015829

REPORT

APOSTLE ISLANDS MOISTURE MITIGATION STUDY

Division of Cultural Resources Management
Midwest Region

29 July 85

TABLE OF CONTENTS

ITEM	PAGE
Sand Island	1 - 4B
Rasberry Island	5 - 6B
Michigan Island	7 - 11B
Outer Island	12 - 15C
Devil's Island	16 - 17B
Summary or Recommendations	18 - 19
Suggested Priorities	19
Appendix A	20
Appendix B	21
Appendix C	22
Appendix D	23 - 29
Appendix E	30 - 36
Appendix F	37 - 38

SAND ISLAND LIGHTHOUSE

1. Psychrometer Readings (Relative Humidity--RH):

South Basement: RH = 97% (high)
North Basement: RH = 93%
Tower Basement: RH = 86% (solar fan in operation)
Kitchen - near stairs to basement: RH = 68%

Discussion: (see Appendix A) The solar fan in operation in the tower basement is obviously working to reduce relative humidity. This practice should be continued, and we recommed the installation of additional fans in the remaining rooms of this building.

2. Moisture Readings: (see Appendix B)

South Basement:	Face of masonry:	20-25
	Mortar joints:	50+
	Floor slab:	46-50
	Interior brick wall:	50
North Basement:	Exterior walls (face):	23-28
	Floor slab:	25
	Masonry joints:	50+
Tower Basement:	Walls (north):	20-27
	Walls (south):	45-50
	Floor slab (gen.):	25
	Southeast slab:	50+

Discussion: All of the moisture readings taken were rather high. Of special note were the readings taken through the masonry joints: the walls were quite damp within.

3. Additional Observations (Photodocumentation): Photos # 1 and 2 show a typical situation in the basements of the Sand Island lighthouse. The slab is saturated to a point three to four feet from the exterior walls. Moisture present beneath the slab works its way up at the joint between the brick wall and the slab, and then into the slab at its edge. As well, the walls are damp up to around four or so feet from floor level. In Photo #2 there is evidence of wood rotting at the base of the frame. The brick at both sides of the opening has deteriorated. Photo #3 illustrates the condition known as "rising damp." Moisture is wicked up into the walls through capillary action. A "high tide" line can be seen between dry and moist masonry. It is at this line that many salt deposits may be seen. Photo #4 was taken in the tower basement. This area was the wettest. At the southeast

corner, the slab is saturated, and a portion has heaved and broken apart. Due to rising damp, the once whitewashed (or painted) walls have forced the coatings loose. Photo #5 was taken at the base of the tower stair. This slab is completely saturated. It is possible that water has drawn into the slab via the pipe column supporting the stair, as well as at the junction of the slab and wall. Plaster has failed in this area due to the extremely high concentration of moisture in these walls. Photo #6, taken on the north elevation of the lighthouse, shows possible effects of rising damp on an exterior, above-grade wall. There is a deposition of salts as well as mold and lichens in the corner below the downspout. (It is very likely that a leaking gutter added to the problem). This should be checked--all joints should be tight, and the run-off should be directed away from the building.

4. Conclusions / Recommendations:
We recommend installing a perforated perimeter drainage system around the entire building, at the level of the footings--or the bottom of the foundation wall. The exposed foundation walls should not be touched (do not attempt water- or dampproofing--the walls must "breathe".) This method of reducing the moisture equilibrium in the immediate area of the foundation walls is the most practical and also the most cost effective. Noticable reduction in rising damp can be expected almost immediately. Design of such systems should be done by consultants familiar with such work, as proper layout, installation, and provisions for proper recompaction must be undertaken.

If there is evidence of severe masonry or mortar deterioration ("severe" = one third of the bearing area of masonry units, or one-third of the bedding area of the mortar has disappeared) selective repairs should be undertaken (not full-scale repointing or replacement of walls). In calculating loss of bedding or bearing area: if the wall is a total of twelve inches thick, and four inches of masonry has deteriorated, repairs should be undertaken. In the case of individual bricks, if about 1 1/4 inch of mortar has decomposed from beneath a brick, that area of the wall only should be repointed. Repointing guidelines are included in the attached Preservation Brief (Appendix D).

The perimeter drains will reduce the amount of water working its way into the foundation walls and floor slabs. In the area of the tower basement, we recommend replacing the slab, and installing a sump (and solar-powered pump) in the slab beneath the tower stair.

