NATIONAL PARK SERVICE

HANDBOOK

PREHISTORIC RUINS STABILIZATION HANDBOOK
Part 2 - Field Methods

RELEASE NO. 1
May 3, 1962

The enclosed material is a revised version of the material on Ruins Stabilization formerly issued as Volume 23 of the old Administrative Manual.

This portion, Part 2, has received priority over Part 1 since it contains needed information on some of the later experiments with stabilization materials, techniques, and methods of recordation. It will be of immediate aid to crews in the field who must deal firsthand with stabilization problems.

Part 1, dealing with history, policies, and definitions, will be released at a later date. This will then complete the valuable information providing guidance on ruins stabilization which has been compiled by Mr. Roland Richert and Mr. Gordon Vivian.

A copy of this Handbook is being sent to each park and office. Additional copies may be obtained by indicating your need on the tear-off portion of this transmittal sheet and sending it to the Washington Office. Please limit your request to the number of copies currently required.

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HANDBOOK for RUINS STABILIZATION

Part 2
Field Methods

UNITED STATES DEPARTMENT OF THE INTERIOR

NATIONAL PARK SERVICE

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INTRODUCTION

The Problem

The problem of stabilizing and maintaining prehistoric sites is one that has almost as many ramifications as there are individual structures. Of necessity, this Handbook, originated and written in Region Three, is concerned in the main with prehistoric masonry structures, and to a lesser extent with monolithic soil structures.

From the standpoint, then, of Southwestern archeological structures, it seems of value first to examine their structural faults and inherent weaknesses, and second to look briefly into the forces that have contributed to their deterioration. Some understanding of these faults and forces is necessary before effective measures can be taken to counteract them.

A difficult aspect of the problem is that anyone who sets out to stabilize almost any prehistoric structure will find that he has two conflicting objectives to satisfy. The first of these is authenticity--the preservation of irregular and relatively primitive construction--and the second is permanence, the requirements of sound building practice.

Structural Faults. The prehistoric mason was, for his day no doubt, a progressive architect and builder. The Anasazi progressed in a short span of 300 years--10 or 12 generations--from pit houses to multistoried buildings of 400 and 500 rooms. Yet in each period and area, he followed a rather set pattern of plan and construction circumscribed by the limitations of local materials. Any village was at any one time an acretion of ruined, decaying, remodeled, and new units. Rooms were often built on the partially razed wall of older structures, on loose fill, and often foundations were narrower than the walls they supported. Walls were normally not bonded at corners or other junctions.

The materials encountered in almost all possible combinations are:--abundant soil mortar with spalls stuck in the surface, soil mortar with unshaped or slightly shaped stone, facing where there is stone to stone contact, dry masonry, wattle-work, jacal and similar "pole and mud" construction. In structures of soil, the soil was always laid in a plastic condition--in thick courses at Casa Grande, in plastic loaves in "Turtleback" walls of "Pueblo I"

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sites, and in roughly squared plastic blocks in ruins on the Animas and at some late prehistoric Rio Grande pueblos.

In brief, the structural faults most commonly encountered, aside from the fact that only mud and stone and wood which was difficult to process, were used are: (Figs. 1,2,3)

1. No foundations.

2. Foundations narrower than the walls they support.

3. Construction over loose and unconsolidated fill.

4. Long spans over openings often supported by extremely small lintels.

5. Lack of bond at wall junctures.

6. Lack of headers or ties through walls, where there is more than one width of stone.

7. The incorporation of large horizontal wood beams in masonry walls.

8. The inclusion in walls, at ceiling height, of horizontal areas of bark, splints, rods, and other ceiling materials.

Natural Weathering. The breakdown of an abandoned structure follows a rather set pattern. First, there is the deposition on the floor of wind and water-borne material. This deposition continues until it is covered by collapse of the roofing and dislodged sections of wall. Once the roofing is gone, stability of walls is markedly weakened and the generally poor materials and faulty construction are particularly vulnerable to the elements. Moisture from snow and rain melt out the mud mortar; thin unbonded facing is separated by frost action; rotting of wood parts (beams, lintels, or ceiling inclusions) leaves overlying masonry unsupported; pressure from fallen material dislocates remaining walls, and the accumulation of debris ponds surface water leaving basal areas subject to moisture penetration and erosion.

Depending mainly on the type of construction and the location of the structure, these various forces proceed at different speeds.

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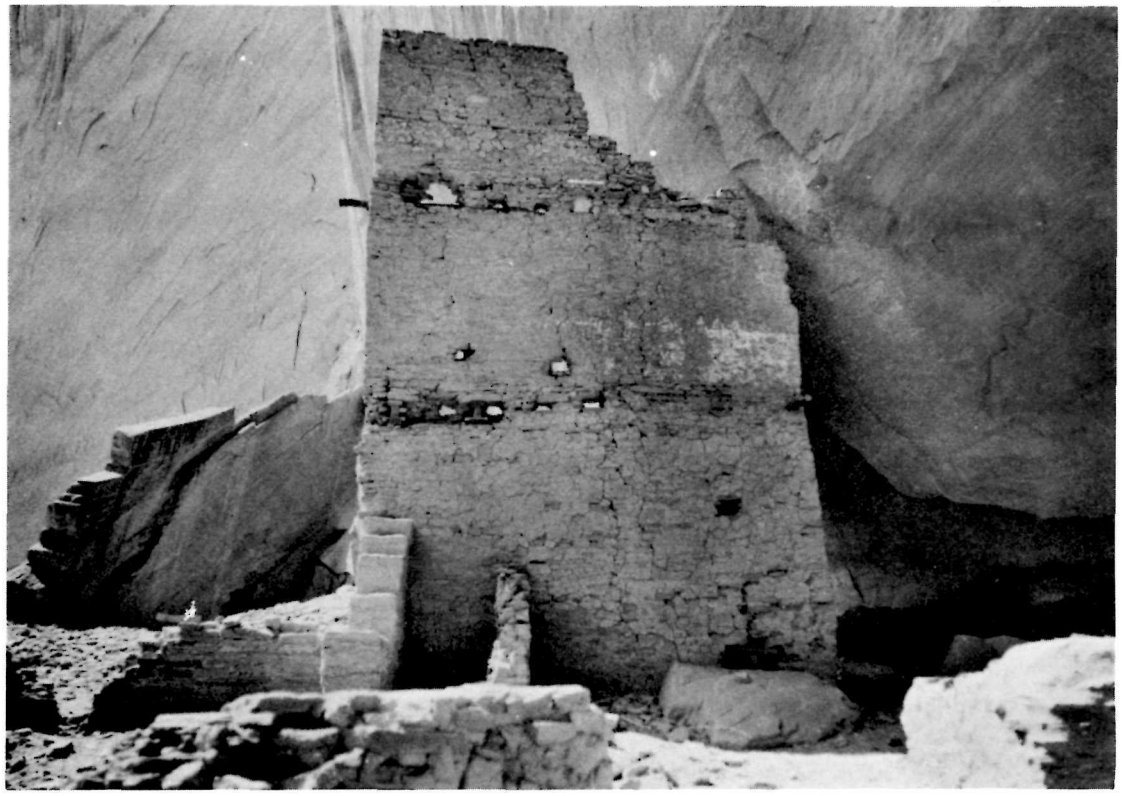

Fig. 1. Settling caused by lack of foundations and unstable fill. Bond between stone and soil mortar is poor. Holes are caused by decay or theft of wood members.

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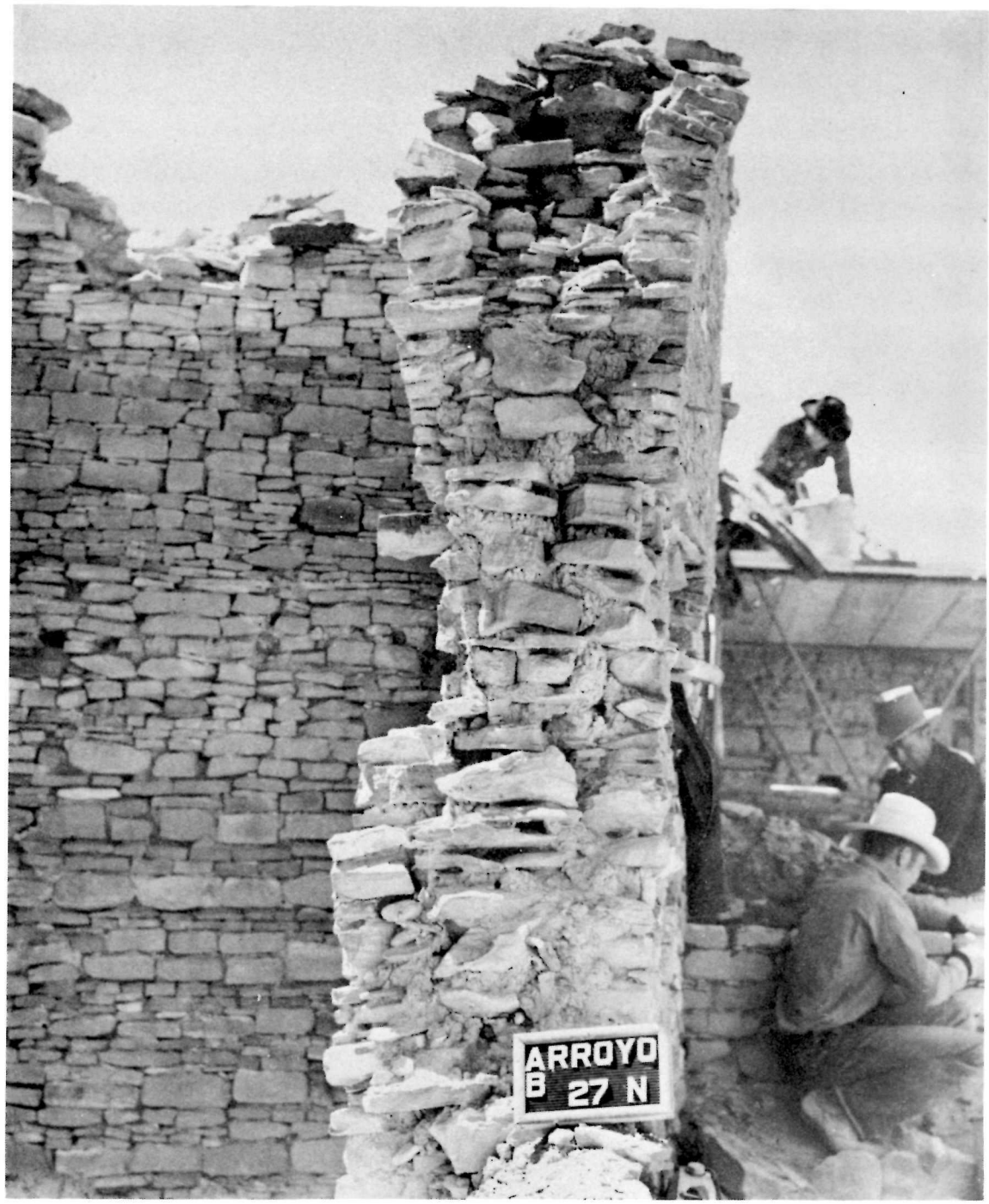

Fig. 2. Aboriginal construction often left narrow strips at ceiling line. This wall is much wider at the top than in the center.

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Fig. 3. The inclusion of heavy timbers within cored-type walls was a usual practice of prehistoric builders. Collapse of walls from flood damage exposed 300 logs, similar to those above, in one area of Chettro Kettle.

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In small open units, usually thin-walled, the downward erosion of natural forces is most rapid and large areas of collapsed wall are rarely found.

Within large sites of heavy construction and in protected sites, this downward erosion is less rapid; here collapsed sections of large wall area are more often encountered, due to horizontal erosion at base and ceiling lines, and decay of wood members.

The action of natural forces outside the structure also has an important bearing on its preservation. Weathering of soft sandstone outcrops on which pueblo ruins stand, and of wall bases, has become serious at Hovenweep and in sections of Wupatki. Important sites in caves are being damaged at Navajo and Canyon de Chelly National Monuments due to removal of supporting fill and portions of the bedrock by wind and stream action. Within historic times, about 75% of one 40-room site in Chaco Canyon has been lost to arroyo-cutting.

As opposed to erosion, finally, the deposition of wind and water-borne materials adjacent to sites can alter the topography sufficiently to destroy natural drainage and cause flooding.

Human Disturbance. Vandalism of unprotected sites is well known; and it was often a larger factor in the destruction of prehistoric buildings than is generally supposed. In the first place, the inhabitants themselves periodically tore down old houses in order to reuse the timbers and building stone. Judd notes prehistoric vandalism at Pueblo Bonito, at a time following its abandonment, by groups seeking precious objects of turquoise, jet, and shell. Similar plundering and salvaging continued into the historic period. Early settlers in the Chaco speak of the Navajo removing wagonloads of timbers from Chettro Kettle for firewood. These same settlers did so themselves, and also utilized building stone from the Chaco Canyon ruins.

The most well-intentioned, carefully-planned, and systematically executed archeological excavation, however scientific, is also likely to create difficult preservation problems. (Figs. 4,5.)

The principal cause of destruction resulting from excavation is the fact that the work generally neither proceeds nor ends upon a single plane. This leaves the site partially filled at many

The Problem (con.)

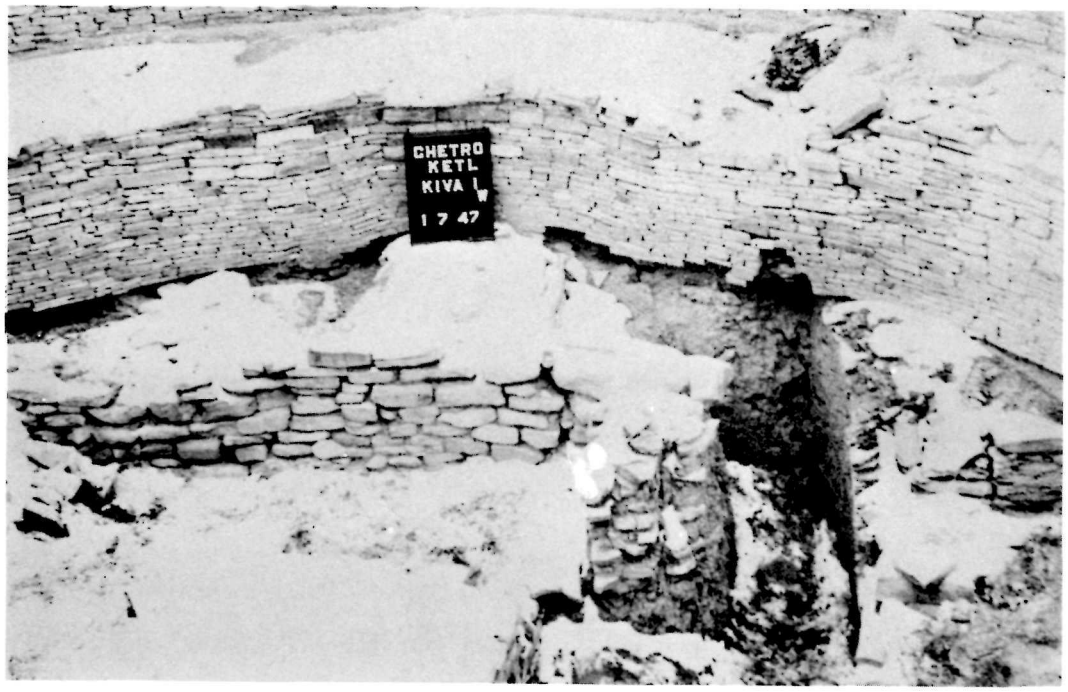

Fig. 4. Excavation neither proceeds nor ends on a single plane and often leaves walls unsupported.

Fig. 5. Clearing of depressed areas leaves them open to surface runoff and rapid destruction.

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different levels. Water collects in an area of two or three rooms, and cuts its way to lower levels. Deeply-excavated portions are subject to the pressure of damp fill. The loose, moisture-absorbing fill in rooms transfers moisture to concealed walls and diminishes the strength of adobe mortar. In a site of any complexity, burrowing and tunneling are particularly destructive, even when backfilled, since the backfill is never compacted to the density of the removed materials.

No matter what condition standing walls are found in, it must be remembered that the entire depth of the wall is seldom exposed and that the exposed portions--which form a base over which the stabilization is being done--have in the past been subject to nearly all the forces listed above: surface weathering, construction over loose fill or partial walls, breakdown or theft of wood members, erosion at the base, buckling from pressure, excavation and backfill.

MATERIALS

Portland Cement Concrete and Mortars

Durability. Properly made and placed in thick sections, or in thinner sections upon an unyielding material, concrete has great resistance to weathering.

Compressive Strength. Up-to-date mixes of portland cement concretes give compression strengths of 4,000 to 6,000 pounds per square inch, and mortar strengths (concrete without the coarse aggregate) of 3,000 to 4,000 pounds per square inch. These strengths are far in excess of any compressive strains that will be encountered in ruins stabilizations.

Color. Concrete can be colored almost any desired tint, either by the addition of dry mortar colors or by stains.

Texture. While various textures from glass smooth to rough can be obtained with concrete, it is practically impossible, due to the size of the sand grains, to match a soil mortar texture.

Shrinkage. Concrete shrinks slightly upon setting. This shrinkage is increased slightly by a high water-cement ratio and by too rapid curing.

Tensile Strength. The tensile strength of concrete is very low. It is a very brittle material, which is something that is generally not realized or often ignored. Specifications for tensile strengths of mortars (portland cement and sand, as would be used in setting stone) call for strengths of from 275 to 350 pounds per square inch. As one authority, Bauer, says, "The question is frequently raised as to the value of a tension test when the concrete rarely ever is considered as having any tensile strength." Lack of tensile strength is the cause of most concrete failures, particularly the cracking of very thin capping.

Resistance to Moisture. Ordinary concrete or mortar is 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. In ordinary commercial work, waterproofing of concrete is accomplished in various ways:

Portland Cement Concrete and Mortars (con.)

1. By the use of special waterproof cements. These have a waterproofing agent, usually tannin, added at the time of manufacture.

2. The addition, at the time of mixing, of hydrated lime or waterproofing compounds such as emulsified asphalts.

3. Richer mixes than 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.

In most commercial work, however, concrete or mortar that must be waterproof is treated after laying. Basement walls are protected by porous fill and drains and then mopped with hot asphalt or painted with various materials intended to seal the exterior surface. The tops of masonry walls (stone, brick, tile, cinder blocks, etc.) laid in concrete mortars are either coated with asphalt or covered with asphalt-impregnated cloth or paper, or with a combination of these methods.

With these restrictions, then, the waterproofing of concrete and mortar for stabilization is practically confined to the addition at the time of mixing of waterproofing compounds such as emulsified asphalts, or by the use of special waterproof cements.

Field Control of Concrete and Mortar. The design of concrete mixes or the drawing of specifications for cement and aggregates is properly a function of the Division of Engineering. For any work involving the extensive use of concrete, that Division should be consulted for the proper specifications. However, the following data on proportions and mixes are supplied for the field man who may not have technical assistance readily available for minor jobs.

The strength of concrete or cement mortar is affected by a number of factors. Among these are: the ratio of aggregate to cement, ratio of water to cement, length of mixing, gradation of the aggregate, and length of moist curing.

Of all these factors, the relation of the water to the cement is most important. Few supervisors and no workmen believe this. Figure 6, following, strength curves for various water-cement ratios, should be examined as it shows graphically the rapid loss of strength as the ratio of water to cement increases.

Portland Cement Concrete and Mortars (con.)

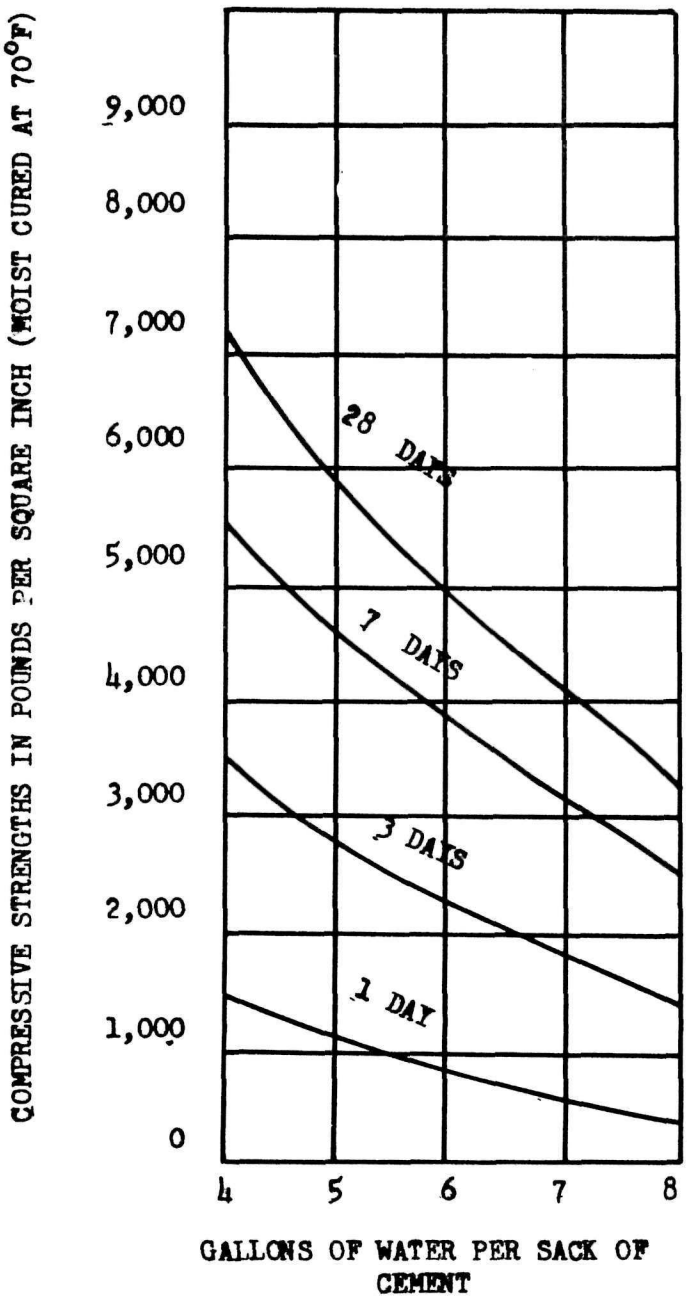


Fig. 6. Data from Design and Control of Cement Mixtures, Portland Cement Association.

Portland Cement Concrete and Mortars (con.)

In most specifications the water-cement ratio is the controlling factor in the design. The following table is taken from a handbook, The Design and Control of Concrete Mixtures, issued by the Portland Cement Association, and is for the construction of concrete piles, thin walls, light structural members, exterior beams and columns:

Exposure	Ratio
Extreme. Severe northern climate, alternate freezing and thawing, wetting and drying.	5-1/2 gal. water per sack.
Severe. Northern climate, rain and snow, freezing and thawing but not in constant contact with water.	6 gal. 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.	7-1/2 gal. per sack.

Trial Mixes. Trial mixes may be easily made in the field to determine proportions of sand and cement to use with any given water-cement ratio chosen for the strength required. Materials are used from a weighed or known quantity of aggregate, and when a suitable mix has been obtained, the unused material is weighed or measured and the quantity required for the mix is determined. To conduct a trial mix, a set of scales and a measure or box of 1/10 cubic foot are needed.

Concrete or mortar employed in stabilization will be laid in thin sections and often exposed to extreme weather, but it will not be in constant contact with water. A ratio of 6 gallons of water to the sack is chosen. Following is an outline for preparation of trial mixes:

A sack of cement weighs 94 pounds and has a volume of 1 cubic foot.

Portland Cement Concrete and Mortars (con.)

Fill the 1/10 cubic foot measure with cement. The cement should weigh 9.4 pounds.

Measure out, say 4 volumes of sand and weigh them. In this example call the weight 32 pounds.

Six gallons of water to the sack would be 6x8.33 or 49.98 pounds of water for a whole sack. Water required for 1/10 sack is 4.998 or 5 pounds.

Mix the 5 pounds of water with the 1 volume of cement (1/10 cubic foot or 9.4 pounds). The water-cement ratio for the mix is now established and no more water should be added.

To this mix add some of the 32 pounds of sand measured out. Continue to add sand until a workable mix is obtained.

After a workable mix has been arrived at, weigh and measure the sand that remains of the original 4 volumes or 32 pounds.

If the sand remaining measures 1-1/4 volumes, the mix used, at 6 gallons of water to the sack was, by volume, cement 1 part, sand 2-3/4 parts.

If the weight of the remaining sand is, say 10 pounds, the mix was 1 part cement to 2-2/3 parts sand by weight.

With this ratio established, larger mixes may be made, always based on a portion of a sack of cement.

For 1/3rd of a sack of cement mix (a convenient size to use in the smaller mixers):

Cement . .	1/3 sack
Water. . .	2 gallons
Sand . . .	9/10 cubic foot (at 1 part cement to 2-3/4 parts sand by volume).

Masonry Cements

Masonry cement is a combination of portland cement and hydrated lime, usually in proportions of 1 to 1, packaged in 1 cubic foot bags weighing from 65 to 80 pounds.

Masonry Cements (con.)

Characteristics. In commercial work, setting brick, tile, masonry blocks, etc., masonry cements have more widespread use than straight portland cement mortars. The major reason for this extensive use is that mortars containing lime are much more "workable" than portland cement mortars. They are easier to handle and they trowel much better. Further, masonry cement is cheaper than portland cement. However, masonry cements are not as strong as portland cement mortars in either tension or compression. They are much less resistant to abrasion and should not be employed in capping or sections that may receive some visitor traffic.

Masonry cements may be colored with dry mortar colors in the same manner as portland cements.

Evaluation. The principal objection to using masonry cements in capping is their lack of resistance to moisture penetration. Since manufacturers of waterproofing materials do not recommend using their products in lime-cement mortars, there seems to be no way to overcome this fault. Lime-mortar cements are not, then, recommended for capping.

However, due to their other good characteristics as well as their slightly lower cost, these mortars should prove of value in the setting of large patches where very slight shrinkage and good bond with stone are needed.

Field Control. Mixes of lime-cement mortars are usually made by volume and not on a water-cement ratio. Most common mixes call for 1 part masonry cement to 2 to 3 parts fine sand, with sufficient water to make a workable mortar.

Soil-Cement Mortars

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% to 20% by volume of the finished product. (Fig. 7).

The primary reasons for employing soil-cement in lieu of other mortars in stabilization work are (1) cost, (2) the extreme difficulty in obtaining concrete sand in some locations where it would have to be packed in, (3) appearance, in some special applications, (4) suitability in monolithic soil structures.

Soil-Cement Mortars (con.)

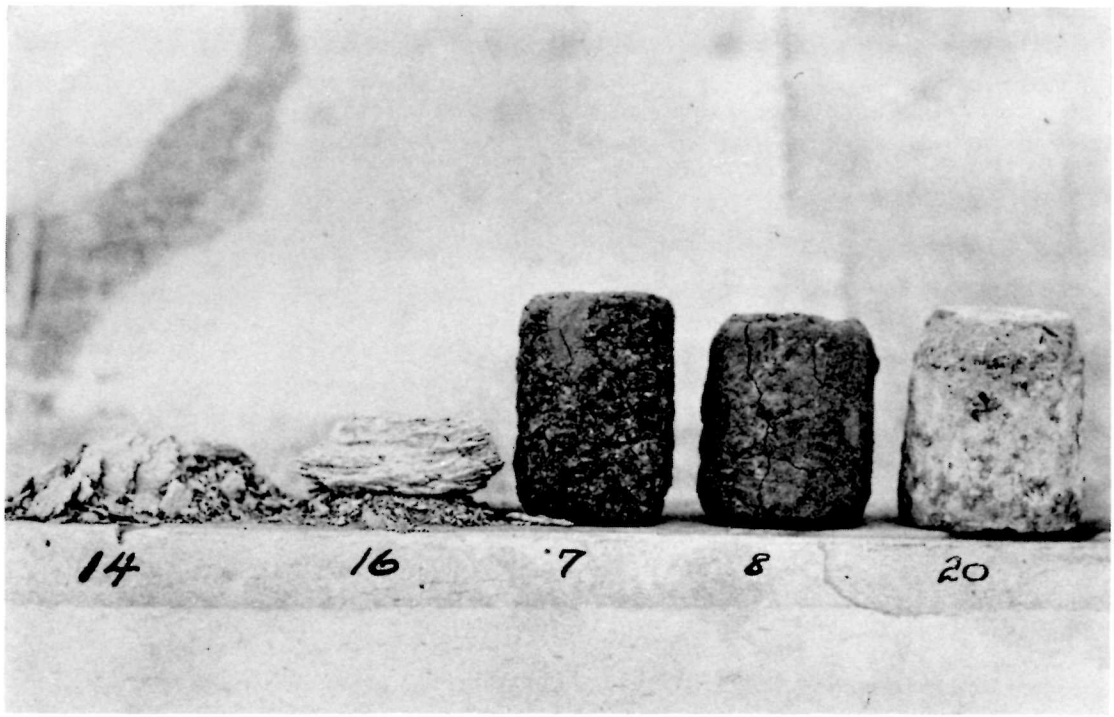


Fig. 7. Freeze-Thaw Test Results: Illustrated are cylinders used in conducting the freeze-thaw test. Cylinder No. 14, made up of equal parts of clay and silt-loam with 10% cement by volume, failed at the third cycle, as did Cylinder No. 16, which had 12% cement by volume. Cylinder No. 20, with 15% cement by volume, is shown at the twelfth cycle. Cylinders Nos. 7 and 8, consisting of three parts clay, two parts silt-loam, and emulsified bitumen were tested in conjunction with the soil-cement tests, and are shown at the fifteenth cycle.

Soil-Cement Mortars (con.)

It is difficult to compare soil-cement intended for ruins stabilization with the same material in its various commercial applications. Soil-cement used for roads, airport runways and hard standings, ditch linings, etc., is always laid fairly dry (at optimum moisture) and is heavily compacted. The compactive effort here is equivalent to the force exerted by a 5-1/2 pound tamper being dropped a distance of 12" 75 times upon 1/30th of a cubic foot of the material. Obviously, these requirements of moisture and compaction cannot be obtained when laying mortar.

All material published on soil-cement is directed toward these commercial applications, and there is no known research on its use as a mortar.

Durability. The first tests of soil-cement made expressly for stabilization purposes were those conducted by A.E. Buchenberg between December 1941 and May 1946. (Buchenberg, December 1951.) These tests were carried on at Wupatki National Monument, and were simply outdoor exposure tests made on 6x10x3/4" briquetts of the mortar.

It should be noted (1) that they were made on mortar samples only and did not include samples of masonry laid with this material, and (2) that the briquetts were made in a semi-compacted state--a condition that is not possible to obtain when laying mortar.

At the conclusion of the 4-1/4-year test period, Mr. Buchenberg found the material to be satisfactory. "A mixture of soil and cement stands up very well under exposure to climatic conditions, with an approximate admixture of from 15% to 20% cement..." (Buchenberg, May 1946.)

Later, a series of tests was carried on at Chaco Canyon to determine (1) the durability of soil-cement mixtures under conditions of wetting and drying, and freezing and thawing, (2) the strength of the bond between mortar and stone under the same conditions.

Of the soils used in the tests, only two general types were available for use in stabilization work in the area. One type, classed as Soil A in the notes, is a heavy, dark-colored and

Soil-Cement Mortars (con.)

poorly drained clay, 64% combined silt and clay. It appears to fall into USBPR Class A-6, A-7. The other, classed as Soil B, is a silt loam, rather fine, poorly graded, combined silt and clay 18%; probably USBPR Class A-5. Both of these were tested singly and in combination.

In these tests the mixes at varying cement contents were made above optimum moisture at a consistency which could be troweled.

The wet-dry tests were run on molded cylinders of soil-cement approximately 1/30 cubic foot in volume. Test cylinders were moist cured 7 days after molding.

Each soil-cement cylinder was placed under water at room temperature for 5 hours. It was then dried for 42 hours. This completed one cycle. The cycle was then repeated. Twelve cycles are considered a complete test. The cylinders in question though were run through 22 cycles.

Standard wet-dry tests for soil-cement as required by the American Society for Testing Materials (ASTM Designation D-559-44) require that each cylinder be wire brushed at the end of each cycle, the cylinder weighed, and the soil-cement loss computed. Lack of suitable balances prevented the completion of this part of the test.

In the freeze-thaw test the same kind of cylinders, cured the same length of time, were used. After curing, the soil-cement cylinders were placed on absorptive pads which extended into a pan of water. Thus the soil-cement had a constant supply of moisture and there was no limit to the amount available for absorption. Soil-cement, and portland cement too, will absorb large quantities of moisture (up to 20%) and it is useless to try a freeze-thaw test without making moisture available.

