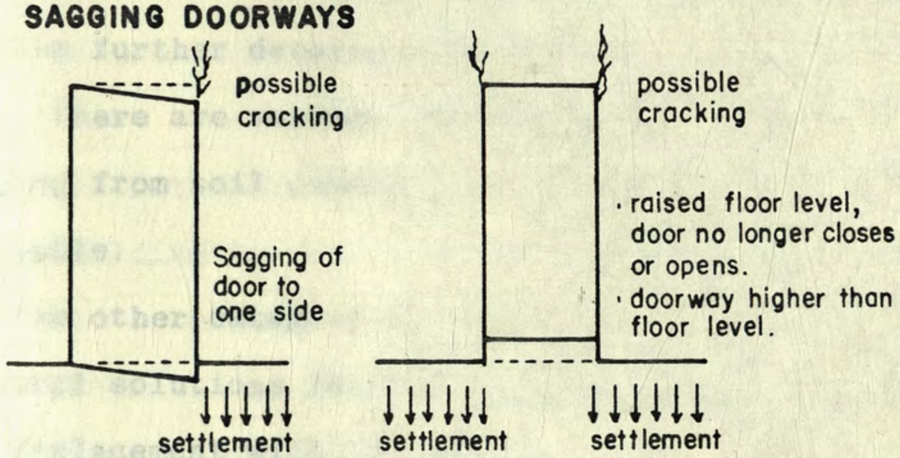
CHART I: IDENTIFICATION OF DETERIORATION

Visible Problem	Possible Cause	Explanation
POWDER ON SURFACE · Comes off with a brush of the hand. · Whitish powder	· Evaporation of moisture and redistribution of Soluble Salts, EFFLORESCENCE.	· See Pages 8, 13, 24
CRUMBLING/FLAKING OF SURFACE	· Same process as efflorescence only on a larger scale. Instead of a powder large particles fall off. · Abundance of moisture, soluble salts and temperature changes.	· See Pages 9, 15, 24
CRACKING OF SURFACE COVERING · Noticeable at corners, vigas, windows and doorways.	· Expansion and contraction of surface covering from temperature changes and moisture.	· See Pages 8, 15, 18

Visible Problem	Possible Cause	Explanation
 ERODED ADOBE · Roof · Drains	· Furrowing or channeling of water down across the adobe surface. (Erosion at base of structure could be caused by splashback.)	· See Page 9
 DEPOSITE OF SALTS · Garden plants	· Moisture seepage from watering plants. · High moisture level in the air and on the surface.	· See Pages 20, 22
 DEPOSITE OF SALTS ON INSIDE WALL & FLOOR	· Moisture seepage through the adobe from the outside. · Moisture from the inside (example being a wall across from a bathroom with high humidity present).	

Visible Problem	Possible Cause	Explanation
COVING ACTION  	· Started by spalling but intensified by capillary action and the redistribution of soluble salts through moisture evaporation. · Splashback of water from rain or run-off on the ground which erodes the adobe.	· See Pages 9, 13, 24
SLUMPING ACTION  	· Intense capillary action plus addition moisture weakens adobe masonry till it becomes mud and collapses.	· See Pages 27
FOUNDATION SETTLEMENT  	· Lack of sufficient foundation for support. · Moisture seepage has weakened the soil under the foundation.	· See Pages 32-35

Visible Problem	Possible Cause	Explanation
LEANING OF WALL 	· Irregular settlement coupled with outward force of structure's weight. · Outward force of structure's weight but there is no structural settlement.	· See Pages 32 - 39
EQUAL SETTLEMENT 	· Settlement of both foundations from moisture seepage. · As the foundations settle, the edges of the floor may also settle.	· See Pages 30 - 39
UNEQUAL SETTLEMENT 	· Weakening of soil under one portion causing that portion to settle and the remaining portions stabile.	· See Pages 30 - 39

Visible Problem	Possible Cause	Explanation
SAGGING WINDOWS  	· Settlement of one portion of the foundation and wall, shifting of structural weight. · Settlement on both sides of windows with none directly under under the window.	· See Pages 30-39
SAGGING DOORWAYS  	· Settlement on one side causing the weight of the structure to shift forcing part of the door to sag. · Settlement on both sides of doorway, causes either the floor on the inside to rise above the door level, or the door settles.	· See Pages 30-39

SECTION IV
SOLUTIONS FOR DETERIORATION

There are various solutions available for stabilizing adobe structures from deterioration. There are solutions which are defined as non-physical. These solutions involve the use of chemical agents to stop further deterioration of the surface. The purpose of the chemical agent is to prevent further seepage of moisture from the surface to the adobe masonry which causes efflorescence, spalling, etc. The agents do not alter the physical structure in any way, but stabilize it from further deterioration such as coving action or slumping. There are various categories of chemical solutions ranging from soil cement to a water or chemical base solution available.

The other category of solutions is classified as physical. Physical solutions involve the removal of the damaged portion and replacement with new material; for example, the removal of adobe masonry which has experienced coving action and rebuilding of the section with new masonry, or the digging of a trench along the base of a structure to drain away ground water which is seeping into the adobe masonry through capillary action and causing damage.

Which solution to use depends on the type and amount of deterioration. The following discussion will show the various approaches used to stabilize adobe. The discussion will list techniques available and factors involved, but will not recommend a specific technique, because certain solutions may not work in one area but will work in a different area. This is due to the environmental impact of temperature change and moisture levels being different from one area to another.

Solutions for Major Forms of Deterioration

Solutions found in this category deal with reconstruction of the eroded fabric, adobe. These solutions are always regarded as a last resort in the stabilization of adobe, but necessary if the structure is to remain intact. Reconstruction is a last resort because of the loss of the original fabric, the possible loss of a style or particular construction technique, and the possibility of causing even further damage. Therefore, once the decision has been made to rebuild, one should remember it will not be an easy task, and there are risks with each solution that should be taken into account.

Rebuilding is most commonly used when the wall has either coved out or slumped. Depending upon the amount of coving action the adobe wall has experienced, the solution will either be minor or major rebuilding. In the case of minor coving action where only a couple of centimeters of the adobe has eroded, the solution is easy; for example, if one to two courses of adobe have eroded to a depth of one to three inches (Reference Figure 2-1).

The first step is to stop the source of moisture causing the deterioration (methods discussed later on). The solution is minor patchwork of the eroded section. This involves the removal of any or all adobe bricks which might be partially eroded or badly affected by moisture. If all that has to be done is to scrape off the spalled adobe to reach stabile adobe, then the solution is to fill the area with a mixture of soil cement (Reference Appendix A). All that is left to do is to resurface the area (Reference Figure 2-2).

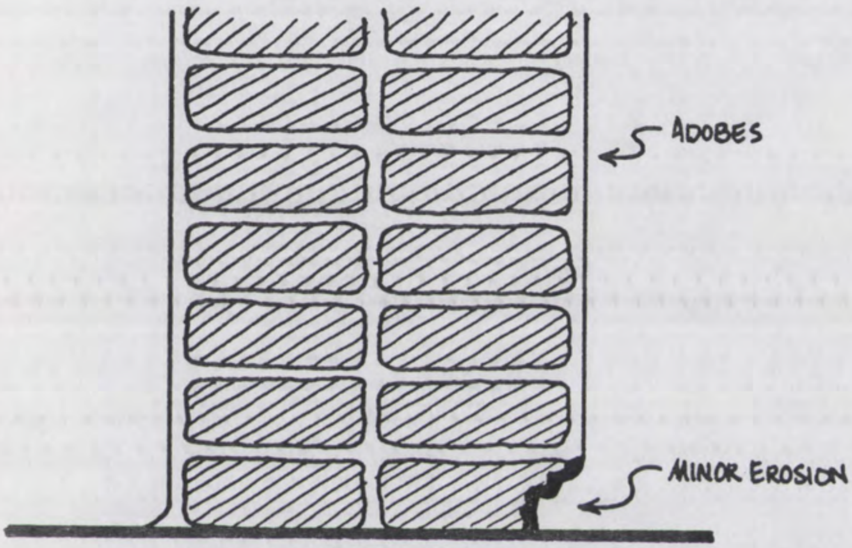


Figure 2-1. Minor Damage

A patchwork solution is sometimes a temporary solution, depending upon the amount of deterioration. If the same area should continue to erode, the next step is to replace the bricks. After removing the damaged bricks, prepare the surface against further moisture seepage by lining the area with a damp proof course of soil cement (Reference Figures 2-3 and 2-4). Then replace the eroded adobes with reinforced (stabilized) adobes (Reference Figure 2-5).