The grading around the building should be checked by a site survey consultant to ensure that run-off is guided away from the foundation walls. This is a rather critical item, and perhaps the greatest cause (coupled with inadequate, damaged, or lack of gutters and downspouts) of wet basements.

Monthly inspections should be done on wood framing members (joists, etc.) for evidence of wood rot (decay) caused by fungi. (See Appendix C)

Damaged wood members should be repaired by installing treated parallel companion members. The masonry walls should also be examined for failing masonry units or mortar, and repaired / replaced as above. Wood members in contact with damp slabs, as shown in Photo #2 should be repaired by "scabbing" a treated member onto the damaged portion.

Bricks like those on either side of the opening in Photo #2 should also be replaced. The key is finding brick of a similar period, and of prime importance is matching the new mortar in color and consistency to the historic mortars. A mortar with a high Portland cement content will cause differential movement, and will most likely cause more problems with the surrounding masonry than it was meant to correct. These new mortars are much harder than historic high-lime content mortars. (See Appendix D).

The slab in the tower basement should be replaced, but only after the perimeter drainage system has been functioning for a couple of months.

We strongly recommend not coating or re-coating the interior sides of masonry walls. Since these walls are moist, and will continue to be moist, coating these walls will only trap moisture, and moisture that is trying to escape will cause repeated failure of these coatings. With the installation of perimeter drains, and the subsequent change in the moisture content in the ground surrounding the building, the walls should begin drying out, however, this will take time.

The plaster situation at the base of the tower should be left as is until the tower walls begin to dry out. Replacing plaster at this time would be pointless because of the high concentration of moisture in these walls. The plaster would only continue to fail.

All windows and other openings through exterior basement walls should be properly sealed and weatherstripped.

Lastly, and most importantly, the guttering system around the

building should be checked for damage. Downspout leaders should be run at least three feet from the building and all leaders must terminate in stone (preferred) or concrete splashblocks. Also, the grade should take this building run-off away from the foundation walls. It would be pointless to take these precautions without also ensuring that there is positive drainage away from the building. We recommend following this guidance for all buildings.