Standard procedures (ASTM Designation D-560-44) require that the cylinders be frozen for 22 hours at -10°F. This temperature requirement could not be followed in the field. No freezing cabinet was available so the cylinders were frozen outdoors at temperatures down to -24°F. After freezing, the cylinders were thawed the required 22 hours. This completed one cycle.

Soil-Cement Mortars (con.)

No standard tests for bond were known to determine the strength of the bond between rock and mortar, so the following was devised in the field:

After the wet-dry and freeze-thaw cylinders were made, two average sized rocks were dampened, the mortar spread roughly on one, and the second rock tapped lightly into place. Thickness of the mortar between the rocks averaged 3/8". These were cured for 7 days.

These mortar specimens were tested for resistance to wetting and drying, along with, and in the same manner as, the cylinders for 6 cycles. The freeze-thaw test on cylinders was being run at the same time.

It was found then, after the tests had started, that this soil-cement had far better resistance to wetting and drying than it had to freezing and thawing. So at this point, the wet-dry test on mortar was stopped and the rock samples with mortar between were transferred to the freeze-thaw test. Thus all the mortar samples passed 6 cycles of wet-dry before undergoing the freeze-thaw.

To conduct the test, the rock samples were placed on edge on the absorptive pads so moisture would be available to the mortar. Following is a tabulation of 10 of these tests and some observed results and evaluations.

Soil-Cement Tests

Cylinder Number	Soil	Percent Cement by Volume	Freeze-thaw	Wet-Dry	Bond (Freeze-Thaw)
14	A-1		failed	passed	
15	B-1	10	3rd cycle	22 cycles	
16	A-1		failed	passed	
17	B-1		3rd cycle	22 cycles	
20	A-1				
21	B-1	15	passed	passed	failed at
22			12 cycles	22 cycles	3 cycles

Notes: 20, 21, 22 - Cylinder absorbs moisture rapidly.

Soil-Cement Mortars (con.)

Soil-Cement Tests (con.)

Cylinder Number	Soil	Percent Cement by Volume	Freeze-thaw	Wet-Dry	Bond (Freeze-Thaw)
23 24 25	A-1 B-1+	12+ bitumen	passed 12 cycles	passed 22 cycles	failed at 6 cycles
26 27 28	A-2 B-3	14+ bitumen	passed 12 cycles	passed 22 cycles	failed at 6 cycles
29 30 31	A-1 B-2	14+ bitumen	passed 12 cycles	passed 22 cycles	failed at 6 cycles
32 33 34	A-1 B-3	14	passed 12 cycles	passed 22 cycles	failed at 6 cycles
35 36 37	A-1 B-3	20	passed 12 cycles	passed 22 cycles	failed at 6 cycles
45 46 47	B-100%	16	passed 12 cycles	passed 22 cycles	failed at 6 cycles
54 55 56	B-1 sand 1 (concrete sand)	16	passed 12 cycles	passed 22 cycles	passed 12 cycles

Notes: 23, 24, 25 - Rather heavy salt (?) deposit on cylinder.
26, 27, 28 - In spite of failure of bond the mortar remains hard. Salt (?) deposit.
29, 30, 31 - Absorbs moisture rapidly.
35, 36, 37 - Mortar hard.

Soil-Cement Mortars (con.)

1. Mixes of straight Soil A, adobe, were very hard to work and tended to crack. They were disregarded and do not appear in the tabulation of results.

2. As little as 10% cement by volume gave satisfactory resistance to wetting and drying. All cylinder samples at or above 10% cement passed 22 cycles without failure, and 6 cycles without destroying the bond between rock and mortar.

3. Cement contents for cylinder samples had to be at least 14% to resist the action of repeated freezing and thawing. Cylinders at cement contents less than 14% disintegrated at the third cycle. (Observation of the cylinders undergoing test indicates that no amount of cement will prevent the soil-cement from absorbing moisture either under F-T or W-D conditions. It is simply that the cement strength must be high enough to resist the force of freezing after the moisture has entered the specimen. Moisture rise in a cylinder 4" high was 2" to 3". When cylinders failed under freezing, there was not a gradual wearing away of the exterior, but rather a breaking up of the whole area that had absorbed moisture.)

4. Freeze-thaw tests on the bond were far more severe than either F-T or W-D tests on cylinders. Thus the fact that samples pass a freeze-thaw test is no guarantee that they will retain a strong bond with stone when subjected to weathering. This failure is probably attributable to the fact that some of the moisture entering the soil-cement is free to be absorbed by clay particles which causes the entire mass to expand and it is this expansive force that breaks the bond.

Note samples 54, 55, and 56. Here Soil B, which contains only 18% combined silt and clay was mixed with equal proportions of concrete sand. These samples had the greatest resistance to the F-T test on mortar bond. They still absorbed moisture, but it caused no appreciable weakening of the bond. The clay content here was reduced to 9% which evidently is low enough to prevent much change in the volume of the mass upon repeated freezing and thawing.

5. Mixes containing large amounts of clay were less stable than those with less clay and more sand. Twenty percent cement with clay gave no more strength than 14% with a lower clay content.

Soil-Cement Mortars (con.)

6. In all cases where the bond failed, the edges of the mortar remained hard and sharp. Failure of the bond does not necessarily mean that the soil-cement has disintegrated.

7. The addition of a bitumen to samples 23 to 31 demonstrated that bitumens do not increase the moisture resistance of soil-cements and compound the problem of tinting them.

Compressive and Tensile Strengths. Soil-cement is usually tested by its reaction to the wet-dry and freeze-thaw tests, and seldom by compression. No tests for tension have been found. Recorded compression tests indicate 28-day strengths of from 200 to 1,078 pounds per square inch. This is considerably less compressive strength than is developed by concrete mortar, but under all normal circumstances is sufficient.

Color. Buchenberg at Wupatki was able, by carefully selecting dark red soils there, to make a suitable mix without the addition of mortar color. However, in most areas the addition of standard mortar or cement colors will be required to obtain the proper tint.

Texture. The texture of soil-cement is good. It more nearly matches the texture of prehistoric mortar than does either cement or lime-cement mortars.

Moisture Resistance. Soil-cement is not particularly moisture resistant; no more so than concrete or cement mortars. In the cylinders tested, there was a moisture rise of from 2" to 3" in cylinders 4" high. It is the strength of the cement in the mix that prevents disintegration with such high moisture absorption.

Evaluation. Soil-cement is not recommended as a mortar in setting stone unless its use is unavoidable in remote areas. In this event the cement content must be unusually high, 15% to 20% to insure the best possible bond. The more sandy soils should be selected.

Because of its good texture, soil-cement is particularly adapted to applications where large amounts of mortar must be left exposed; these include heavy grouting of exposed longitudinal sections where facing is not replaced. (Figs. 8, 9.)

Soil-Cement Mortars (con.)

Fig. 8. Heavy grouting replacing native soil, between random stone exposed in longitudinal section after 10 years exposure.

Fig. 9. Soil-cement in heavy cross section is suitable for repairs to slab-house walls.

Soil-Cement Mortars (con.)

Soil-cement is particularly suited to large repair sections in monolithic soil structures and it is also valuable in stabilizing the sides or ends of cuts in excavations which must be left open for interpretive purposes. (Fig. 10.)

Procedures for making optimum moisture and density tests for determination of cement requirements are not reproduced here as they require equipment and data not generally available in field areas. Detailed instructions may be found in Soil Cement Mixtures, Laboratory Handbook, The Portland Cement Association; Testing and Construction Criteria For Soil-Cement For Highway Ditch Linings, Levee Faces and Similar Structures, The Portland Cement Association; and Manual on Sampling and Testing for Construction Control, Airport Paving, Roads and Streets, U.S. Corps of Engineers.

Field Control of Soil-Cement. In general practice, the cement contents for soil-cement must be based on the percent of cement by volume to the volume of the completed product. It is also standard practice to make trial cylinders of the mix at varying cement contents, and with several available soils, subjecting these test cylinders to standard ASTM wet-dry and freeze-thaw tests before establishing a mix for any particular job.

The following information on cement requirements is suggested as a basis for conducting field tests of soil-cement mixtures. Any tests should be made well in advance of actual work.

(1) 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 may require up to 18% cement.

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

(3) 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 the soil rises. Heavier clay soils not only require higher cement

Soil-Cement Mortars (con.)

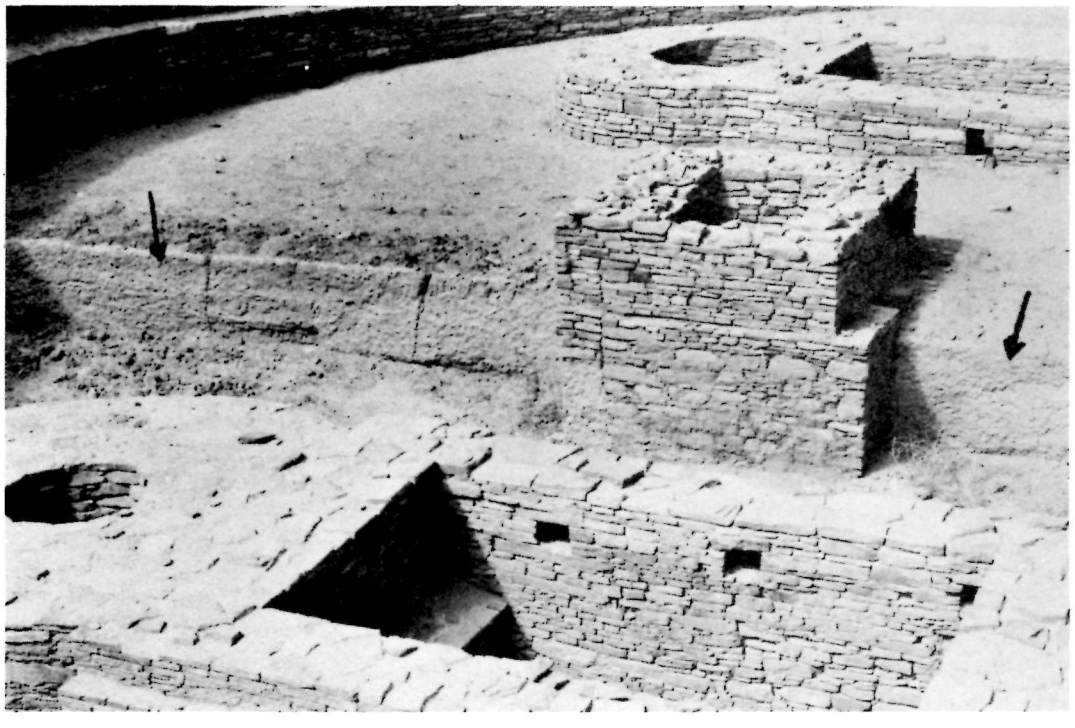


Fig. 10. Formed soil-cement is particularly adapted for retaining sections of fill which must be stabilized to show portions of structures on varying levels.

Soil-Cement Mortars (con.)

contents, but are much harder to handle and place than are the lighter and more sandy soils; they should be avoided if at all possible.

Treatment-Curing. Soil-cement may be mixed by hand for small jobs or in a standard plaster mixer with rotating blades. It is difficult to handle in a drum type mixer.

Soil-cement cannot be handled to any advantage unless it is in a plastic consistency. It should be plastic from the start to keep the workmen from adding uncontrolled amounts of water. It need not be so thin as to be "buttered" on when used as a mortar, but should be plastic enough so that when the stone is set and tapped into place the mortar will flow to meet the inequalities in the surface of the stone. The weakest part of such construction is the bond. The stone should be well dampened to aid the mortar in adhering and to prevent the stone from absorbing excess moisture from the mortar. It takes at least 7 days of damp curing for soil-cement to set--the same as with other cement mixes. The same precautions should be taken in curing soil-cement as are taken with portland or masonry cements. Keep it damp under wet earth, sacks, or other covering.

Soil-Bitumen Mortars

Soil-bitumen, or asphalt stabilized soil, is a mixture of emulsified asphalt and soil with sufficient mixing water for the purpose intended. Upon evaporation of the mixing water the soil particles are left covered with a thin film of bitumen. There is no chemical action involved, nor does the bitumen act as a binder, glue, or other cementing agent. In all soil-bitumen mixes, the strength of the resulting product is dependent solely upon the cohesive action or quality of the clay particles in the soil and upon nothing else.

In the commercial field the use of soil-bitumen has been limited to the manufacture of bricks for building construction. One point that is brought out in specifications for buildings of this type is that manufacturers of emulsified bitumens do not recommend the use of their product in mortar for setting stabilized bricks or adobes. They recommend only the use of a sand-concrete mortar without the addition of lime.

Soil-Bitumen Mortars (con.)

On the other hand, experiments conducted by the U. S. Office of Indian Affairs on stabilized adobes indicate that a soil-bitumen mortar, in the same proportions as used for adobes, may be successfully used in laying them. (Hubbell, p. 91.)

The first extensive use of soil-bitumen in ruins stabilization was by the C.C.C. Mobile Unit at Chaco Canyon National Monument beginning in 1937. Its use was dictated by funds quite limited in proportion to the number of man-days available for labor. Since the termination of that program, the use of soil-bitumen has been limited to small areas of plating, walkways and similar applications.

Durability. Properly made and laid soil-bitumen products are durable, as an examination of jobs at Pueblo Bonito, Wijiji, Kin Klizhin and Aztec ruins completed from 1937 to 1940, demonstrate. With a few exceptions which can be laid to poor technique, this work is standing up well. Its useful life without repairs is estimated at 25 years.

Where unsatisfactory results have occurred, often in applications not connected with stabilization--use as plaster, roof platings, thin walks, etc.--failure can be attributed to three primary causes: (1) a durable soil-bitumen mix cannot be made where the soil contains more than 2% of soluble salts. Lack of proper tests for salts resulted in several failures. (2) Improper amounts of bitumen, as an excess over that necessary to waterproof the clay particles in the soil, results in excessive shrinkage and a total lack of bond. (3) Improper applications, as in thin plating and roof coverings where it was presumed that the bitumen provided strength above that inherent in the soil. This is a mistaken assumption.

Failures of soil-bitumen in ruins stabilization are seen in these instances (1) where it was used in very thin "membrane capping". Failures were due to cracking and lack of bond, not loss of waterproofing. (2) Very thin vertical patches at the sides of doorways where there was lack of sufficient bond with the remaining wall. Some of these failures were also due to excessive use of bitumen in the mix. (3) Vertical sections and patches at corners in doorways, etc., which were subject to heavy visitor traffic.

The most satisfactory employment of soil-bitumen is seen in (1) heavy capping where 3 to 5 courses of masonry were relaid in

Soil-Bitumen Mortars (con.)

the mortar. It was most effective in thick core-type walls where there is an excess of mortar over stone (2) in areas of large patches (3) in repairs made to correct basal erosion in damp areas. Soil-bitumen mortars are far more moisture resistant than other types.

Evaluation. Present day uses of soil-bitumen are rather limited and no extensive data are presented here. Details on testing, strengths, water permeability, selection of soils, etc., can be found in Specifications, Bitudobe Brick and Building Conforming to Minimum Requirements Approved by Pacific Coast Building Officials Conference, (supplied by American Bitumuls Co., 200 Bush Street, San Francisco, California); Technical Paper No. 53, Hydropel Emulsified Asphalt, issued by the American Bitumuls Company; Bulletin BMS 78, Structural, Heat Transfer and Water Permeability Properties of Five Earth Wall Constructions, National Bureau of Standards, Washington, D.C.; and Interim Report on Experimental Ruin Stabilization at Wupatki National Monument, A. E. Buchenberg, ms., May 20, 1946.

The first requisite of soil for soil-bitumen mortars is that it contain not more than 2% soluble salts. If there is doubt in this matter, the soil should be tested by a competent laboratory, as the deleterious effects of the salts will not become apparent until some time after the mortar has been laid. If it is satisfactory in this respect, the next requirement is that it contain from 30 to 45% clay, or combined silt and clay, which will pass a 200-mesh screen. Should the only soils obtainable contain too large a percentage of clay, they may be tempered by the addition of sand.

To determine roughly the best proportions of bitumen to be added, test bricks can be made using from 4 to 8% of bitumen by weight. After a drying period of two weeks these bricks can be examined for shrinkage and cracking. Those that are satisfactory in this respect can be further tested by soaking in water, or subjected to a stream of water to determine their resistance to erosion. In general the most satisfactory mixes will be those which while water resistant do not contain an excess of bitumen.

During hot, dry weather, soil-bitumen capping and plating will require some protection to prevent too rapid drying and resultant

Soil-Bitumen Mortars (con.)

cracking. Probably the best and easiest covering to apply is damp soil, preferably a light sandy loam that dampens easily. It can be applied after the surface has become firm and it need not be removed.

Concrete Admixtures

Asphalts. Emulsified asphalts are added to concrete and cement mortars at the time of mixing for the purpose of reducing moisture absorption. They are intended for use in foundations and mortars; manufacturers claim a reduction in moisture absorption of from 75 to 85%. Claims are also made for increased workability and consequent reduction in the water-cement ratio.

Experiments have been made with a heavy asphalt called "Floor Mastic Binder" which was intended for use in floors and foundations. It was incorporated in concrete used as a foundation for damp kiva walls. Two drawbacks were encountered. First, it was extremely hard to handle; it gave the concrete a molasses-like consistency that could be neither pored, shoveled nor troweled. Secondly, it was coal-black which required that it be well disguised with soil pointing. It would appear to be unsatisfactory as a mortar.

The emulsified asphalt known by the trade name of "Hydropel" and intended specifically for use in mortars was satisfactorily employed in damp walls at Chettro Kettle during 1947. Its color is somewhat dark, and it appears to be unaffected by mortar colors incorporated in the mix. This is a minor inconvenience, and if necessary can be overcome by pointing with soil or other native mortars.

Mortar Colors. To properly blend with the remainder of the structure, concrete mortars should be tinted with dry earth colors. The correct shades of mortar or cement colors are often difficult to obtain from local sources. Color charts may be obtained from manufacturers and the materials ordered well in advance of the intended starting dates. Note should be made that the colors are certified to be lime proof, non-fading and that 85% will pass a 200-mesh screen.

Samples should be made up in advance of actual work to test the reaction of the color with the particular cement in use; some

Concrete Admixtures (con.)

brands of cement are harder to color than others. The color of the dry mix is a fair guide to the appearance of the completed mix, but do not use more than 10% color in any case as it may affect the strength of the concrete.

Add the color to the dry cement first. It is most convenient to mix a quantity of the cement and color in a large can or half barrel. It does not matter too much if the various batches are not all exactly the same shade; in fact, it may be necessary, where much mortar is exposed, to change them often to meet changes in the original material.

Wood Preservatives

Most modern treatments for the preservation of wood are based upon poisons such as pentachlorphenol which prevents the growth of fungi. They may be used in stabilization for preservation of replaced timbers or for the treatment of wood members already in place.

Most preparations are sold in concentrated form and are designed to be mixed with petroleum oils. Kerosene, very light fuel oils or napthas have been found satisfactory. It is suggested that prior to actual use, test specimens be made up with the type of wood involved. Some preparations will produce "blooming", the appearance of iridescent colors on the surface. Since this is apparently due to the petroleum dilutent, various types can be tried and those with the best appearance employed.

Caution. When mixing and handling these preparations, extreme care must be taken to protect the eyes and face. Limited contact with the hands is not serious, but prolonged contact is to be avoided.

Application. New material or beams which have been removed and are to be replaced can best be treated by soaking. Timbers in place are harder to handle. Exposed parts can be painted in several applications, but the portions of any timbers which need treatment most are those embedded in walls or other parts of the structure. The most satisfactory, though not perfect, solution is to drill a 1/2" or 3/4" hole on an angle into the embedded end and keep this full of solution until it has soaked through to the surface, plugging the hole after the treatment.

Silicone Water Repellants

Evaluation. The long history of waterproofing agents applied to prehistoric structures, particularly those of soil construction at Casa Grande National Monument, is reviewed elsewhere in this volume. The history was one of failure. Failure in almost every instance was due to the fact that the waterproofing compounds always formed an impervious skin or surface. Moisture absorption from the soil below the wall, differential expansion of the impervious surface and the wall interior and other factors, in each instance forced a separation of the treated surface from the remainder of the wall. The damage caused by loss of the treated surface was often greater than that from natural weathering. While these waterproofings were suitable for hard surfaces as brick or limestone they were not applicable in the treatment of soil walls.

Additional difficulty was encountered in that many of the surface treatments discolored the aboriginal surface or gave it a sheen or gloss.

Recently developed silicone waterproofings for masonry provide a water repellant surface and avoid many of the difficulties encountered with the older type. Their effectiveness is based on their peculiar surface structure. They do not form an impervious skin. Rather, when applied to masonry and other semiporous surfaces their surface becomes a network of small open cells or pores. This surface repells water. It also permits moisture entrapped within the wall to evaporate through this honeycomb surface. As a result there has been no separation of treated surface from the rest of the wall in structures which were treated 5 years ago.

The silicone preparations do not form a glossy or noticeable surface. The treated surface will appear somewhat darker for some time after application but this effect is lost within a few weeks.

Limitations. No silicone water repellants harden a surface to which applied. If the surface is friable before treatment it will remain so after treatment. Should such treatment be applied to areas that are brushed by heavy visitor traffic or otherwise abraded, regular inspection will have to be made to insure that the treatment is not lost. Inspections made during a rain will instantly disclose areas on which the water repellant is no longer effective.

Silicone Water Repellants (con.)

Types, Silicone Content. The basic silicones for water repellants are made by a few large manufacturers. These silicones are then processed by other manufacturers into a bewildering array of masonry and other water repellants. Of the types which have been tested for use on monolithic soil or masonry structures only those which have a hydrocarbon base or vehicle are approved. Other types with a water base and caustic action may prove satisfactory but have not as yet undergone sufficient testing to be recommended.

When testing of silicone products began, a number of producers were contacted regarding the guaranteed silicone content of their products. One manufacturer guaranteed a silicone content of not less than 5% and not more than 8%. This was the highest silicone content found, though one manufacturer offered to produce a water repellant at any desired silicone content.

As a result of these inquiries, all testing and application of silicone water repellants has been with material having a silicone content of not less than 5%. It is recommended that no applications be made with products having a lesser silicone content.

Application. To date applications of silicone water repellants have been made on the following structures: south wall of the "Big House" at Casa Grande, numerous walls in Compound A which had been previously covered with a soil-cement coating, and heavy soil-cement sections in Compound B. (Figs. 11, 12.) At Tumacacori the entire Granary was treated and an application was made on the patched upper surface of the barrel vault roof on the sacristy.

The applications on the above structures were made because of the extreme porosity of their surfaces and their susceptability to weathering. There is no reason why silicone water repellants should not be applied to masonry structures. Silicone water repellants should greatly extend the life of cement mortar capping and similar repairs.

However, on typical porous Southwestern structures it is recommended that no application be made at a rate greater than 1 gallon to 50 square feet. Application is best made by a low pressure spray adjusted so that a very coarse stream is produced. Do not use a fine spray. Application should be heavy enough so that there is a rundown of from 6" to 8" below the strip being sprayed. The hydrocarbon vehicle is toxic if breathed in a confined space and it is

Silicone Water Repellants (con.)

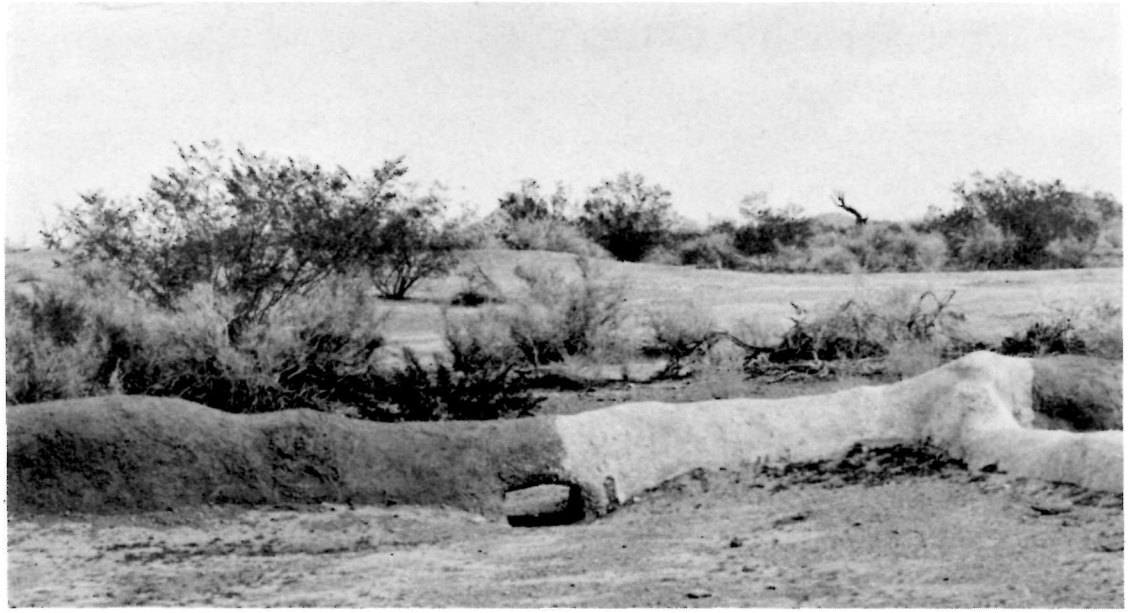


Fig. 11. Silicone waterproofing at Casa Grande immediately after a rain. The light areas were treated and repel water. The darker areas were untreated and have rapidly absorbed moisture.

Fig. 12. A year after application of water repellant, two hairline cracks were filled. The untreated smears of plaster have absorbed moisture from the rain while the treated wall remains dry.

Silicone Water Repellants (con.)

recommended that workmen wear an approved type painter's mask or respirator.

Plastic and Resin Compounds

The use of plastics in ruins stabilization is in the experimental stage. They appear to have some uses in the special applications noted below.

There is an almost unlimited number of plastic compounds of the polyethylene, polystyrene variety. They are specifically compounded for a variety of uses. Some of them which are produced in pellet or granular form can be dissolved in various solvents, the type of solvent depending upon the characteristics of the plastic. (Some plastic coatings can be dissolved in water.) The thought behind recent experiments is that plastics may find a use in hardening floors of such exhibits as pit houses, floors with special features which it is desired to preserve, and possibly the soil walls of pit houses and similar substructures.

One type of polystyrene in pellet form can be dissolved in benzene. Penetration of this solution into soil is excellent. The resulting product is an impregnated soil which is waterproof and also proof against most acids or other substances which would be encountered in a substructure. However, it is not durable enough to be walked upon. This may be the result of improper technique in application since polystyrene is a thermosetting plastic and it may require additional heat in order to reach its maximum strength. On the other hand, compounds of greater impact strength now being tested may provide sufficient durability without additional heat.

Some emulsified types of polyethylene in liquid form which are used for strengthening a variety of products from asbestos shingles to paperboards may likewise be suitable for these applications.

Epoxy resins such as Bakelite's resin # E R L 2795 are receiving increasing commercial use for applications ranging from cementing precast curbs and gutters on concrete roadways to the cementing of loose section of coal mine roofs. (The Coal Age, Vol. 63, Jan. 1957.)

Plastic and Resin Compounds (con.)

While it is doubtful if the day is fast approaching when an entire site can be indefinitely preserved in plastic, some of the new materials now under test may provide solutions to specific preservation problems.

Herbacides

The use of nonselective herbacides in keeping areas, particularly room interiors, free of weeds has had a brief history in the Southwest. First trials of a wettable powder, "Telvar-W", were made at Chaco Canyon in 1954. This small successful test was followed the next year by application at Aztec Ruins, Tuzigoot and Tumacacori National Monuments, later at Gran Quivira. We are particularly indebted to then Superintendent John Stratton and Archeologist Peck for the careful photographic and written records kept of results at Tuzigoot. After three years' use, they report excellent results in keeping rooms and other areas clear of local weeds including Russian Thistle, Puncturevine, Arizona Poppy and Trailing Four O'clock. The only vegetation which persisted were small clumps of an unidentified bunch grass. Less complete records from other areas indicate equal success in eradicating local weeds.

The only herbacide which has been well tested by the Stabilization Unit is this wettable powder, "Telvar-W". There are numerous other herbacides on the market, many of which may prove equally efficient. Some types containing large percentages of borax and which require heavy concentrations, were not tested as it was feared that quantities of borax might produce undersirable leaching in masonry walls.

In general, nonselective herbacides act upon the root systems of plants and in effect sterilize the soil for varying periods of time dependent upon the rate of application, porosity of the soil and amount of rainfall. Application after the growing season starts and plants have attained some size is not as effective as applications made at the start of the growing season when plants are in the seedling stage. In any case the manufacturer's directions should be followed for maximum effectiveness.

Herbacides as described above are authorized for use in keeping rooms and small areas within sites free of weeds. Their use is far more economical than hand cutting or hoeing. In larger areas where

Herbacides (con.)

a large expanse of barren ground might be objectionable, consideration should be given to low types of ground cover or sod where such can be established. In any event herbacides must be strictly controlled to prevent their being washed into areas of valuable plantings.

Poisons and Rodent Repellants

In some archeological locations extensive damage can be caused by rodents, particularly rats and ground squirrels, burrowing through or under masonry or adobe walls. Particularly dangerous instances have been those in the cliff dwellings at Tonto National Monument where the structures are located in a dry cave, and at the Schoolhouse at Tumacacori where the adobe schoolhouse is enclosed within a modern protective structure. Rodents there had found a protected runway between the original walls and those of the enclosing structure.

In areas of moderate infestation and where the affected structure is somewhat isolated as at the Tumacacori schoolhouse, poisons have been found effective. Extreme care must be exercised in their use. It is recommended that only those poisons employing warfarin base be permitted. (Warfarin based rodenticides are stocked by GSA.) The warfarin base has a cumulative effect and must be consumed repeatedly over a period of time to be fatal. Thus it is not extremely dangerous as are poisons employing arsenic, strychnine and similar quick-acting ingredients. In any event, the poison should be placed in an approved type bait station with a locked cover.

In areas of heavy infestation and in areas where the rodent population is extremely dense in the immediate vicinity, poisons have limited use unless a determined effort is made to reduce the rodent population over a wide area. In such instances the use of poisons should be combined with repellants which act only to repel rodents from selected areas. Various areas in Region Three participated in a recent test of rodent repellants on a small scale; the limited tests indicated that such repellants, either in liquid or pellet form might prove successful in clearing ruin areas of rodents. Further tests in confined archeological sites are being carried on at present and the results will be available as amendments to this Handbook.

Poisons and Rodent Repellants (con.)

A general evaluation of, and list of reference material on repellants used to protect pine seedlings is available from the Department of Agriculture, Pacific Northwest Forest and Range Experiment Station, Comparison of 2 Rodent Repellants In Broadcast Seeding Douglas-fir, May 1957.

TECHNIQUES

Control of Erosion from Capillary Water - Masonry Walls

Capillary water is a term used to designate moisture occuring in walls and fill and is considered as ..."Ordinary water which occurs in small voids so that the surface tension of the water becomes an important factor in determining its behavior."... (Plummer & Dore, 1940, p. 59.) Use of this term will distinguish it from hygroscopic moisture which surrounds and is closely associated with the individual soil grains and cannot be evaporated by air drying. Gravitational water on the other hand is water occurring in sufficiently large amounts to behave according to usual hydraulic laws. Where there is percolation down through a fill against a structure this might be considered as gravitational water; but for the purpose of handling it in ruins stabilization there is no difference between it and capillary water since it rapidly becomes the latter.

Problem. This section deals with moisture entering masonry walls either by upward movement of capillary moisture or the outward movement through walls of moisture entrapped in fill areas. Capillary moisture acts either upon the aboriginal soil mortar in the masonry or upon the softer varieties of sandstone and is one of the major factors in ruin disintegration, particularly in excavated sites. It is also one of the most troublesome conditions to control.

The effect of erosion caused by moisture at the base or lower portions of a wall becomes rapidly cumulative; erosion of narrow but long sections results in severe damage to or loss of higher areas through settling or collapse. The surface disintegration of a masonry wall is caused by the movement of water through it. The damage occurs at the point where the moisture leaves the masonry and comes in contact with the air. Even soft sandstone which is continually damp below the surface of the ground remains in fair condition so long as it is not exposed to alternate cycles of wetting and drying. Where one side of a wall remains damp from contained fill, the damage occurs not on that side but on the opposite side at the point where the entrapped moisture reaches the air.