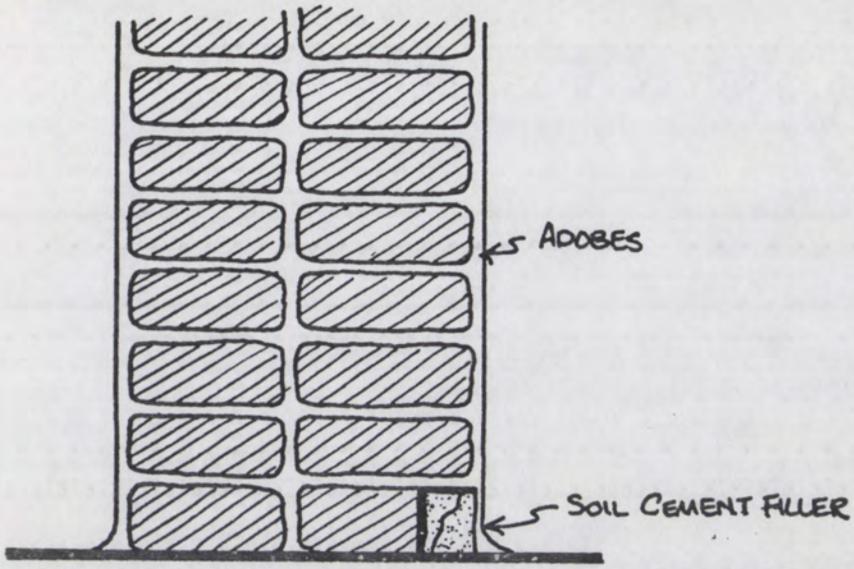


Figure 2-2. Patchwork Solution

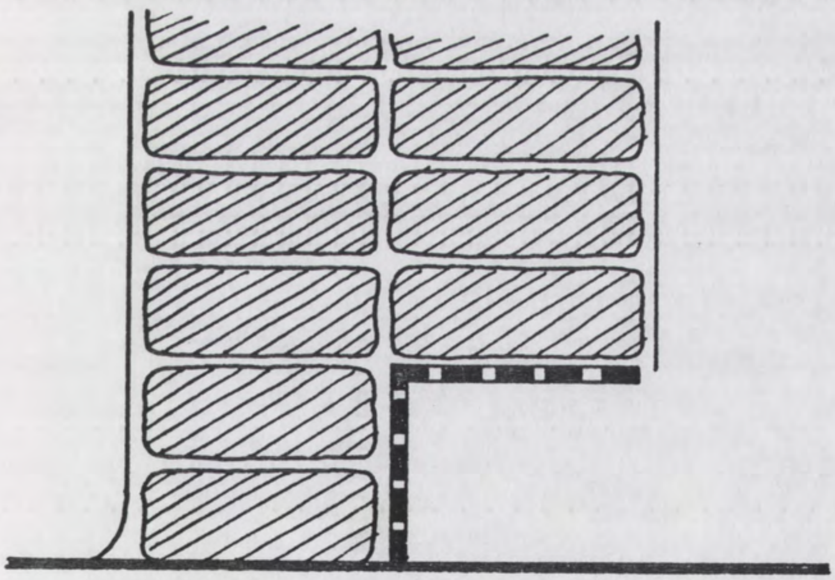


Figure 2-3. Removal of Damaged Adobes

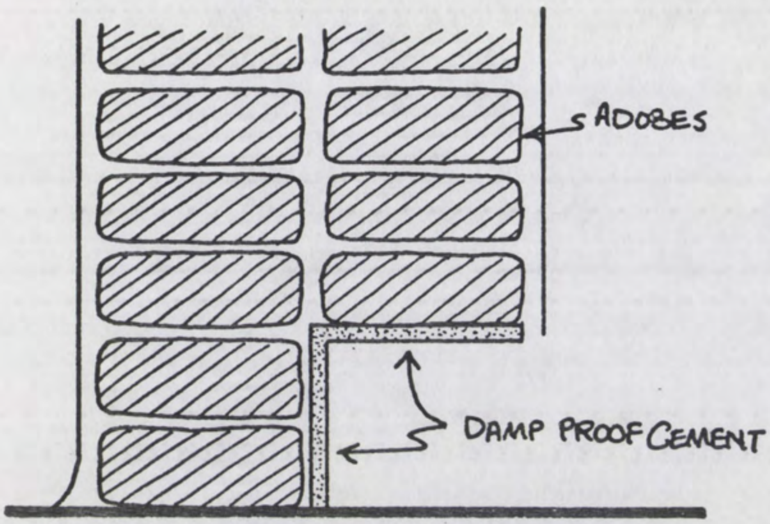


Figure 2-4. Wall Preparation

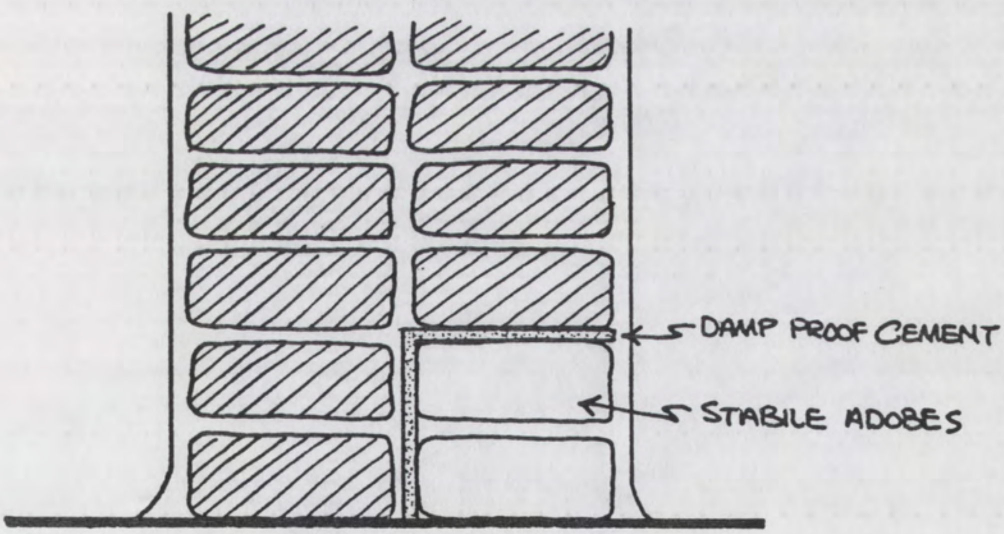


Figure 2-5. Rebuilding

There are certain situations where rebuilding the coved out section of the adobe wall might be difficult and call for a different approach. For example, a direct load above the eroded area makes the problem more difficult. Removing damaged bricks to begin rebuilding could make the wall unable to support the weight, which could result in collapse of the wall section (Reference Figures 2-6 and 2-7).

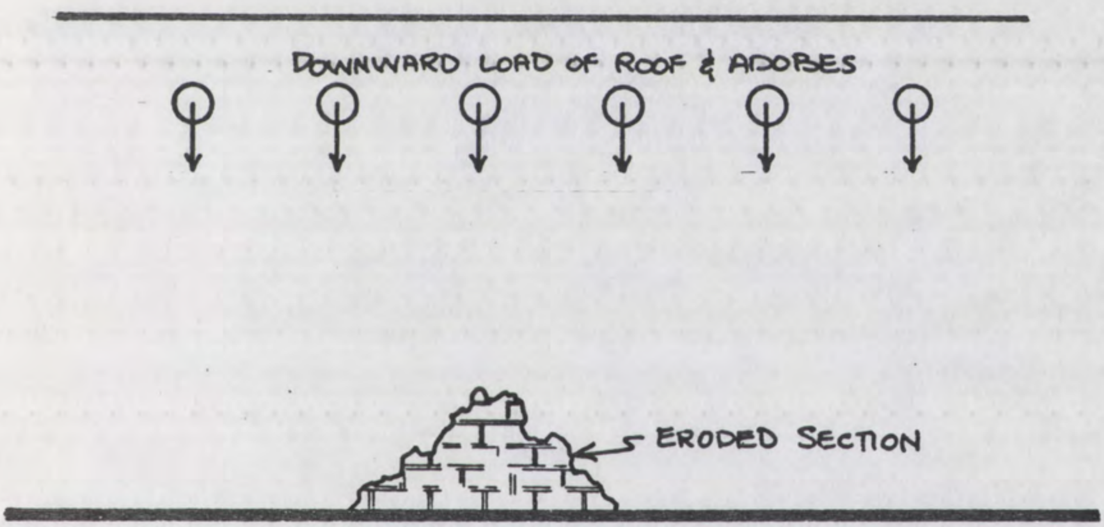


Figure 2-6. Load Bearing Wall

The first step is to relieve or transfer the pressure away from the weekened area. This can be accomplished by the use of supports and bracings (Reference Figure 2-8). After this has been accomplished, then the removal of damaged bricks and basic preparation of the section for rebuilding may begin. In most cases, the removal of damaged bricks involves cutting

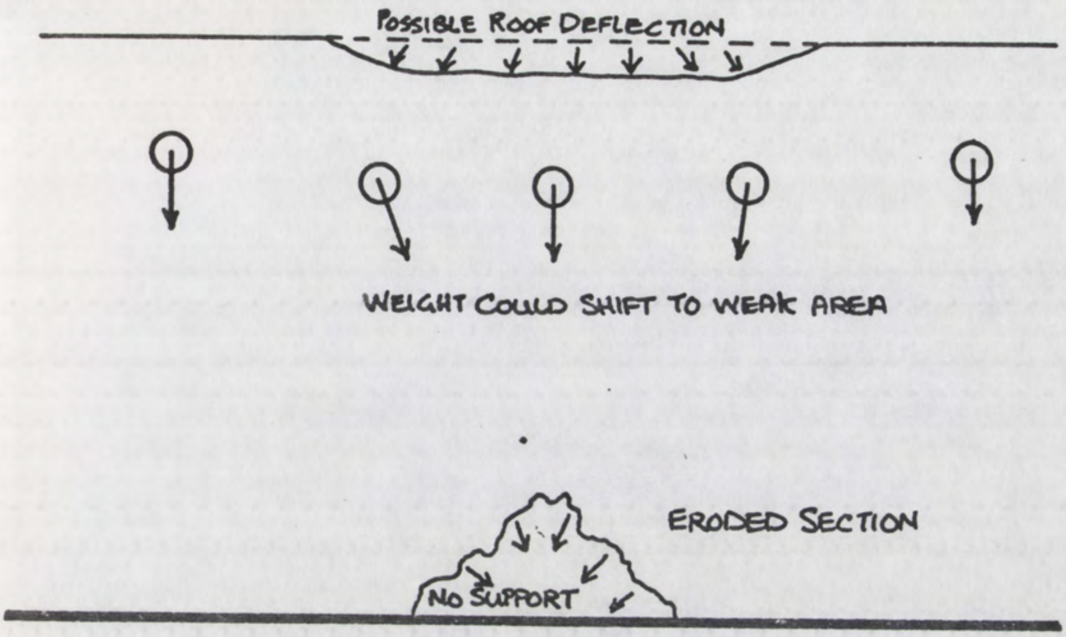


Figure 2-7. Possible Collapse

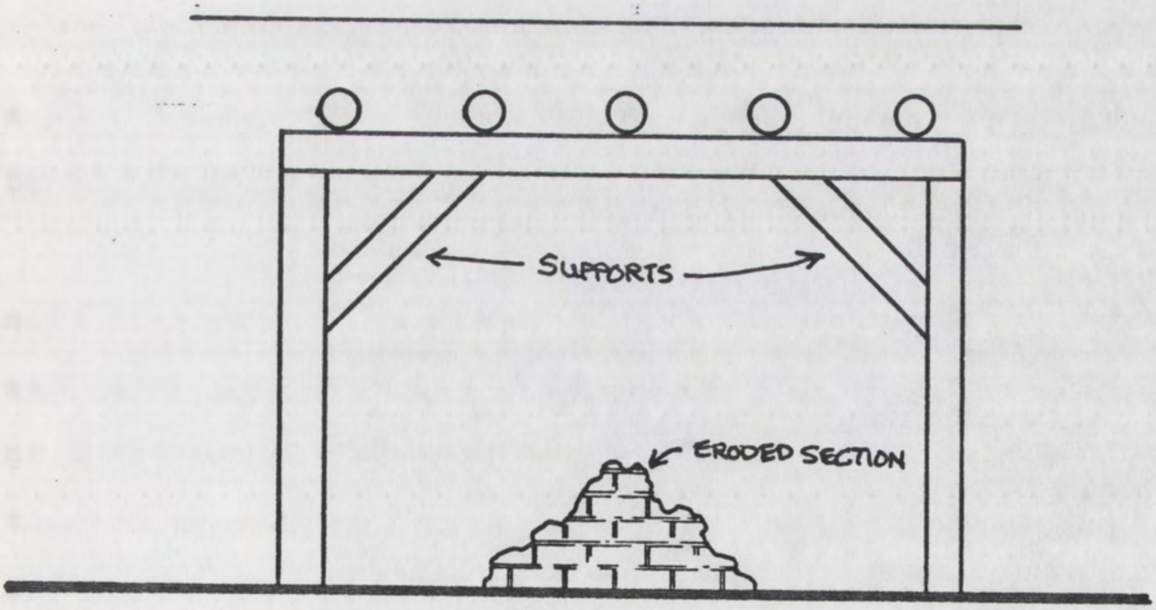


Figure 2-8. Relieve Load Above Section

away until encountering stabile bricks or at least eliminating bricks that are seriously spalled (Reference Figure 2-9).

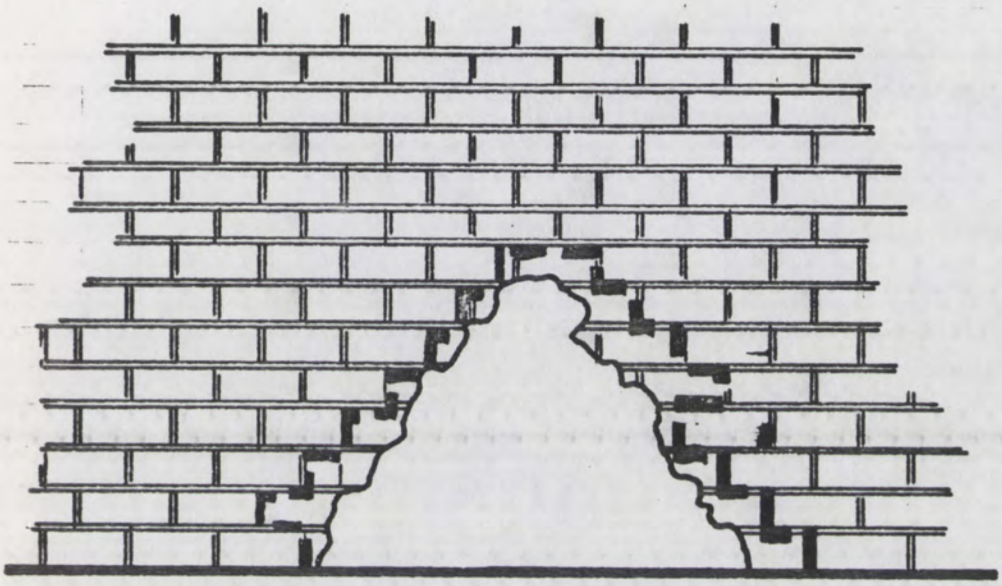


Figure 2-9. Cut Away Eroded Adobes

To prevent further moisture seepage, line the area with a damp proof course of soil cement before placing new adobe bricks (Reference Figure 2-10).

After rebuilding the wall, let the new masonry set up until stabile before allowing the pressure to be applied to the new wall section. This is done because the new adobe will settle at a different rate from the old adobe which has had a longer time to set. This could lead to separation between the new adobes and the old adobes. This separation could allow moisture to re-enter from surface run-off and cause the erosion to start again. Another reason for maintaining watch after

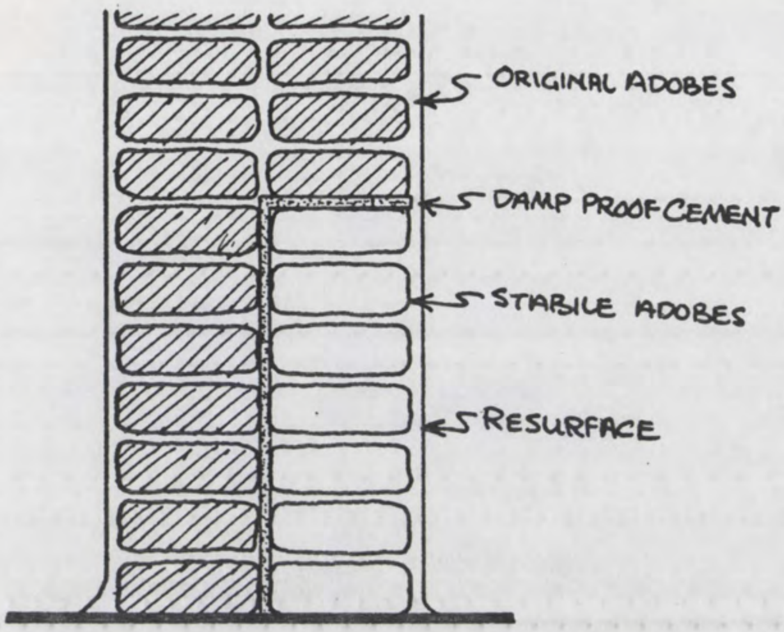


Figure 2-10. Rebuilt Section

rebuilding is to see if the new adobe can withstand the pressure of the roof load. The old adobe has already adjusted to the weight, whereas the new hasn't. If the adobe cannot withstand the pressure, there will be some noticeable settling of the roof. This could lead to some cracking of the adobe, and the process of eroding could begin again.