SAND ISLAND

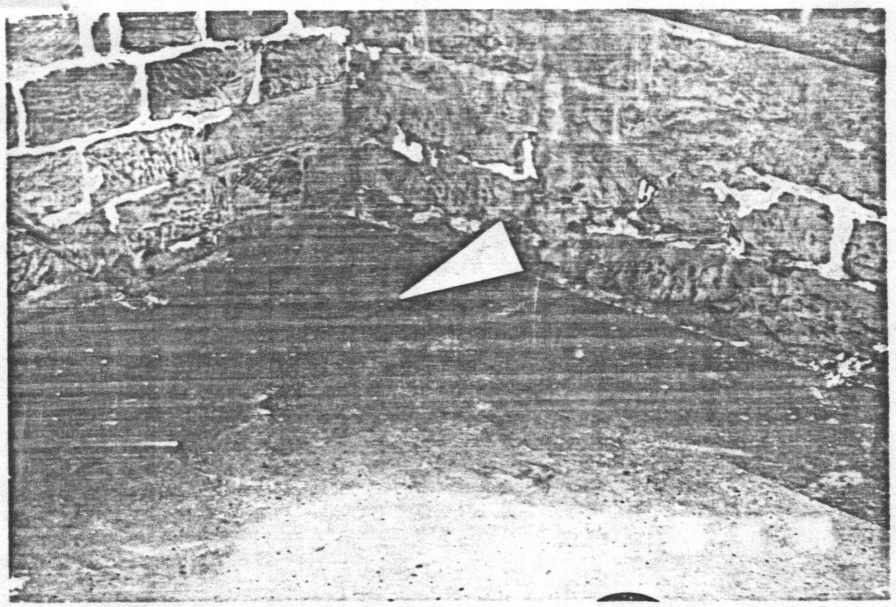


PHOTO #1

NOTE DAMP SLAB AT PERIMETER WALLS

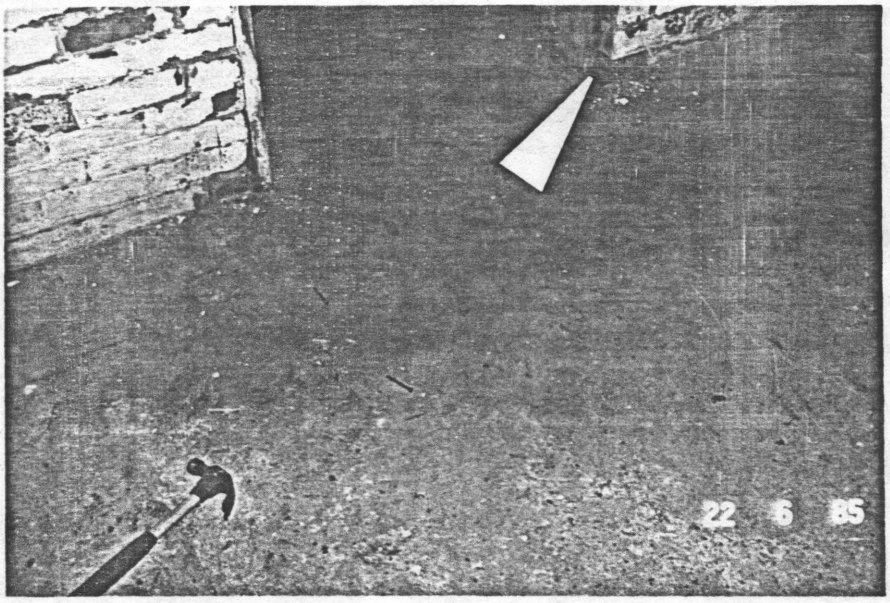


PHOTO #2

NOTE ROTTEN DOOR FRAME AND BRICK

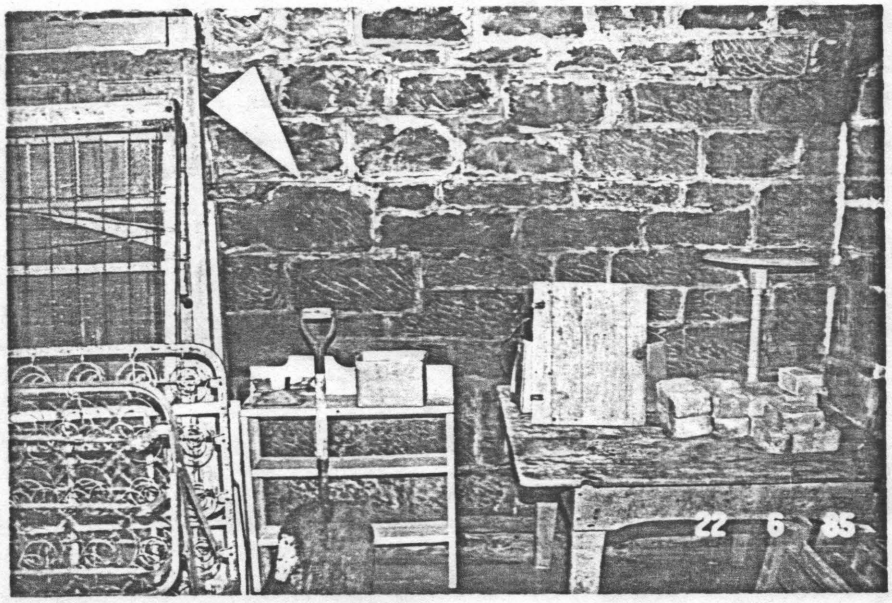


PHOTO #3

NOTE "RISING DAMP." ARROW POINTS TO "HIGH TIDE LINE"