Control of Erosion from Capillary Water - Masonry Walls (con.)

The area of efflorescence and decay may be at some distance above ground level--at the limit of capillary rise from moist soil. (Fig. 13.) It may be toward the upper part of a retained damp fill or in a protected location where there has been surface absorption from melting snow. For example, the moisture content of a silty-loam fill from within a drained area at Pueblo Bonito was found to be 16%, and this in a month when precipitation was less than 1/2" (.42). This same type of erosion of face stone amy be observed in cave sites even though the walls are based on bedrock. Moisture here is derived from the drip of melting snow, rainfall, or seepage on the cave floor. (Fig. 14.)

Where masonry is constructed of a durable stone, or there is thick bedding of the mortar, this efflorescence becomes first noticeable and more pronounced in the mortar than in the stone.

In open sites at more northern latitudes, most of the capillary water in soils or structures is derived from melting snow (despite the fact that precipitation from rainfall may be heavier during other seasons of the year). There is little surface movement of this moisture; it is absorbed into the soil or wall immediately as it melts. For this reason, it is extremely difficult to control by ditching, tiling, dry-barreling or other drainage measures.

Evaluation of Methods. Methods employed in the past to prevent moisture from reaching and being absorbed into walls have included (1) surface drainage, (2) subsurface drainage by means of tile and gravel backfills, (3) construction of concrete curtain walls to cut off the movement of water, (4) sealing the backs or subsurface portions of walls with impervious coatings.

An evaluation has been made of 21 walls, retaining fill, which had been repaired by the above methods singly and in combination. These walls retain from 1/2 to 1-1/2 stories of fill behind them. The evaluation was confined to walls which had been in the most hazardous condition and which were considered to present the greatest problems - walls which were of soft and poorly cemented sandstones, usually without bedding planes, and which in themselves

Control of Erosion from Capillary Water - Masonry Walls (con.)

Fig. 13. Damage caused by outward movement of moisture from fill behind this kiva wall. Most severe damage is at the limit of capillary rise, just below the concrete capping.

Fig. 14. Damage is caused not by general weathering but by rising moisture from melting snow. Note that decay is confined to the limit of capillary rise in the mortar column.

Control of Erosion from Capillary Water - Masonry Walls (con.)

have little resistance to weathering. (Samples of deteriorating stone removed from Pueblo Bonito and oven dried to a constant weight show moisture contents of from 4% to 26%. Thirty percent is the theoretical limit for sandstones.) Only walls where erosion from capillary moisture took effect near the base or center of the wall were considered. Areas that required only capping were excluded.

Of these 21 walls retaining fill, after a period of 10 to 15 years, 13 remained in good to excellent condition; 8 showed moisture absorption in varying degrees from small damp spots that appeared during the winter only to 4 instances where it has been necessary to replace disintegrated stone. Eleven of the 13 walls in good condition were so located that it had been necessary to provide drainage lines through the walls to the exterior. The other 2 were in graded areas.

Seven had been treated after repair by the application of a seal coating to the reverse or fill side. Eight of the 11 drains were still operative. Three had become filled with drifted sand.

Those walls that remained in the very best condition were 6 which had been sealed off from the moisture in the retained fill by a coating of impervious material, and where the drainage remained operative. It is this combination of factors--prevention of moisture absorption from the banked fill and removal of surface moisture on the face side--which gives the best results.

Of the remaining 7 in good condition, 1 had been seal coated on the reverse side but the drainage plugged, as it was in 2 other instances; drainage remained open in 2 and the last 2 of the 13 had required grading only. All of these walls are in good condition, but they do not show the absolute freedom from moisture as do the 6 where seal coating was combined with maintenance of the drainage.

Of the last 8 walls, 4 with large damp areas and 4 requiring repair, only 2 had been provided with surface drains and both of these had become inoperative. None had been seal coated. Thus the 8 poorest examples lack both drainage and seal coating.

Control of Erosion from Capillary Water - Masonry Walls (con.)

Six of these 8 walls had not been provided with drainage to the outside, due to location (deep rooms enclosed on all 4 sides by 2 to 3 rooms of fill). Of these 6 which it had been impractical to drain, 4 had been provided with a measure of subsurface drainage--backfilling against the base of the wall with gravel and then broken rock. This proved to be inefficient. Considerable windborne material has drifted over this gravel backfill since it was laid. Whether this has any bearing on the problem is not certain, but it seems unlikely.

A similar evaluation was made of 19 walls, not retaining fill, constructed of and repaired with the same class of soft stone as in the 21 tested which retained fill; 15 remained in good condition. Four showed large wet areas where failure of drainage lines had impounded water. (Figs. 15, 16.)

In the testing and evaluation of methods for the control of erosion by capillary water, experimental walls were constructed, in various techniques and mortar materials, in the form of square areas that could be filled with wet soil and kept damp in accelerated weathering. The tests have shown the following results.

1. In the treatment of stone, the soft friable individual stones laid in the wall were treated with several of the commercial masonry waterproofings. (These were types for below-ground masonry and are not to be confused with above-ground repellants employing silicones.) Clear types did not prove effective; heavier, opaque types such as "Aquella" painted on all but the exposed surface proved effective in preventing moisture absorption into the facing stone. Such treatment is time-consuming and the opaque types are difficult to use since the treatment must be withheld from exposed portions of individual stones.

2. A test for moisture resistance was made with concrete mortar containing an emulsified asphalt "hydropel". Care was taken to completely embed the stone except for the exposed face, in this treated mortar and to avoid stone to stone contact. A similar method was employed in setting a patch in a continuously damp ruin wall. In the test and in the ruin there was no moisture absorption through the mortar into the stone. The treated mortar is more resistant than plain concrete and there appears to be no movement of moisture along the line of bond between stone and mortar.

Control of Erosion from Capillary Water - Masonry Walls (con.)

Fig. 15. Basal erosion from Capillary moisture is particularly damaging in the interiors of excavated sites where the drainage is poor.

Fig. 16. It continues until the wall is almost completely undermined, a stage followed by collapse.

Control of Erosion from Capillary Water - Masonry Walls (con.)

3. In stone laid in soil-bitumen mortar, failure became evident first at the base, the area of greatest moisture penetration. The stone became damp and there was progressive disintegration of the surface. Despite the condition of the stone the soil-bitumen mortar remained hard and dry. It is evident that penetration of moisture was due to lack of bond between the mortar and the stone.

4. In stone set in ordinary concrete mortar in the tests there was some moisture penetration; stone at the base became damp and there was some disintegration of the surface. The mortar also became damp and here it was evident that moisture had moved through the mortar into the stone.

In summary, the results of field use and accelerated weathering tests indicate that maximum control of percolating moisture from entrapped fill and the rise of capillary moisture is achieved only by a combination of factors (1) sealing of the wall as effectively as possible from the moisture-bearing soil, (2) the maintenance of proper drainage and (3) the employment of a moisture resistant mortar. Specially treated mortars were the most moisture resistant. Ordinary concrete mortar permitted the passage of some moisture and soil-bitumen mortar was unsatisfactory. No tests were made on soil-cement mortars but work done subsequent to the weathering tests indicates that thin mortars of soil-cement would be no more resistant to the passage of moisture than was the soil-bitumen and that they also would prove unsatisfactory for this specialized application.

Field Control of Capillary Moisture

Waterproofing. The use either of a concrete mortar whose water resistant qualities have been increased by the addition of an emulsified asphalt similar to "hydropel", or of special waterproof cements is recommended. In either case the manufacturer's recommendations for the specific use should be followed. In the case of "hydropel" 1-1/2 gallons per sack of cement are used.

For a workable mixture, the water or liquid-cement ratio should be kept at not more than 6 gallons per sack of cement. This liquid is to include the "hydropel" or other emulsified asphalt. In all probability, the liquid-cement ratio can be reduced below the 6-gallon limit due to increased workability obtained with the asphalt admixture. The asphalt is added at the time of mixing.

Field Control of Capillary Moisture (con.)

There is great variation in type and gradation of sands, therefore it is advisable to make trial mixes to determine accurately the sand-cement ratio requirements. In many areas mortar sand as opposed to concrete sand can be obtained from commercial sources. The ratio will probably range from 1 to 2-1/2 for the more finely graded. Sand should be clean and free from inclusions of dirt or organic impurities. Mortar should be thoroughly mixed. Thorough mixing improves the plasticity and workability; less mixing water is required to obtain proper working consistency when the mixing time is increased.

Placement. In laying out stabilization for a wall deteriorating from moisture erosion, consideration must be given to any proposed changes in the fill level. (Fig. 17.) Where the eroded wall also retains fill, the treated mortar should extend somewhat higher than the eroded area, in order to take care of any possible increase in the capillary rise. Thus, it is better to include too much rather than too little in the area stabilized. While this might violate the precept of keeping the replacement of prehistoric or original material at a minimum, it is desirable that the replacement be made all at one time rather than over a period of years as moisture works its way around too small a patch.

If breakdown of the lower wall areas has proceeded over any period of time, possible faults in the surface above these areas will also have to be taken into consideration. Cracks, bulged areas, and separation of courses due to settling are apt to occur.

Further, where erosion has cut into the wall some distance it may appear possible to reface the surface using thin stone or other original material without removing the decayed area. This is not a profitable undertaking. It will not permit the use of a heavy mortar bed, and little support is given the upper levels of the structure since a thin patch cannot be tied securely to the original work.

Defective masonry will have to be removed in narrow vertical sections. Some experience is required to determine the amount that can safely be taken out at one time. This is dependent upon the general type of construction and condition of the structure. It is seldom advisable to use jacks and blocking and remove large sections at one time. Removal of stone is best accomplished by cutting the mortar with a cape chisel or other sharp tool, and prying rather than attempting to break or knock material out with a hammer; since the vibrations are easily transmitted, bond in adjacent sections is apt to be broken.

Field Control of Capillary Moisture (con.)

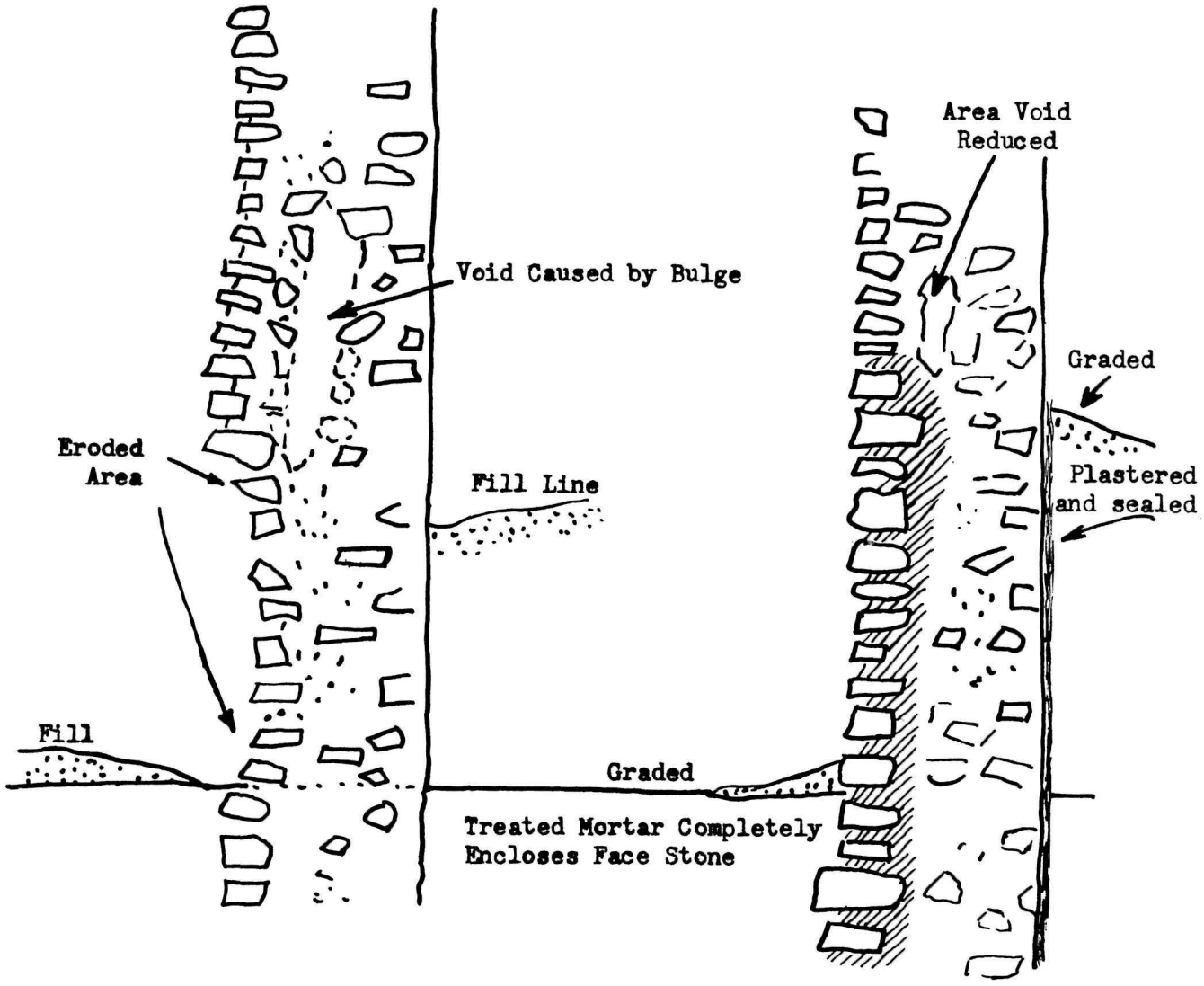


Fig. 17

Field Control of Capillary Moisture (con.)

Before setting stone, dampen it thoroughly. This helps to remove the film of dirt which interferes with the bond and, particularly in hot weather, the absorbed moisture aids in setting the mortar. Do not smooth the mortar bed unduly but leave it slightly furrowed, so that it will meet irregularities in the stone. The stone can be tapped into place with the handle on a mason's hammer.

On finely surfaced walls, the joints between facing stone are often filled with small spalls. Some masons have a tendency to drive the spalls into the joint after the larger stone has been set. Do not permit this. It will raise the larger stone out of the mortar bed and spoil the bond. If spalls of any size are used, they must be set in the mortar first and the upper stone set in place over them. This procedure is time-consuming, since it is difficult to clean the extruded mortar from small spalls.

Treatment - Oblique Surfaces. The most frequent result of moisture erosion in the upper levels of heavy walls retaining fill is loss of the facing on the exposed side. This results in an irregular oblique surface. There are two possibilities in stabilizing these areas. (1) Either the missing face of the wall can be rebuilt and sealed off from the damp fill, or (2) the broken slope can be taken down and relaid in a moisture resistant mortar, and soil-cement pointed for appearance.

Rebuilding the missing face is more time-consuming and expensive but sometimes advisable where the wall is in very bad condition or the additional strength is needed to buttress adjoining walls.

Relaying the oblique surface in a moisture-resistant cement mortar is more effective from the point of general appearance. (Fig. 18.) The only drawback to this method is that large areas of the waterproofed mortar will be exposed. It is difficult, if not impossible, to color cement mortars containing emulsified asphalt. Special waterproof cements, however, can be colored.

Where the extent of exposed mortar is not too great, the appearance can be greatly improved by holding the concrete back 1/2 to 3/4" from the final surface, and pointing to this depth with stiff soil mortar. The appearance of the soil pointing will be much more satisfactory than any that can be obtained with concrete mortars.

Field Control of Capillary Moisture (con.)

APPLICATION OF WATERPROOFED CEMENT MORTAR TO OBLIQUE WALL

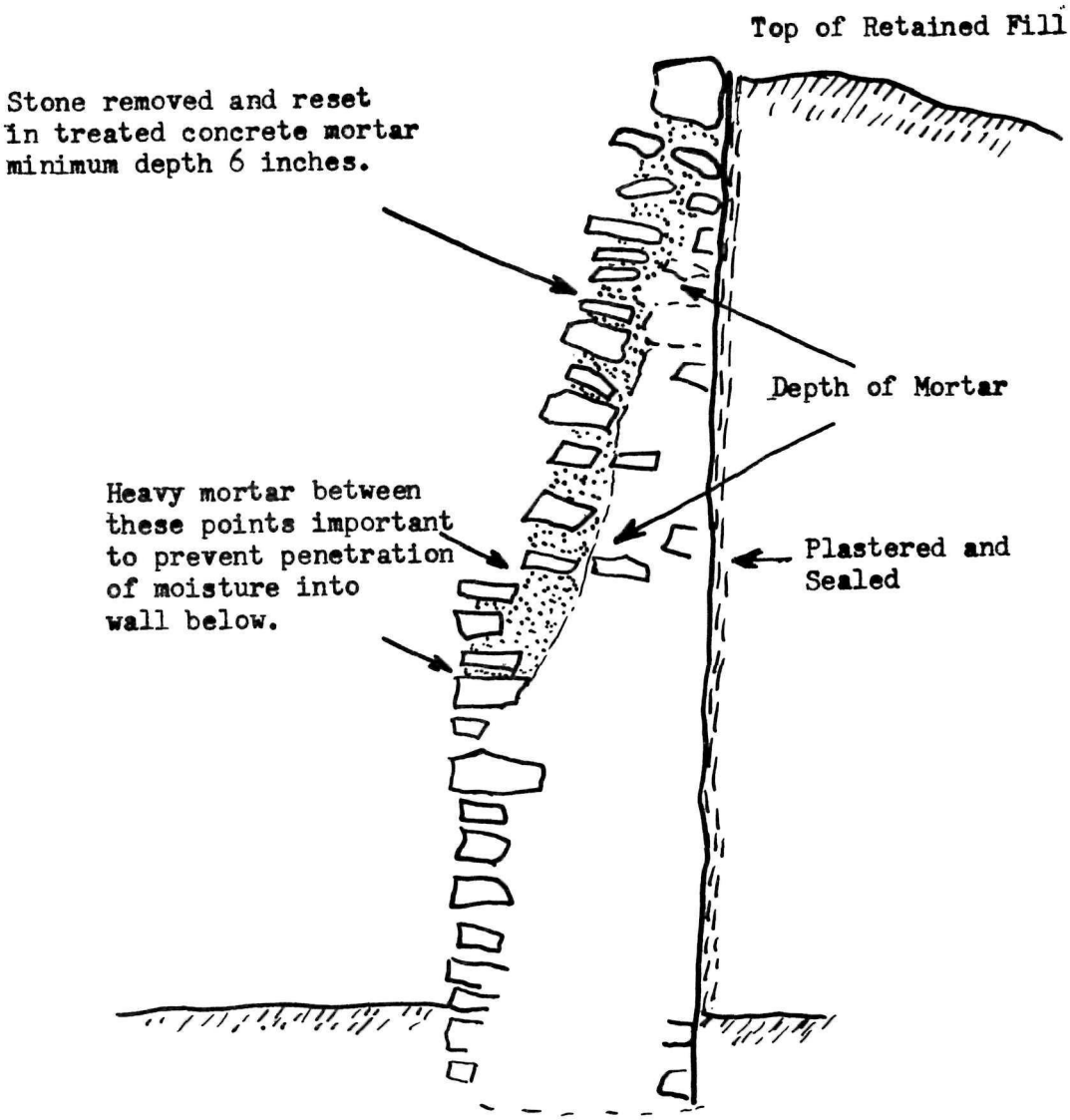


Fig. 18

Field Control of Capillary Moisture (con.)

The soil pointing will require replacement after a few years, but it is an easy job which can be done by unskilled labor with little supervision.

This technique was first extensively used by Earl Morris at Mesa Verde during 1934, though he undoubtedly developed it earlier. (Hamilton, 1936.) It is a particularly valuable method of retaining appearance, while employing durable and moisture-resistant materials in the body of the structure. It can be used in many applications where soil, soft lime, or other distinctive mortars are widely exposed.

In resetting stone on an oblique face it is best to lay the work out in vertical strips rather than in horizontal sections. This aids in maintaining the slope, and it is easier to match the pattern of the adjacent surface. The same method used in setting repairs in the face is employed--each exposed face stone is well bedded in the treated concrete mortar. This will mean that the entire vertical section must be taken down and relaid, rather than merely cleaning out the soil mortar and grouting the interstices with mortar. Depth of mortar will vary with the height of the wall and the size of stone used, but it is suggested that a thickness of 6" be taken as a minimum.

The point of greatest weakness in such an installation is at the bottom where the slope joins the remaining vertical face (if any) of the wall. At this point the vertical face must be taken down and the upper three to four courses reset in the water-resistant mortar. Extra care must be taken at this point to prevent accumulated water from the slope entering the lower wall.

Seal Coats. While the employment of water resistant mortars combined with surface drainage will aid materially in the reduction of moisture absorption in many situations, this procedure should always be done in connection with sealing off the reverse side of the wall wherever possible. To be effective, the sealed area must extend well below the level of the exposed and eroded area. Difficulties encountered in this procedure are irregular surfaces, breaks or holes in the surface to be sealed, adjoining or abutting structures.

Field Control of Capillary Moisture (con.)

Extensive sealing off of wall areas is more often required in excavated sites than in unexcavated sites due to the more porous nature of the fill in the latter. The application of an impervious seal coat to the reverse covered side of a wall will spoil it for future exhibit. This is seldom if ever a consideration in excavated sites; the possibility should be considered however in work in unexcavated sites. Extensive areas were sealed off in the Mission structures of San Isidro and San Buenaventura at Gran Quivira. In both these instances no future excavations were contemplated.

The purpose of sealing off portions of a wall are to prevent the entrance of moisture into the wall from enclosed fill or from higher levels outside the site where the structure is partially subterranean. The procedure is much the same as is employed in making basements waterproof. The area against the wall must be excavated and any abutting walls or portions of structures removed.

Prehistoric walls with soil mortar do not present a sufficiently sound surface on which to work. When the wall is cleaned of loose and friable material it should be plastered with a sound cement plaster, one or two coats as required. Care must be taken to cure this properly so that no cracks develop. After the plaster has cured it is then treated with applications of hot asphalt or an approved asphalt foundation paint.

When the area against a sealed surface is backfilled some effort must be made to compact the fill to near its original density and to provide surface drainage.

Related Drainage

Purpose. Discussed here are drainage problems relating to removal of surface water from areas treated as above, and also the removal of surface water from all areas within a site. Drainage over large, relatively level areas of a site is seldom a problem except perhaps in large plaza areas. In most Pueblo sites surface water within rooms is absorbed into the soil and presents little difficulty. The problems are encountered where adjacent rooms or small areas are at widely varying levels and the problem is either surface washing from one level to another or moisture penetration through a wall.

Related Drainage (con.)

Dry-Barreling. The use of dry-barrels is suggested for enclosed areas where drainage lines to some exterior point would be difficult to construct and maintain. The purpose of a dry-barrel is to quickly drain the water falling into a room to a level below that at which it can cause damage by percolation into adjoining areas.

Generally a dry-barrel is constructed at the center of a room or confined space. (Fig. 19.) A circular hole usually 3 to 4' in diameter, is dug to a depth which is at least 3' below the lowest level in adjoining rooms. The hole is then backfilled with random stone or gravel with fairly well graded material at the top to prevent the entrance of large amounts of silt or fine material. The surrounding surface is graded to the sides of the dry-barrel.

Surface Drains. It has become apparent after years of experience that surface drainage presents some unusual problems in maintenance that are not encountered in ordinary structures. Surface drainage systems are often in sites or portions of sites that do not receive regular maintenance. Change of personnel in areas results in total lack of information on the nature and location of drains. Drainage lines often become rodent burrows and quite frequently interpretive personnel will cover the open ends of drains to hide them, a practice that usually results in complete stoppage.

With this in mind, very careful consideration must be given to laying out any drainage system. Small individual drains to open areas are far better than large systems draining several rooms or areas together. The larger the system, the more rooms that are drained together, the greater is the damage from accumulated water when one section of the system becomes inoperative.

Tile drains with vertical sections and elbows to horizontal runs are to be avoided. Soil in most sites is loose, there is always an abundance of blowing sand or cinder, and such drains become clogged easily.

The preferred drain is one with a small concrete settling box covered with a grate, the tile line extending from the side of the settling box. (Fig. 20.) Tile lines through walls are to be preferred to "weep holes" in spite of the fact that their appearance is not as satisfactory. Weep holes tend to admit water into the

Related Drainage (con.)

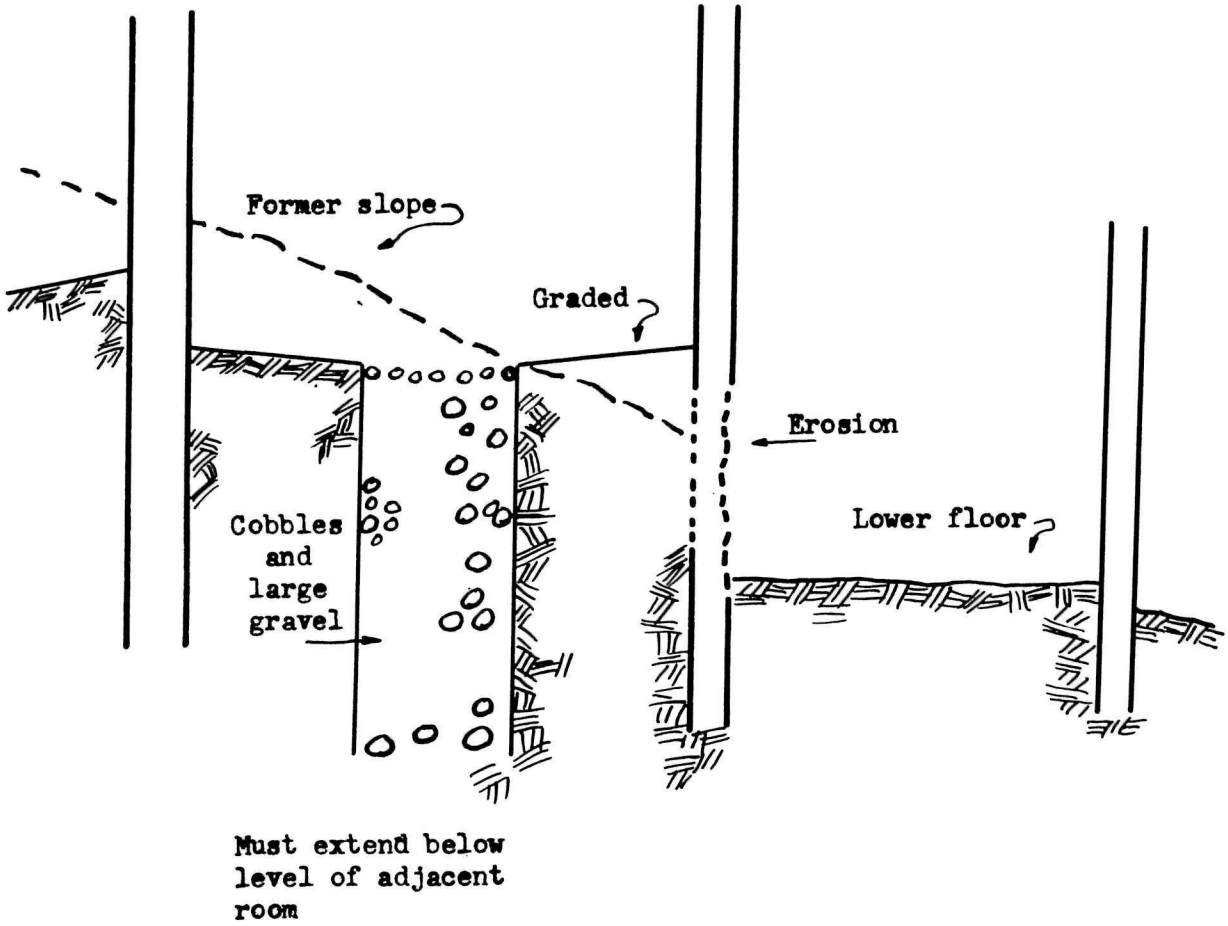


Fig. 19. Drybarreling, it should be carried well below the adjacent floor levels.

Related Drainage (con.)

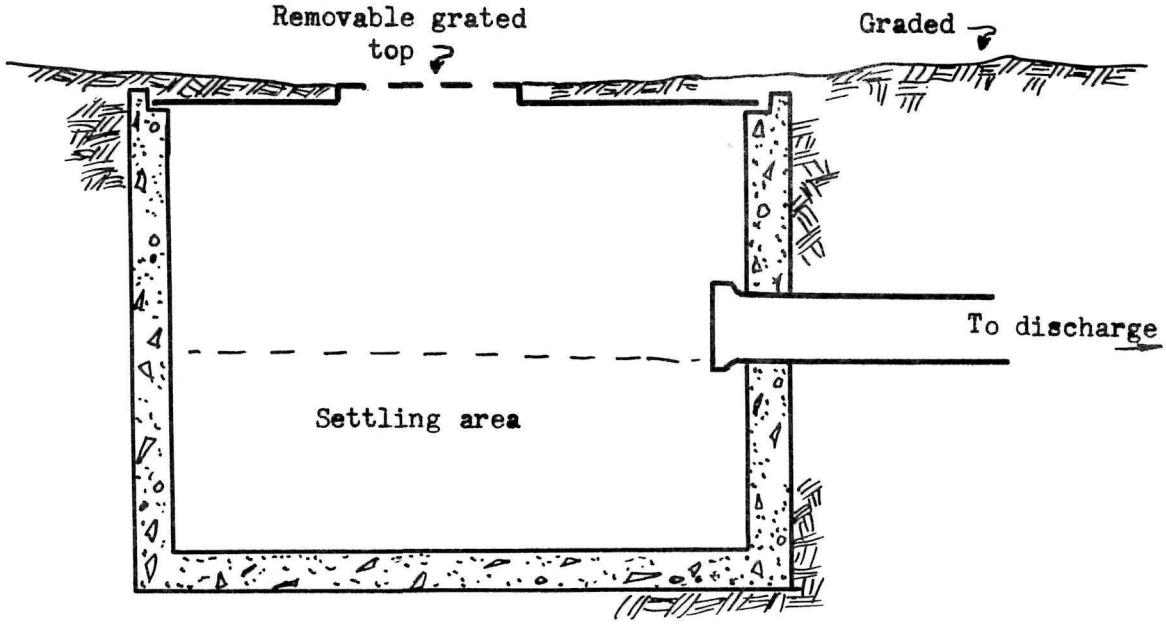


Fig. 20. Settling type inlets for drain lines are preferred over lines opening in the face of walls. The latter require that the water be drawn against the wall before it can enter the line.

Related Drainage (con.)

masonry unless very well constructed. While it is true that the necessities of appearance would seem to dictate concealed or very unobtrusive lines emptying from a small area, annual inspection of numerous sites has demonstrated that such lines are simply not maintained and that an obtrusive line which empties surface water from an area provides far better protection than a concealed line which has become inoperative through accumulations of sand or cinders.

Repair of Wall Breaks

The discussion here will deal with the stabilization of masonry walls containing ordinary structural failures--loose areas, holes entirely through the wall or holes which extend only part way through, as are often found in heavy structures of veneered construction.

Since at least 50% of the repair in the Southwest will be done with stone of some type, this material is examined first.

The stone used in setting a patch should match that in the original wall as closely as possible. There is little chance that the requirement that it "should be discernible upon close inspection" will not be met, since it is practically impossible to construct a patch that cannot be located by expert inspection.

Stone from the ground in the vicinity of a site, as opposed to that saved from an excavation, would seem to meet the requirements ordinarily. However, stone which has lain exposed on the ground for centuries is sometimes not the best. If it is porous, a soft sandstone, it is no doubt partially disintegrated. Where walls must be repaired with faced stone of the softer varieties, it is usually a major problem to locate useable pieces. In some cases the replacement of pecked or dimpled stone will require an exhorbitant amount of time to properly shape and surface the individual stones. (Fig. 21.) Very often porous stone will absorb salts from the soil in which it lies. After it is set in the wall and has become damp and then dried a few times, these salts will leach out, marking the patch as a white area.

Small spalls are also difficult to find and these, due to their small size, are rarely if ever saved from an excavation.

Repair of Wall Breaks (con.)