If the eroded section occurs on a non-load bearing wall, bracing is not necessary. The only weight to be concerned about is the weight of the bricks. Since there is no need of special bracing, the same steps can be used that were used in the case of a load bearing wall. First, cut away eroded adobes, then use a damp proof course before placing the new adobes in place. Again, watch for any noticeable signs of cracking between new and old adobes.

Another major problem can occur when erosion occurs at the corner. This particular problem deals with one wall being load bearing and the other wall non-load bearing (Reference Figures 2-11 and 2-12).

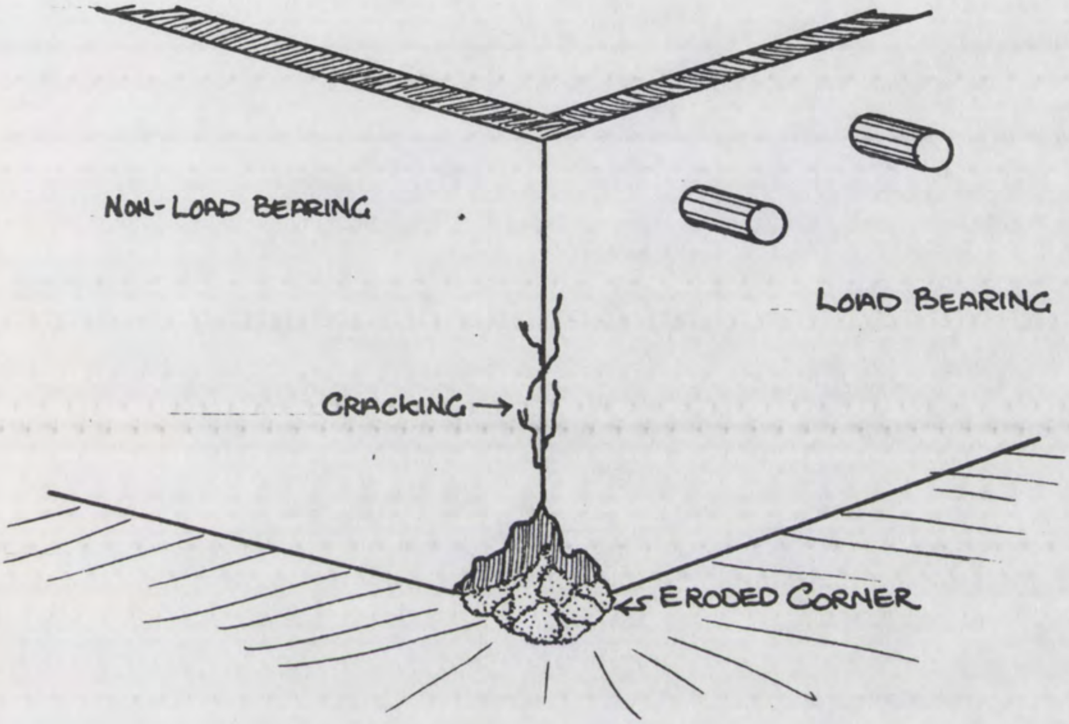


Figure 2-11. Erosion at Corner of Two Walls

In this particular case, steps should be taken to prevent the outward thurst due to the loading conditions. This may be done by bracing the walls and supporting the load so there is no pressure on the corner.

If there is no apparent sign of collapse or major cracking of the masonry inside and out, the solution is simple. Just remove the eroded adobes and replace with stabile adobes. However, if there is major cracking wpward between the two walls inside and outside, a different approach should be taken.

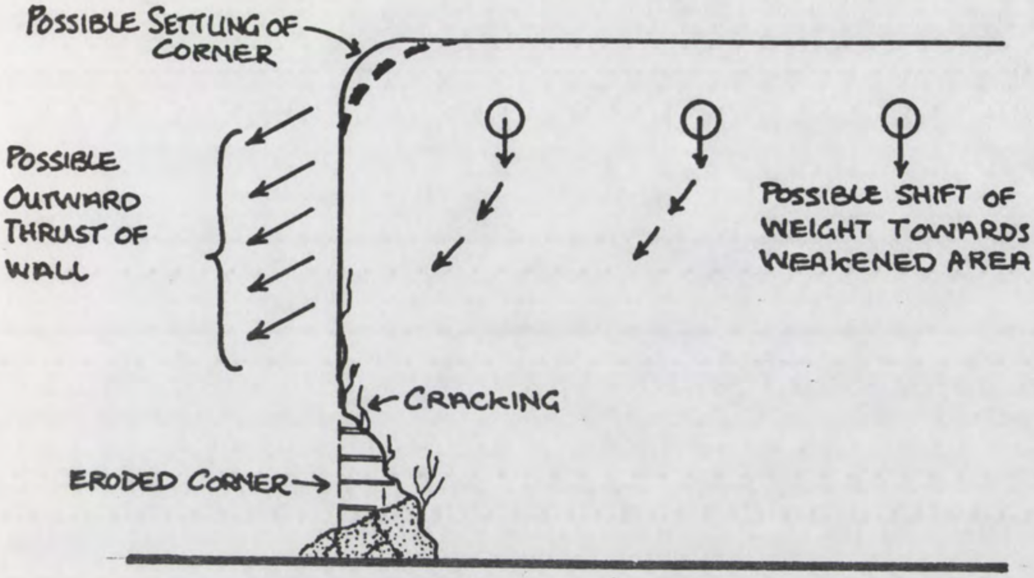


Figure 2-12. Side View of Eroded Corner

The corner will need to be rebuilt from the ground up. This involves removing all pressures, such as roof loads, which, during reconstruction, could cause the collapse of the structure at that point. First brace the load bearing wall and then cut away damaged adobe bricks. This may be done in a stair step pattern (Reference Figure 2-13).

Remove the bricks in a staggered pattern so that the new bricks will rest on the old stabile bricks. This should help in reducing the effects of the new bricks shrinking and settling in place. All that is left to do now is to rebuild the corner with new adobes (Reference Figure 2-14).

After allowing sufficient time for the rapaired section to firm up, the bracing may be removed and the weight can be placed

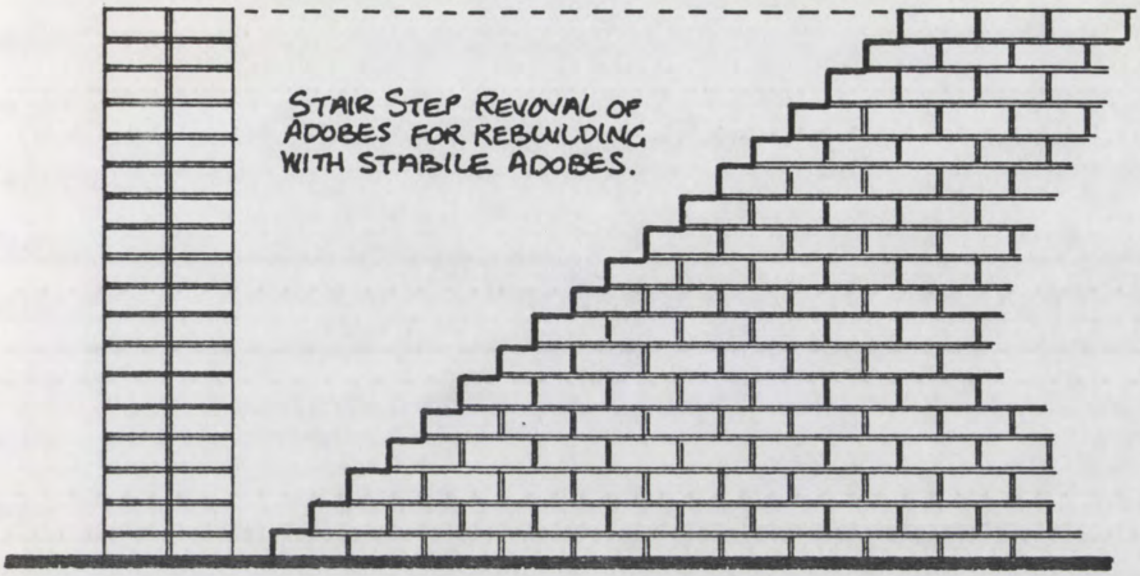


Figure 2-13. Stair Step Removal of Adobes

on the wall. Watch the corner carefully in case of uneven settlement or cracking of the new adobe. This will prevent possible damage by moisture seepage or weakening of the structure from the roof load.

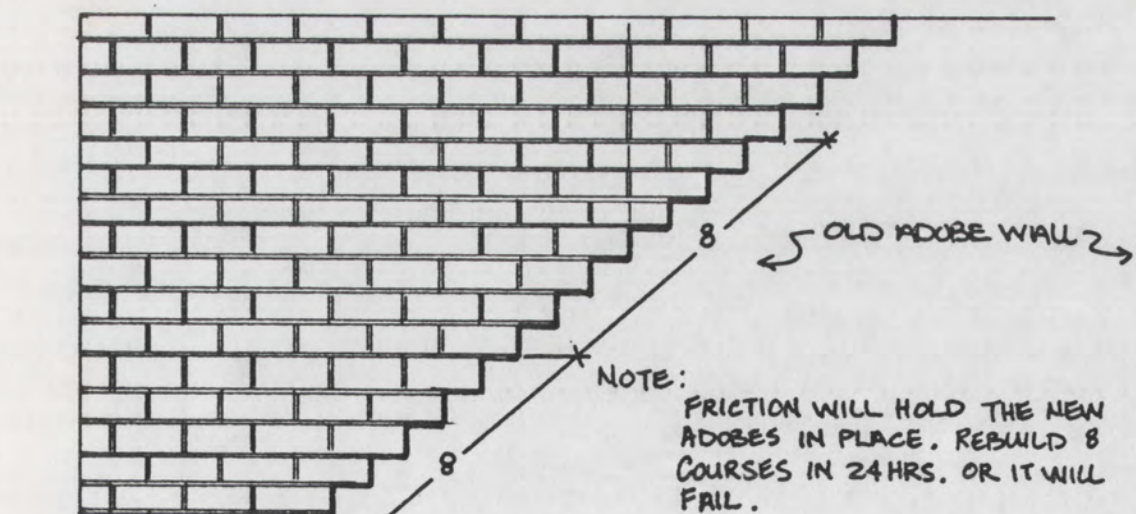


Figure 2-14. Rebuilt Corner

Solutions for Foundation Settlement

The first solution should be to discontinue and prevent moisture seepage causing the settlement. The most common method of accomplishing this is the digging of a trench to divert the moisture away from the already unstabile foundation. The placement of the trench is variable, depending on the source of moisture. If the source of moisture is caused by site drainage, the trench may be located away from the structure. The trench should be used to divert the ground water away before it comes into contact with the soil around the structure (Reference Figure 2-15).