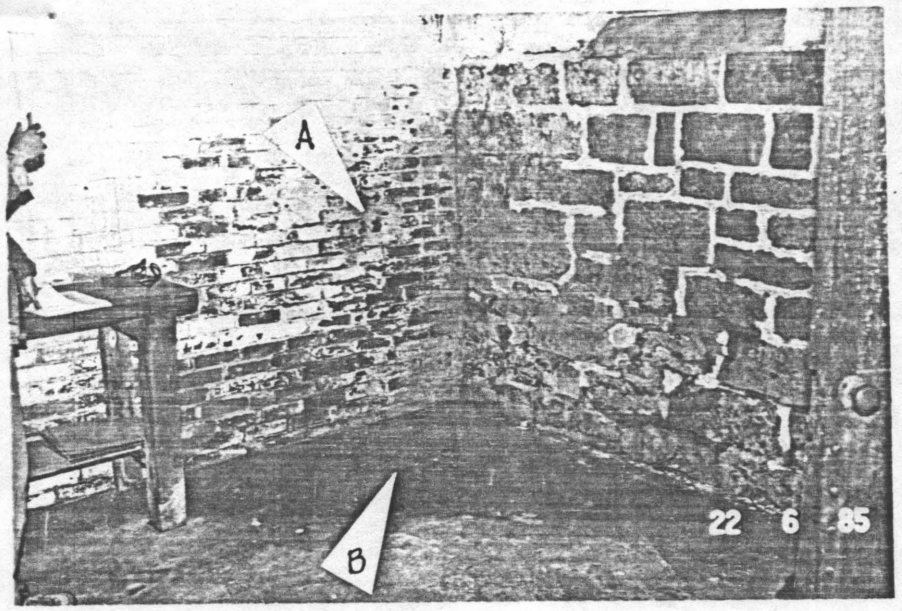


PHOTO #4

A: RISING DAMP HAS CAUSED FAILURE OF COATING

B: VERY WET SLAB AT CORNER

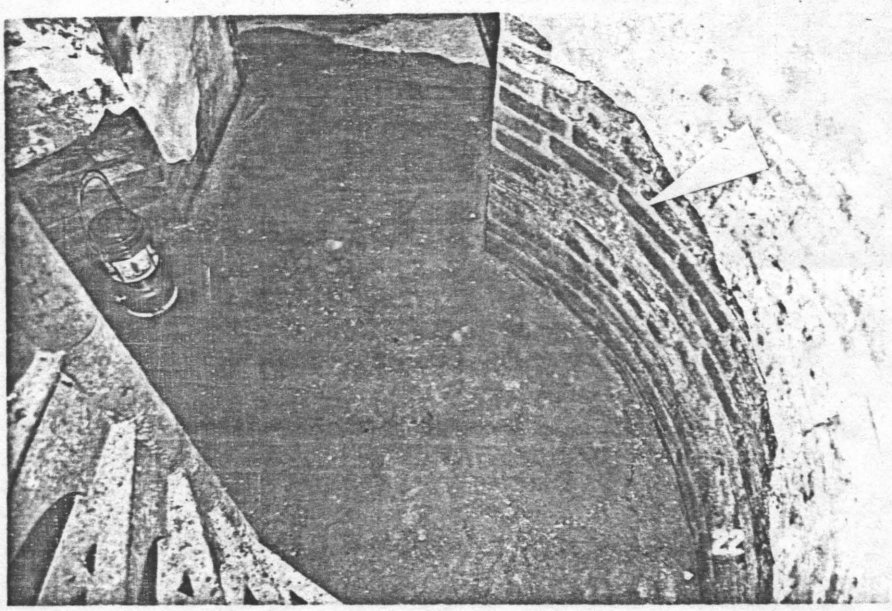


PHOTO #5

FAILURE OF PLASTER DUE TO RISING DAMP

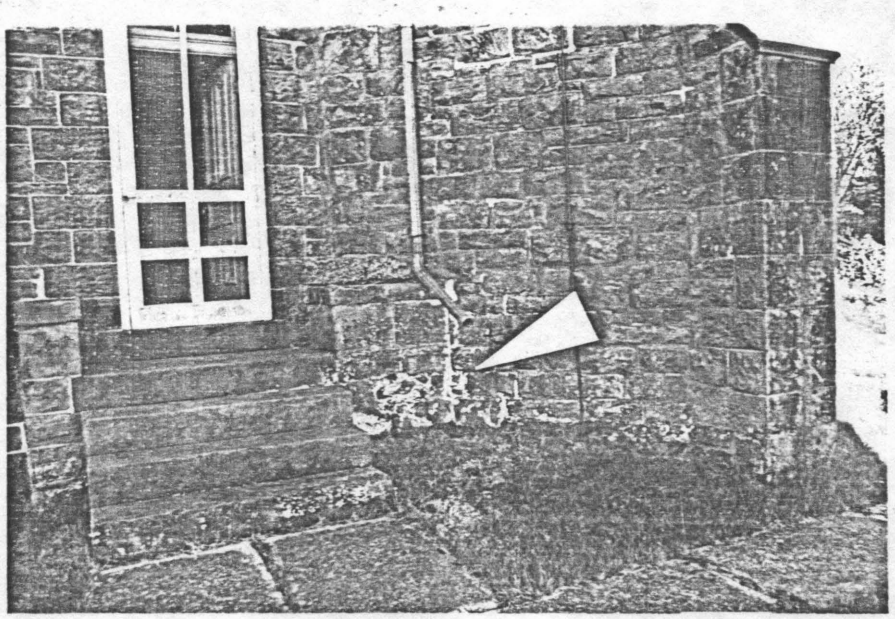


PHOTO #6

NOTE SALTS AND LICHENS DUE TO RISING DAMP. POSSIBLE GUTTER LEAK

RASPBERRY ISLAND KEEPERS QUARTERS

1. Psychrometer Readings:

South Duplex:	
North room (basement):	87% RH
South room:	84% RH
First floor kitchen:	65% RH
North Duplex (bsmt.):	87% RH
Kitchen:	64% RH

Discussion: the relative humidity readings in the basement are quite high. We recommend the installation of solar-powered exhaust fans.