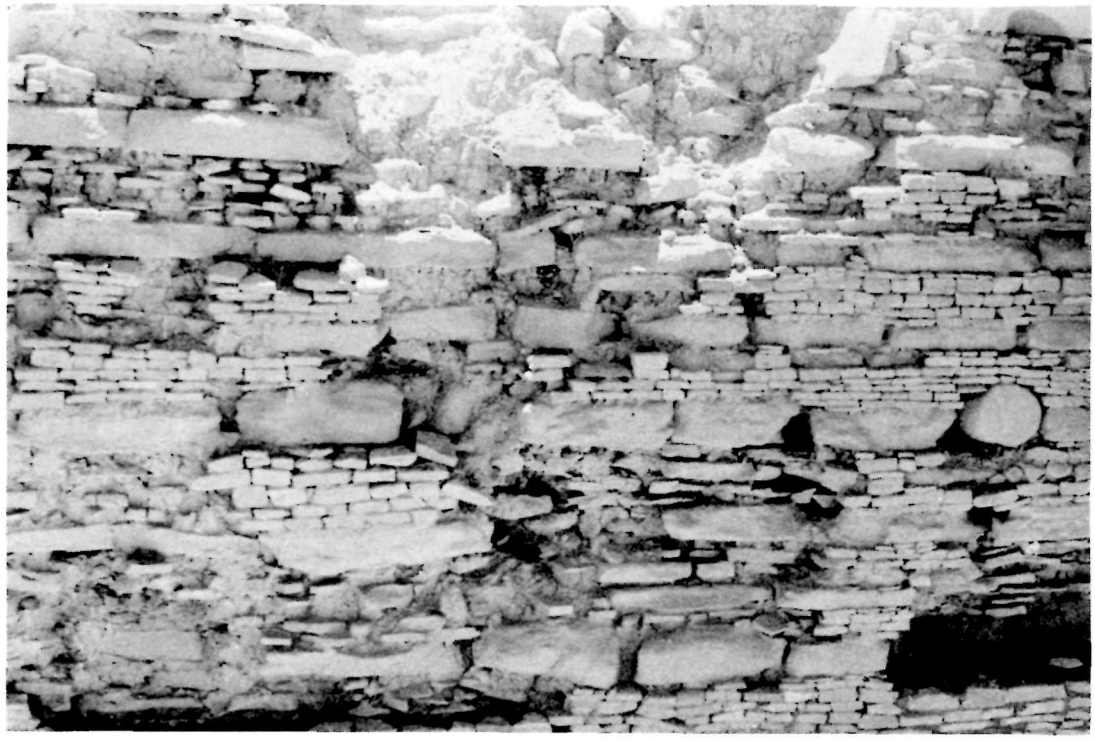


Fig. 21. Replacement of soft, pecked and dimpled stone in random areas over the surface requires extreme care if the character of the wall is not to be changed.

Repair of Wall Breaks (con.)

Time can be saved if suitable rock and spalls are quarried. Useable quarries can often be located close to the work, and a single truckload of spalls will save many miles of walking after individual pieces.

Simple Wall Breaks - Patches. Determining what caused the break in the first place will be of some aid in planning how to repair it satisfactorily and to prevent a recurrence. This is particularly true when the forces that caused the break are still active and must be counteracted before the patch can really be called effective.

Two of the most common types of simple breaks are: (1) those caused by breakdown or removal of some wood member, rotting, excessive weight, or vandalism, (2) disintegration of soil mortar where it forms a major part of the wall.

Often a break has become enlarged over the years so that it is difficult to determine just how it did get started. This poses a problem if it is desired to fill the hole completely with repair masonry. Should it be filled in solid or was there a doorway, small opening, or a beam socket in the center of what is now only a hole?

Oftentimes doorways were partially filled during the time of occupancy. Close examination of the masonry remaining in the bottom of the break will sometimes give evidence of an opening. Removing a few stones may show up the side or jamb of a door. Changes in masonry style are another indication of filled openings. Within a room, the examination of the opposite wall will serve to indicate the position of beam sockets.

In placing a patch, care must be taken to clean the masonry surface surrounding the break. (Fig. 22.) All loose stone and unsound mortar should be removed. This might necessitate excavating around it to a depth of several feet. In large sites, if the bottom of the break cannot be reached for one reason or another, the base of the patch should be laid in reinforced concrete to form as good a footing as possible.

There are only two essential requirements; the patch should be laid in the same type of stone and in the same pattern as the adjoining wall, and it must be tight. Excessive shrinkage is apt

Repair of Wall Breaks (con.)

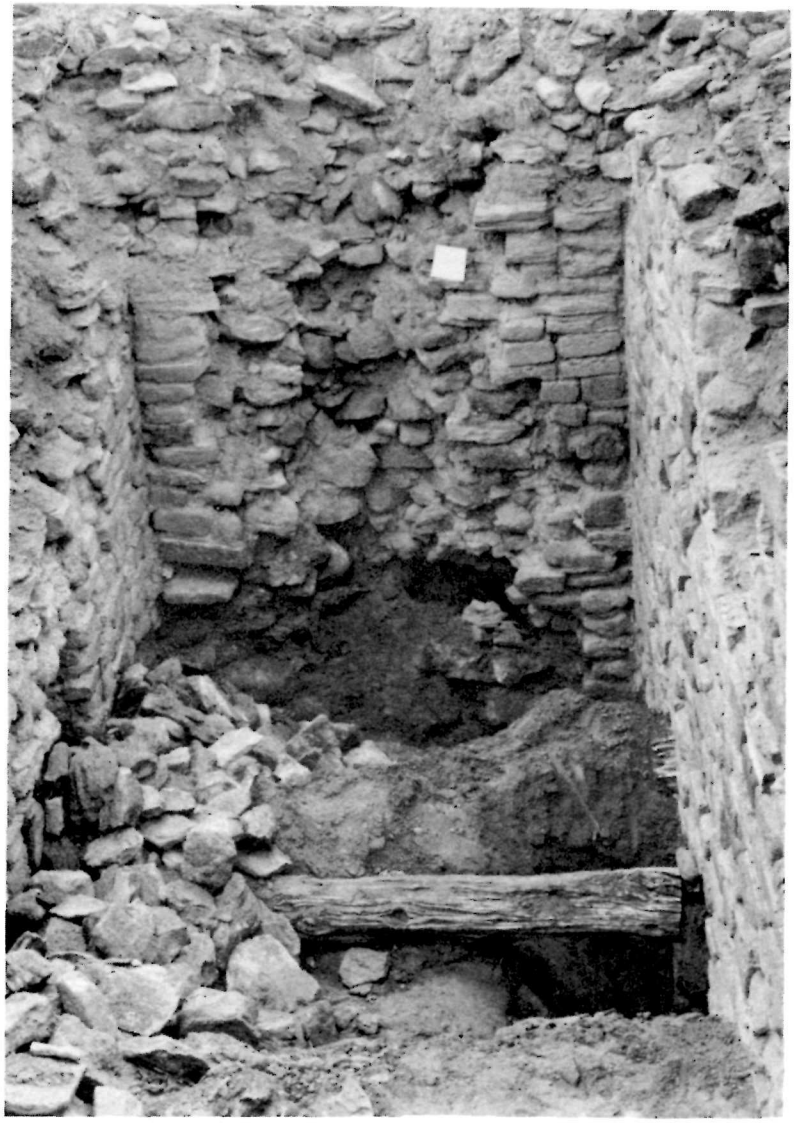


Fig. 22. Wall break in a partially excavated site. Patch must be designed to prevent further flow of water and fill at the top. Some excavation will be required to base patch on sound masonry. Patch will be subject to pressure of contained fill.

Repair of Wall Breaks (con.)

to cause the most trouble in soil-mortar patches; if this is likely to be a problem, it would be best to use cement or masonry mortar.

The stone being placed in the patch must be clean and damp. A film of dirt prevents bonding with any kind of mortar. The masonry adjacent to the patch must also be clean and damp for the same reason. Whisk brooms can be used for dampening the original masonry; and the fine spray on a back pack pump gives excellent results.

In a great number of cases there is going to be as much mortar exposed on the wall face as there is stone. In anything but soil mortar, slick trowel marks will show as long as the mortar lasts. The best way to obliterate tool marks is with a whisk broom or by hand, before the mortar has gained its initial set. If left they will certainly spoil the appearance of the job.

In cases where colored soil-cement or concrete mortars are used, this matter of troweling is also important. Troweling of colored mortars brings a thin film of the color to the surface and it also produces a reflective surface. It must be remembered, particularly with colored mortars, to rake or scratch thin mortar joints and brush large areas after the mortar has dried but before it has set hard. The most effective method of retaining good appearance is to point the surface with soil mortar as noted previously.

Doorways and Large Openings. Breaks in doorways and other large openings usually take the form of an inverted triangle, the apex at the bottom and the greatest breadth higher in the wall. (Fig. 23.) In repairing these the temptation is always to replace only the missing stone, but unless the material is of large size and the wall exceptionally clean, this is apt to be a poor investment in labor and materials.

There is very little strength in the bond between stone and mortar in prehistoric walls. The replaced stone at best will not bond too well with the original work, due largely to the amount of soil mortar exposed in the interior of the wall. This results in the patch being one solid unit, an inverted triangle, and in too little bond with the rest of the wall. When such patches fail they do not break up but separate in one piece from the remainder of the structure.

Repair of Wall Breaks (con.)

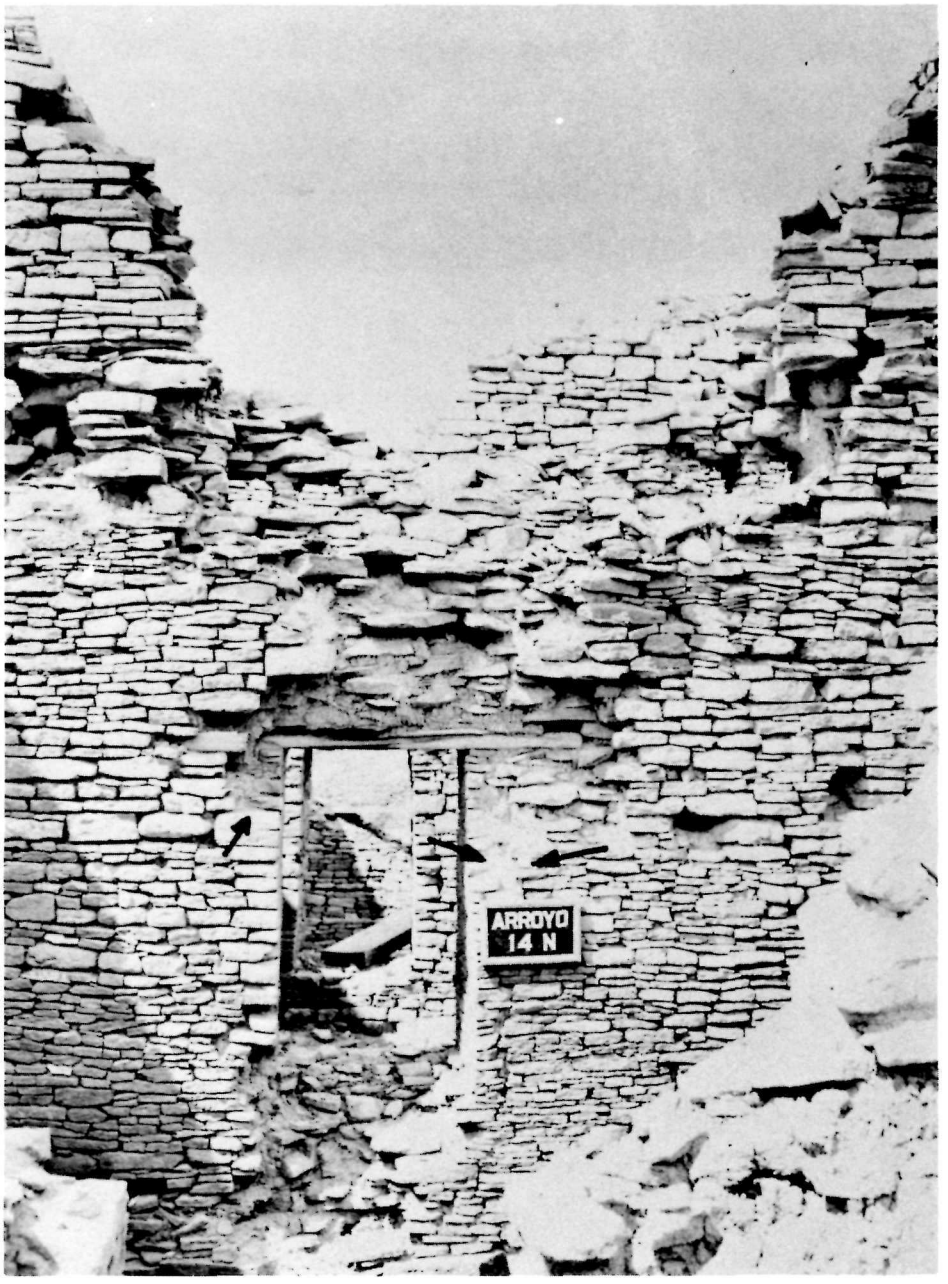


Fig. 23. Repair here will be based on a very small area in comparison with the total size of break. Every effort should be made to tie the patch securely to the existing wall.

Repair of Wall Breaks (con.)

It is therefore better to remove sufficient original material to reset it in a patch whose base is somewhat larger than the base of the original break and which will be stable in itself without dependence upon the bond with the original work.

Slumped and Filled Areas. One effective method of handling small slumped or loose areas was developed at Wupatki National Monument by Buchenberger. Here small vertical sections of the slumped areas were cleaned of soil mortar, and cement or soil-cement mortar packed between the stone. This makes an authentic-appearing repair, provided the color and texture of the replaced mortar is not too conspicuous. To be effective, the grout must extend from 1/4th to 1/3rd of the way through the wall. This is particularly true with soil-cement mortars. Grouting in an area of slumped stone not only keeps a ruin looking like a ruin instead of like an unfinished building; it is far cheaper in labor and material than the other alternative--replacement of the entire section.

Vertical Surfaces. Vertical wall areas containing an excess of soil mortar at the surface often become badly weathered while the interior of the wall remains sound. Large wall sections can be saved and future repairs reduced extensively by grouting between the exposed surface stone. (Fig. 24.) The same cautions must be exercised here as noted above. Loose soil mortar must be removed and sufficient depth obtained so that there will be some bond between stone and mortar.

Respalling. Where masonry walls containing a large proportion of spalls or chinking on the surface are subject to extreme weathering in exposed locations, the repair of the surface may become a time-consuming project. As the spalling is lost to weathering, the soil mortar between individual stones is then exposed. It weathers far more rapidly than did the spalling, and decay of the wall is accelerated. In repair, loose and softened soil mortar must be scraped from between the individual stones, the space then partially filled with cement mortar and the spalls tapped into place in the mortar. Large walls require considerable equipment and an experienced crew. (Fig. 25.)

Break Where Weight is a Factor. Considered here are partially displaced or shattered areas which still furnish some measure of support, but which must be removed in order to effect repairs.

Repair of Wall Breaks (con.)

Fig. 24. Deep grouting with soil-cement on the badly weathered face of this cobblestone wall will not change its appearance but will halt the rapid rate of erosion.

Repair of Wall Breaks (con.)

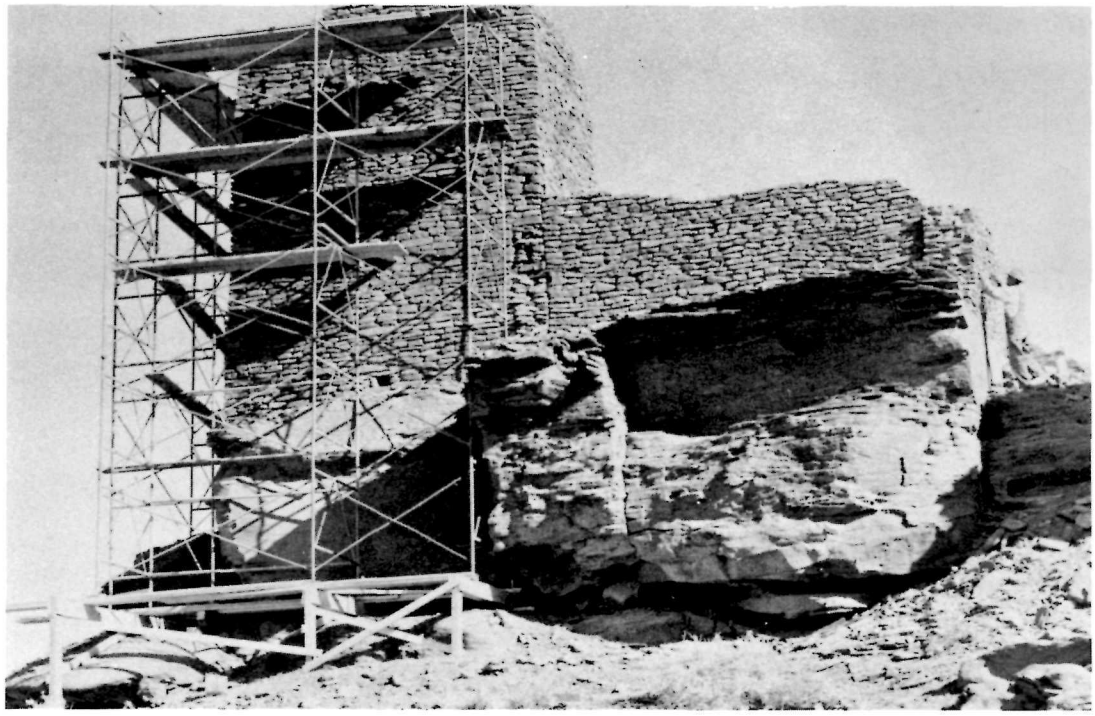


Fig. 25. Scaffolding in place at completion of respalling and grouting wall surfaces.

Repair of Wall Breaks (con.)

In general the same cautions pertaining to other stabilization apply here with added force: repair work laid in a high strength concrete or masonry cement mortar, based on sound foundation, the edges of the adjoining original work clean, sound and dampened, and all replaced stone firmly seated in the mortar.

Temporary Support. A fairly common situation encountered involves heavy walls (Figs. 26, 27, 28) in which one side has been broken away due to excess weight or shifting of the upper structure. The problem is support of the sound part of the structure while removing and replacing the damaged area. This can usually be accomplished by the use of jacks and timber blocking. It might involve cutting a narrow vertical section in the displaced portion in which to place the supports. Since construction and soundness of walls varies even from room to room in a single site and no two situations are identical, only very general suggestions can be given for temporary support of walls during stabilization as follows:

1. Only screw type jacks should be employed. Do not try to use ratchet jacks.

2. Solid foundations must be provided. Never place a jack on top of an upright timber, but use cribwork to reach the desired height.

3. Neither the base nor the head of the jack should bear directly against the masonry. Both must be separated from it by means of steel plates (or wood blocking in temporary installations) and cement grout.

The use of plates greatly increases the bearing surface, permitting support of more than a single stone. A layer of cement grout at proportions of 1 to 1 will take up inequalities in the stone or between several stones and provide an even distribution of force. Due to the irregular nature of building stone it is usually impossible to seat a jack squarely against it anyway.

In some cases, especially in small areas, it will be impossible to support breaks by extending beams through the wall. It will be necessary to place jacks within the break itself. (Fig. 29.) In either veneered or single width walls, examination will indicate the approximate center line of masonry to be supported.

Repair of Wall Breaks (con.)

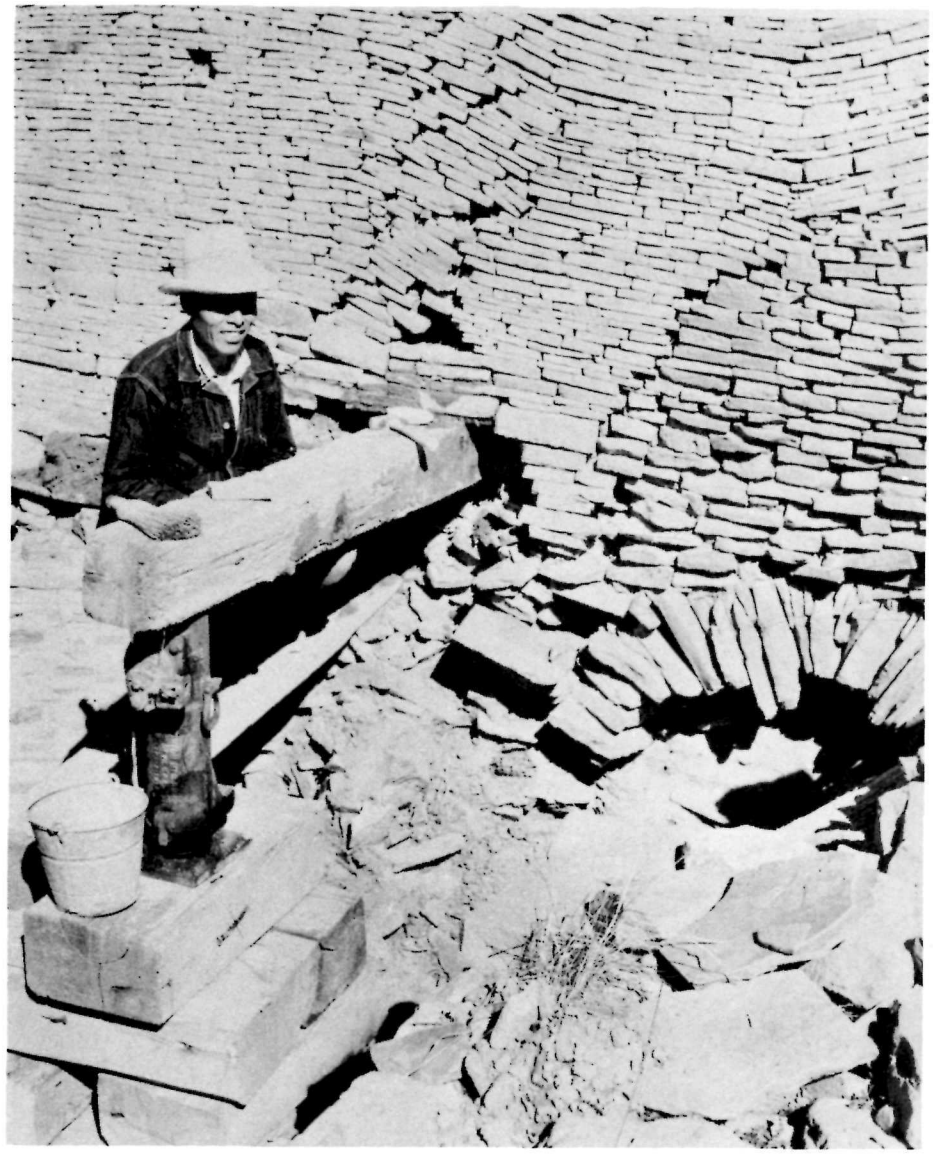


Fig. 26. Temporary support. The arch section, lower right, was a repair measure of the 1920's. The arch is being replaced to halt further settling and because of its incongruous appearance in an area where the arch did not occur. First step in supporting the wall is placement of the beam through an adjacent hole. Masonry above the beam is being repaired.

Repair of Wall Breaks (con.)

Fig. 27. A second beam resting on jacks is placed through the wall. Arrows indicate extent of steel plates above the beam. With some upward pressure the area of settling was reduced.

Repair of Wall Breaks (con.)

Fig. 28. Jacks and beams provide support while arch section is removed and break is filled with repair masonry. (Clearing away the rubble showed that the arch had been built over a broken doorway; this was rebuilt.)

Repair of Wall Breaks (con.)

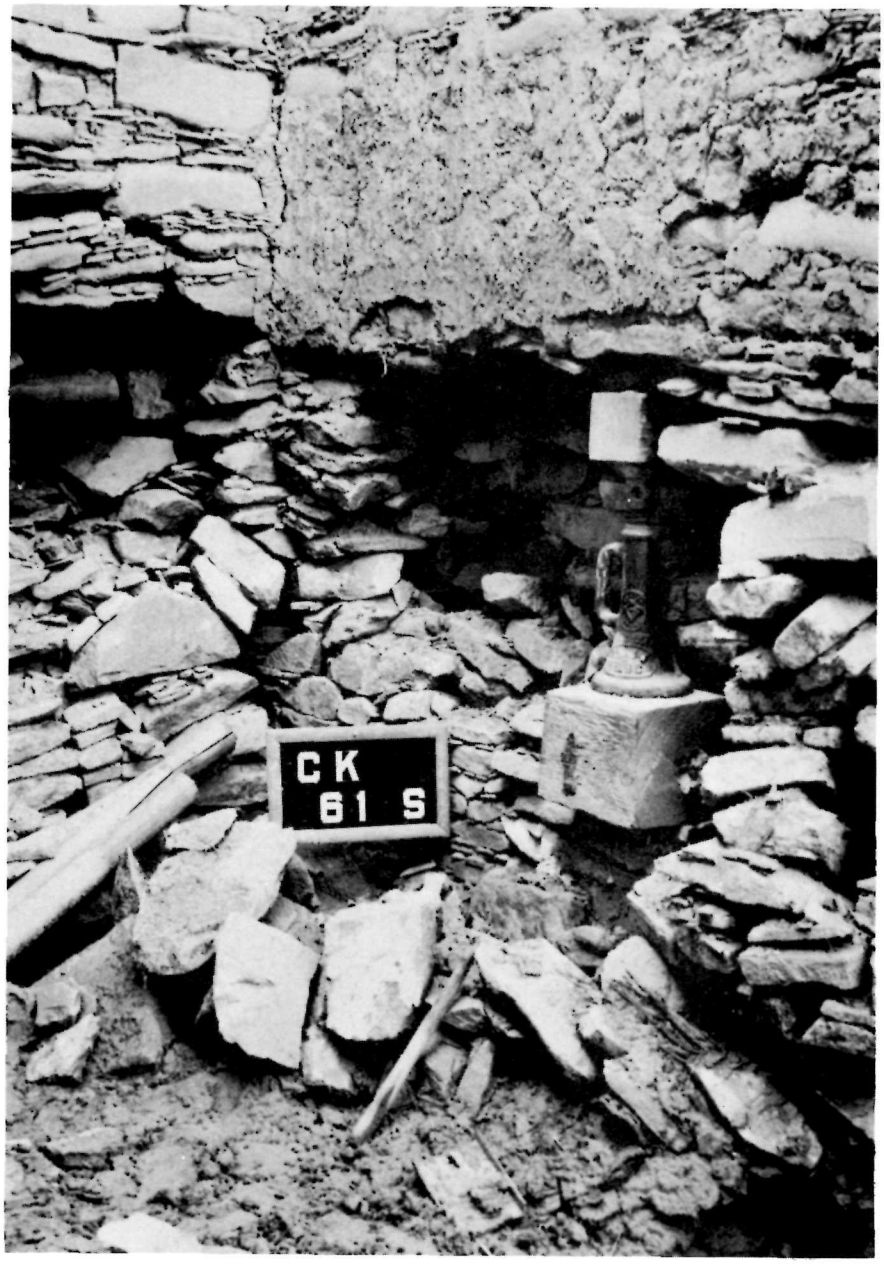


Fig. 29. Placement of jack in line with shattered facing near the bottom of a 14 foot wall. It provided support while the broken area at the right was being replaced.

Repair of Wall Breaks (con.)

The jack must be placed as nearly as possible in this line. A variation toward the center of the wall will tip the masonry above downward and out when force is applied; and conversely if the jack is too far out when it is run up, pressure will act toward the center of the wall and tend to kick the jack out of place.

Once the jack is placed with plates and grout, it can be run up with light pressure until the plates are forced evenly against the masonry and some of the grout is extruded. With the grout conforming to the shape of the supported masonry, allow sufficient time, at least 24 hours, for it to gain an initial set before more pressure is applied.

Always take enough time when setting jacks. If more than one is to be used, set them on succeeding days. While temporary jacks are in place they should be tested frequently. The grout will shrink slightly as it sets; if wood blocking is used it will be compressed to some degree. Cribwork resting on soil will settle. The jacks must be taken up to compensate for all of this shrinkage.

Permanent Support. Due to limitations of space or the nature of the break, it will sometimes be much more satisfactory to install jacks permanently in the wall. This is also a quick method of providing support when a section of masonry has been taken down. The requirements here are much the same as with temporary installations, except that wood blocking cannot be used.

For permanent installations, once the jack has been set masonry can be built around it up to the level of the screw. Then wait until both the grout and masonry have set before placing a full load on the jack.

In both permanent and temporary installations, just how much pressure to exert with the jacks is somewhat of a problem. Masonry will weigh some 120 pounds per cubic foot. A column of masonry 12' high, 1.5' thick, and 2' wide will weigh a little over 2 tons. Since this column has some support of its own or it would not be standing, it is doubtful if more than half the weight, or 1 ton, will come completely on the jack. A jack with a screw 1" in diameter has a capacity of 5 tons; one with a screw 2" in diameter a 20-ton capacity. This might give some indication of how much weight is being taken up.

Repair of Wall Breaks (con.)

Probably the best procedure is to take the jack up a slight amount each day and carefully examine the wall above for signs of movement.

Somewhat the same procedure as outlined above for small areas, can be employed in supporting large sections of wall where the entire width must be removed. This is also a useful method of support where large horizontal timbers are to be replaced with cast members. (Fig. 30.) In supporting large and heavy sections it is best to run large timbers or steel beams entirely through the wall, supporting the ends with jacks. All precautions listed above for other temporary support should be followed in regard to placement, grouting between the supports and the masonry, cribwork bases for the jacks and frequent compensation for settlement.

Working conditions can often be made safer by the use of external bracing against bulged or shattered areas. Jacks with timber set in sleeves are much more satisfactory than timbers alone, as the use of jacks allows some force to be applied to the surface. Timbers alone will not take up much stress until there has been some movement of the structure against them. To be effective, pressure must be applied at the point of greatest movement or distortion.

Realignment

Realignment of distorted, out-of-plumb walls is seldom practicable unless the wall is in good condition otherwise. (Figs. 31, 32, 33.) If the wall has to be realigned and is in poor condition, it must first be strongly repaired using a soil mortar. Do not repair it with cement or stabilized soil mortars.

Considerable time, care, and equipment are required to realign a wall of any size and the general requirements are, first that it must be completely formed on both sides, and second that it must be thoroughly damp if it is not to be cracked further or distorted in some other direction.

The steps taken should include:

1. Before any work is done, run small hones through the base of the wall in order to tie the two sides of the form together with wire or thin bolts.

Realignment (con.)

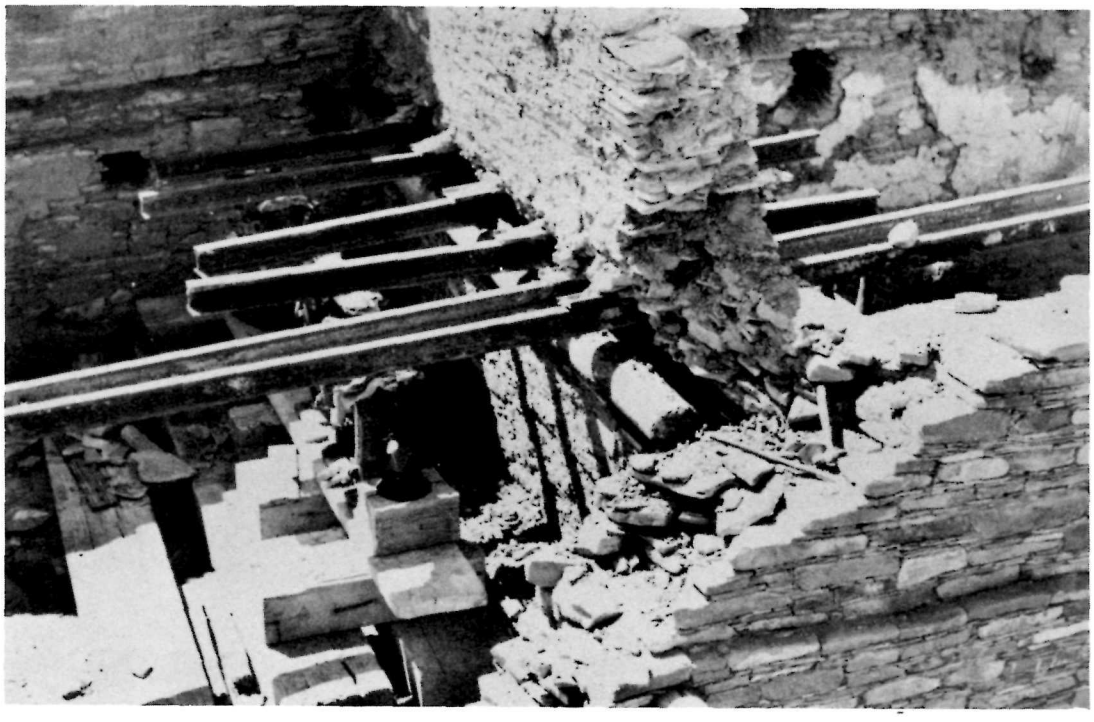


Fig. Temporary support. Six steel beams support the upper half of the wall while a decayed horizontal timber is replaced. The timber is partly removed here. With a little care, steel beams can be run through pole sockets or other natural openings without damage to the wall.