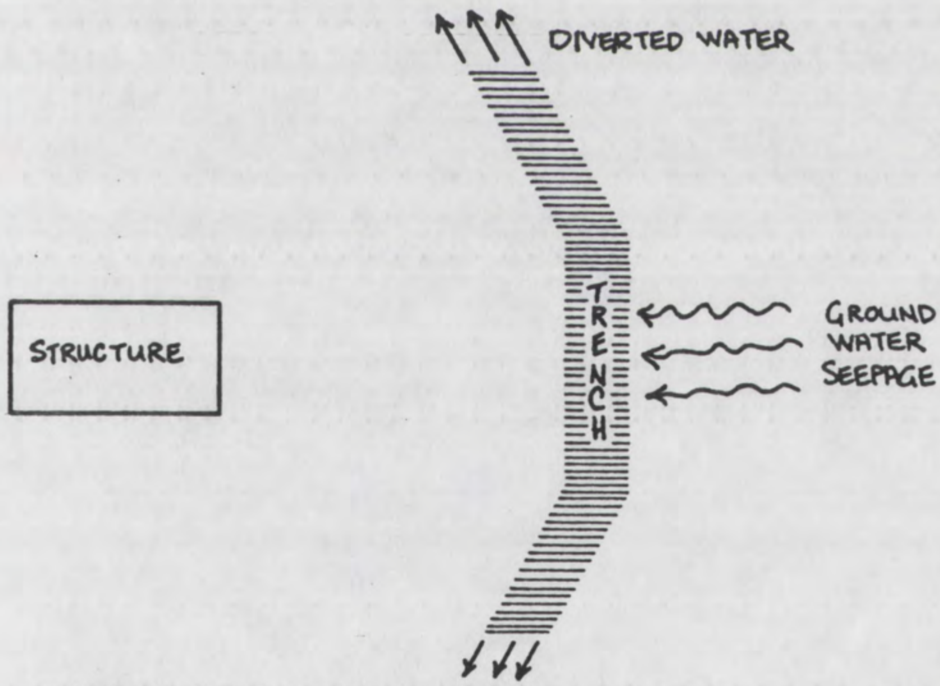


Figure 2-15. Perimeter Trench

This should stop further settlement of the structure. However, a certain amount of settling may continue as the water table beneath the structure drops because of the diverted water;

the structure will settle as the water table settles. So, this may be a temporary solution, but it may have a latent effect on the structure that should be considered (Reference Figure 2-16).

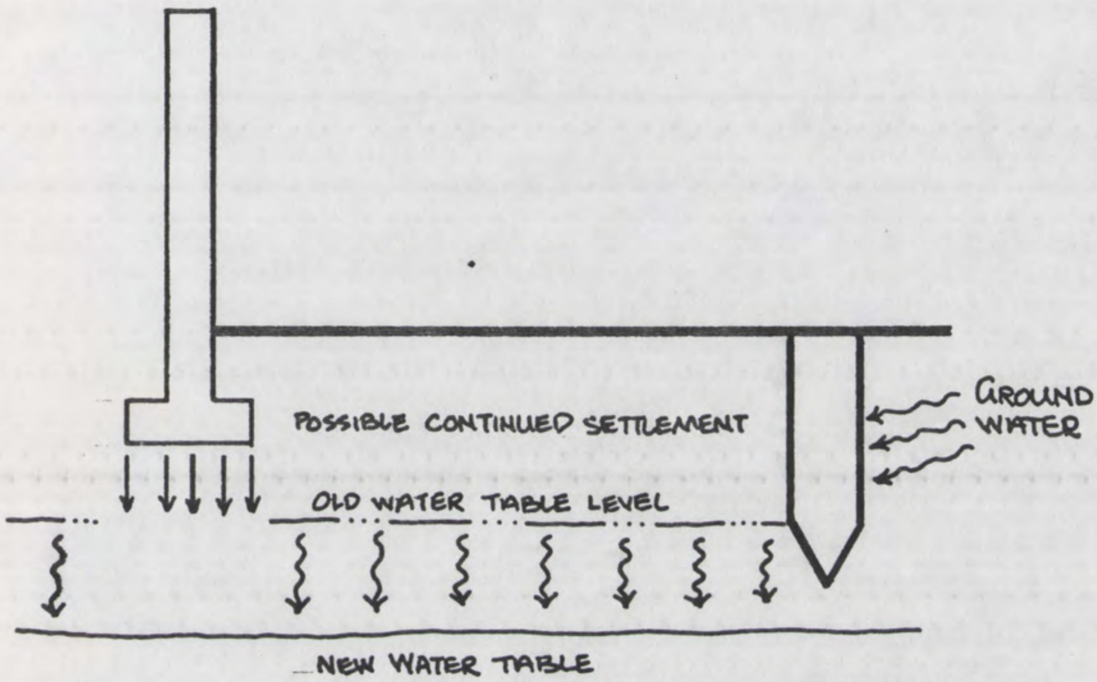


Figure 2-16

The trench may also be located next to the structure if the moisture causing the problem is from water run-off from the roof or the immediate vicinity. In this case, the trench is dug down beside and below the bottom of the foundation. This is to insure that further moisture cannot seep upward and continue weakening the ground supporting the foundation. Instead, moisture is trapped and drained away from the foundation (Reference Figure 2-17).

In most construction of the drain trench, the side of the trench next to the foundation is lined with a waterproof membrane--usually sheet plastic. A drain pipe is placed at the bottom of the trench to help collect and drain the water away from the foundation. On top of the pipe, pea size gravel (¼" to ½") is placed. The gravel allows for the collection of moisture down to the drain pipe. The earth is placed on top of the gravel and tamped down so that the trench will not erode (Reference Figure 2-18).

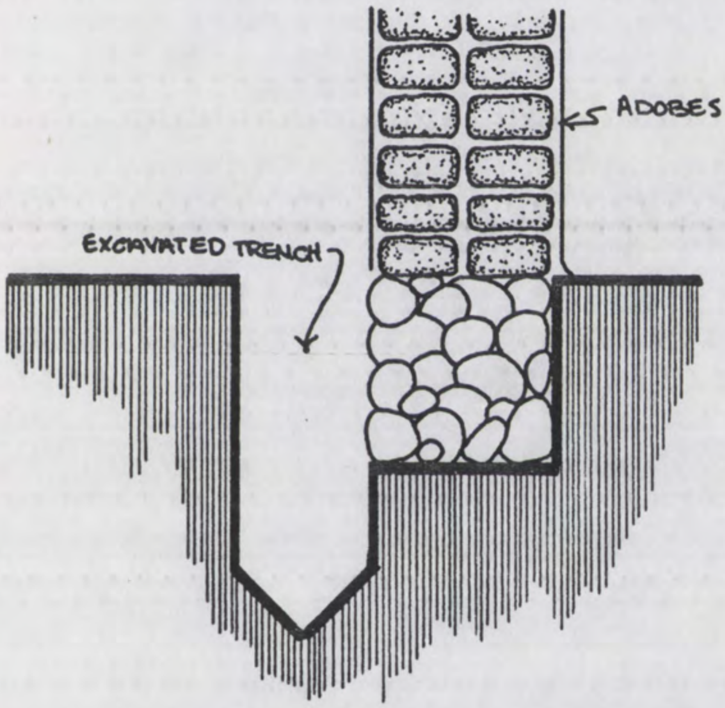


Figure 2-17

If the foundation continues to settle, the next step would be to rebuild the foundation. This may be accomplished by underpinning the foundation. First, a second foundation may be constructed around the original foundation. This solution calls for the excavation of earth away from the foundation. Before excavating around the foundation, mark off sections of

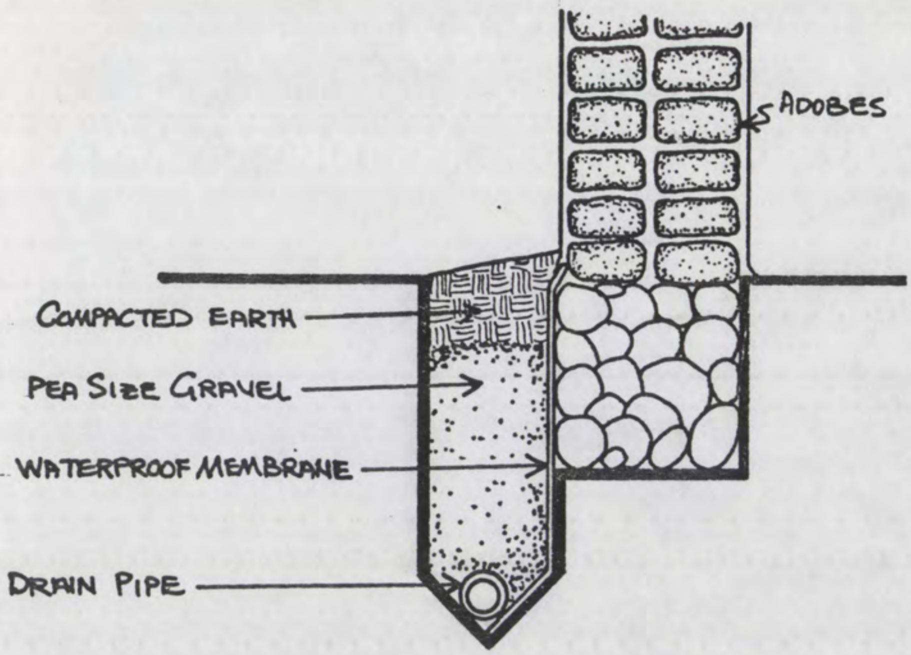


Figure 2-18. Trench Construction

equal length. These sections can be anywhere from four to eight feet. Then remove the earth from every other section. This method leaves earth between the excavated sections to act as supports. Since the foundation is already weakened, any major excavation of the earth could cause the foundation to settle further, which in turn could lead to structural cracking or collapse (Reference Figure 2-19). The excavation goes only part way under the existing foundation (Reference Figure 2-20).

After excavating the sections, forms for the second foundation can be erected and rebar placed for the pouring of the concrete. After allowing the concrete to set, the unexcavated sections may now be excavated and the process repeated until the foundation is completed.

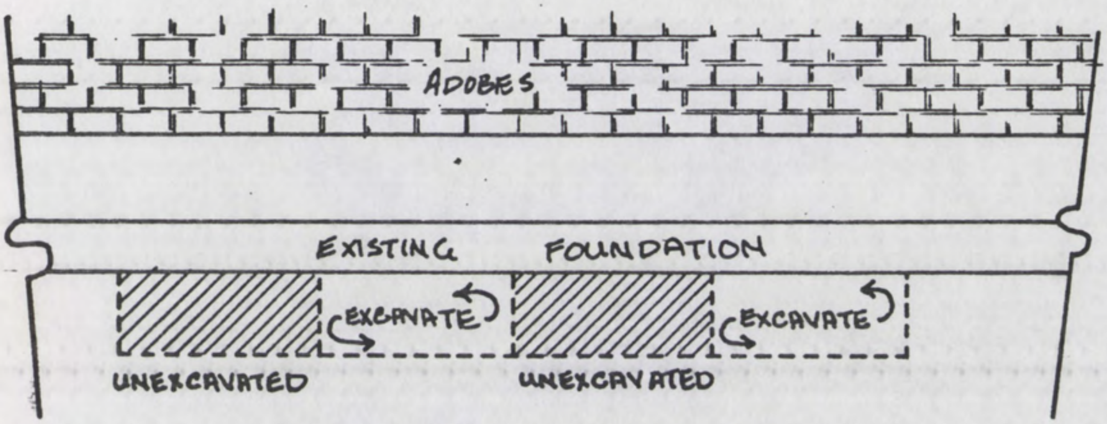


Figure 2-19. Excavation of Foundation

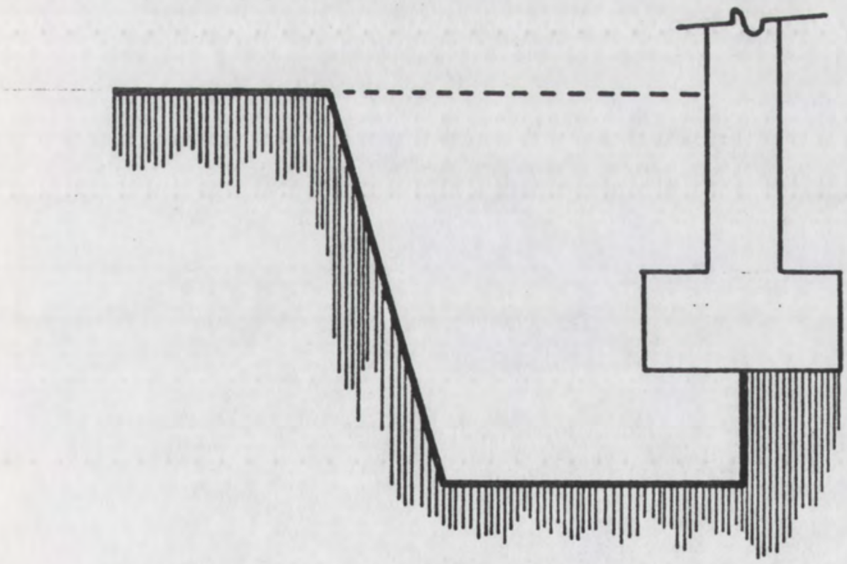


Figure 2-20. Section Showing Excavation

The last method of underpinning is a difficult and a delicate undertaking. This process also involves the marking off of equal sections along the base of the structure. Instead of excavating only half way under the foundation, the process calls for complete excavation under the foundation (Reference Figure 2-21).