2. Moisture Readings: Brick walls: 10-25
Mortar joints: 27

Discussion: These readings are low, due most likely to the fact that the foundations appear to be relatively new (perhaps having been replaced within the past 10 or so years). The brick and mortar, as well as the concrete slabs are recent. It was obvious that a Portland cement was used in both the slab and mortar, as it was practically impossible to drive concrete nails into either to take moisture readings. The nature of new brick and the harder concrete make for a more impervious situation here.

3. Additional Observations (Photodocumentation):
Photo #7 shows the condition at the joint of the slab and the exterior walls. There is also a deposition of salts due to rising damp. The plaster on the floor is from the ceiling above. Most likely this ceiling damage has resulted from improper application, rather than excessive moisture. With the exception of the junction of the floor and wall, the basement is relatively dry.

4. Conclusions / Recommendations:
The only evicence of moisture was at the joint between the slab and exterior brick walls. The only instance observed of rising damp was at the northeast corner of the south duplex basement. This condition is not serious enough at this time to warrant corrective action such as perimeter drains.

All gutters and downspouts should be checked. The basement walls should be monitored monthly for evidence of rising damp and presence of salts forming on the face of the masonry. Deterioration should be noted. However, this is unlikely due to the newness of this foundation. Also, wood framing members should be monitored and put to similar testing and corrective action as outlined above.

All windows and other openings through exterior basement walls should be properly sealed and weatherstripped.

RASPBERRY ISLAND

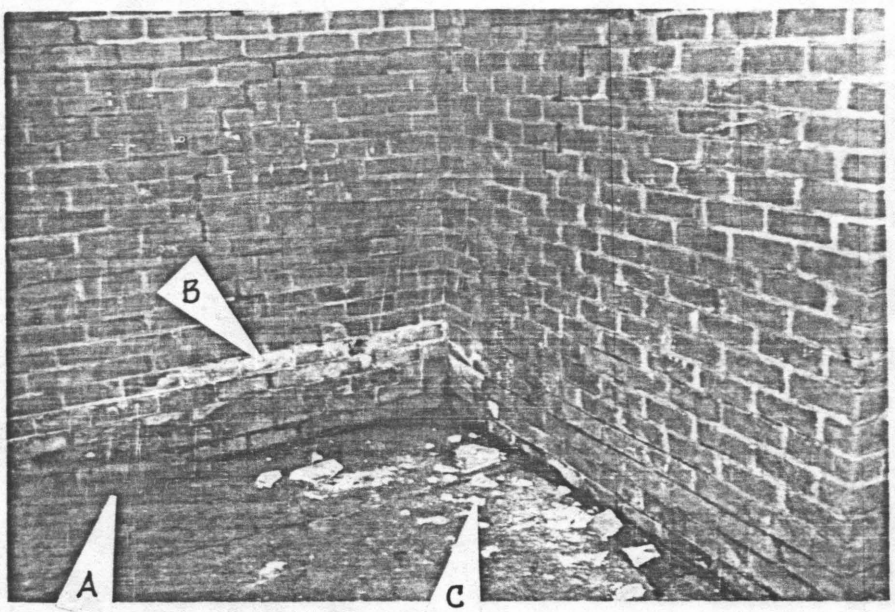


PHOTO #7

A: DAMP SLAB AT JUNCTION OF WALL AND SLAB

B: RISING DAMP: DEPOSITION OF SALTS

C: PLASTER FROM CEILING

MICHIGAN ISLAND

A. 1858 Lighthouse

1. Psychrometer Readings: 87% RH

Discussion: This basement had a solar-powered fan in the southeast window, however the Michigan Island buildings also showed the highest degree of moisture presence, hence the high RH reading. We advise continued use of the fan.

2. Moisture Readings:

Conc. slabs (exc. at NW corner):	15-22
Conc.slab at NW corner:	33-40
East wood floor joists:	16-17
East wood wall sheathing:	15-17
North wall sheathing:	20-22
North-west stone wall:	24
South stone wall:	25
North stone wall:	50+

Discussion: the readings in all areas except the northern end of the basement were relatively low (very littly moisture in the walls or slabs). It was real obvious that the north wall and slab had high concentrations of moisture--rotting wood, etc.