Realignment (con.)

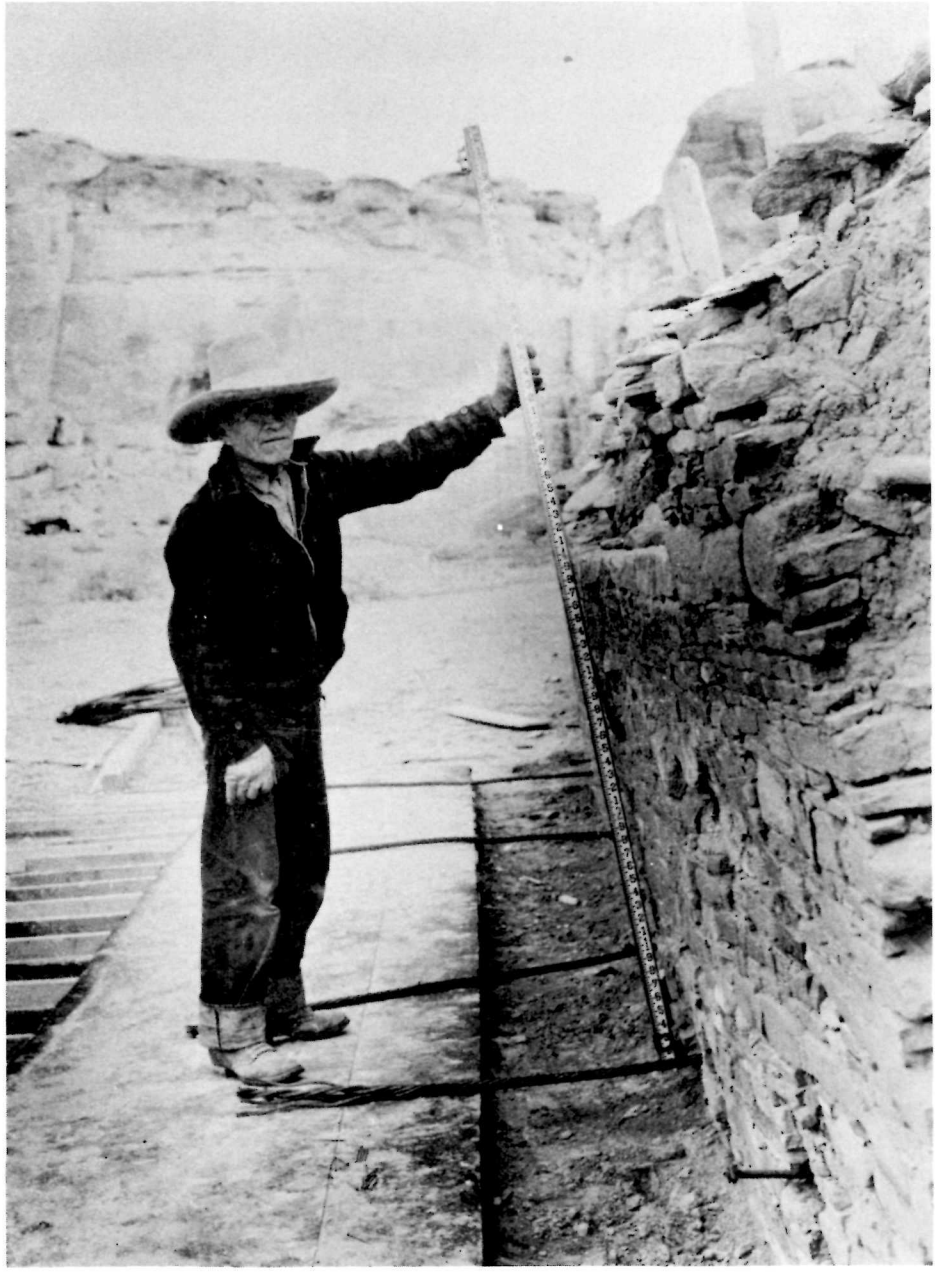


Fig. 31. Realignment. Cables have been placed through the base of the wall to be tied to the jacks. Note bolt, lower right for holding frame against wall. The framework is partially completed.

Realignment (con.)

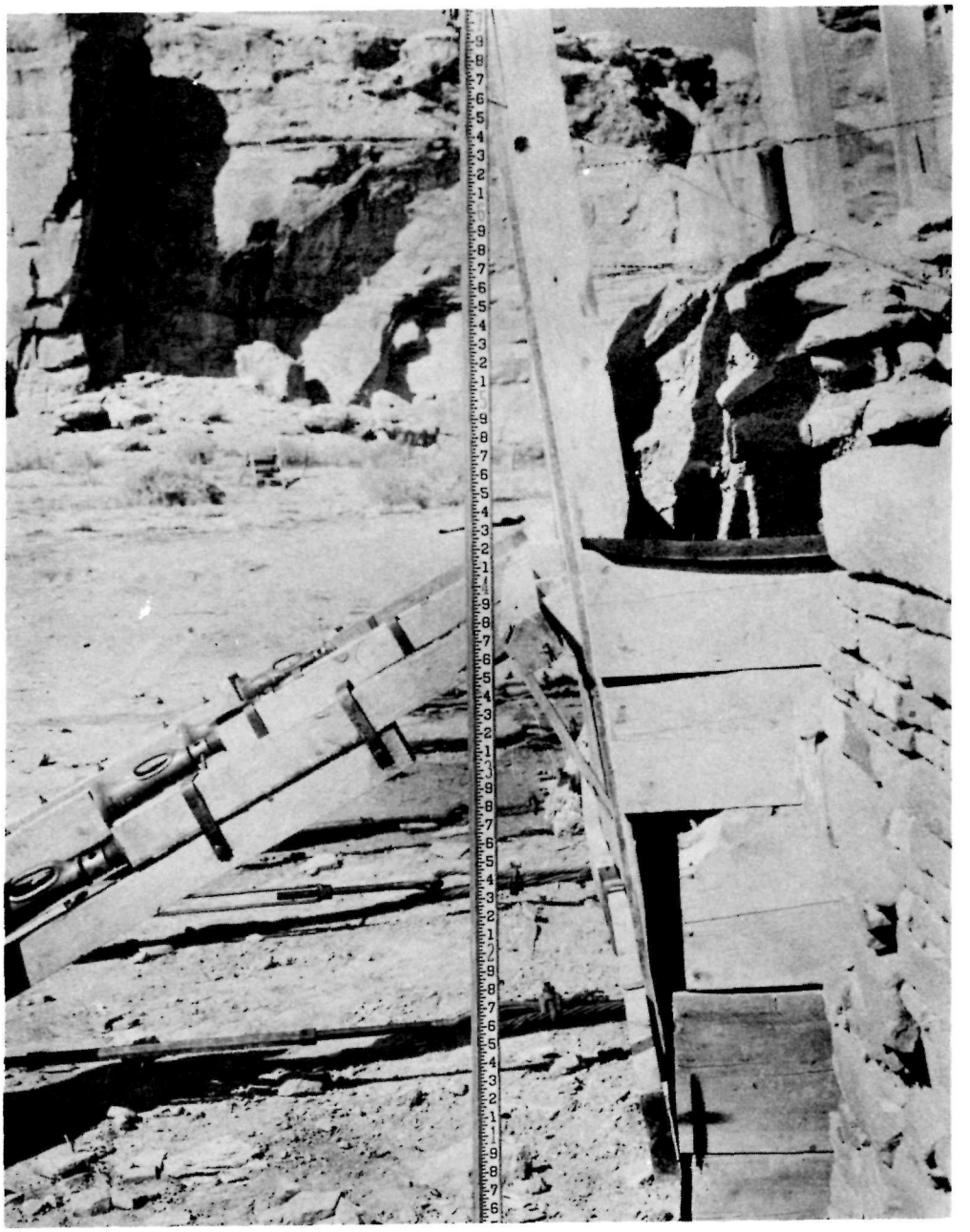


Fig. 32. Realignment. Framework in place on both sides and tied together. Frame lined with asphalt paper, space between frame and wall packed with sand. Note that the five screw jacks in sleeves bear against a 4 x 4 timber to distribute the pressure.

Realignment (con.)

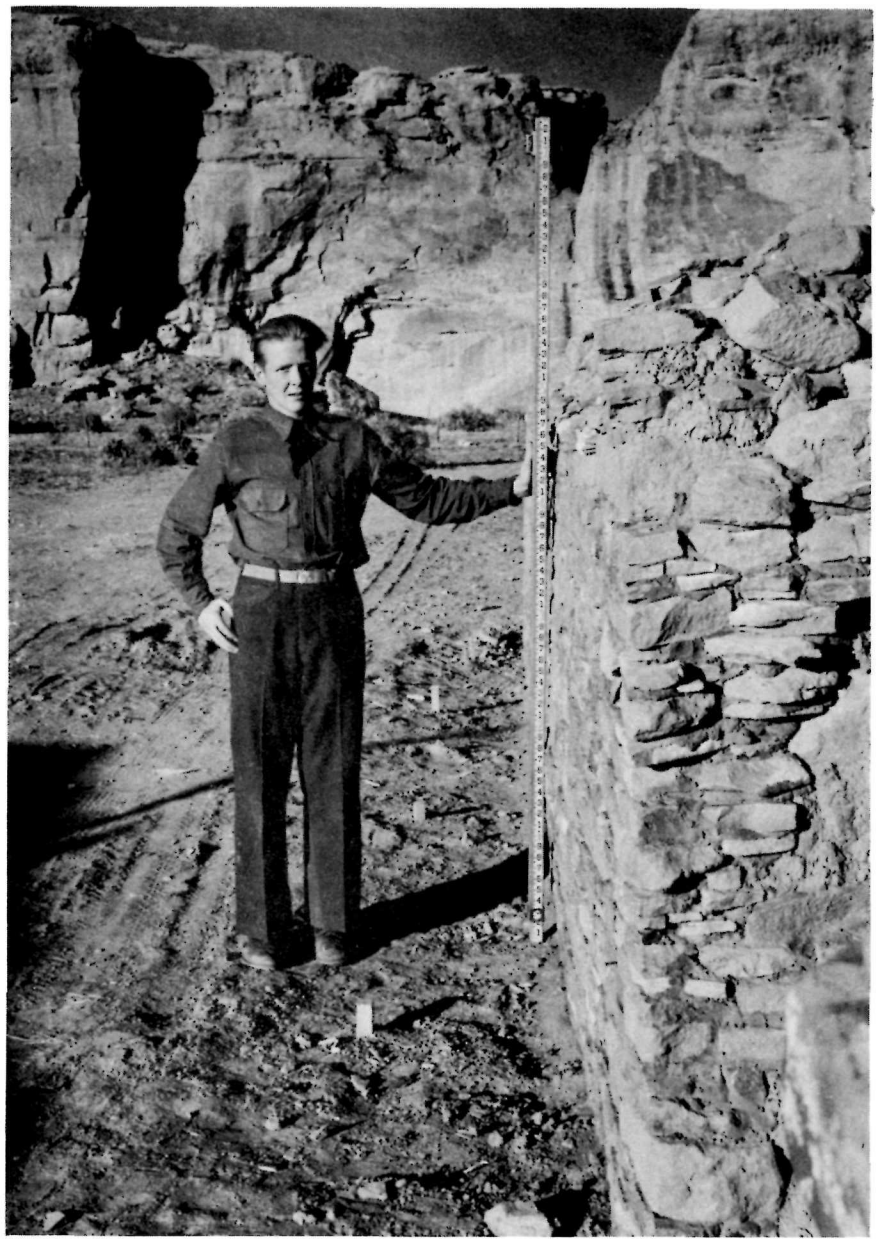


Fig. 33. The wall after pressure had been applied for three weeks by means of jacks in sleeves.

Realignment (con.)

2. Construct heavy forms of 2" lumber large enough to completely cover the area to be moved. Line the inside of these forms with asphalt building paper.

3. Set the forms up; leave a space of between 2 to 3" between each form and the surface of the wall. Tie the forms both top and bottom.

4. Pack this space with wet sand. Be sure there are no voids in it. Cover the top of the wall also. Begin to keep this sand continually wet. This requires time and patience. Do not flood the wall in order to hurry the process, as this will only wash out the soil mortar instead of dampening it. Allow from 3 weeks to a month to dampen a wall 2' thick.

5. While the wall is being dampened, set deadmen or other supports against which the jacks can be placed. Timbers in sleeves are necessary to keep the jacks in alignment.

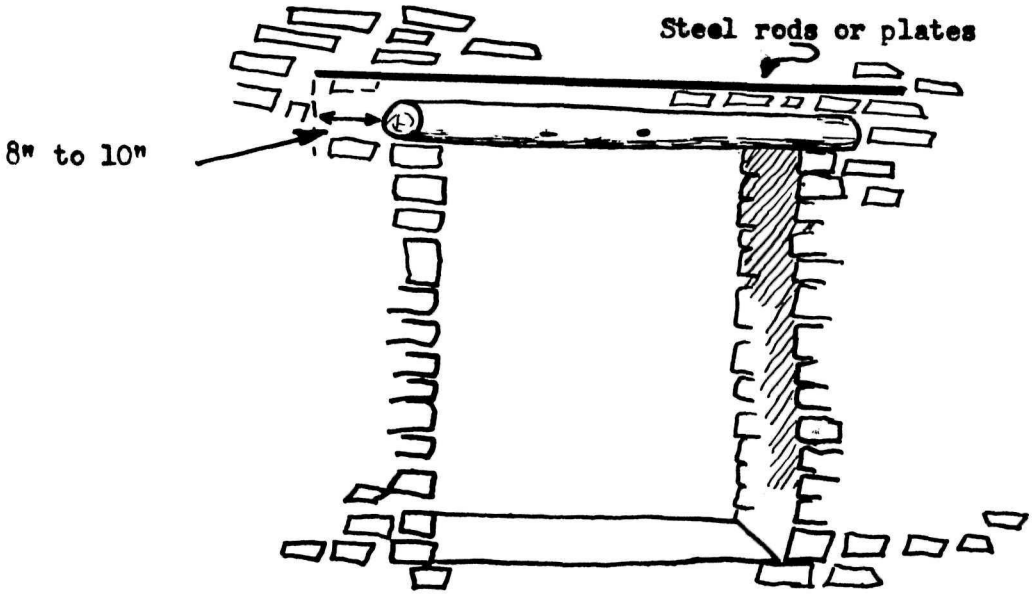
6. After the wall is damp, begin to apply gradual pressure with the jacks. Mark the top of the form and set stakes or other points so that movement in the wall can be measured. It will require from 2 to 3 weeks to straignten a wall. Do not try to hurry it. There will be some compression in the forms and timbers, and settlement of the deadmen, so additional blocking behind the jacks will be required.

7. After the wall is straight, allow it to remain in the forms for another week or two to start drying while it is still supported.

Repairing Wall Features

Replacing Wood Members. Crushed, sagging, or rotted wood members will often be found in place over open or filled doorways, windows, or other openings. In low and narrow walls there is little that can be done except to remove the timbers and replace them, either with wood or cast members, rebuilding the wall where necessary. Where wood is the replacing material, some effort must be made to reinforce it. In short spans, steel plates may be set above the lintels, while in longer spans the wall above the wood must be set in reinforced concrete mortar. In any case, the steps are the same. (Fig. 34.)

Repairing Wall Features (con.)



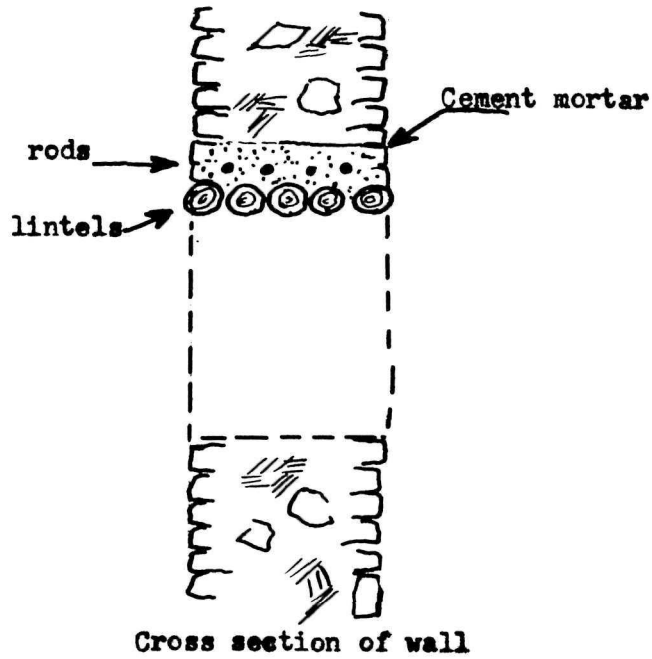


Fig. 34, placement of reinforcing in concrete mortar over pole lintels.

Repairing Wall Features (con.)

1. Masonry above the lintel must be removed for the entire width of the opening, plus at least 6 additional inches beyond each end of the new lintel. In thick walls, one side may be completed first and the other side done after this has set.

2. Place the new lintel above the opening after the sides have been repaired and build up the masonry at the ends till it is slightly above the level of the new lintel.

3. If plates are used, lay them over the wood but make sure the ends rest on the masonry at the end and not on the wood. If a reinforced section is to be used, run a thin layer of concrete mortar over the wood. Embed reinforcing steel in this, likewise making sure the steel and concrete extend beyond the ends of the wood. Complete filling space above the lintel with masonry set in concrete mortar. The amount of reinforcing and height of the concrete band will be determined by the span of the opening.

Support With Wood Members in Place. If cracked or decayed timbers are found above an opening which has been partially or completely filled in prehistoric times, as is often the case, the best and easiest method is to leave the outside poles in place and base the repair masonry on the fill, carrying it up through the center of the wall. The exterior poles or lintels are left for appearance only.

The steps in stabilizing such an area are:

1. Repair the prehistoric fill in the doorway up to the level of the wood which is to be left in place. At one side of the opening make a small hole above the outside timber deep enough to expose the interior lintels.

2. Cut out sections of the interior lintels. The length to be removed depends on the span of the opening and the condition of the wall above. One-third to 1/2 of the total length is enough to remove at one time. In large openings, or where the wall is particularly unstable, 1/5th or 1/4th is sufficient.

Lintels are most easily removed by a combination of drilling a row of holes across them and sawing between these holes, rather than chopping or chiseling them out. Pounding on them is apt to bring down most of the wall in fragile areas.

Repairing Wall Features (con.)

3. With 1/3rd or so of the lintel out, build up a vertical section of repair masonry from the patched fill below to the original wall above.

4. After this has set, repeat the process of cutting out a section of the interior lintels and bring the repair up behind the outside lintel.

Beam and Pole Sockets. A great deal of prehistoric construction seems to have followed this course: (1) the walls were raised to ceiling height and the vigas laid; (2) these were covered with small poles or savinos and on top of these went the matting, split cedar, bark, or whatever was handy; (3) this in turn was covered with soil for the next floor; (4) after this ceiling and floor combination was laid, the walls were raised for the next story.

This sequence, with the ceiling and floor being finished before another story was added, often resulted in (1) the upper story being set back; (2) the upper story overhanging the first one, or a combination of these two, set back at one end of the room and overhanging at the other; (3) a weakened strip where the ceiling material and dirt floor extended into the wall. Quite often there is no continuous contact of the masonry, vertically, from one room to that above--there is a strip of soil that was the floor, or partly rotted vegetal material that was the ceiling, separating the two.

In repairing these strips, whatever remains of the ceiling material will have to be removed if it has not entirely rotted out (as is most likely). However, the location of the pole or savino sockets should always be preserved.

In cleaning out the back part of the strip, the location of the sockets can usually be found; or at least enough of them to indicate the location and spacing of the remainder.

The most satisfactory method of repairing pole or savino sockets is to cut several stub poles that are the same size as the originals. Oil them. After the location of each socket is determined, set a stub in place of the original and make the patch around the stub. The stub need not be set in the wall the entire depth of the original, and the space behind the stud should be well filled with mortar. When the patch is completed and the mortar set, the stub

Repairing Wall Features (con.)

can be removed. The hole is left in the exact shape of the stub; and the stabilized mortar will hold the stone in place at the top of the hole.

The same method can be used in repairing large beam sockets, since in the original masonry they were seldom if ever finished off with a slab on the top or made to that they would stand without the support of the viga. In rebuilding big viga sockets around a stub viga, it is usually best to use concrete and leave the stub in place some 24 hours to allow the mortar to gain an initial set.

Cast Concrete Members. Wood is the least durable material used in ruin repair. It may be treated with preservatives and protected from weight in the wall above by integral members which carry the load. However, large timbers are difficult to treat thoroughly unless facilities are present for complete immersion. Further, integral members are time-consuming to construct in small horizontal sections. Integral members made in conjunction with the replacement of wood beams and lintels cause some disturbance to the adjoining masonry. The use of cast lintels and poles eliminates many of the above difficulties. They permit the replacement of wood with little disturbance; they provide a strong, rigid and very durable member. Cast lintels take the same surface and texture as the wood from which cast; with a little care they may be stained to faithfully reproduce the original. (Fig. 35.)

Excellent instructions for making casts may be found in Chapter VII of the National Park Service Field Manual for Museums. The data given below assume some familiarity with those instructions, with casting in general, and are given only as supplemental, applying only to the casting of concrete structural members in a 3-part mold.

For ease in handling, when several pole lintels are to be cast it is preferable to make a lumber form to hold the mold, as long as the longest piece to be cast, and some 4 to 6" wider and deeper than the diameter of the largest piece. This form will hold the plaster mold made around the original wood lintel and it will also hold this mold while the concrete piece is being cast. The form should either be hinged so that the sides swing away without interfering with the mold or they may be bolted together with light bolts and wing nuts for ease of assembly.

Repairing Wall Features (con.)

Fig. 35. Cast concrete lintels have the same appearance as the originals from which cast, are easy to install and are durable.

Repairing Wall Features (con.)

In using plaster molds the piece to be cast must be dry and clean. Deep cracks and holes should be filled to within 1/8" of the surface with plasteline or similar material. The piece should then be well oiled with an oil designed for use on concrete forms or with a light motor oil.

Close the lumber form and place 1 or 2" of fine damp sand in the bottom. Place the wood lintel on this sand and add more sand until only the upper third of the pole is exposed. At this point provision must be made to key the parts of the mold together so that they can be replaced in exact alignment after the pole is removed. Rounded depressions may be made in the sand and the plaster flowing into them will act as keys for the adjoining side of the mold. A more accurate method is to place a bolt toward each end of the cast, thread down in the sand and with the head protruding enough so that it will be set firmly in the plaster. This permits the parts of the mold to be bolted together and prevents movement in any direction. The bolts must be long enough to extend entirely through the sand.

Most field men are familiar with mixing plaster of Paris and detailed instructions may be found in Chapter VII of the Field Manual for Museums. Enough plaster should be made for the first pour to cover the exposed part of the lintel and fill the wooden form to the top. Care should be taken not to entrap air-bubbles in the plaster. When the pour is made, smooth off the top as the mold will be turned over and this part becomes the bottom on which the remainder of the cast will rest.

If the mold is to be a large one, for casting timbers or vigas, it is best to reinforce it with strips of burlap dipped in plaster, with small dry branches, pieces of discarded reinforcing steel, etc.

After the plaster has set, pull back the sides of the form. Turn the form over gently and remove the sand. One third of the pole will be set in plaster with the other 2/3rds exposed. Shellac the edges of the plaster where the keys have been made. Oil this edge and the exposed part of the pole.

Place the part just made, with the pole attached, in the bottom of the form, the pole up, and reassemble the sides and ends. Place a strip of 2" lumber lengthwise on the center of the pole. This is

Repairing Wall Features (con.)

to separate the two remaining parts of the mold. Fill any inequalities between the strip and the pole with plasteline.

The second pour of plaster is made on both sides of the longitudinal strip, level with the top of the form, and completes the three parts of the mold. When the plaster has set, break down the form and remove the three parts of the mold from the pole. Some care must be exercised in taking these various pieces apart.

When the parts of the mold are completely dry, shellac them thoroughly. Reassemble them back inside the wooden form making sure that each fits correctly against the other. (There will be a 2" opening, lengthwise, between the pieces along the top.) Tighten the form so that there is no movement.

Oil the interior of the mold. Cut the correct length of reinforcing steel of 1" or 5/8" diameter. Mix a grout of sand and cement at 1 to 1 plus enough concrete with fine aggregate to fill the mold. The most difficult part of making a cast is placing the grout so that all inequalities in the surface of the mold will be filled, as this work must be done through the 2" opening. Coat the interior with the grout, place part of the concrete in the mold and embed the reinforcing in the center of the cast, complete filling the mold with grout and cement.

There are various ways in which the cast poles may be colored. One of the most satisfactory involves two steps: (1) when the grout and concrete are prepared a small amount of mortar color is added as a ground color. It must not make the mix darker than the lightest part of the wood lintel which is being copied. This serves as a base or background for the following stain.

After the concrete is removed from the plaster mold it should be cured in a warm, damp atmosphere for 7 days and then let dry out slowly or it is apt to flake. (2) After the curing period, scrub the concrete with zinc sulphate and let dry. It is now ready to stain. Ordinary penetrating wood stain (not varnish stain) is recommended by the Portland Cement Association. Start with a light stain and do not apply it evenly. Follow the directions as to rubbing it off after a few minutes. Continue to stain the piece using darker colors until the desired effect is obtained.

Repairing Wall Features (con.)

The suggestions above have been given for making the mold of plaster of Paris, a material fairly easy to work and one that sets rapidly. Experienced workers may wish to employ any of the various latex molding compounds if they are making large runs of one particular pole lintel.

Once the technique of simple casting has been mastered there is no end to the possibilities. Lintels may be cast with withes in place, duplicating the actual withes with which they were tied together in the wall. Particular logs which have been badly cracked or partially rotted may be cast in exact replica and these placed back in position in the structure. (Fig. 36.)

Integral Structural Members

An integral structural member is an internal, reinforced concrete beam constructed within the repaired portion of a structure to give it added strength. It may be employed (1) in arch form to stabilize holes either partway or entirely through walls, (2) used for both vertical and horizontal support, (3) to give added strength over horizontal timbers embedded in the wall, and (4) as bracing for overhanging sections.

Reinforced Arch Sections. With arch sections, large irregular holes may be stabilized "as is". The hole is still present and it has the same appearance and irregularity as before. The only change is that it is slightly smaller and will not develop further.

Full Width Sections. Almost any size or shape of hole can be stabilized by this method, but little time or money is saved by using it for very small holes and they are tedious to do.

To start a reinforced arch in a large break entirely through the wall, first clean the break to sound masonry and lay at least two courses across the bottom of the break, in concrete mortar. More may be necessary in very large holes, or additional courses may be built up on the sides of the hole to form a good base on which to rest the steel which will follow.

Next, two pieces of light reinforcing steel 3/8 or 1/2" are bent to fit within the outlines of the break. One piece goes on each side of the wall and just far enough inside the opening to

Integral Structural Members (con.)

Fig. 36. A horizontal, cast log replaces the original timber which had rotted on the interior and in the embedded portions.

Integral Structural Members (con.)

allow a facing of masonry to cover it. The two ends of each piece will rest on the masonry just laid across the bottom of the opening. (See Fig. 37.)

When the steel is in place it should be securely wired and tied together with additional bracing where required. The purpose now is to build up a thin band or lining of masonry set in concrete mortar, around the reinforcing steel. The repair masonry is laid in horizontal courses right across the extent of the break but only that part which encloses the steel reinforcing is laid in concrete mortar. The portion of each course which does not enclose the reinforcing is laid dry but it must be laid solidly because it will have to support, without shifting, the projecting stone in the vertical irregularities and also all of the top of the patch until the concrete mortar is set. If the stone is very irregular, it is well to lay some in the center with soil mortar to give it more stability.

This procedure is followed--concrete mortar between the stone on the outside next to the steel and dry masonry or soil mortar in the center--until the top is reached. The top courses will also be set in concrete.

After the hole is filled, the concrete mortar area must be kept damp until the concrete has set. Then the dry masonry in the center is removed and the hole is left in the same irregular shape (but slightly smaller) as originally, and protected from further breakdown by the reinforced band. (Fig. 38.)

Partial Wall Sections. Exactly the same type of reinforced arch sections may be constructed in thick walls where only one side of the masonry is broken out. Here, ordinarily, only one piece of reinforcing is required.

Vertical and Horizontal Members. The principal application of these members is to tie together sections of separated and out-of-plumb walls, to reinforce walls against which there is pressure of retained fill, to re-lay overhanging and precarious sections, and to provide support over horizontal logs. (Figs. 39, 40, 41.)

Since conditions and structures vary so greatly, it is difficult to anticipate all possible applications. The requirements in general are:

Integral Structural Members (con.)

Fig. 37. Integral members. Starting a reinforced arch section. Reinforcing rods have been bent to fit the contours of the break and are wired in place. The workman is laying the courses across the bottom of the break in concrete mortar to provide a solid base for the reinforced section. Above this level, masonry on the perimeter of the hole will be laid in concrete mortar which will also surround the steel rods. Masonry in the center of the hole will be laid dry or with a minimum of soil mortar; its only function will be to support that laid in cement until the latter has set. This dry masonry will then be removed.

Integral Structural Members (con.)

Fig. 38. Integral member, a large reinforced arch section. Here the size of the break through the wall precluded filling the center with dry masonry as support, and this timber framework was substituted. The heavily reinforced band is socketed in the cliff wall at the left side and based on bedrock at the right. The integral member has just been finished and the mortar has not yet dried. After the mortar has set the timber framework, the dry masonry at the right and that on top of the horizontal plank were taken down, leaving this large hole with its original outline, only slightly smaller and strengthened against collapse.

Integral Structural Members (con.)

Fig. 39. Integral members. Steel in place for a narrow vertical section. The steel must be tied in securely to the cross wall at the top to provide support for the overhanging area. Some support will be required for the vertical strip of masonry as it is being laid and until the concrete mortar has set.

Integral Structural Members (con.)

Fig. 40. Reinforced integral members are of particular value in the stabilization of tall spirelike structures such as this where considerable strength must be added without serious or objectionable alteration of the original profile. (See Fig. 41.)

Integral Structural Members (con.)

Fig. 41. Detail. Placing reinforcing in the third story portion of the structure shown in Fig. 40. The purpose is to heavily reinforce the vertical capping which will be laid up the exposed ends of the wall to both prevent further erosion and to tie this part of the wall together. When this part was completed a short reinforced column tied into that below, was run up into the top, precarious fragment.

Integral Structural Members (con.)

1. Vertical sections must be based on adequate foundations, and the top should always be well tied into a stable part of the structure by means of longitudinal rods.

2. Care must be taken to have as good a bond or tie as possible between the member and the supported wall. Sufficient patching should be done adjacent to the member to prevent any separation from the wall.

3. In arch sections, in overhanging areas and wherever the steel will provide the major part of the support, care must be taken to adequately support the member, by framework, dry masonry or the like until the concrete has gained its full strength. Correct curing of the concrete in these thin bands is essential.

Capping

Capping is considered here as all repairs which extend to and include the tops of walls, and all work done in resetting or otherwise altering the upper courses in masonry, brick or adobe construction to provide additional strength or protection against weathering. Capping is intended to tie the upper courses of masonry together and may employ light reinforcement for this purpose where walls are out-of-plumb or there are slight overhanging areas; it is intended to provide a water resistant layer at the top of the wall and to provide additional strength where walls are subjected to unguided visitor traffic.

In brick or adobe construction, primary reliance for the effectiveness of the cap will have to be placed upon the substitute masonry units used--stabilized adobes made for the purpose, new or treated brickwork. In setting cappings in stone masonry the effectiveness for strength and waterproofing will depend upon the substitute mortar employed. Standard construction practices require the use of continuous metal flashings in the upper courses of exposed wall tops, parapets, cornices and the like. This requirement can be met and the method employed where regular units laid in courses, brick and adobe walls, are being repaired. Standard architectural requirements should be studied and followed in this respect.

The use of metal flashings is impractical in sloping, random coursed masonry walls particularly where there are great variations

Capping (con.)

in elevation in a single wall. There, any capping is a compromise between sound, watertight construction, appearance and authenticity.