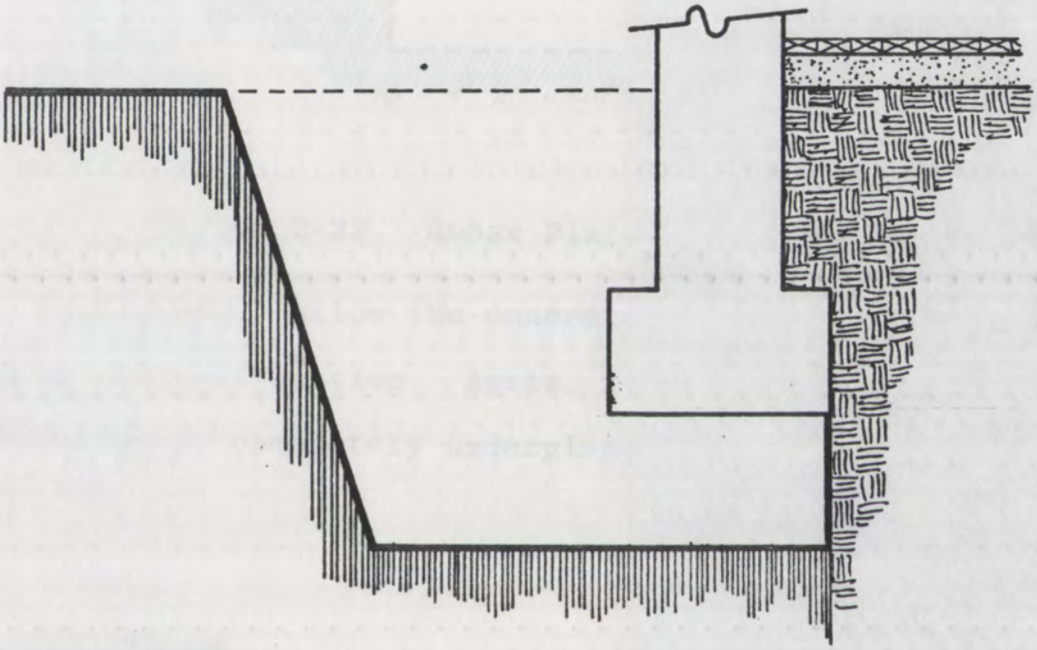


Figure 2-21. Sectional View

After excavating every other section, drive rebar halfway into the two unexcavated sections. Then take another piece of rebar and wire it to the ends of the protruding rebars (Reference Figure 2-22).

Next, erect form work to contain the poured concrete (Reference Figure 2-23). The concrete is then forced into the form so that there are no air pockets which migh weaken

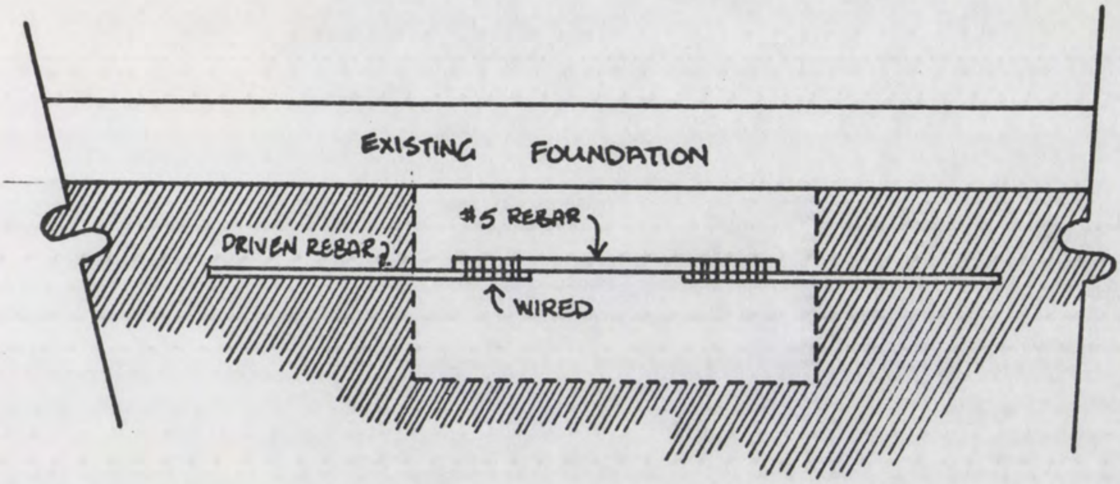


Figure 2-22. Rebar Placement

the new foundation. Allow the concrete to set in place before excavating the next section. Again, repeat the process until the foundation is completely underpinned.

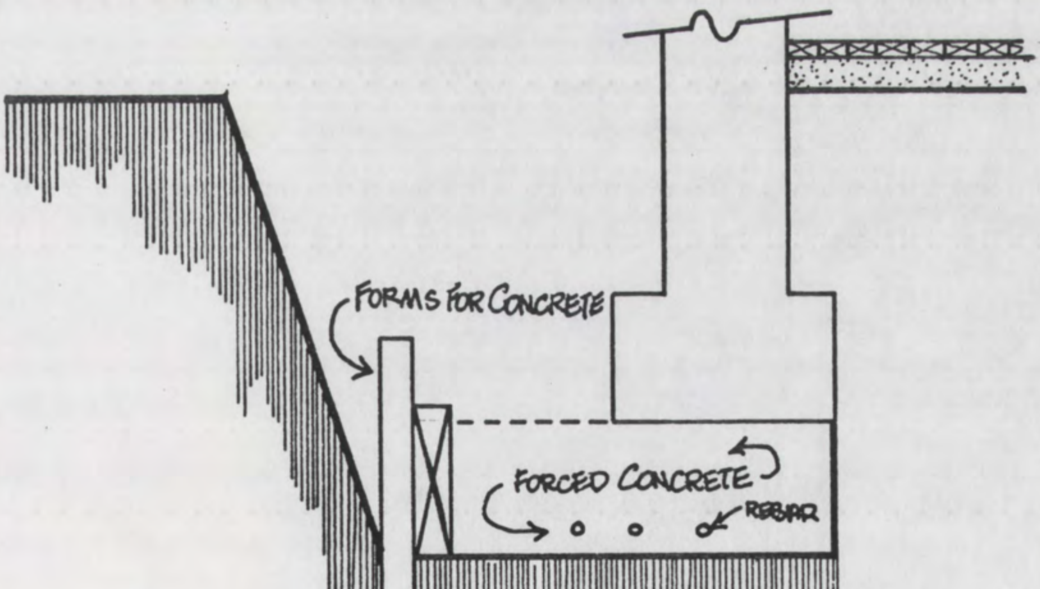


Figure 23

Solutions for Minor Deterioration

Solutions in this category deal with the deterioration of the first couple of centimeters of adobe. Any deterioration beyond the first inch or so is considered major and should be dealt with in a different manner. These chemical solutions deal with the effects of moisture and temperature which causes efflorescence and spalling. These solutions come in a variety of compositions such as silicates, acrylic polymers, polyurethane resins, waxes, concrete sealers and hardners, and are used to prevent further moisture seepage into the adobe surface. Another purpose of chemical agents is to reinforce the weakened surface so that the adobe will not weather away and deteriorate further.

There are basic steps in the preparation of the wall prior to the application of the chemical solution. First, remove the decaying adobe down to a stabile surface. This may be accomplished by using a wire or stiff brush to remove the first few centimeters of the deteriorated surface, or the surface can be sand blasted. Sand blasting can be risky, however, in that often more adobe may be removed than is necessary. An air hose should be used to remove dust that may be deposited on the adobe after brushing. Removal of the dust is important in that it might inhibit the absorbtion of the solution into the adobe. The bond between the adobe and the solution is critical in the solution's effectiveness. Without an adequate bond the surface may not seal sufficiently and moisture may seep in causing the deterioration to continue.

Most chemical agents used in stabilizing adobe are thinned with water or a chemical solvent for application. Since the agent is in a liquid form, it is absorbed through the pores of the adobe. As the moisture or chemical solvent evaporates, the solution is left in place. Depending on the type of solution, complete evaporation or lack of moisture in the adobe is required (Reference Appendix A) for the presence of moisture may repel the solution and render it ineffective. Other solutions require the presence of moisture in the adobe. Some chemical agents, Adobe Seal or Soil Seal, use the evaporation of moisture to carry the chemical into the adobe. Others, such as Pencapsula or Masonriseal, use a petroleum chemical which is a better wetting agent than water to penetrate the adobe.

Method of application of the chemical agent will vary with the viscosity of the agent. Most chemical agents after being thinned can be applied with an airless sprayer. Others may be either brushed or mopped on, depending on the thickness or thinness of the solution. Some solutions are applied in layers, much like spraying a car with paint. The layers of the solution are slowly built up until the adobe surface is sealed. Often, one heavy application of the chemical agent may not be as effective. If a "one-shot" heavy application is used, chances are some of the solution will be absorbed, but the remainder may evaporate away before reaching the adobe. This is an unnecessary waste of chemicals, money, and time.

With every solution there are always some risks or latent side effects that should be mentioned. Temperature change and moisture can have an effect on a chemical solution. This effect may not occur right away, but may develop at a later date. Because of possibel side effects, most manufacturers of chemical agents stress testing before applying to the adobe in order to prevent damage to the adobe.

For example, a chemical agent was introduced on the market which was more rigid than any other agent and had a deeper penetration. The agent was quickly applied to several adobe structures in southern and northern New Mexico. After the first year the results showed that indeed the agent was successful. However, during the second year certain side effects began to develop. The treated structures in the north began to show signs of cracking and deterioration. In some cases, large sections of the treated surface flaked off, exposing the adobe underneath. The treated surfaces of the structures in the south showed little or no deterioration.

The surfaces in the north failed, due to differences in moisture levels and temperature changes. The southern section was semi-arid with little moisture. The temperature difference between nighttime and daytime was nominal. The northern section had a larger amount of moisture present (rain, snow, humidity, etc.). The range of temperature change was far greater in the south.

The treated surfaces in the north failed because the solution was too effective. It was designed to penetrate deep into the adobe, and when exposed to freeze-thaw conditions, it expanded at a different rate than the adobe. As the treated surface expanded and contracted, it carried part of the adobe it had penetrated (Reference Figures 3-1 and 3-2).

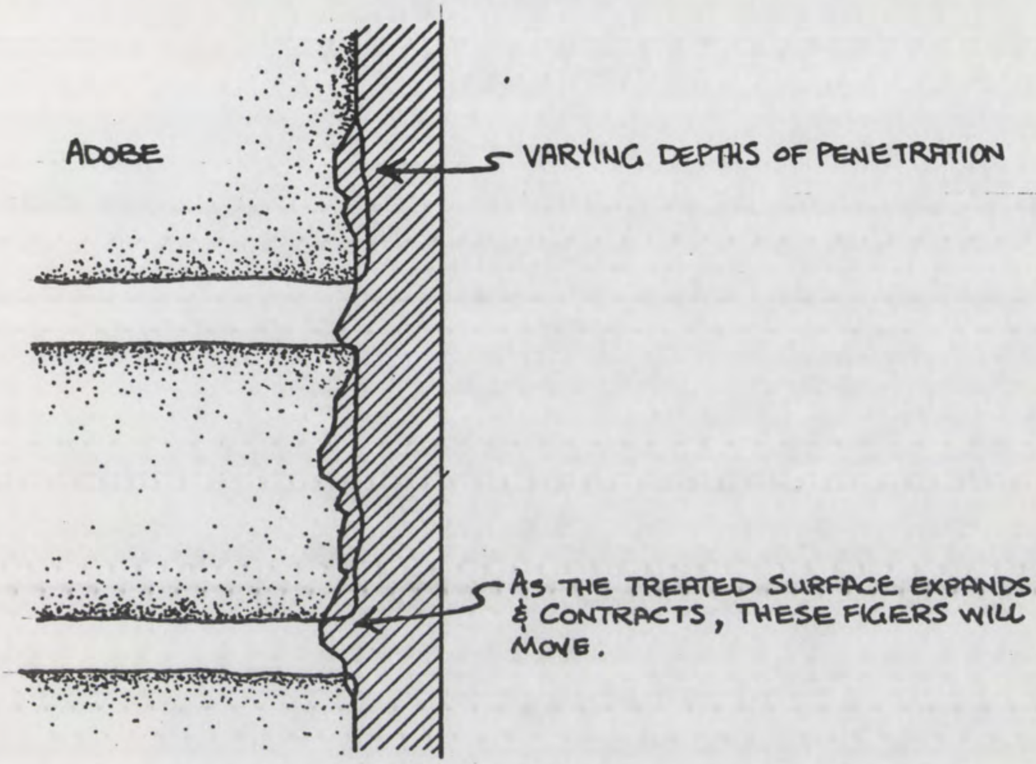


Figure 3-1. Sectional View of Treated Surface Showing Various Depths of Penetration

After a while the treated surface separated from the adobe forming a gap. Because of the high humidity level in the atmosphere, water condensed in the gap, adding further to the deterioration of the solution and the adobe.