3. Additional Observations (Photodocumentation):
Photo #8 shows water penetration into the wood joists from either the stone wall behind the wood sheathing or from the wood sheathing itself, or both. The wood sheathing in this basement was found to be quite damp (especially the north wall). Rising damp has worked its way into the joists as is evidenced by the discoloration of the wood. This photo also shows a situation--not moisture related--which should be corrected as soon as possible: asbestos-wrapped piping. Photo #9 shows presence of moisture (at one time or another) at the top of the columns. The water has been introduced into the top of the columns via the beam, which has drawn moisture from the stone walls on which it bears. Photo # 10 was taken looking at the north wall--which had the highest degree of moisture. The wood sheathing has rotted away in this section, exposing the stone wall behind. This wood sheathing wall was pretty well saturated, and we could see droplets of moisture on the stone behind. Photo #11 was taken on the north elevation of the lighthouse. There is possible evidence of rising damp which has worked its way above grade--most noticably on the north. This is evidenced by the peeling paint (whitewash) in the area of the stoop. Ground moisture in the immediate vicinity (from the grass) is another probable cause.

4. Conclusions / Recommendations:
We recommend installing gutters and downspoouts on this building as a primary order of concern. This will lessen the problems associated with building run-off (which works its way down directly along and into the foundation walls). Ideally, the gutters should terminate in underground drain lines which would day-light along the shoreline, emptying into the lake. This method would be the least intrusive visually, and also the most effective. A shortcoming is its additional cost. The alternative would be to install stone (preferred) or concrete splash blocks at the termination of each downspout. This is a minimum requirement.

Next, a perimeter drainage system should be installed around the lighthouse, following the guidelines for the Sand Island lighthouse. (There is no need for a sump here).

Regrading of the site around the building should be accomplished if there is positive drainage toward the foundation walls.

All wood framing members will have to be watched for evidence of wood rot, following the information given within this report. Since this building has experienced a very high influx of water penetration--as evidenced by the condition of the wood members--careful attention must be paid to the wood structure. Monthly inspections, along with color photographs of a few isolated framing members is a necessity. Any changes in color, hardness, sound, cracking, etc. should be noted.

All windows and other openings through exterior basement walls should be properly sealed and weatherstripped.

We would strongly suggest removal of portions of the interior wood sheathing so an inspection of the stone wall behind can be made. Based on the information contained in the balance of this report, the wall can be checked for signs of deterioration (exfoliation, spalling, loose or crumbling mortar, presence of salts, etc.). Again, follow the guidelines previously given for repairs. A difficult decision rests on whether or not to replace the portion of rotted sheathing on the north. Even though this situation is historic, we are merely covering up potential problems (we have no idea what is happening to the stone wall behind). And it is this portion of the structure (the stone wall) which is doing all the work of carrying the building. For the interim, we suggest removing those portions of severly rotted members on the north wall, and leaving them off. We

also recommend the use of removable panels of selective areas of sheathing in the remaining portions of the basement, which will give visual access to the stone wall on a monthly basis.