Evaluation. The most durable capping laid in the Southwest on masonry structures from the point of service are some of the 1917-1918 cement caps made at Aztec by Earl Morris, and the 1920-1921 cement cappings laid at Chettro Kettle by Sam Huddelson for the School of American Research. Soil-bitumen capping laid on various other Chaco ruins in the period from 1937 to 1940 had also, in most cases, proved quite durable. These three capping jobs employed the same technique, in that sufficient depth of stone was relaid in the mortar to provide some measure of tensile strength--an average depth of a foot or more. Each contained embedded stone laid in the same manner as the original work and in about the same proportion of stone to mortar. Examination of these and other examples suggests that to be successful a capping must have sufficient strength and thickness to be a complete unit itself, fastened to the top of the wall, rather than being considered as a thin sheet or membrane laid over the wall to serve merely as a waterproofing.

Field Control, Visitor Traffic. There were 921,500 visitors to archeological and historical monuments in the Southwest in 1961, exclusive of Casa Grande. The greater proportion of these visitors made unattended trips through the historic and prehistoric ruins. The day is past when ruins stabilization work, particularly capping, can be concerned only with protection from the elements. Prime consideration must also be given the areas receiving heavy use by the ever increasing numbers of visitors.

Thus, for the capping of masonry walls it is recommended that wherever possible only the best cement mortar, made with clean sharp concrete or mortar sand, be used. In many areas this graded sand will have to be trucked in from commercial sources. It is expensive but it is also more economical than replacing a job done with inferior materials.

At extremely isolated sites where materials would have to be transported long distances by pack animal, soil-cement made with local soils may be substituted for sand-cement mortar. However this should be only a last resort as soil-cement, while resistant to weathering, does not, usually, produce a durable bond against foot traffic, climbing up protruding stone, and similar abuse.

Capping (con.)

1. In capping of any wall, sufficient loose and decayed material must be removed to insure a good bond with sound masonry - stone, brick or adobe - below. (Figs. 42, 43.) Where regular units are employed in coursed walls, a sound, even surface must be reached or built up on which to place the flashing. In most cases sufficient courses should be removed to provide the desired depth of capping without the addition of new units. Where the upper levels of a patch are to form a cap, new stone or other units will have to be employed. (Fig. 44.)

2. If possible, the work should be laid out so that each wall will be capped as a unit. It is not advisable to attempt to run capping across wall junctures. It makes for poor appearance; there is also apt to be some movement at this point and if capping is carried across the juncture it will break either there or at some weaker point.

3. The capping on wide walls should be sloped or tilted to drain water away from wall junctures for a short distance and laid so that moisture does not pond on the tops. A point of weakness with any capping is at the outside bottom edge where the cap comes into contact with the wall face below. Capping should not be feathered out at this point but should retain its full cross section. This is the point at which runoff enters the wall below and every effort should be made to produce tight mortar joints with the underlying wall face.

4. Any capping is still a comparatively thin and weak part of the structure. Every effort must be made to produce a durable job. All stone employed should be clean and free of soil. It should be damp when placed in the mortar to insure good bond and prevent too rapid drying of the mortar. Control must be maintained over the mixing to prevent excessive amounts of sand or water. Lastly, some provision must be made to insure proper damp curing.

5. While no data have been accumulated, it is suggested that treatment of capping, particularly those employing adobes, stabilized adobes and similar units, with silicone waterproofing will materially increase their effectiveness.

Capping (con.)

Fig. 42. In many instances it is difficult to draw a distinction between general wall repairs and capping. Here the wall will have to be carried up to the level of the outside fill to prevent further washing over the top. Whatever type of mortar is used for these wall repairs the top courses must be set in a cement mortar to provide as durable and waterproof a cap as possible.

Fig. 43. Here patching of the hole will have to be combined with a short section of horizontal capping plus vertical capping or protection for the exposed and weathered vertical rise of wall.

Capping (con.)

Fig. 44. In a badly deteriorated wall, such as this example, a good deal of repair masonry must be laid to fill the wall breaks and support undercut areas. Some support must also be provided for the embedded timbers. In the major part of this work it is permissable to use soil or masonry cement mortars, preferably the latter. The upper courses must, however, be laid in concrete mortar as capping to halt further washing from the top. In this example, damage was started by surface water from adjacent, unexcavated fill and every effort should be made to divert such surface water.

Roofing and Roof Support

In the past, a variety of methods have been used for protecting existing prehistoric ceilings and roofs in situ. They have ranged from the elaborate evaporation-pan type of roof installed at Aztec Ruins in the early 1920's to simple, temporary structures. Due to the very nature of the problem--intact ceilings often a story or two below the upper limits of the walls--protective coverings have been difficult to construct and a few have been unqualified successes. Protective covering of permanent type have seldom been constructed near the tops of walls, a story or more above the ceilings because (1) of the difficulties in roofing the very irregular wall tops, (2) of the unsightly appearance of roofs protruding above the masonry, (3) there are often openings between the ceiling level and the wall top which have to be closed or sealed off, (4) the aboriginal ceilings often require some support from the protective covering.

The early evaporation-pan type of roofs installed at Aztec were soundly designed and constructed. They were of concrete slab construction, made so that they did not drain but held water until it evaporated. Such a design obviates the need for drainage lines and downspouts and does not mar the appearance of a site as do numerous spouts. These roofs functioned quite well during the summer and fall rains; they had ample capacity for seasonal rainfall. During the winters however, they accumulated great depths of melting snow and ice, and the water level rose above the limits of the pan. At this level, water worked through the masonry and entered the ceiling material below. In time, also, the concrete of the pans subjected to almost constant moisture and alternate freezing and thawing, began to crack and the surface to disintegrate.

As a remedy the evaporation pans were remodeled into roofs with drains. Concealed tile drains were installed in the heavy walls and the concrete slab was covered with a built-up type roof covering, finished off with pea gravel or chips. This solution has been only partly successful since difficulty was encountered with stoppage of the tile drains. The majority of them are so situated at the north side of the site that they became stopped with alternately freezing and thawing snow and ice during the winter months. Some of the more troublesome of the drains were later converted to larger size, opening directly to the exterior of the wall. The result is less attractive but it has provided a watertight roofing.

From this and similar experience with difficult roofs, evolved the coverings designed for and installed over 14 prehistoric ceilings

Roofing and Roof Support (con.)

in the East Ruin during 1957. (Figs. 45, 46.) These were in an unexcavated site where only previous protective measures had been the temporary bracing of cracked and broken timbers.

Requirements and dimensions for a protective covering will vary from room to room. However, the major limiting factor is the strength and condition of the walls which will have to support the new roof. In many instances in the heavy-walled construction of Pueblo III, stabilized walls are sufficiently strong to support a slab type permanent roof. Where the weight would be excessive for the existing walls, the same type slab roof as noted below can be constructed, supported not by the walls themselves but by upright members, steel I-beam supports, rising along side the walls and based on concrete slabs at floor level. The vertical columns will support the slab while lateral stability is provided by the walls. The vertical supports will have to pierce the aboriginal ceiling and they must do so at points where they do not interfere with its important members but where they also furnish the required support.

Slab Roofing. Since ceiling areas to be protected vary considerably in size and span and the condition of the walls also varies, the following are general suggestions only on the construction of concrete slab type coverings for their protection and support.

1. Lightweight concrete made with commercial lightweight aggregates has extensive use in the construction of modern roof decks. Every consideration should be given to its use when designing slab type coverings. Weights of concrete made with lightweight aggregate run from 25 to 50 pounds per cubic foot as against an average of 150 pounds per cubic foot for concrete made with sand and crushed rock aggregate. This permits coverings where the weight of heavier aggregates would be prohibitive and also permits the use of much lighter members below the slab. When sand is added to the lightweight aggregate a mediumweight concrete results and a wide range of strengths may be obtained by varying the proportion of sand to lightweight aggregate. In general, lightweight slab construction should be based on corrugated metal such as Corruform or Tufcor rather than upon paperbacked metal lath or ribbed metal lath. The thickness of ordinary lightweight concrete decks varies from 1-1/2" to 3".

Roofing and Roof Support (con.)

Fig. 45. Roofing, Aztec. Temporary support by means of jacks and timber props for the numerous cracked and broken beams in this ceiling. There was approximately 6' of overburden on this ceiling and the temporary supports were in place for several years before the overburden could be removed and a protective roofing constructed.

Roofing and Roof Support (con.)

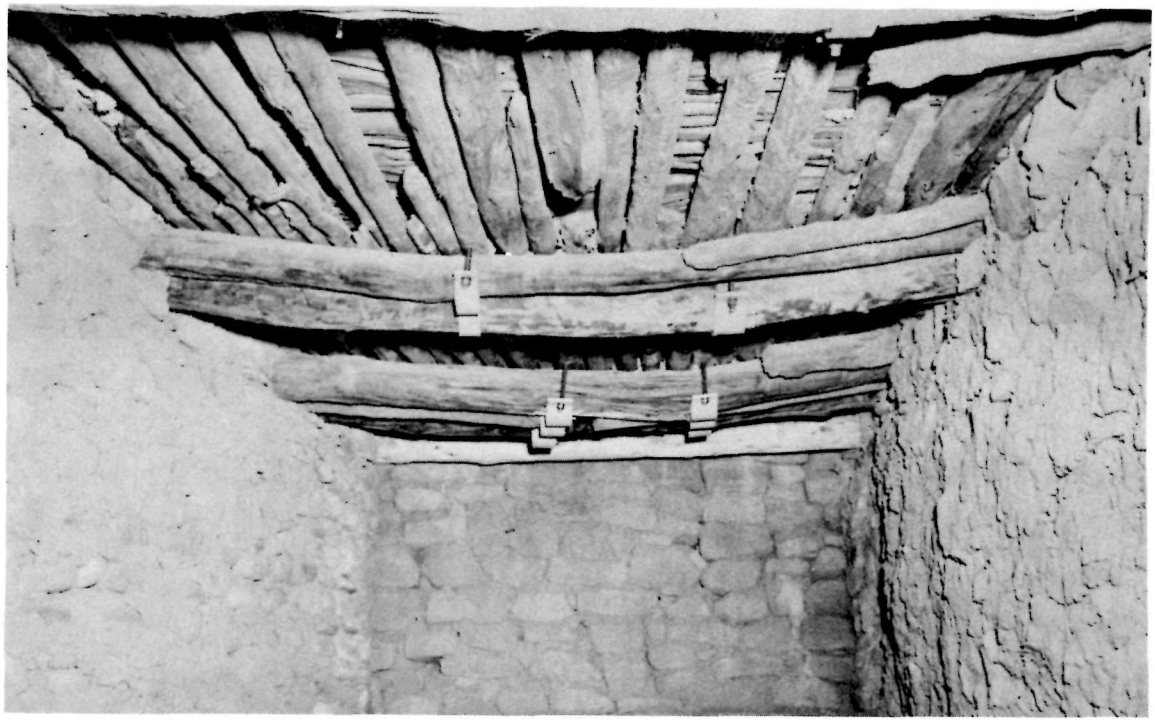


Fig. 46. Roofing, Aztec. The ceiling shown in Fig. 45 after removal of the overburden and construction of a slab roof which both protected the ceiling and permitted the support of broken beams. The bolts are fastened in the slab above and were taken up enough to transfer most of the weight from the old ceiling beams to the new roof.

Roofing and Roof Support (con.)

2. The general design requirements for slab type roofings are shown in Figs. 47, 48, 49. No part of the new roofing may be supported by the aboriginal ceiling either during or after construction. This requires that the construction be self-supporting during the time that the concrete is being poured. In ordinary usage, concrete forms for floors and decks are often supported during pouring by vertical members from below and the supports and forms are removed after the concrete has set. This is not possible in the placement of slabs over existing roofs where the space between the new slab and the old ceiling is usually less than a foot and there is no means of access between the two.

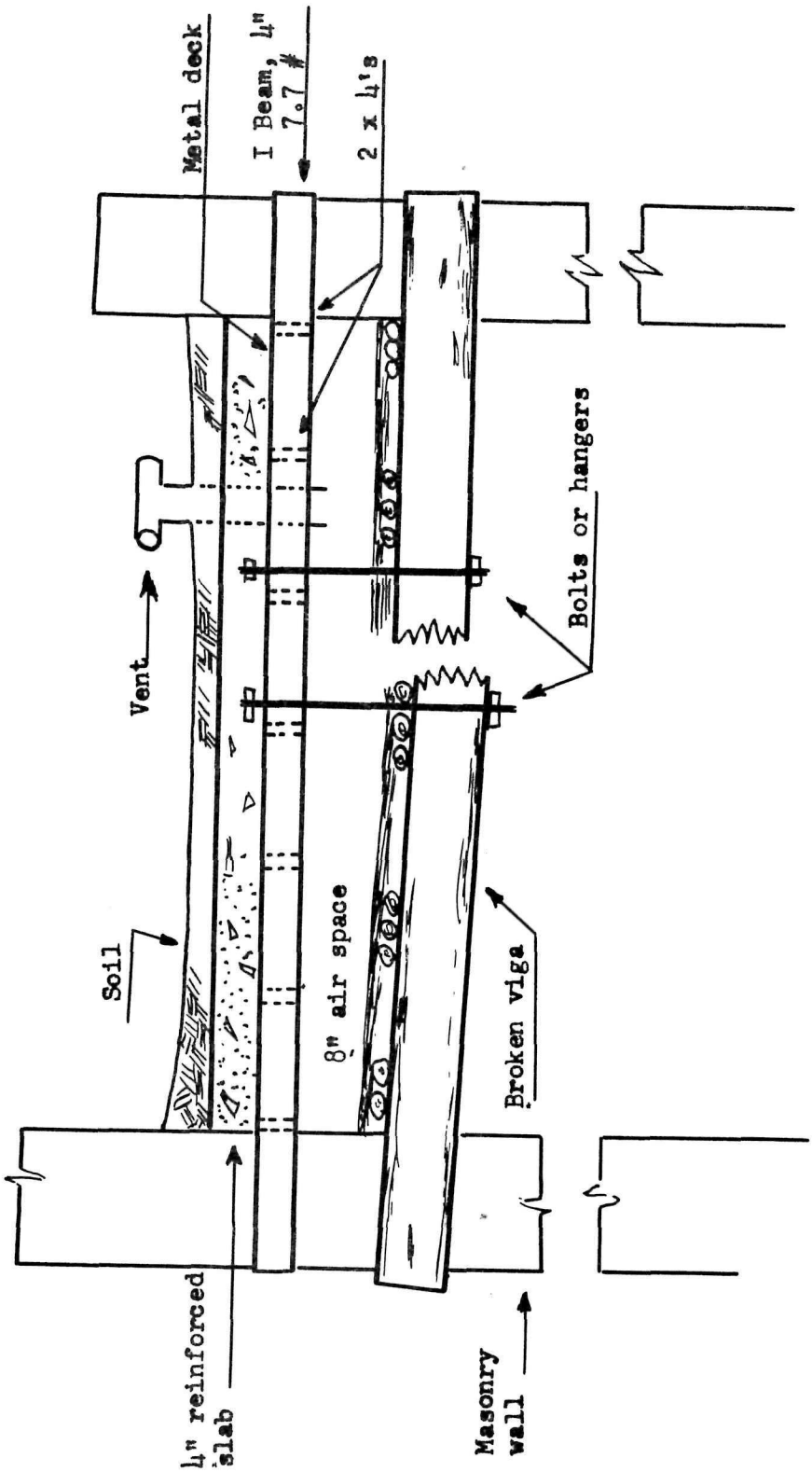
The basic members of the new roofing should be steel I-beams. Their construction permits the wood members of the roofing, the rafters or purlins, to be inset in the sides of the beams. Thus there is no wood separating the concrete from the main supporting members. Wood left in this position would rot and let the roof settle. Dimensions of the I-beams are determined by the span involved, the placement of the beams and the type of slab, normal or lightweight concrete, to be used. Those in roofs with a span of 6' to 8' will normally require 4" beams of 7.7 wieght, on 4' centers. In setting the I-beams, they should be run through the full width of the wall and rest on a concrete pad if possible.

Likewise, the number and placement of the wood members of the roofing is determined by the type and thickness of the slab to be poured. They should be ample to support the wet concrete and be well nailed and braced.

While paperbacked metal lath can be used under lightweight concrete, it is preferable to use one of the standard corrugated metal deckings as a covering for the structural members and a base for the concrete; it is light in weight, and easy to handle and cut.

Whatever type of concrete is used it should contain reinforcing. The amount depends somewhat upon whether the slab is to support large sections of the ceiling below. As an example, in the roofs noted with beams on 4' centers, #4 rebar was placed on 8" centers, at right angles to the main supports, the I-beams. Number 3 rebar was used at right angles again, the short dimension of the slab, on 18" centers. Concrete slabs will usually be about

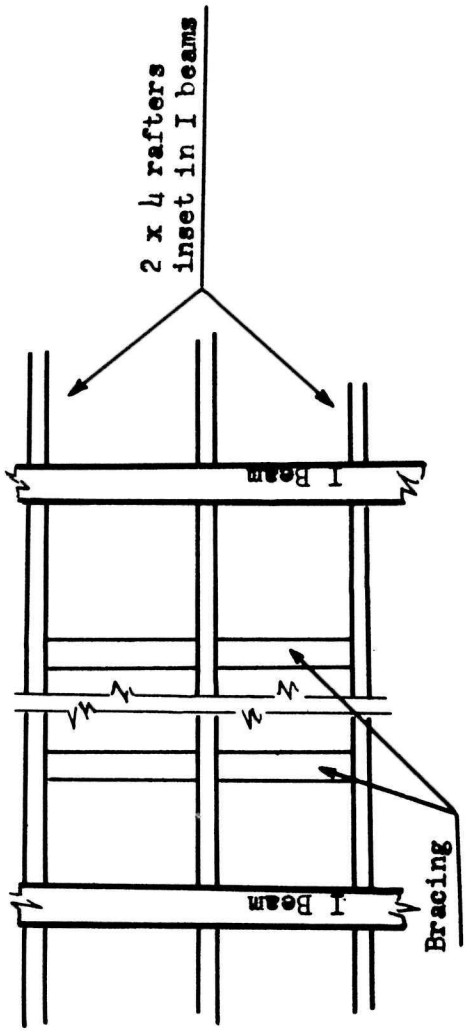
Roofing and Roof Support (con.)



TYPICAL ROOF COVERING AND SUPPORT, AZTEC RUINS

Fig. 47

Roofing and Roof Support (con.)



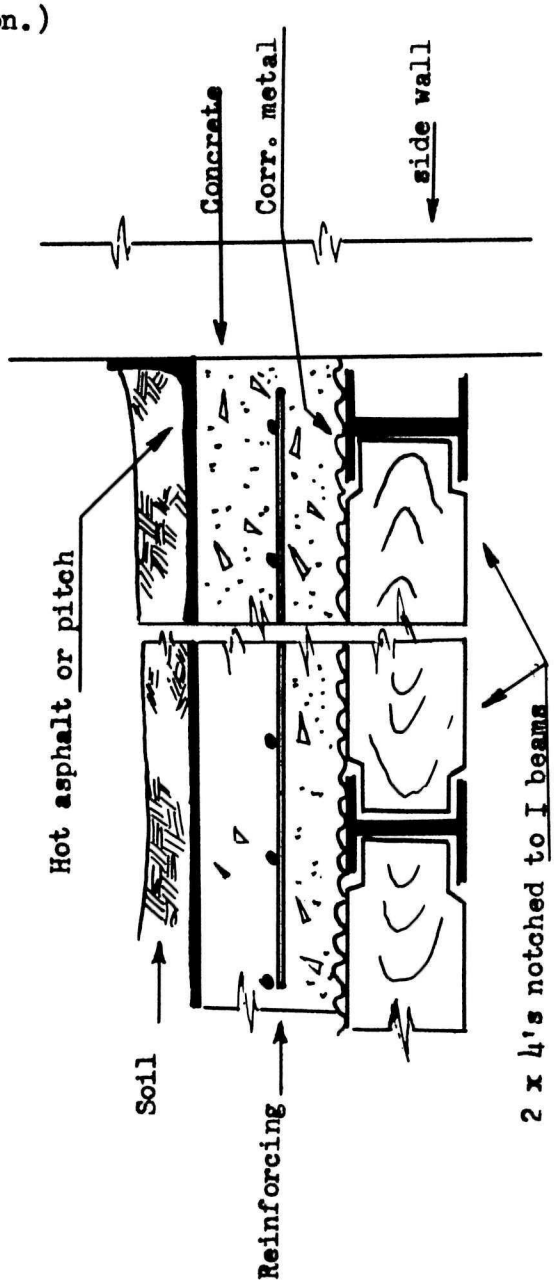


FIG. 48. DETAILS OF ROOF

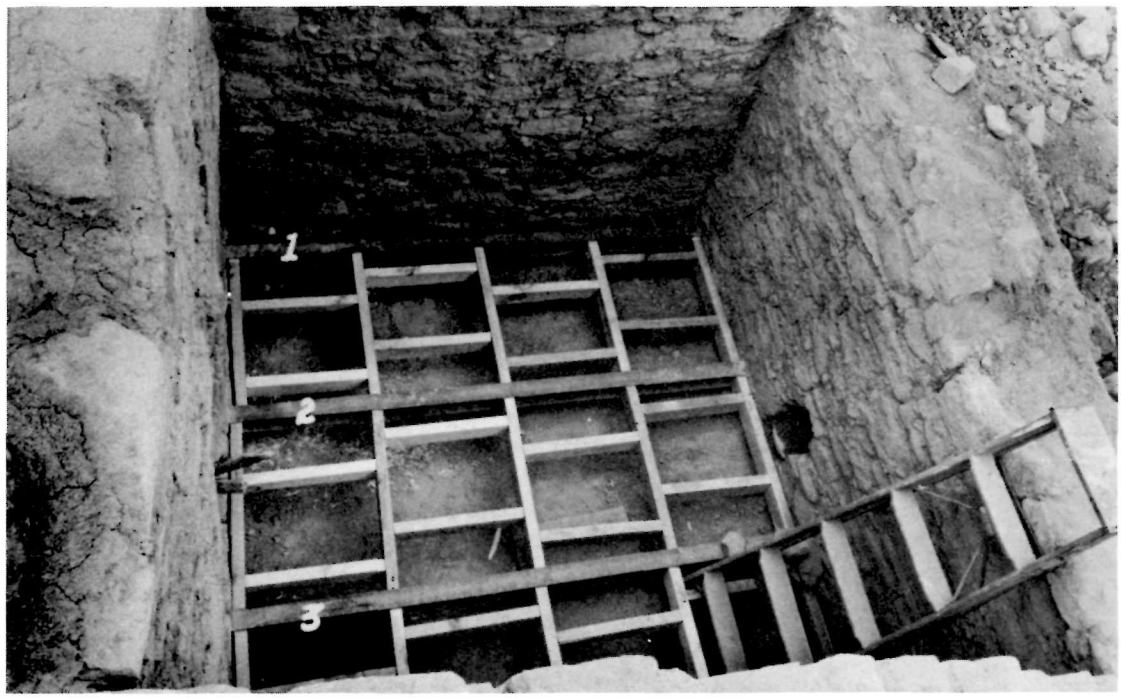


Fig. 49. During construction of a slab covering. The numbered members are I beams run through the heavy masonry walls. The longitudinal members are 2 x 4's inset in the I beams as purlins. Corrugated metal decking will be nailed to the wood as a base for a concrete slab. A covered vent will be provided through the concrete; drainage will be by tile line through the wall at the right.

Roofing and Roof Support (con.)

3" thick and the reinforcing should be above the center, supported on "chairs" of steel or similar material. All reinforcing should be securely tied. It is preferable to purchase the reinforcing already cut to length and the ends bent if desired.

Ceiling Supports. If the prehistoric ceiling has been subjected to heavy overburden or has been wet, it will probably require some support from the protective slab. Provision for this support must be made when the slab is first being laid out. Support can either be by bolts which extend up through the center of broken or cracked beams or by pairs of bolts, one on each side of the beam, which support a hanger under the beam. Bolts should have ample threads (threaded rods are preferable to standard bolts) so that they can be taken up sufficiently to support most of the weight on the beam. In normal concrete, large cut washers are sufficient to anchor the bolts; in lightweight concrete the upper ends of the bolts or rods should be tied in to the reinforcing.

Ventilation must be provided between the old ceiling and the new roof to prevent the accumulation of excessive moisture from condensation. Most prehistoric ceilings are not tight enough to prevent some movement of air. However, when clearing debris or whatever covering, preparatory to constructing a slab, sufficient should be removed to permit some percolation of air through the ceiling. Provision should also be made for ventilation through the top. This is best accomplished by including a vent of 4" pipe in the slab, the ends covered with screen or turned down.

Finishing - Flashing. One of the most troublesome problems encountered in the construction and maintenance of roofs set deeply within structures is that of flashing. It is impossible to place metal flashing in the usual irregular ashlar of a ruin wall without tearing out a wide band of the masonry and re-laying it with the flashing in place, a dangerous procedure in deep rooms, impossible in narrow walls and always weakening to the structure.

To avoid the difficulties of inserting metal flashing, well-formed cant strips should be employed. They do not always provide the absolute freedom from water seepage that a correctly employed metal flashing will, but they are often as is noted above, the only possible alternative. In placing cant strips, either in new roofs or in repairing existing slab roofs, the wall where the

Roofing and Roof Support (con.)

strip is to lay should always be cleaned and the joints well-pointed with cement mortar some distance above the top of the strip; this strip can then be waterproofed with hot asphalt, pitch or whatever material is used on the remainder of the roof.

In pouring the slab, every effort should be made to produce as dense and watertight concrete as is possible. The water-cement ratio of normal concrete should be strictly controlled. When poured, the material should be well-rodded and the top screeded to slope with a true even surface. Whether of normal or light-weight type, it must be damp cured for no less than three days and in hot weather protected from excessive drying for a longer period.

Either type of concrete used will require a waterproofing surface. Either kind must be thoroughly dry before the surface is applied. Lightweight concrete should be covered with a built-up type roofing, surfaced with chips or pea gravel. While normal concrete is employed it also must be waterproofed. A built-up type roofing can also be used.

In situations where it is desirable to cover the slab with soil for improved appearance, the slab may be waterproofed by an application of hot pitch mopped on. Pitch does not deteriorate as rapidly under a soil covering as do the usual asphalts used for built-up roofings. If a soil covering is to be used, the wall surface should be repointed with concrete to at least the depth of the soil and this area also waterproofed by an application of pitch.

Monolithic Structures

The history of the preservation of monolithic soil structures such as occur at Casa Grande, detailed elsewhere in this volume, has in general been one of experimentation, frustration and unsatisfactory results. The early use of burned brick in repairing and supporting large undercut sections of the "Big House" in Compound A has proven eminently satisfactory. Much less satisfactory have been the preservation attempts on low exposed walls in the remainder of Compound A, Compound B, and the Clan House. While waterproofing and hardening solutions have been tried, the major effort directed toward preservation has been with thin

Monolithic Structures (con.)

coatings or plasters of soil-cement, soil-cement made with caliche, cement stuccos, a covering or capping of formed adobes.

None of these have proven to be the ultimate, one-application panacea sought for. The various coatings or plasters have all had to be renewed. However, it should be pointed out that neither were they all complete failures. While having to be replaced, these coatings have also protected and saved a large extent of prehistoric wall.

The earliest of the coverings were of thin cement stucco; they were followed by the use of soil-cement at a fairly stiff consistency, and tinted to match the original work. They were plastered over all exposed surfaces of the prehistoric wall. The weakness of these applications, soil-cements and cement stuccos, was the absolute lack of bond between the prehistoric wall and the "plaster" and the tendency of the plaster to absorb moisture and thus aggravate the lack of bond. The appearance of such surface coverings also left something to be desired.

The addition of woven wire and other reinforcing material in the plaster has lengthened the life of some of these surface applications of soil-cement. Recently developed water repellants applied to the surface indicate that they also will materially prolong the useful life of the repair.

Since long experience at Casa Grande has demonstrated that it is impossible to make a thin covering of either cement, stucco or soil-cement which will adhere to the original wall, will not crack, and will remain waterproof, a slightly different approach has been tried recently on exposed walls of Compound B.

The thought behind this approach is that a heavier, thicker, section of soil-cement or caliche-cement would not be dependent upon the prehistoric wall for bond and support but would be, if thick enough, self-supporting. In the present state of knowledge it appears evident that we will not be able to develop and thoroughly test any preservative or hardening solution, to be applied to exposed soil walls, within sufficient time to abandon other tried though partial solutions. It is for this reason that formed soil-cement or caliche-cement coatings have been used recently at Casa Grande and are suggested, with perhaps modifications, for

Monolithic Structures (con.)

similar situations. They represent the latest step in the evolution of plaster-like coverings and it is possible also that they may prove to be the final solution.

Formed repairs to badly weathered caliche walls at Casa Grande, (exposed since the excavation was completed in 1908) are more natural appearing than are the thinner, plastered coverings. These latter followed the undulating, irregular, undercut convolutions of the wall. The formed repairs are somewhat more regular and more nearly match the formed appearance of the original wall surface.

Following is a brief description of the latest work at Casa Grande in the way of formed wall surfacing.

In all caliche walls of monolithic type encountered in Compound B, weathering had greatly reduced the original width above the surface of the ground. Both sides of the wall were trenched until the original width was reached. This was at depths up to 18". Forms of heavy plywood, reinforced with 2x4's, were then placed at the edge of the wall (Fig. 50), rising vertically from the uneroded subsurface line. The space between the remaining wall surface and the forms was wide enough so that the caliche-cement would be sufficiently thick to stand by itself and not be dependent on the aboriginal wall for support. General requirements for placing concrete forms were followed; they were oiled, and securely braced.

Trial mixes of several local soils were made. Selected for use as most nearly matching the prehistoric wall and providing the hardest product was a caliche obtained from commercial sources. A mix at 18% cement with a small amount of mortar color was used. Mixing was done in a portable, drum type mixer.

The prehistoric wall was dampened and the mix placed between it and the form (Fig. 51), well-tamped in place to fill undercut spots. It was placed to a depth to sufficiently cover the rise of the wall face and then sloped to conform to the irregular, sloping surface of the wall top. After curing, the forms were removed and when completely dry the entire surface was treated with silicone water repellant (Fig. 52). This use of heavier, self-supporting coverings of native materials parallels the already proven use of heavy sections of soil-cement in the repair of pit houses and for making facings in cuts in soft fill. (Figs. 9 and 10.)

Monolithic Structures (con.)

Fig. 50. Soil-cement made with caliche. Forms in place, braced and tied at the top. Upper left, the completed wall with forms removed. The form is not always filled to the top, only enough material is placed to cover the wall to a predetermined depth.

Fig. 51. The start of placing caliche-cement mix. Note that the forms follow the irregular line of the wall.

Monolithic Structures (con.)

Fig. 52. John Wero applying a silicone water repellant. It is applied in a coarse stream, sufficient to produce a rundown of 6 to 8".

RECORDATION

A stabilization record is a structural history of a site or an architectural unit of that site: a room, a wall or a doorway. It is intended to provide full information on the original condition of the unit including any inherent structural weaknesses, any previous protective or preservation measures and, in detail, the techniques and materials employed to bring the unit to its present state of preservation. It is advantageous to record the various steps of unusual or difficult solutions, of new or experimental techniques and special features of the site or project. The amount of detail that will be required will vary with the size an complexity of the individual project, ranging from the brief description necessary for a wall fragment uncovered in grading operations, to the full reporting required to document the realignment of walls and the installation of integral members.

Comprehensive Stabilization

The preparation of comprehensive stabilization records is often a time-consuming task. They may require a good deal of research into the past history of the structure, i.e., the comprehensive stabilization of Talus Unit excavated and partly stabilized by the Museum of New Mexico and on which there are the excavator's notes but no publication. In such situations sufficient time must be scheduled to permit the search for and inclusion of pertinent data in the individual room records. Stub walls and partition walls are often removed by the excavator to facilitate the search for or clearing of lower structures and it is valuable to know the former location of these and their extent in planning the preservation of any particular area. It is also of particular value to know the location of loosely backfilled areas for these often hide areas of undercutting and weakness, and pose problems in surface drainage.

In addition to their requirement for record purposes, good stabilization records in conjunction with cost records are of inestimable value in estimating costs for future programs.

Maintenance Records

Maintenance work is often a problem to record. Minor maintenance such as cleaning of drains and the resetting of small areas of masonry where it has been dislodged by visitor traffic

Maintenance Records (con.)

does not need to be added to stabilization records when this maintenance does not change the structural history of the unit; such work should be recorded however when a change is made in materials or in location of accessory items such as drains. As an example: a good deal of the capping done 20 years ago in the Southwest was done in soil-bitumen mortar. It has become necessary to replace some of this within the last few years, particularly on low walls that are close to self-guided trails. When the stones in this capping are reset in tinted concrete mortar, this constitutes a change in materials and though the same stone is used and the appearance of the unit has not been altered, the substitution of concrete for soil-bitumen should be recorded.