Had the solution been tested prior to application, damage to the adobe could have been avoided. Instead of preventing the deterioration of the adobe, the solution itself became a form of deterioration. Because of differences in environmental conditions any solution chosen should be tested before use.

Another example of latent side effects was observed in a solution used at Pecos National Monument, New Mexico. The

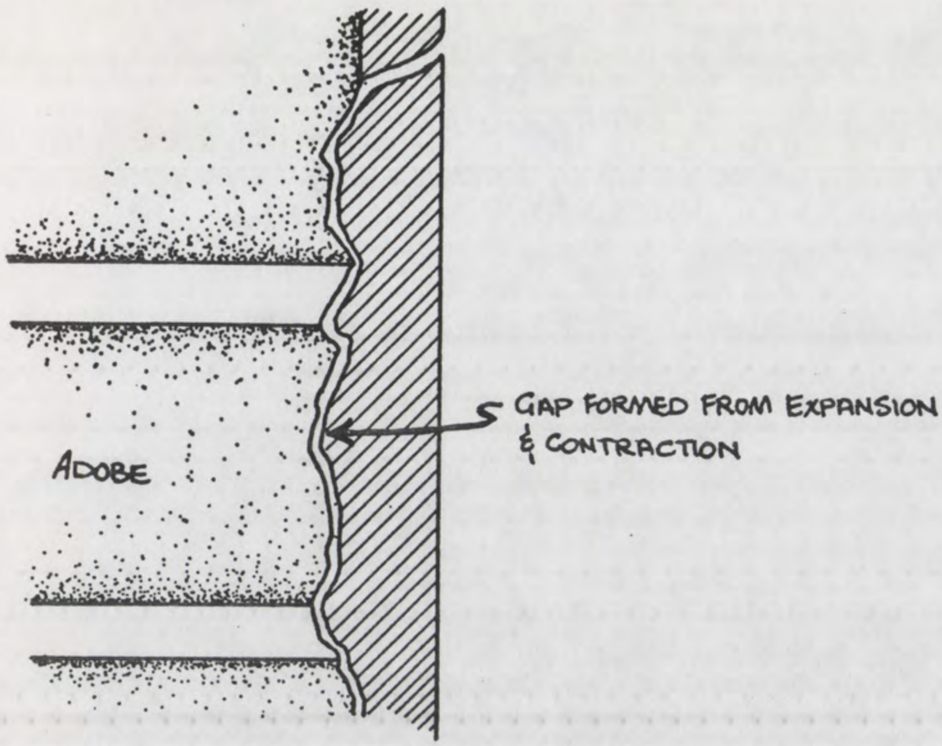


Figure 3-2. Formation of Gap Between Adobe and Treated Surface.

solution was a rigid surface covering applied to the lower portion of the adobe wall where the wall curved (Reference Photo 3-1). The surface covering was showing signs of cracking, and the adobe underneath the covering was eroding.

Apparently what seemed to be causing the failure of the covering was that water was running down the wall surface and across the surface covering. As the moisture would run down the surface, the moisture would begin to seep under the top edge of the covering and into the adobe (Reference Figure 3-3).

Then, as the cover and the adobe began to dry out, action by "soluble salts" combined with freeze-thaw conditions weakened the bond. As a result, the covering cracked and fell

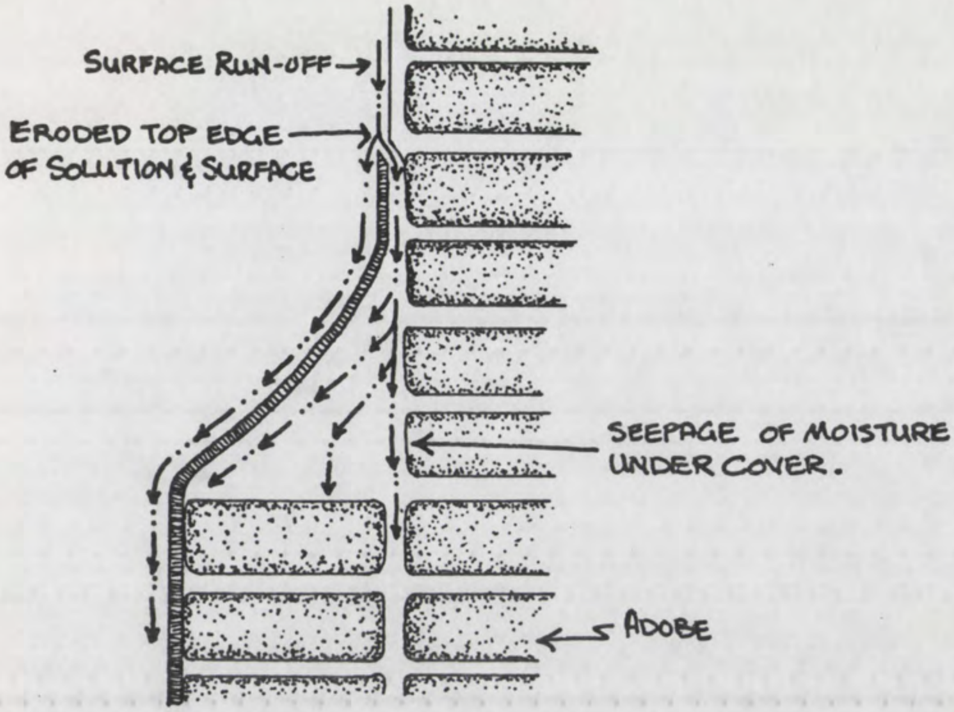


Figure 3-3. Sectional View Showing Moisture Seepage

off exposing the adobe to deterioration. Also, because the covering had separated from the adobe, moisture was able to remain in the adobe without evaporating and slowly eroded the adobe. Had the top edge of the surface covering been treated differently so that it blended into the adobe, moisture running down the surface would have been less likely to erode the top edge and then work its way into the adobe underneath.

Another effect that seems to occur is a solution which uses a material that either weakens faster than the fabric (adobe) or it lasts longer. The best example is when the solution calls for capping the top of a wall. This solution is used when the top of the structure is decaying from rainfall or melting snow. As moisture is left on top, it slowly seeps downward through the adobe and causes deterioration. To prevent this moisture seepage a cap is generally placed on top to protect the adobes (Reference Figure 3-4).

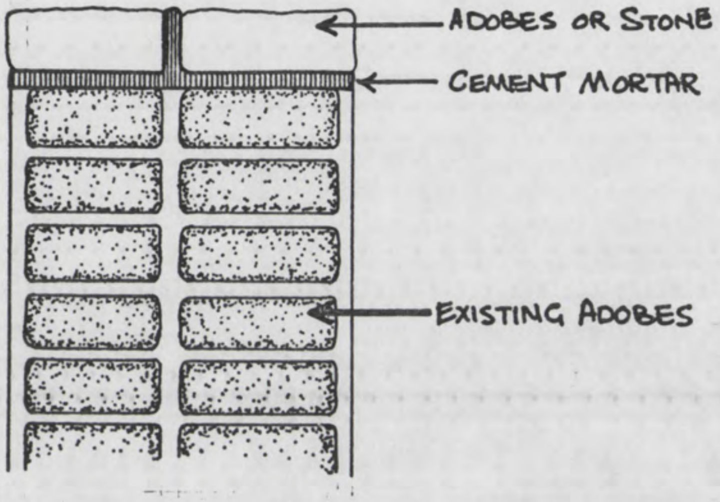
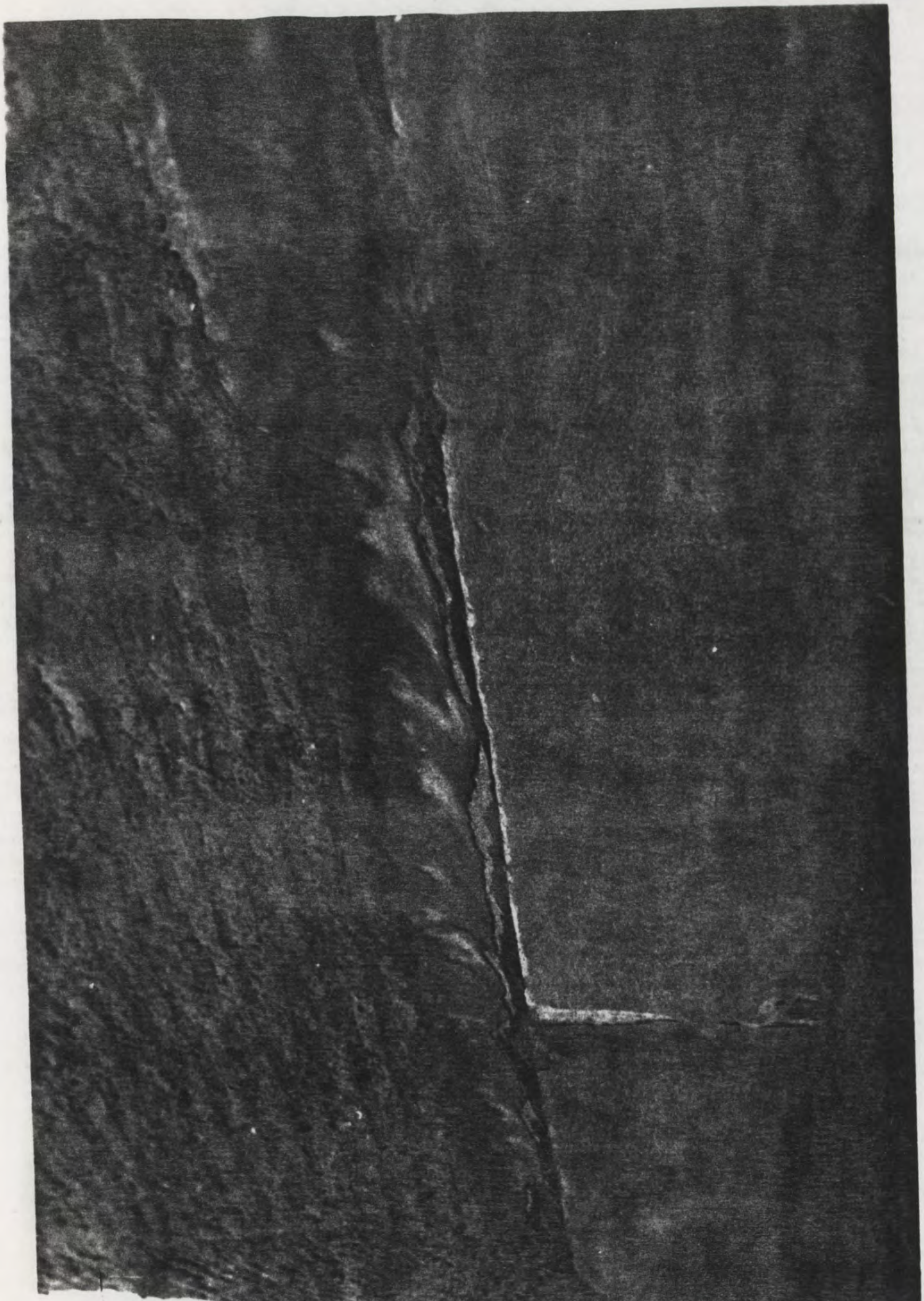


Figure 3-4. Capping Solution

This cap consists of cement mortar placed on top of the existing adobe and either stone or adobes are set in the mortar. The mortar should prevent the downward seepage of moisture.

This has usually been found to be an acceptable solution with only one slight drawback. Occasionally the adobes or stones used in the solution will erode, resulting in a honeycomb appearance (Reference Figure 3-5).

All of the aforementioned solutions work in halting the spread of deterioration of adobe. The main success of these solutions is constant maintenance whenever a slight fault begins instead of letting it get worse. The other successful aspect of solutions is when they are applied with great diligence instead of being hastely applied.