MICHIGAN ISLAND

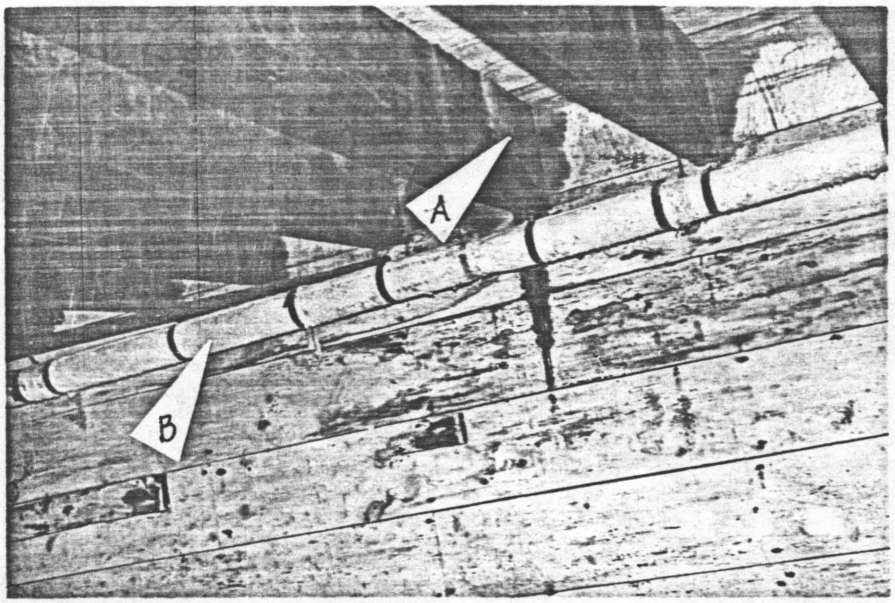


PHOTO #8

A: WATER STAINED JOIST

B: ASBESTOS-WRAPPED PIPE

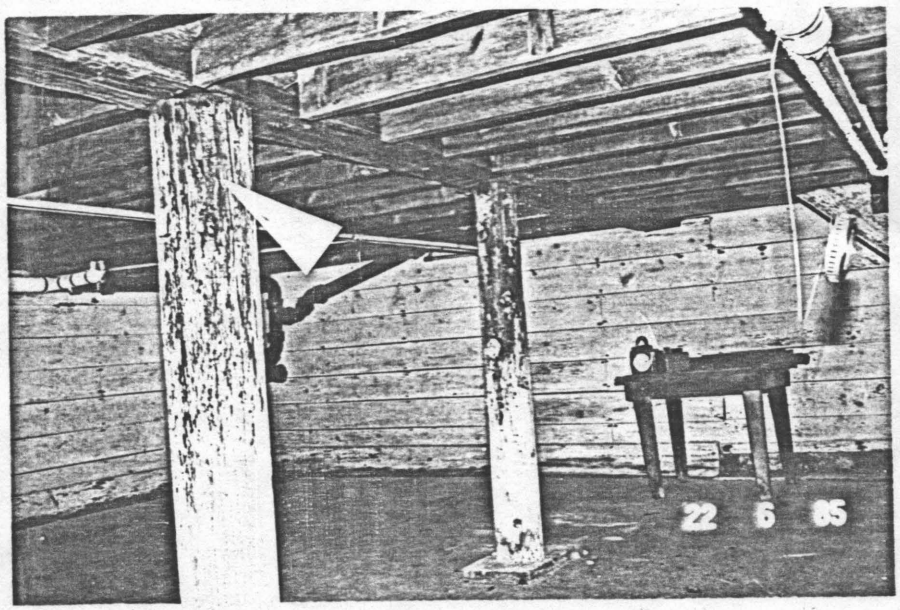


PHOTO #9

WATER HAS ENTERED COLUMNS FROM ABOVE

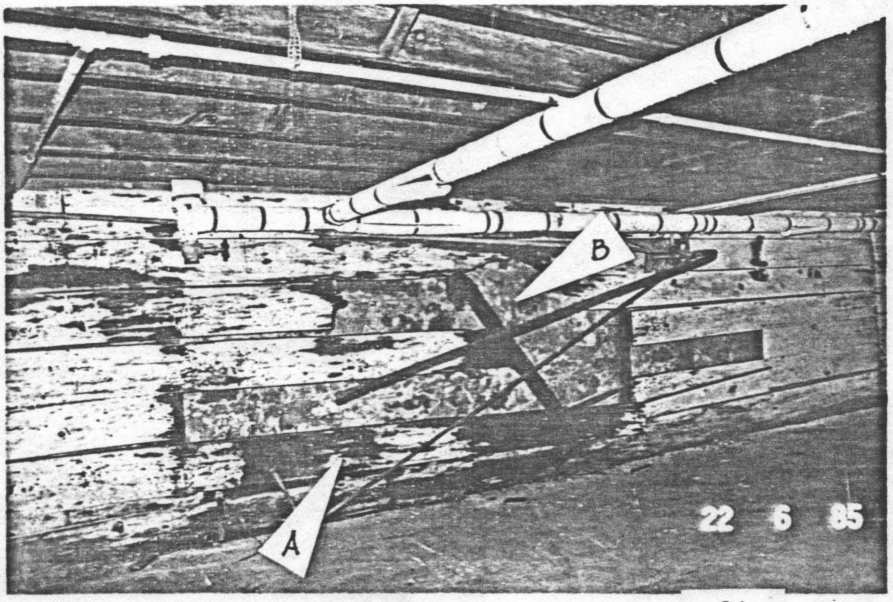


PHOTO #10

A: ROTTED WOOD SHEATHING

B: STONE WALL BEHIND

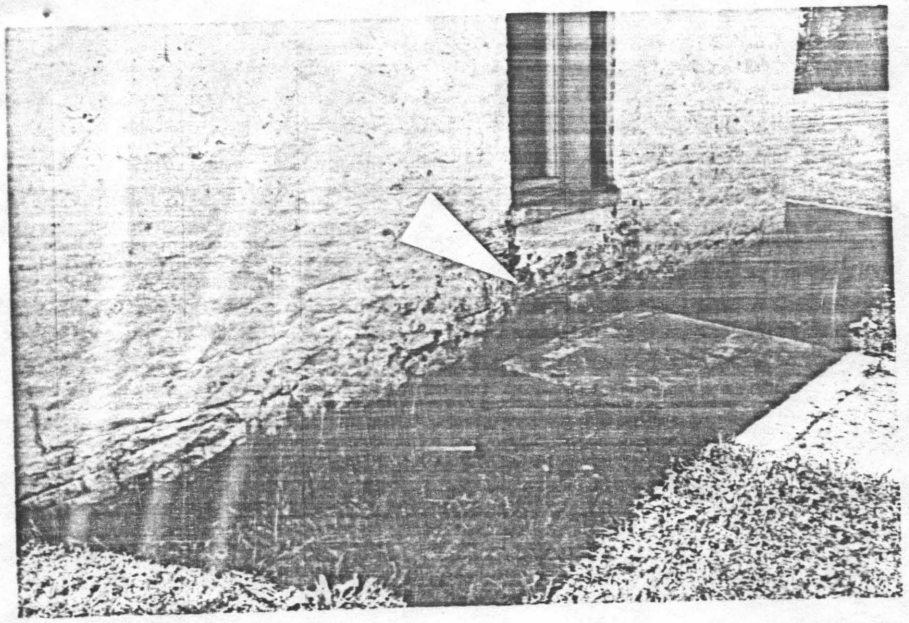


PHOTO #11

RISING DAMP HAS CAUSED PEELING WHITEWASH ON THE EXTERIOR

B. Keepers Quarters

1. Psychrometer Readings: North basement: 94% RH
   South basement: 87% RH

   Discussion: These readings are high, especially at the north portion, where a considerable amount of moisture was observed. (In some places along the base of the wall, standing water was observed). We strongly suggest the use of exhaust fans in this basement.

2. Moisture Readings: (because of the newness of the foundation and slab, hence the use of very hard mortar & cement, all readings were surface readings rather than through-the-wall / slab readings--the latter which give considerably higher readings):

East wall:	13-22
South wall:	14-23
West wall:	13-25
North wall:	17-25

   Discussion: although the readings don't vary a great deal, a visual inspection of the basement immediately showed evidence of an extremely wet situation along the north wall.

3. Additional Observations (Photodocumentation):
   Photo #12 was taken at about the center of the basement, and shows a fireplace foundation and ash pit. The dark staining around the pit is dampness from the saturated slab. Photo #13 was taken at the north-east corner of the basement. Note the extremely damp slab, and the high concentration of salts as high as five feet up on the adjacent brick walls. There were a few instances of