In such instances, unless the maintenance is very extensive, it is not necessary to make a new, two-sheet stabilization record as this is time-consuming and results in excessive duplication. For ordinary maintenance in any site, one new "First Sheet" can be used to cover the entire site, the principal entry on this sheet being that this is maintenance work and that the detailed entries can be found in the comprehensive record; give the year and page number of this comprehensive record. Then it will only be necessary to enter the maintenance work on the "Second Sheet." Ordinarily, stabilization records for each site are bound in permanent volumes by years. Since maintenance records are seldom very extensive, this results in some rather thin bound volumes but this system has proven more effective than attempting to add additional data to the larger comprehensive records. If there are a small number of sites in an area and two or more receive maintenance in the same year, these records can be bound together.

Field Notes

It will be necessary to keep some form of a daily log or field notes, not only to record progress but also so that an accurate record of man-days and materials expended will be available at the completion of each project. While on many smaller projects the required data for the record sheets can be entered directly on these sheets in the field; some additional record will be required from which to take the amounts of materials used. An engineer's field book is convenient to carry and eash to use if the tendency to crowd the small pages is avoided. Separate columns can be taken for materials and man-days or any arrangement used that makes it easy to add up these quantities at the completion of each unit of work.

Field Notes (con.)

If one job, a single wall or room, is being done at a time, arriving at the total materials used is a simple matter. However, several small units will probably run concurrently and the materials such as concrete mortar, soil-cement, etc., will be distributed from a central point. In such cases, the total work done can be measured at the end of the day and the materials prorated among the separate jobs. If a little effort is spent at the beginning of the work to determine just how much cement or bitumen or other material is required for a definite unit of work (a square foot of capping or a cubic foot of wall repair, etc.,) and this is checked from time to time, the total materials used can be more easily prorated among the various individual jobs.

Costs

While the individual record sheets, as now made up, have entries for individual architectural unit costs--man-days and materials per room or area--it is more realistic to keep total project costs. This permits the inclusion of truck and equipment costs, supervision, and other overhead charges that cannot be accurately prorated among many small units. At any rate, whether or not individual room costs are kept, some record should be made of total project costs. These then can preferably be broken down into whatever are the most convenient units for future estimates. Breaking this back down into the cost per room is one method of obtaining quick estimates. Another method is to work out costs per unit of work--so much per lineal foot of capping on walls 12' high or over, so much for lower walls, the cost of patching a square foot of masonry, or the cost of grading and draining a square yard of room interior. This unit of work method provides slightly more accurate results though it does take more time to work up and more time to apply.

Record Sheets

The permanent record sheets designed by the Southwestern National Monuments about 1937 and still in use with few modifications, are self-explanatory. With a few minor changes in headings, which can be made on the job, they can be used for a wide variety of work. Used in a clip board or binder, most of the entries can be filled out in the field. Accumulative data can be entered from a daily log at the completion of each unit. The

Record Sheets (con.)

presentation of data can be somewhat modified in practice depending on the kind of site and amount of work required. There are two pages to each stabilization record, a "First Sheet" for the references, justification, orientation and architectural background. Where a series of small adjacent rooms or similar units have the same references, justification, orientation and the same architectural background, only one "First Sheet" need be filled in to include a group of contiguous rooms; a separate "Second Sheet" will be used to show in detail the condition prior to the start of work, previous and current repairs. Examples of record sheets with appropriate photographic coverage are contained in Appendix I at the end of this Chapter.

Photographic Coverage

The individual record sheets should be followed by pages showing at least one "before" and one "after" picture. Rather complete photographic coverage is desirable and may range from general overall views showing the conditions of adjacent terrain which may affect the site, to detailed shots of specific techniques. Where a portion of a structure is to be reset or where a portion will have to be replaced, as in setting integral members, it is a decided advantage to take the photographs well in advance of the actual work. Enlarged prints can then be used a guides in resetting masonry, to obtain authentic contours of wall tops and in filling in small details. If the work is large and there are many of these small details, the addition of vertical and horizontal scales in the photograph will insure accurate dimensioning of the preservation measures.

The maximum size print that can be used to show both a "before" and "after" on the same page is 4"x5". In special cases it will be advantageous to have general overall pictures in 8"x10" mounted on a single page. A good photographer, using 35 mm. file and making careful enlargements, can produce excellent 4"x5" prints for record purposes at a considerable saving in cost. However, most supervisory personnel will not always have good darkroom facilities at their disposal, and unless custom finishing is available, commercial 4"x5" enlargements are not apt to be as satisfactory as those from larger negatives. To date, the 4"x5" press-type camera and contact prints have been the most useful and presented the greatest savings in time.

Photographic Coverage (con.)

Photographic Materials and Processes. These are random observations based on the somewhat over 12,000 negatives now on file by the Ruins Stabilization Unit. Particularly in smaller communities, check local services before entrusting them with film for development. Most photofinishers use DK-20, a long-lived developer, that is fair for some film but totally unsuited to materials in the Eastman Royal Pan family. Negatives are apt to be too thin to use. The most satisfactory system has been to develop negatives in the field if at all possible. This permits checking their quality almost immediately and they can be re-taken if necessary. Daylight tanks holding a dozen sheet film, prepared chemicals, and washing aids or hypo eliminators to cut washing time, reduce the work involved. The use of a hardener in warm weather and a wetting agent before drying, permits the production of good quality negatives.

By the use of a hypo eliminator, archival quality negatives and prints can be made whose long-range keeping qualities are far superior to untreated materials. This service is not always obtainable from commercial establishments.

The type of film used will depend primarily on personal preference and familiarity with the characteristics of a particular brand or type. In general, extremely high-speed types are to be avoided and the best results are had with the group of films known as medium speed and having fairly good contrast. The use of filters with panchromatic films is often a decided advantage. On the other hand, some of the most satisfactory photographs from a personal view, made by the present writer, were results of attempting to duplicate old glass plate pictures taken by Jackson and Mindeleff. These were done with an old view camera using Eastman Commercial film, a slow orthochromatic emulsion. Skies were lost but the rendition of surface texture and detail in masonry was excellent.

Photographic coverage of a site takes time and should be started far enough in advance so that advantage can be taken of the correct position of the sun for good lighting. In the Southwest, at least one of the major faults of contact prints are areas of deep shadow in which all detail is lost. These shadows can be compensated for somewhat in development, but the best course is to take the picture when the lighting is correct for the area to be shown. If it is impossible to do this with natural sunlight and

Photographic Coverage (con.)

reflectors, it is well to remember that flash bulbs for fill-in lighting give a more contrasty light, more closely approximating sunlight, than do the electronic speedlights. Supplementary lighting is good for close-ups of details and at moderate distances, but requires more experience and often extensive equipment for use in large areas. Some of the best architectrual record shots are made on overcast days with negatives developed to a fairly high contrast. A vexatious problem not aided by additional lighting, is often that of making one specific part of a structure stand out in a photograph without having it confused with extraneous background material that cannot be kept out of the picture. An experienced photographer with a relatively long lens can usually throw the background material out of focus. A large lightweight piece of canvas can be held as a background cloth to isolate specific walls or sections; the improvement in clarity is worthwhile.

The only satisfactory method of mounting prints for the record pages is thermosetting mounting tissue. While a press is an advantage, small quantities can be done with an ordinary household iron that has settings for different fabrics. One way to avoid the use of mounting tissue and the resulting extra bulk, is to print the photographs, two to a page, on ad-type paper. At the time that the Region Three Office was operating a photo lab, all of the Stabilization Unit's records were printed on ad-type paper and most of them were excellent. Very high commercial costs and the reluctance of most photofinishers to attempt printing two negatives of differing densities on a single contact sheet have prevented the continuing use of ad-type paper.

Supplemental Methods

The general method shown, using the stabilization forms and photographic pages should, with minor changes for local situations or special circumstances, be used regularly for all archeological stabilization work and for historic structures whenever possible. This method can be supplemented, particularly in historic buildings, by additional means of recordation. Entering repairs or other changes on HABS records or comparable measured drawings where these are available, forms a particularly good means of supplementary recordation and of convenient presentation. For an archeological site of any size an accurate ground plan is a necessity. While not approaching the detail of HABS sheets, ground plans can be used to

Supplemental Methods (con.)

show type and location of work accomplished. While successive jobs on a building over a period of years will be shown in different reports, large ground plans are an effective medium for recording and presenting the cumulative total of preservation measures.

RUINS STABILIZATION RECORD (First Sheet)

Room _____
Kiva Tower

Date Sept.-October 1956 Chaco Canyon National Monument

Project number _____ Name of ruin Kin Ya-a

Personnel of party on this job: Wall (N.E.S.W.) All four

R. Richert and 4-6 Navajos Floor, roof _____

References to publications and justifications for job:

See Introduction

ARCHITECTURE

Orientation, plan and type (Situation, evidence of additional stories, period of construction relative to surrounding rooms, evidence of burning, etc.) This is a circular kiva set within four square retaining walls, located along the north wall of the house mound and approximately in the center. The Tower Kiva forms the nucleus for the pueblo. This unique round tower within a square one is impressive because portions of the north and east enclosing walls stand 4 stories high. On both the east and west sides of the tower there are at least 3 tiers of rooms. The main house block, however, is to the south and is quite mounded over but contains perhaps 4-5 tiers of rooms. All exposed masonry appears to be of the same type, indicating a single construction period. The third and fourth stories of the inner, circular kiva burned.

Floor (Floor type: additional notes)
Site is not excavated and there is no data on this.

Roof (Roof type: additional notes)

Details (Notes on doorways, lintels, etc.)
See additional pages for detailed notes pertaining to condition description, materials, construction, etc., with respect to each individual wall of the kiva.

RUINS STABILIZATION RECORD

September-October, 1956

The Tower Kiva
Kin Ya-a Ruin
Chaco Canyon NM

R. Richert
6 Navajos

Justification

The fragile tower kiva remnant, a unique architectural development of the Chaco Culture, was reinforced and repaired to preserve it in nearly an "as found and as is" condition as possible and in such manner which will not impair any future, proposed excavations.

References

The site is unexcavated and most references are only general. However, a listing of tree-ring dates appears in the following publication:

Smiley, T. L., A Summary of Tree-Ring Dates From Some Southwestern Archeological Sites. University of Arizona Bulletin, Vol. XXII, No. 4. Oct. 1951. Laboratory Bulletin of Tree-Ring Research, No. 5, Tucson, Arizona.

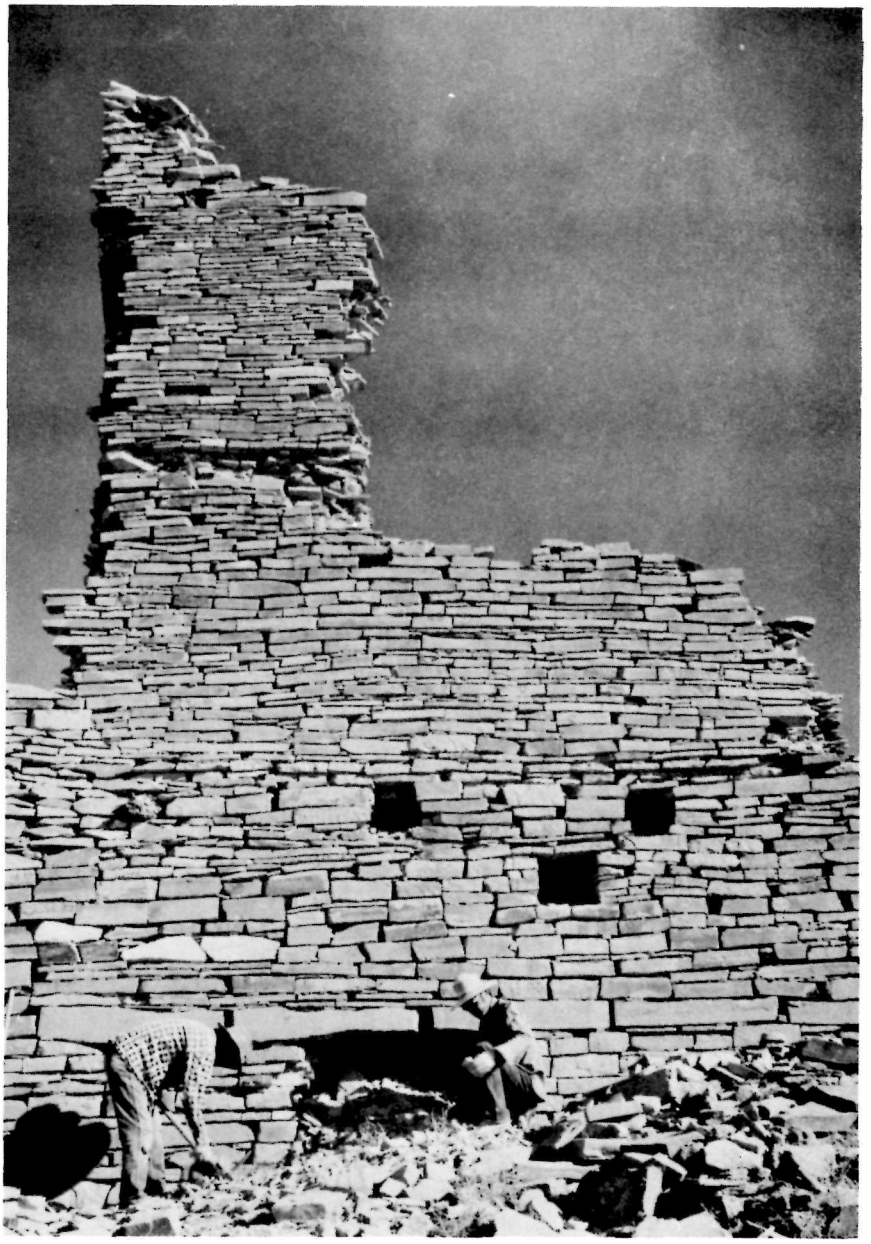
Condition, Description

The Tower Kiva, north wall exterior. (See Pages 3-5.) In profile this is an L-shaped wall remnant, the vertical arm of the L forming a narrow section 8' wide, beginning at the second story and tapering at the top to an area only one stone wide. It is four stories high, measuring 32' 10" from the base at present surface level to the top stone. The exposed base of the wall at the top of the debris slope is 4' 6" higher than the surrounding ground level; hence the assumed base of the wall is at least that much lower, making the wall 37' 4" high, conservatively.

Three beam stubs are embedded in the masonry in the north-south direction, the ends projecting slightly beyond the exterior facing. They are nearly in line one above the other, at the first, second and third stories. They are not roof supports as they extend into the thick kiva corner and stop there. It would appear that they were either reinforcing ties for the kiva corner, or their projecting

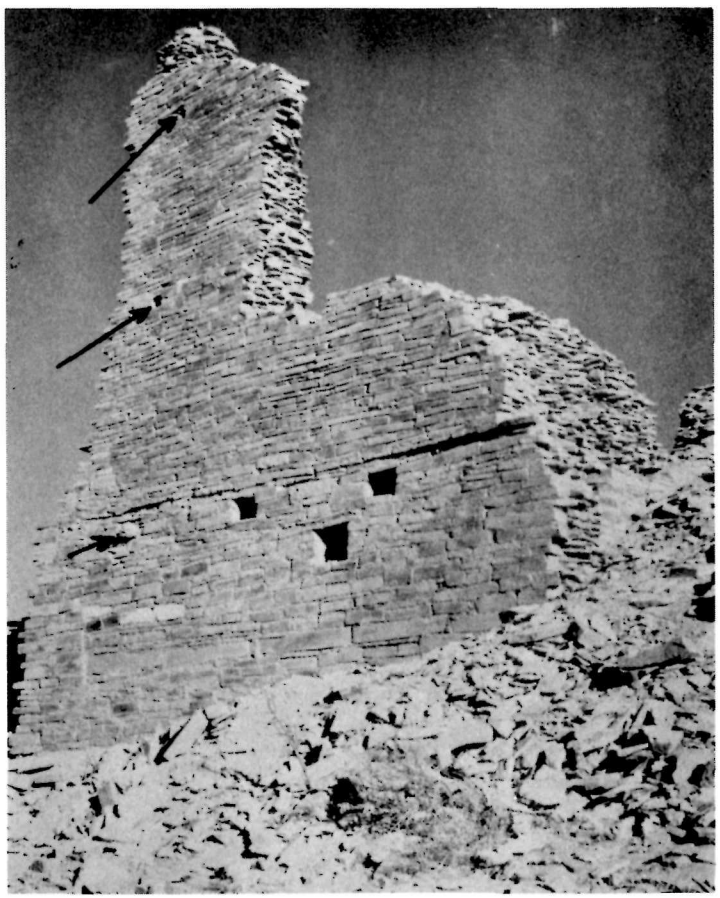
General view of Kin Ya-a from the north. Tower Kiva occupies central part, flanked by house mounds on each side. Ruins stabilization work and supply area in the foreground.

Condition, Description (con.)



Close-up of north wall, Tower Kiva.

Tower Kiva, north wall exterior. Note large hole at base, and eroded insets (arrows) where second, third and fourth stories were slightly stepped back.



Hole at base, square openings (the two upper held beams, the lower was a ventilator) and insets repaired and wall stubs capped. Beam stub at left and two beam holes in line above (arrows) either represent reinforcing ties for kiva corner or supports for some sort of prehistoric scaffolding used in construction or a balcony.

Condition, Description (con.)

ends served as a support for some sort of balcony or perhaps scaffolding along the outside for construction of this high wall.

At the first story level, in a horizontal line with, and to the west of the lower beam stub mentioned in the preceding paragraph are two square openings. These formerly held beams as they still retain the molds. Spaced at 5' 8" intervals with the first beam, they may have served as projections to hold a scaffolding or catwalk. About two rows of stones beneath, and closest to west opening, is a third square opening which is a ventilator and largest of the three (15" wide, 16" high). In cleaning the top of the wall section above these openings, there was found the lower part of a fourth: a T-shaped ventilator 12" wide at the base and 16" in width above the shoulder. The two ventilators in this wall communicated with the kiva.

Beginning at the second story level, the wall is inset 3" to the south; and at the second story elevation it is inset 6", presumably to insure better balance for such a high wall.

At a height of 39" above present surface level, the exterior facing contains one row of extraordinarily large, oblong blocks, the largest measuring 51" long, 6-9" thick, and 9" wide or deep. As a rule the stones in the lower story are thicker and larger than those in the upper three stories. The north wall exterior is further characterized by considerable spalls between the courses of large stone blocks. This straight wall averages 22" wide, is for the most part faced on both sides, and has a core of smaller flat stones with irregular edges, set in thick amounts of soil mortar.

Considering its spectacular height, the wall is in good condition, but must be strengthened by repairing, reinforcing and capping to preserve its present condition.

The Tower Kiva, north wall interior. (For illustrations covering work on north and east wall interiors see pages 7-12.) The north wall interior contains the north arc of the kiva. The kiva wall is not perfectly circular as there are at least two somewhat angular surfaces evident in the facing where the prehistoric builders were unable to make the square or oblong stones form a circular surface. The kiva wall at this north side has two eccentric ledges or benches. The lower bench varies from 0" to 20"

Condition, Description (con.)

General view of northeast interior of Tower Kiva at start of project. The circular wall is stepped back or inset at two points (1) at narrow ledge or bench where Mr. John Wero is beginning repairs, and (2) where facing is gone, exposing core (arrow).

Another view (below) shows general condition of lower part of interior.

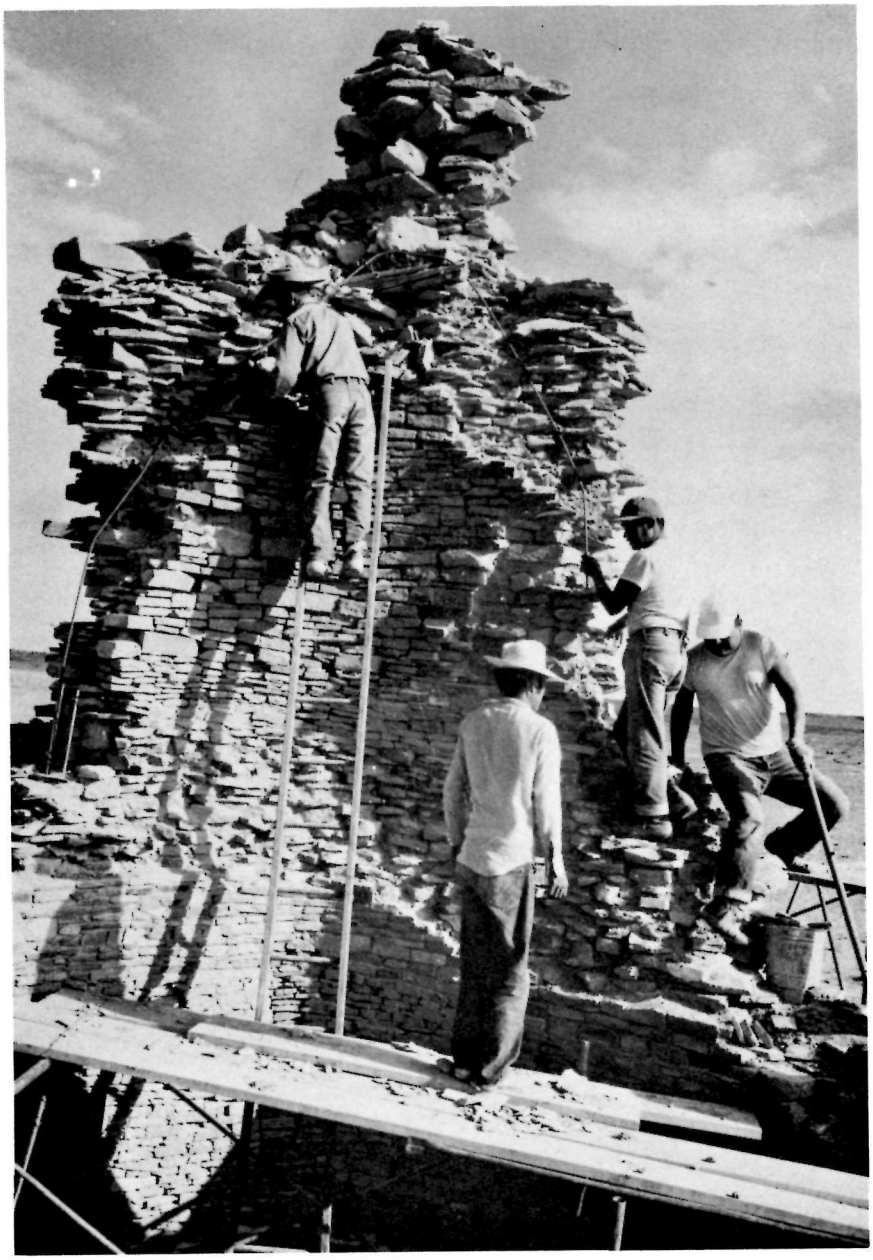
Condition, Description (con.)

Detail of hole in Tower Kiva, east wall interior, caused by breakdown of savino sockets, the beams for which extended part way into this wall from the opposite side and originally supported the ceiling of the adjacent room.

Condition, Description (con.)

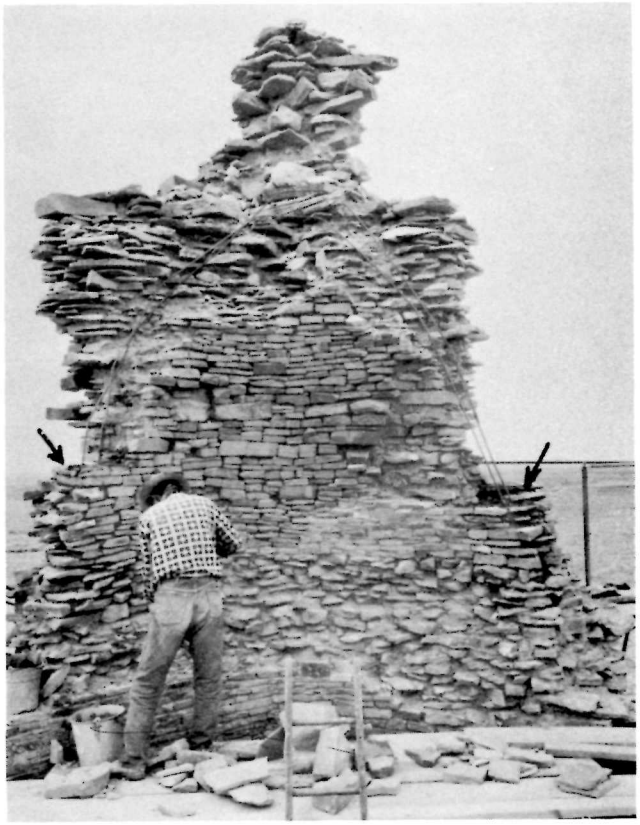
Lower portion of Tower Kiva, north and east segments, after stabilization. Offset ledges repaired, holes filled with repair masonry, facing reset (arrow A), top capped and inset core (arrow B) grouted. Compare with photos on two preceding pages.

Condition, Description (con.)

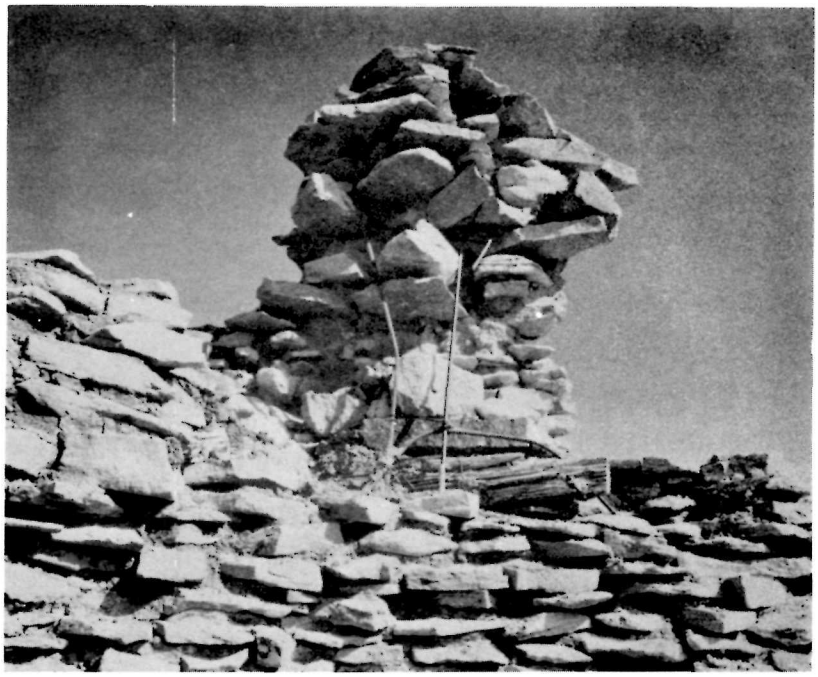


Tower Kiva, interior northeast corner, during installation of integral members to strengthen the highest wall section.

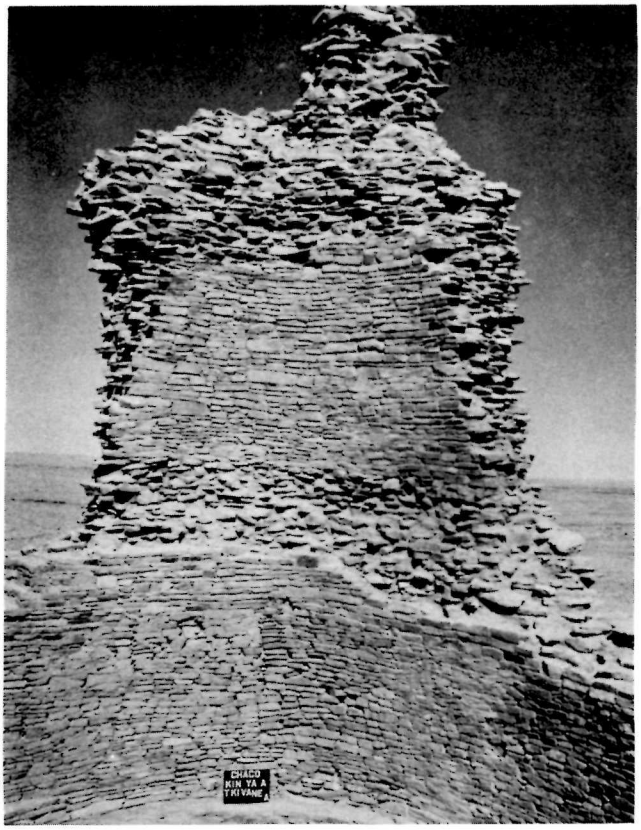
Upper portion of Tower Kiva, northeast corner interior, after the integral members were anchored in masonry.



Beginning the vertical, reinforced capping (arrows).



Integral members in the form of a T were installed in this top fragment of core masonry after the lower wall section had been strengthened to that point.



This completion picture shows a considerably strengthened and tightened wall, without serious or objectionable alteration of original profile. (Compare with preceding photos.)

Condition, Description (con.)

above fill level and varies 0" in width at the east where it merges with the facing to 27" wide at the north side. Another short ledge is 7-1/2' above the lower and extends for a distance of only 67" along the north wall. Whether these very narrow ledges were ceremonial or utilitarian is unknown. The kiva must have been extremely deep, as the wall at the northeast corner within the kiva measures 19' above present fill line, and it is possible that this deep chamber had several floors and ceilings. The eccentric ledges may have supported cross beams for these ceilings. Excavation of the interior of this interesting structure might provide the answers to some of these questions regarding an aberrant architectural form.

Materials, Construction, Etc.

The Tower Kiva, north wall exterior. The high, sloping east and west wall stubs were capped, extending the east stub slightly eastward to provide a short, nevertheless strong buttress section. Two integral members were placed in the west stub where it rises vertically, beginning at the second story level, the members extending to those rising from the east wall. The second and third story ledges or insets were repaired. The several openings including the two square beam holes, and the ventilator beneath them, and the beam holes at the east side were all repaired. The large hole at the base of the wall was filled with repair masonry in cement, the rough interior core being set in cement and the face stones laid in matching tinted cement. Following the above work, the entire wall face was grouted, pointed, and respalled. It was necessary to reset a few loose stones here and there in the facing.

The two offset, eccentric ledges along the north arc just above fill line were repaired. The lower half of a T-shaped ventilator in the center of the wall was repaired--this is between second and third story levels. East and west stubs reinforced with paired integral members in connection with work on north wall exterior, already described. Within the upper kiva wall (includes the upper, spire-like fragment) considerable face stones were reset, and, where core was exposed, this was reset and pointed with soil mortar. At the very top spire fragment itself, paired T-shaped integral members were installed.

Condition, Description

The Tower Kiva, east wall, exterior. This wall rises at the north end to the same height as the north wall against which it is abutted. Parts of four stories are clearly visible as indicated by three rows of savino sockets. In profile, the wall top slopes up from south to north, to the spire in wavy fashion. In the first floor ceiling level there are 23 savino sockets; in the second story ceiling, 13 savino sockets remain, 7 of which still contain stubs. In the third story ceiling there are 4 savino stubs. This exterior or east side of the wall formed the west side of the first room adjacent to the tower kiva on the east. Facing contrasts sharply with that of north wall. Whereas the north wall was composed of nice oblong blocks dressed on one side, and rather large as a rule, the face stones in the east walls are generally smaller, less well selected and shaped.

The wall was in rather poor condition. It had several vertical cracks, one of severe proportions. The most serious condition, however, was a large hole extending through the midsection at first story level where eroding beam sockets were producing an ever increasing opening.