(3-1)

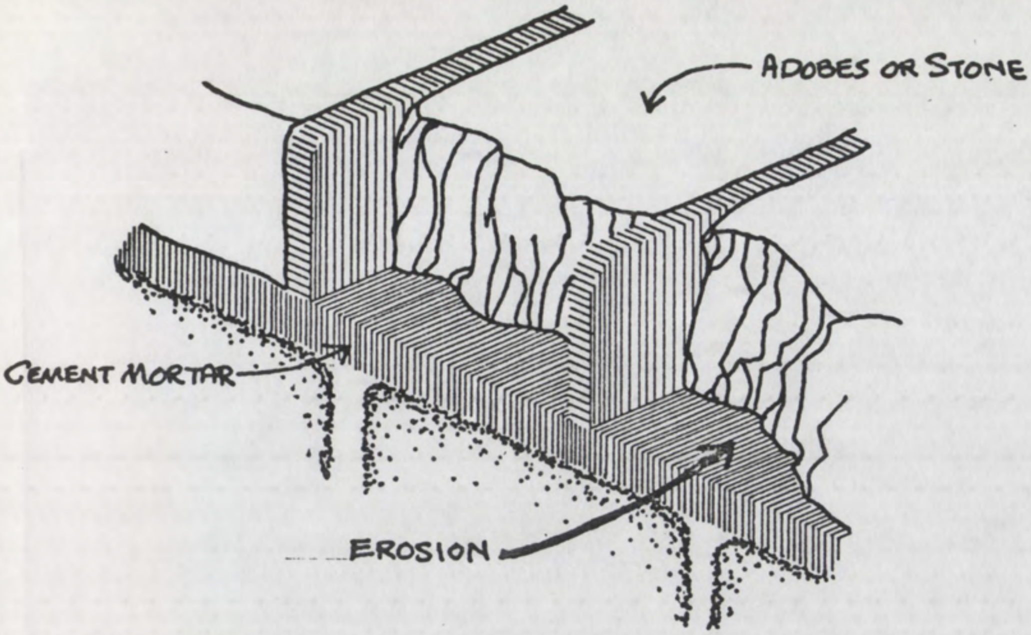
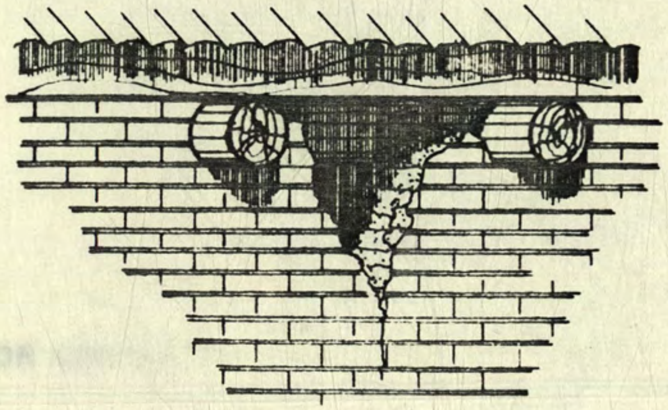
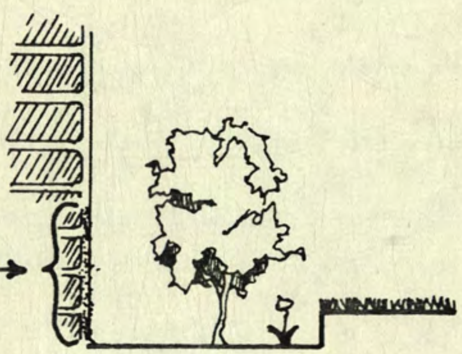
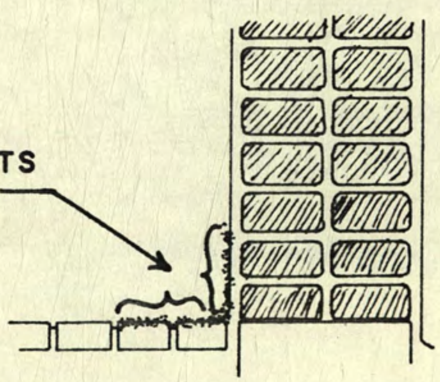
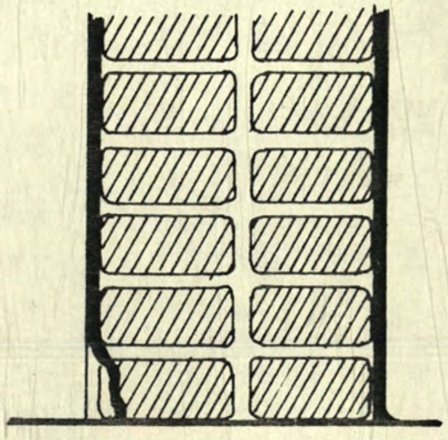
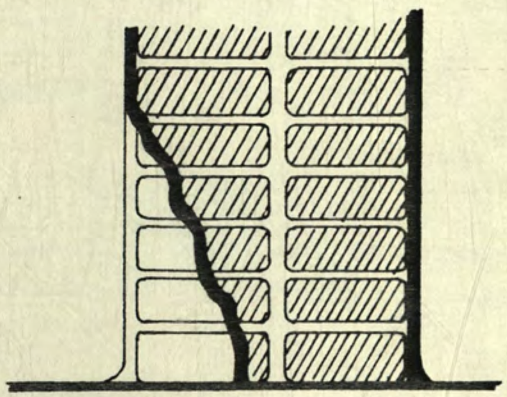
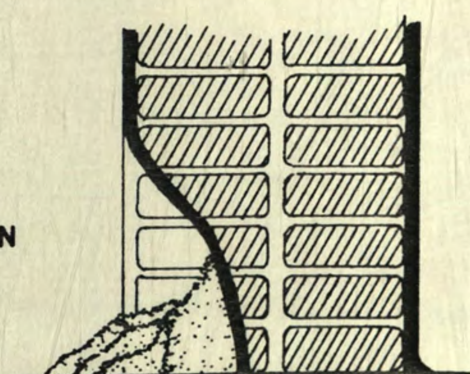


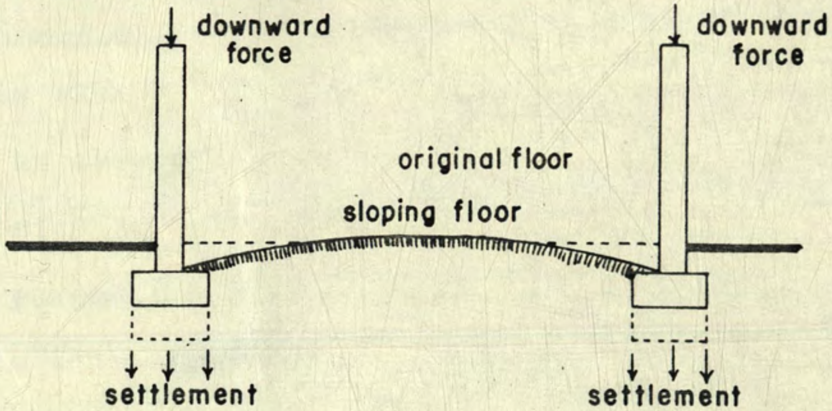
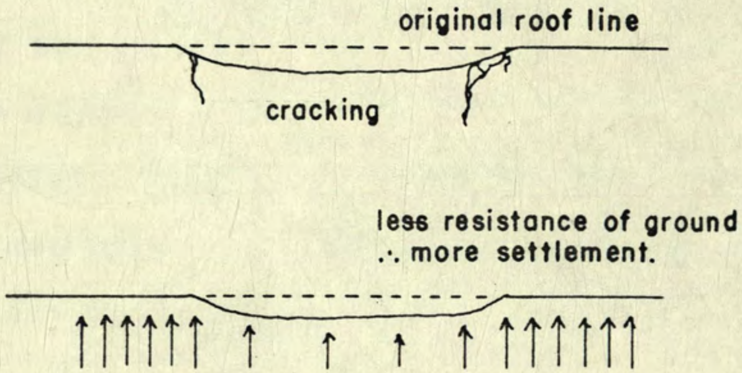
Figure 3-5. Erosion of Cap

CHART II: POSSIBLE SOLUTIONS

Visible Problem	Possible Solution	Explanation
POWDER ON SURFACE (EFFLORESCENCE)	• Removal of powder by either light air hosing or brushing the surfacing. • Use of a chemical spray-on solution to help strengthen the surface against further moisture seepage and soluble salt deposits.	• See Page 60 - 69
CRUMBLING OF SURFACE (SPALLING)	• Remove decaying surface until suitable stabile material is reached. • Resurface the area or if it is the adobe patch the area with cement.	• See Page 60 - 69
CRACKING OF SURFACE COVERING	• Remove the entire surface covering and re-surface. • Injection of a Polyvinyl Acetate to cement the cracks.	• See Page 60-69

Visible Problem	Possible Solution	Explanation
 ERODED ADOBES	• Rebuilding of eroded adobes with stabilized adobes.	• See Page 42-46
DEPOSIT OF SALTS 	• Remove some of the plants to allow sunlight in to remove the moisture and prevent further build-up. • Treat surface with a chemical solution to prevent soluble salt deposit.	• See Page 60-69
DEPOSIT OF SALTS ON THE INSIDE 	• Stop the source of moisture causing the deposit of salts. • Brush the surface removing most of the salts. • Treat the surface with a chemical solution to prevent further possible deposit.	• See Page 60-69

Visible Problem	Possible Solution	Explanation
MINOR COVING 	• Remove the source of moisture causing the erosion. • Remove as much of affected adobe as needed to reach stabile adobe. • Use a cement of some type to patch (fill) the hole. • Resurface the area.	• See Page 42-45
MAJOR COVING 	• Rebuild the eroded section with stabile adobes.	• See Page 42-52
SLUMPING ACTION 	• Same solution as major coving.	• See Page 42-52

Visible Problem	Possible Solution	Explanation
EQUAL SETTLEMENT  UNEQUAL SETTLEMENT  SAGGING OF WINDOW & DOORS	· Construction of a perimeter trench. · Construction of a trench next to the foundation. · Underpinning of the foundation.	· See Pages 53–59

APPENDIX A. CHEMICAL SOLUTIONS

COLLOIDAL SILICA "LUDOX"

Firm: E.I. DuPont de Nemours and Company
120 Montgomery Street
San Francisco, California 94104

Description: "Ludox" solutions can be used to stabilize porous stone or clay structures. The colloidal silica solids form an irreversible gel structure when dried. The low viscosity of "Ludox" water solutions allows good penetration of a porous structure. The colloidal silica particles will form a water insoluble gel when the water has evaporated to give a 60-70% silica solids concentration. The silica gel will become progressively less soluble as the moisture content of the treated brick decreases. There will, of course, be some migration of silica particles to the surface during the initial evaporation, but once a gel has formed, there should not be any significant migration of silica. The silica gel cannot be reversed once gel precipitation has occurred.

Because of these properties, poorly bonded adobe or stone should benefit due to the binding action of the gel. This should also tend to retard the migration of other water soluble salts occuring in the adobe. A 10-15% solids water solution of "Ludox" H5*40 is quite adequate for spray or dip treatment. The treated structure will show a strength improvement in proportion to the solids add-on and depth of penetration.

Tests: Test results of temperature and moisture effects are not available at this time. Tests are being conducted in the Tucson, Arizona and New Mexico areas.

ADOBE-ACRI SEAL AND ADOBESEAL

Firm: Adobe Wholesalers, Inc.
3393 N. Dodge Blvd.
Tucson, Arizona 85716

Description: Adobe-Acri Seal utilizes an oil-base carrier to get the agent to penetrate the adobe. Adobe-Acri Seal will not tolerate the presence of moisture (the surface must be bone dry, so to speak). Adobeseal employs water as a carrier and therefore does not require a high degree of dryness. It should appear dry but the presence of a small amount of moisture in the adobe will actually accelerate the absorbtion of the agent much like a "damp-dry" towel will absorb water faster than a perfectly dry one.

Depth of penetration is a factor of the volume of liquid applied per square foot, plus the absorbency of the adobe (too variable to make a respectable prediction). If applied to burnt adobe at a rate of one gallon per 50 square feet, expected depth of penetration is expected to be 1/16" to 1/8", depending upon the adobe. Depth of penetration, of course, is important to the longevity of the seal. Degradation of the seal can only occur where it is exposed to the sunlight, not where it is hidden. Both sealers will allow the masonry to "breathe" so as to allow the escape of entrapped moisture.

Tests: Tests of temperature and moisture effects are not available at this time.

MASONRISEAL

Firm: Graves Industries
4642 East Don Jose Drive
Tucson, Arizona 85718

Description: Masonriseal has been used primarily by painters who use it for protecting masonry surfaces from the elements. Masonriseal requires a dry moisture-free clean surface. It should not be applied when temperatures fall below 32^{o}F before curing (24 to 48 hours). Comes in a concentrated form and is diluted with water for application to the adobe surface. As the water evaporates, the solution is absorbed into the adobe. Expected depth of penetration into the adobe is about 3/8" when application is properly made. Work from bottom to top of vertical surfaces, so that run-off of solution will saturate the surface previously covered. Apply with a spray at pressure not to exceed 5 lbs. per square inch. Coverage depends on absorbtion of the surface being treated. Apply to point of run-off--in general, 100 square feet per gallon of solution.

Vertical Surfaces: One part concentrate to 32 parts water for burnt adobe, adobe bricks, slump block, stucco.

Horizontal Surfaces: One part concentrate to 25 parts water. Apply with mop and avoid leaving a surplus on the surface.