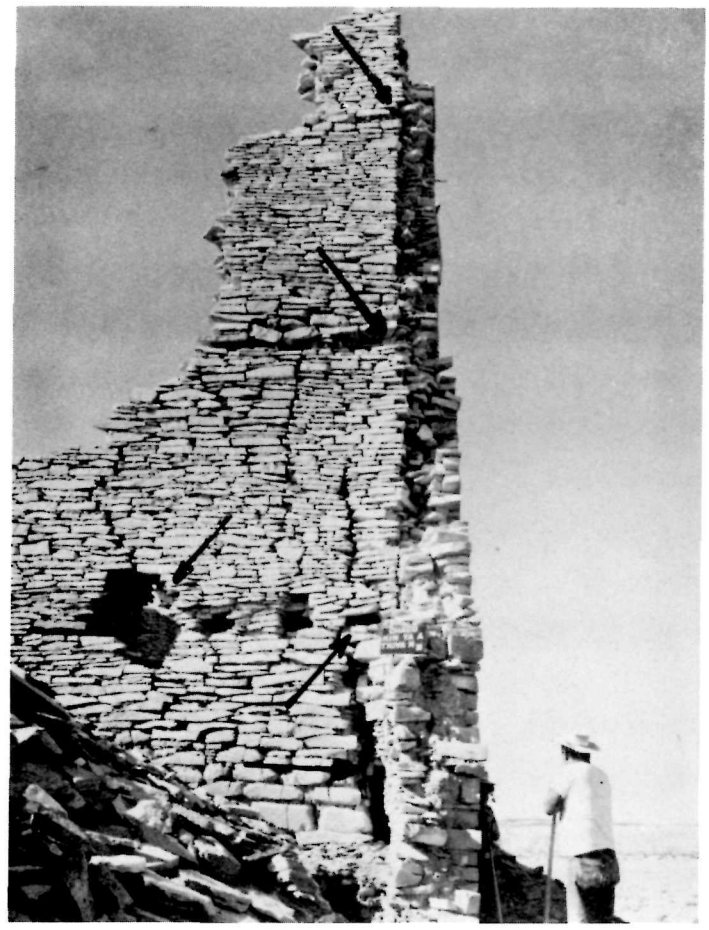
East wall, interior. The two narrow benches mentioned in connection with north wall interior merge with the wall, i.e., disappear along the east wall. The fill is banked higher along this wall and the south wall than elsewhere. The hole in midsection extending through the wall, caused by breakdown of beam sockets on the exterior side, is larger on this side. Broken and missing face stones need replacement, rough exposed core in upper sections should be reset, and the vertical wall stub forming northeast corner reinforced.

Materials, Construction, Etc.

The Tower Kiva, east wall, exterior. The three rows of savinos and/or savino sockets, the vertical cracks, and the large hole at midsection were repaired. Entire facing was respalled, grouted and pointed.

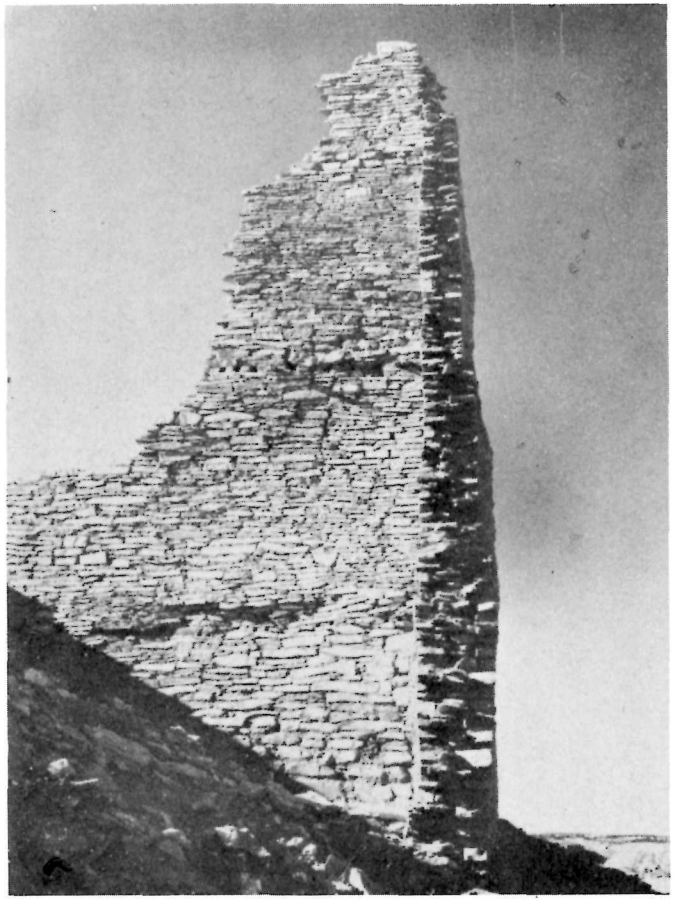
East wall, interior. The south half of the top was horizontally capped. The vertical or sharply sloping north half was reinforced with paired integral members which arch up and cross over near the top spire and are joined with those from the north wall. Circular wall facing grouted and pointed and stones reset as needed. Large hole in center at fill line patched.

Materials, Construction, Etc. (con.)



Tower Kiva, east wall exterior at juncture with north wall stub (at sign). Note the vertical cracks, eroded savino sockets (arrows) and loose, fragile spire. Portions of 4 stories are visible.

Materials, Construction, Etc. (con.)



Two views of wall shown on preceding page showing vertical cap (left, north wall stub buttressed (right), vertical cracks repaired, savino sockets re-molded, and the facing grouted.

Condition, Description

The Tower Kiva, south wall. Fill was banked up all along the south wall and the top was obscured at central portion. Thick core was exposed at both southeast and southwest corners. The remaining portion of circular kiva wall is lower at this point than along the other three quadrants. This area needs cleaning to obtain a base on which to perform repair work in order to preserve and show original wall outlines.

Materials, Construction, Etc.

The Tower Kiva, south wall. The top was cleaned to reveal the straight, south wall enclosing the kiva. The thick kiva corners and the straight enclosing wall were capped. The exposed facing of the interior, circular wall was gone over by grouting, pointing and respalling.

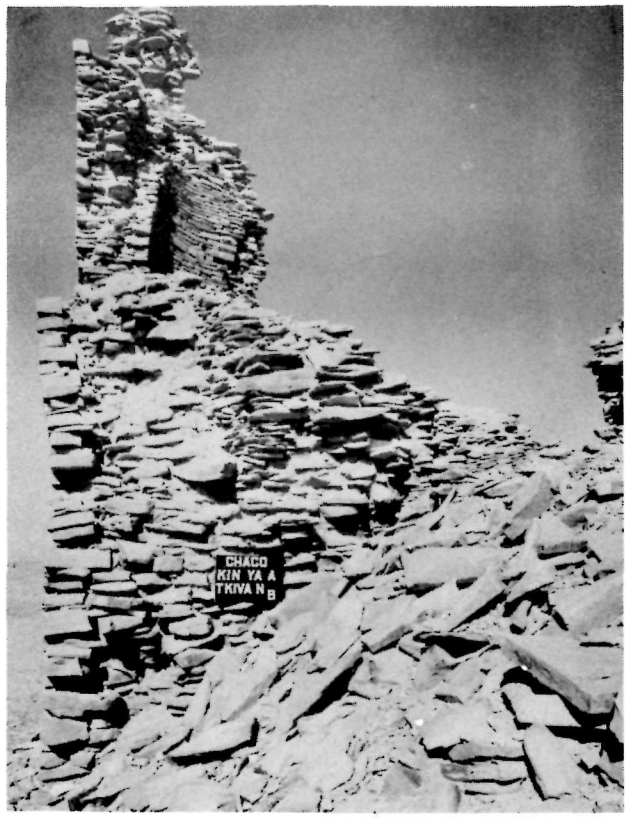
Condition, Description

The Tower Kiva, west wall. The straight wall here encloses the west portion of the circular kiva. The kiva corners enclosed are exposed to a height of 6' above present fill line. Exterior wall facing is either missing or pretty well covered by fill. A 4' thick section of rough core is exposed at the northwest corner. At the center of the west wall and level with fill both inside and outside the room, is a large U-shaped opening probably caused by breakdown of timbers embedded in this wall which provided support for the ceiling in the room to the west. The wall core at this U-shaped opening is thin, loose, and porous and is deteriorating rapidly. Visitors who climb to the Tower Kiva enter the circular chamber at this point. Note: visitation to this little known area may be infrequent but there were three or four visitor groups to the ruins during our project within a period of one month.

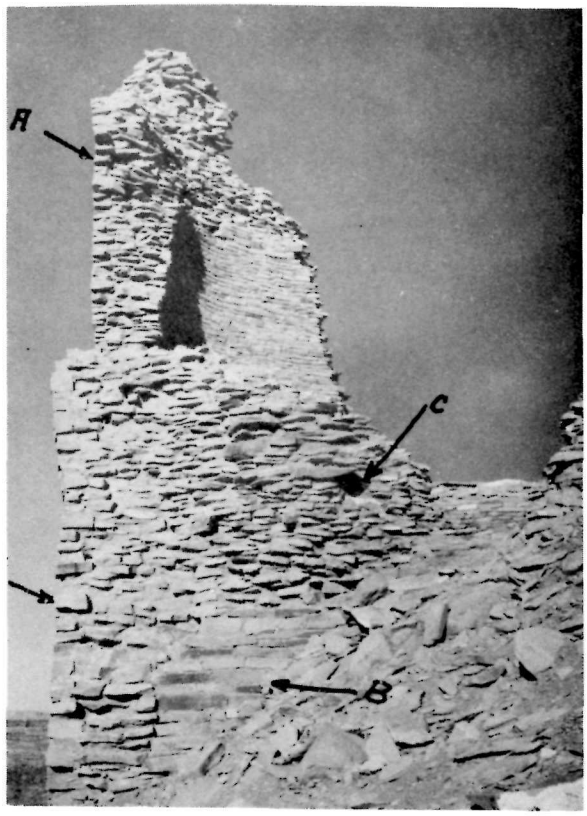
Materials, Construction, Etc.

The Tower Kiva, west wall. Both northwest and southwest kiva corners were cleared of surface debris, and capped. The northwest outside corner was excavated until good foundation was encountered, and then the exterior facing was reset to a depth of 18-20 courses at the north end, and to a depth of 4-5 courses at the south end. The exposed core and veneer around the U-shaped opening in the central section was reset. (See pages 18 and 19.)

Materials, Construction, Etc. (con.)



Tower Kiva, northwest corner.



North wall stub capped (arrows A), lower portion of west wall facing reset (B), and exposed portion of thick core grouted (C).

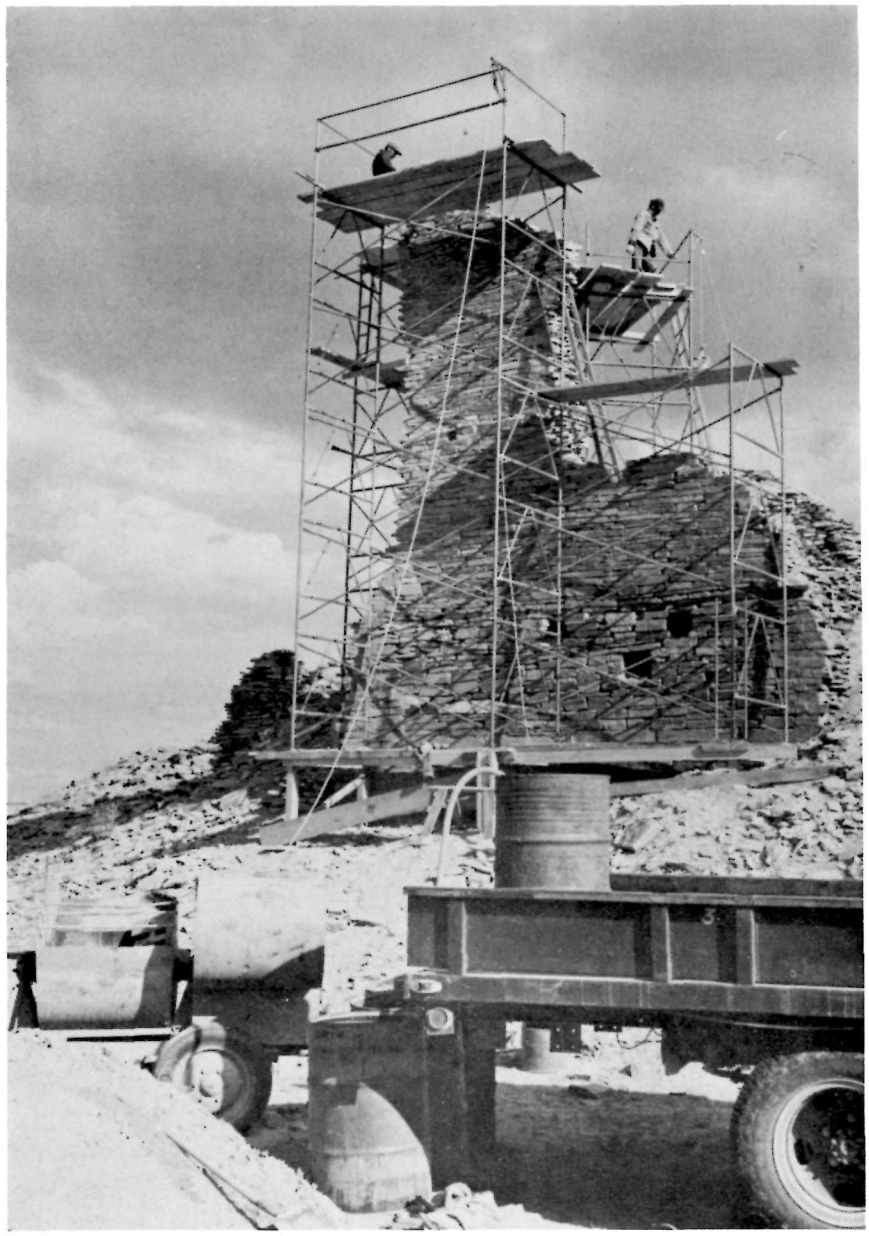
Materials, Construction, Etc. (con.)

Tower Kiva, west wall. This fragmentary wall section of the square tower enclosing a round one was repaired by resetting the facing (arrows A), capping and grouting the thick core (B).

Materials, Construction, Etc. (con.)

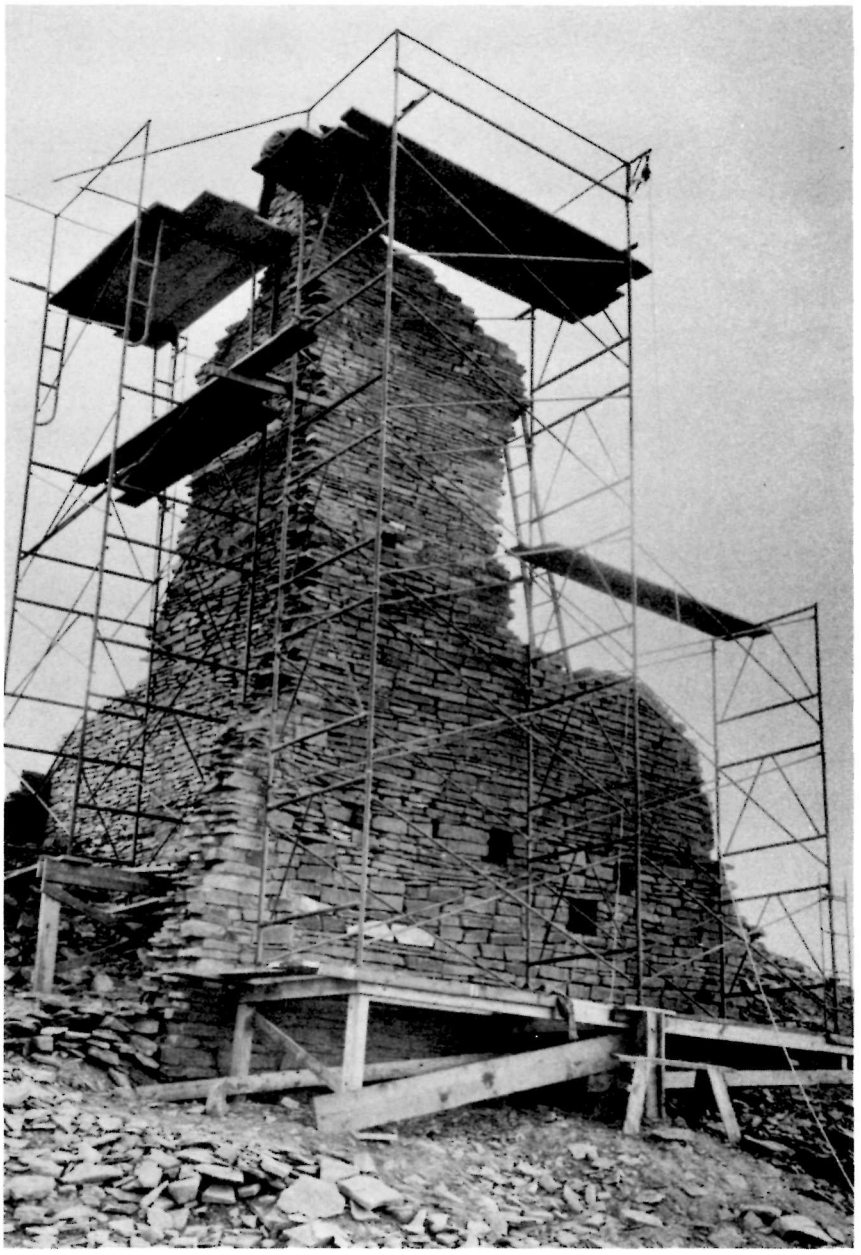
The following pages illustrate some of the work in progress on the Tower Kiva with special emphasis on the use and adaptability of tubular steel scaffolding.

Materials, Construction, Etc. (con.)



During work on the highest portion of the tower, scaffolding completely surrounded the structure. To provide maximum safety for the workmen, the three sets of scaffolding were anchored at the bases as well as across the top and through midsections, since frequent high winds increased the hazards.

Materials, Construction, Etc. (con.)



Because of the steep slope, scaffolding was anchored on firm and level bases built of heavy timbers.

RUINS STABILIZATION RECORD (First Sheet)

Room 27
Kiva

Date 7/27/59 Chaco Canyon National Monument

Project number Name of ruin Talus Unit No. 1

Personnel of party on this job: Wall (N.E.S.W.) All walls

Joel Shiner, 8 Navajos Floor, roof None

References to publications and justifications for job:

Unpublished notes by Paul Walter in 1933 and Margaret S. Woods in 1934. Their work was with the School of American Research.

ARCHITECTURE

Orientation, plan and type (Situation, evidence of additional stories, period of construction relative to surrounding rooms, evidence of burning, etc.)

Long rectangular room of two stories, masonry is Type II (tiered blocks and spalls). It is one of a half dozen rooms which are in two rows.

Floor (Floor type: additional notes)

No floor present now.

Roof (Roof type: additional notes)

Ceiling of first floor shown by a ledge and by numerous beam holes. Roof of second floor is gone.

Details (Notes on doorways, lintels, etc.)

Doorways in south wall on first and second stories.

Room ~~or Kiva No.~~ 27

RUINS STABILIZATION RECORD (Second Sheet)

Condition on date when work started
Ancient masonry:

North wall above the ledge leans precariously into the room.
East and west walls have eroded and are loose at the top. Footings of all four walls are undercut by erosion. Beam holes are eroding where beams have decayed.

Repair or reconstruction previous to this work:

None

Materials, construction, and technique in making repairs or accomplishing job:

Part of the center section of the leaning wall was removed. A horizontal slab of steel-reinforced concrete was poured so as to abut against the junction on the partition walls. Steel rods were fastened through both wall and slab with turnbuckles between. Using the turnbuckles, the wall was pulled back to nearly vertical position. The stones removed were then replaced in tinted cement. East and west walls had already been patched and strongly capped to bear the load. New stones were set in cement around the wall footings. The beam holes were patched in tinted cement.

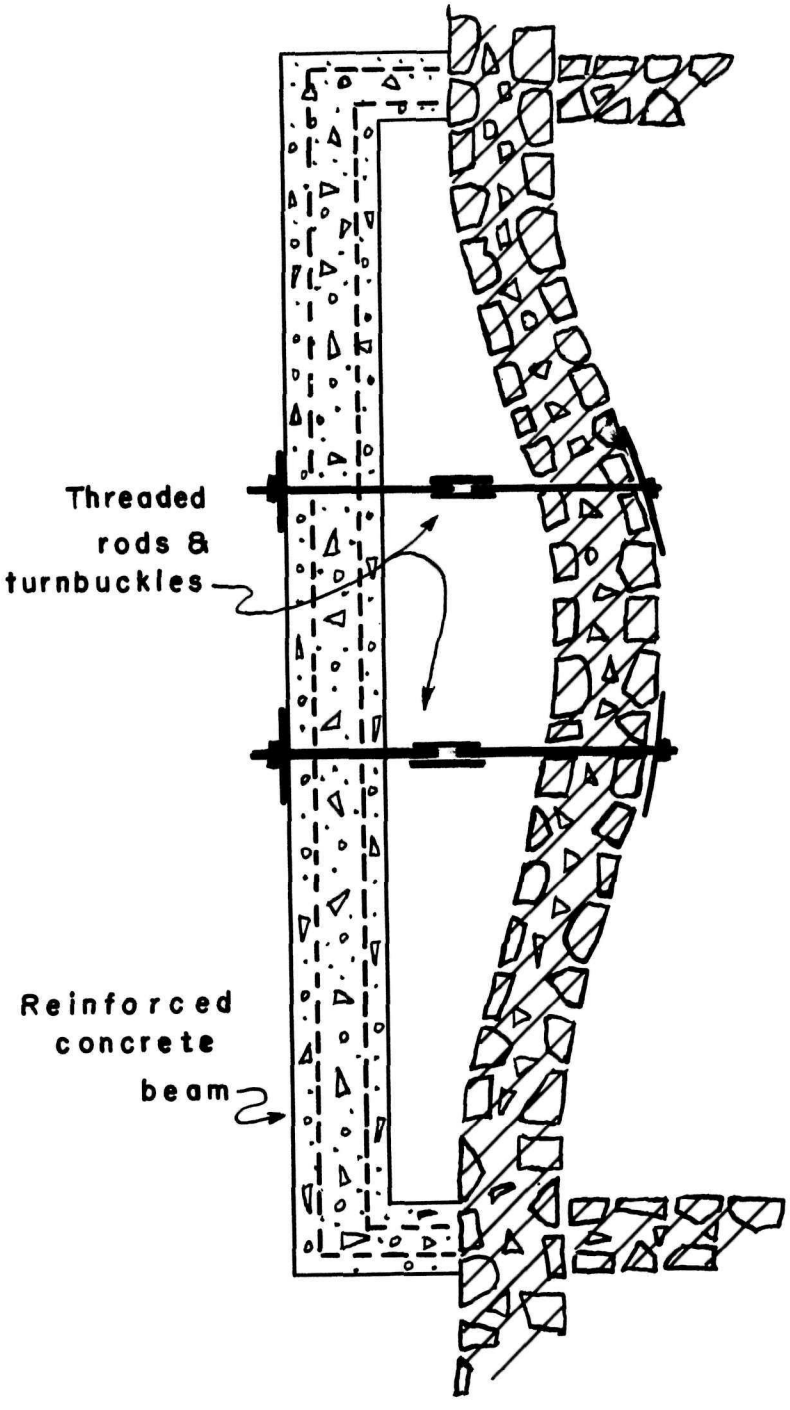
Reference to drawing: **Work authorized by** Roland Richert
Archeologist

Date work started: 7/27/59

Date work finished: 8/14/59

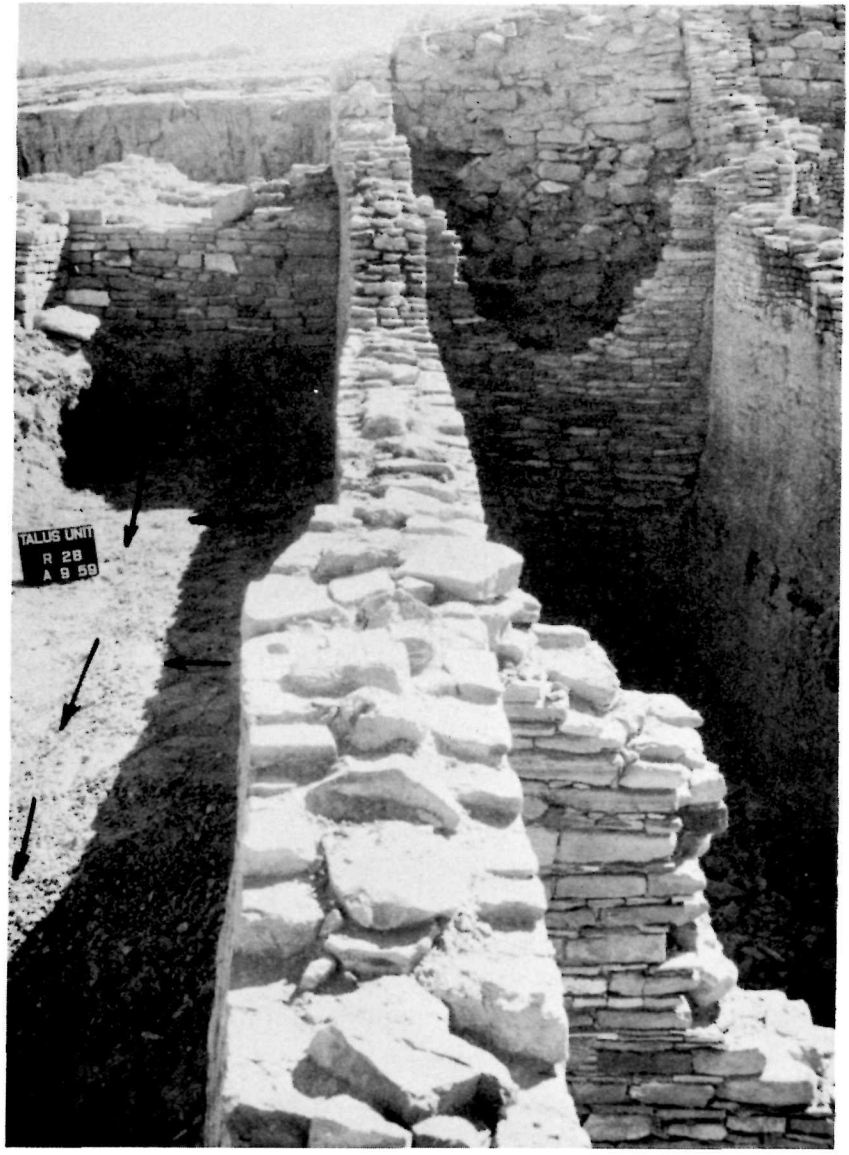
(Note: Place "before" and "after" pictures on blank bond sheets, caption, and keep with these record sheets. Include "during" pictures to show interesting or important details or technique. Use additional sheets for any heading if necessary).

The wall between Rooms 27 and 28 was distorted and pushed out of line by pressure of fill, often damp, at the left. Arrow shows direction of force. The purpose of the stabilization, shown on the next page, was to strengthen the wall against the pressure.



PLAN OF REINFORCED BEAM TO REALIGN AND HOLD NORTH WALL Rm. 27 Not to Scale

Construction of concrete beam shown in plan on preceding page, frame complete and reinforcing rods in place. X - X^1 - beam, Y - location of threaded rods and turnbuckles, Z - temporary braces. The ends of the beam bear against the wall, at each side of the bulged area at points where the wall is braced against movement by partition walls, that at the east shown as A.



Wall has been pulled partly back into line, capping straightened up. The concrete beam dug into Room 28 is covered and the surface of this room graded, arrows, to carry surface runoff away from the damaged wall.

RUINS STABILIZATION RECORD (First Sheet)

Room 1
Kiva

Date October 1955 Walnut Canyon National Monument

Project number _____ Name of ruin NA 333

Personnel of party on this job: Wall (N.E.S.W.) N, S, and E

G. Vivian
R. Richert

Floor, roof. _____

References to publications and justifications for job:

See Introduction

ARCHITECTURE

Orientation, plan and type (Situation, evidence of additional stories, period of construction relative to surrounding rooms, evidence of burning, etc.) This is the southernmost of four contiguous rooms comprising NA 333. Nearly square in plan. Wall junctures indicate that it is at least older than Room 2, but not as old as Rooms 3 and 4. Sequence of construction was probably as follows: Rooms 3 and 4 built as a unit, followed by Room 1 at the south end of the cave, and leaving an open gap as a work area between which was subsequently walled across to form Room 2.

Floor (Floor type: additional notes)

Unexcavated

Roof (Roof type: additional notes)

Cave

Details (Notes on doorways, lintels, etc.)

Doorway in center of east wall. Lintels are missing and the area above the door is broken into a V shape. Door is characterized by a high sill.

Room or Kiva No. 1

RUINS STABILIZATION RECORD (Second Sheet)

Condition on date when work started

Ancient masonry: Fair. North Wall: In poorest condition. A large hole beginning at foundation and extending to midsection, caused by pot hunters has made this wall extremely weak, and collapsed all of the eastern third except a fragile corner one stone wide. East Wall: Good except for eroded foundation, and the lower third of southeast corner which has collapsed. The V-shaped hole over doorway needs grouting on the north side.

Repair or reconstruction previous to this work:

None

Materials, construction, and technique in making repairs or accomplishing job:

North Wall: The large hole measuring 3' x 4' was filled with repair masonry to save the upper section, and the northeast corner was buttressed also to preserve it. Repair work stained with black mortar color to match original.

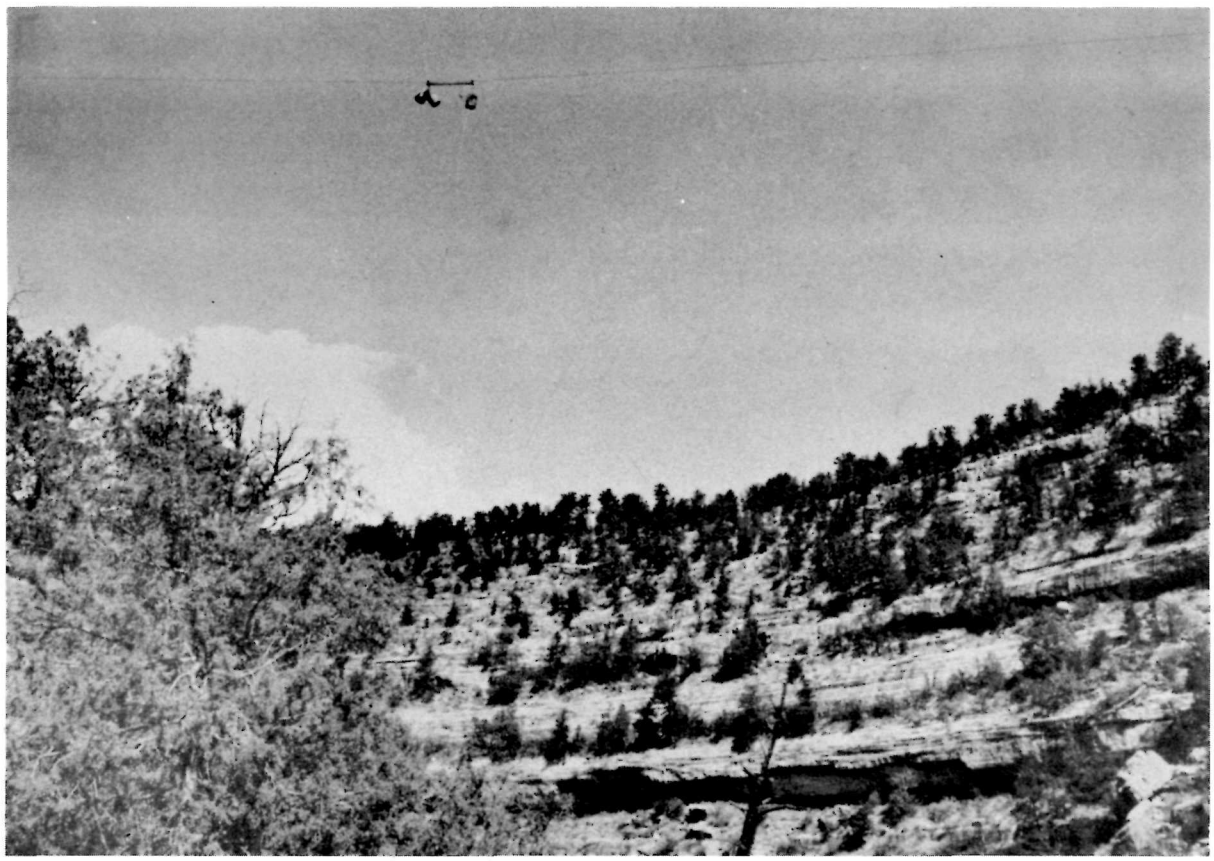
East wall: Entire foundation one stone high was grouted and pointed. The south wall also had a few small holes along the foundation row where original soil mortar had eroded and these were filled. Sill and wall area below door grouted and pointed.

Reference to drawing: Work authorized by G. Vivian
Archeologist

Date work started: 10/12/55

Date work finished: 10/13/55

(Note: Place "before" and "after" pictures on blank bond sheets, caption, and keep with these record sheets. Include "during" pictures to show interesting or important details or technique. Use additional sheets for any heading if necessary).



Cans of water and large bucket of stabilized mortar suspended from carrier and riding across canyon to the project.

Room 1, east exposure. Before and after replacement of fallen corner, grouting of the deeply eroded wall base, and partial resetting of area above doorway. Settling crack purposely not filled to surface.