Wood: One part concentrate to 25 parts water.

Sod Roofs: One part concentrate to 20 parts water.

Tests: Tests of temperature and moisture effects are not available at this time on adobe, as this is a solution mainly for masonry brick.

ACRYL 60

Firm: Standard Dry Wall Products, Inc.
New Eagle, Pennsylvania

Description: Acryl 60 is an acrylic liquid polymer used for patching and curing of concrete and masonry dissolved in water for application. Wire brush the adobe surface to be treated, removing all loose particles. Surface must be free of moisture before applying the Acryl 60 solution. To prepare the solution mix one part Acryl 60 to three parts water, apply with brush, and let dry.

Besides being a spray-on sealer, Acryl 60 may be used as patchwork on adobe or a surface covering. The mixture for covering or patching adobe consists of four parts soil, three parts com-cement, one part sand, two parts cynco cement and stucco patch. Use Acryl 60 and water for mixing solution; also treat area to be patched with Acryl 60. In large voids drive galvanized nails into adobe leaving the head out 3/4" to hold the adobe plaster. This chemical has been successfully used as a apray to harden and waterproof walls in California.

Tests: Tested at Pecos National Monument, New Mexico. Test brick of Acryl 60 was subjected to 31 cycles of freezing and thawing (-13^{o}C to -21^{o}C). No damage occurred to the brick. Capillary absorption test showed that over a period of time the brick showed little moisture absorption. Base remained square and sharp with no signs of erosion. Bricks were exposed to a spray test from a nozzle on a garden hose placed five feet away from the bricks to simulate a driving rain. At the end of

Acryl 60 Cont.'d.

the spray test the brick showed some erosion of the surface. Depth of penetration was of the whole brick, but no signs of disintegration. Even though water had penetrated the entire brick, Acryl 60 seemed most resistant to water.

PENCAPSULA

Firm: Texas Refinery Corporation
Fort Worth, Texas

<u>Description:</u> Pencapsula is a synthetic resin, or to better describe it is a viscid petrochemical solution. Pencapsula when applied does not form a film or a membrane, but is carried into the adobe by the solvent and "encapsulates" the constituent members of the mass. This leaves open the normal tiny interstices which exist between the particles of any material and permits the normal "breathing" made necessary by changes in atmospheric and hydrostatic pressure and thus reduces any tendency for the treated portion of the material to spall. Because of its encapsulated effect Pencapsula does not waterproof any material, but it does make it water resistant.

Depending on the material, a treated surface will look damp for as long as six months, while the solvent is evaporating. After that there is no color change or glaze. Even though the solvent remains in the wall for a comparitively long time, Pencapsula hardens and becomes effective within 24 hours.

Moisture does not have to be absent from the adobe for application. The oil carrier for Pencapsula is a better wetting agent thatn water, and it enters the wall and drives the water out, apparently utilizing the channels for capillary action already established by the water. Pencapsula can best be applied to an adobe wall immediately after a long soaking rain or after spraying it well with water.

Pencapsula Cont'd.

Pencapsula must be diluted for application with a petroleum-derived solvent, usually kerosene or mineral spirits. The proportions are usually one part Pencapsula to five parts solvent. For an effective application it should be sprayed on at a low pressure of not more than 10 to 12 psi. Penetration into adobe should be at least 1" or more. In order to achieve penetration, it is necessary to spray and respray an area several times until capillary action carries pencapsula into the material.

When Pencapsula is sprayed onto adobe it will cause the adobe to shrink as it dries and destroy the bond between the brick and the mortar. It is therefore necessary to rake the joint as deeply as possible (at least 2"). The wall should then be sprayed with diluted Pencapsula. After spraying the joints should be pointed with an adobe martar mixed with Pencapsula. The adobe soil and water should be mixed to create a thick mud to which a diluted Pencapsula of 1:5 in mineral spirits should be added in the proportion of 1/2 pint to two gallons of mud. This results in a slick easily worked mortar to point the joints. If left alone after pointing, the mud will shrink, crack, and pull away from the brick. It is important, therefore, that while the mortar is still malleable (about 24 hours after it is applied) it should be worked into the joints again. The more the mortar is worked at this stage, the better the bond and fewer cracks will result.

Pencapsula Cont'd.

Tests: Tested at Pecos National Monument, New Mexico. Capillary absorption test on bricks with Pencapsula added showed varying depths of moisture seepage from 1/2" to 7/8". The bricks remained square, sharp, with no sign of erosion. After subjecting the bricks to spray testing, most of the bricks showed various depths of erosion ranging from 1/2" to 1" with a depth of moisture penetration of an average of 3/4". Results since this testing show that Pencapsula has worked in arid and semi-arid climates, but not in areas of extreme temperature changes and moisture abundance.

ETHYL SILICATE 40

Report on Mud Brick Preservation in Mesopotamia
International Centre for the Study of Preservation
13 Via San Michele, Rome 00153

Description: Ethyl Silicate hydrolyzes in the presence of acids and water, forming Ethyl Alcohol and an adhesive Silica Gel that becomes progressively dehydrated and contracts (syneresis). Inside clayish materials Ethyl Silicate is known to create silica bridges between the individual plates, inducing a kind of polymerization of the clay that sharply reduces swelling in the presence of water and completely inhibits dispersion of the clay in water.

The solution applied contains Hydrochloric acid and is diluted with 96% commercial Ethenol; no water is added, since the alcohol and the mud-bricks contain enough to carry out the hydrolysis (experiments with the addition of water yielded inferior results). The typical formulation of Ethyl Silicate for spraying is:

Ethyl Silicate 40	66.6% (vol.)
Ethanol 96% Commercial	32.6% (vol.)
Concentrated Hydrochloric Acid	0.8% (vol.)

For spraying the solution is diluted 1:1 (volume) with 96% Commercial Ethanol. The treatment is rather expensive because about two litres per square metre of surface are required to form a weather resistant layer of sufficient consistency (1971 cost of Ethyl Silicate 40 was 55¢ per pound, in 500 lb. drums).

Ethyl Silicate 40 Cont'd.

Soon after the solution is applied, selica gel is formed in the surface layer of the wall, and it becomes inaccessible to further penetration by any liquid. However, some days after treatment the syneresis process sets in, reinstating porosity in the crust. A second treatment at this stage is required and is most beneficial.

Experiments of Ethyl Silicate 40 on horizontal surfaces resulted in failures, the thin crust being insufficient to bear the erosive action of heavy raindrops and streaming rain-water. However, the treatment was successful on vertical surfaces. Treatment for horizontal surfaces were best protected by soil-cement capping, mostly with brick. When symptoms of detachment appear (cracks, hollow sound of the surface, fall of some pieces) it might be counteracted by injection of suitable liquids behind the crust. Synthetic Polymer emulsions may be used for this application. Since Ethyl Silicate is unable to bridge even the smallest gap, it cannot be used to fill cracks or restore adhesion when a surface layer is already half detached from the wall. A Polyvinyl Acetate emulsion, diluted with water and mixed with some soil up to the required consistency, have proved to be quite satisfactory cements.

PORTLAND CEMENT CONCRETE AND MORTARS

Taken from the National Park Service Handbook of Ruins Stabilization

Description: Concrete does have the ability to resist weathering; however concrete or mortar are not particularly water-resistant. Even good concrete will absorb up to 20% of its weight in water. This moisture absorption accounts for the fact that ordinary concrete used in the bases of walls or as foundations will not prevent the capillary rise of moisture into the wall above. Concrete can be colored by the addition of dry mortar colors or by stains. Concrete will shrink slightly when setting and can be increased by a high water-cement ration and too rapid curing.

There are ways to waterproof concrete for use as a method of stabilization.

1. Use of special waterproof cements which contain a waterproofing agent, tannin, added at the time of manufacture.

2. Addition, at the time of mixing, of Hydrated Lime, or waterproofing compounds such as Emulsified Asphalts.

3. Rich mixtures used for concrete not intended to retain water, plus smaller amounts of mixing water. (Restricting the mixing water will result in a much denser concrete.) The longer concrete is moist cured, the more dense and water-resistant it will be.

The strength of concrete or cement mortar is affected by a number of factors, especially the ratio of aggregate to cement, ratio of water to cement, length of mixing, gradation of the aggregate, and length of moist curing. The amount of water to cement is the most important and critical part.

Portland Cement Concrete and Mortars Cont'd.

Exposure	Ratio
Extreme. Severe northern climate, alternate freezing and thawing wetting and drying.	5½ gal. water per sack
Severe, Northern climate, rain and snow, freezing and thawing but not in constant contact with water.	6 gallons per sack.
Moderate. Southern U.S. ordinary weather but not continuously in contact with water unless completely submerged and protected from freezing.	6 3/4 gal. per sack.
Protected. Enclosed structural members, concrete below ground not subject to freezing.	7½ gal. per sack

SOIL-CEMENT MORTARS

Taken from the National Park Service <u>Handbook for Ruins Stabilization</u>

<u>Description:</u> Soil-cement is a mixture of portland cement with a suitable local soil brought to a workable consistency by the addition of water. The amount of cement varies from 5%-20% by volume of the finished product. To obtain a soil color certain selections of dark soils can be mixed into the cement. In most cases, mortar or cement colors are used to obtain the soil color.

Soil-cement is not particularly moisture resistant; no more than concrete or cement mortars. Soil-cement is not recommended as a mortar in setting stone unless its use is unavoidable In this case, the cement content must be high, 15%-20% to insure adequate bonding. The more sandy soils should be used.

Because soil-cement has a good texture, it is best used where large amounts of mortar are exposed, especially where facing is not replaced.

Before applying soil cement it is recommended to test the mixture by standard ASTM wet-dry and freeze-thaw tests (Reference Appendix B). The following information on cement requirements is suggested as a basis for conducting field tests of soil-cement mixtures.

Sandy Soil. Well graded-8, 10, and 12% cement will harden 79% of these soils. A few will require cement volumes of 19% or over. Coarse, little binder-12 and 14% cement will harden 73% of these soils. A few will require up to 18% cement.

Soil-Cement Mortars Cont'd.

Silt soils. 12, 14, and 16% cement will harden 69% of these soils, while 28% will require 18% or over.

Clay soils. 14, 16, and 18% cement is required to harden most of these soils, while a few will need cement contents as high as 21%.

In the proportional requirements a definite trend is observable for the cement requirements to increase as the silt and clay content of soil rises. Heavier clay soils not only require heavier cement contents, but are harder to handle, and should be avoided.

Soil-cement cannot be handled to any advantage unless it is in a plastic consistency. It should not be thinned with water to the point where it can be "buttered" on when used as a mortar, but should be plastic enough so that when the brick is set and tapped into place, the mortar will flow to meet any inequalities in the surface of the brick. The weakest part of this solution is the bond. It takes at least seven days of damp curing for soil-cement to set. Keep it damp under sacks or other covering until cured.

SOIL SEAL CONCENTRATE

Firm: Soil Seal Corporation
3720 West 6th Street
Los Angeles, California, 90005

Description: Soil Seal is an emulsion of balanced copolymers (a water miscible methacrylate). Soil Seal is at best added to clay or mud to stabilize adobe. It may be applied to the outside of an adobe wall as a covering.

Tests: Tested at Pecos National Monument, New Mexico, soil seal showed to work adequately. Under the capillary test, soil seal bricks absorbed water rapidly as much as 1 3/8" rise in the brick. Even though absorbing the water, the base remained square with no sign of erosion. When exposed to spray testing the surface eroded some with complete penetration of water into the brick. When the Soil Seal bricks were set aside to dry, they dried quicker than other solutions tested (12 hours, as opposed to 24 hours).

APPENDIX B. STANDARD TESTING

WET-DRY TESTING (ASTM DESIGNATION D-559-44)

Cylinders of cement mixtures are first formed and are moist cured for seven days after molding. Wet-dry tests are then run on each test cylinder of varying cement mixtures. Each cement cylinder is then placed under water at room temperature for five hours. Note any immediate disintegration while under water. Then if none, the cylinders are dried for 42 hours. This completes one cycle. The cycle is then repeated (twelve cycles are considered a complete test). It is required that each cylinder be wire brushed at the end of each cycle, the cylinder weighed, and the cement loss (if any) computed.

FREEZE-THAW TESTING (ASTM DESIGNATION D-560-44)

In freeze-thaw testing cylinders of various cement mixtures are formed, and cured in the same manner as those used in wet-dry testing. After curing, the cement cylinders are placed on absorptive pads which extend into a pan of water. Thus the cylinders will have a constant supply of moisture. The cylinders are required to be frozen for 22 hours at $-10^{o}F$. After freezing, the cylinders are then thawed for a required 22 hours. This completes one cycle (twelve cycles are considered a complete test). At this point any failure in the cement cylinders should be noticeable.

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