exfoliating brick along the north--which indicates a very high moisture situation given the newness of the brick and mortar (we saw instances of exfoliation in other foundations, but in masonry considerably older and much more likely to be showing signs of deterioration). This situation in the Keepers Quarters has been accelerating rapidly. Photo #14 is rather typical of the north portion of the basement. Of concern here are the wood framing members in direct contact with the wet slab. This door frame should be repaired shortly--with treated lumber. Photo #15 shows a typical situation with many wood joists. This particular member has rotted and must be joined with a parallel member. Photo #16 shows such a replacement: the rotted member on the left, the new member directly adjacent to carry the load which the old member was meant to carry, and cannot.

4. Conclusions / Recommendations:
Gutters and downspouts should be checked for damage. The site should be checked for positive drainage away from the building. Because of the extremely high concentrations of water at the north particularly, this area needs special consideration. It is very possible that a combination of faulty guttering, plus site sloping toward the north face, is causing the very wet condition in the keepers quarters.

All windows and other openings through exterior basement walls should be properly sealed and weatherstripped.

We noticed asbestos-wrapped pipes in this basement also. This situation should be rectified as soon as possible.

All wood members should undergo a thorough inspection and new companion members installed where rotting has occurred. Monthly inspections of the framing system should be undertaken.

MICHIGAN ISLAND

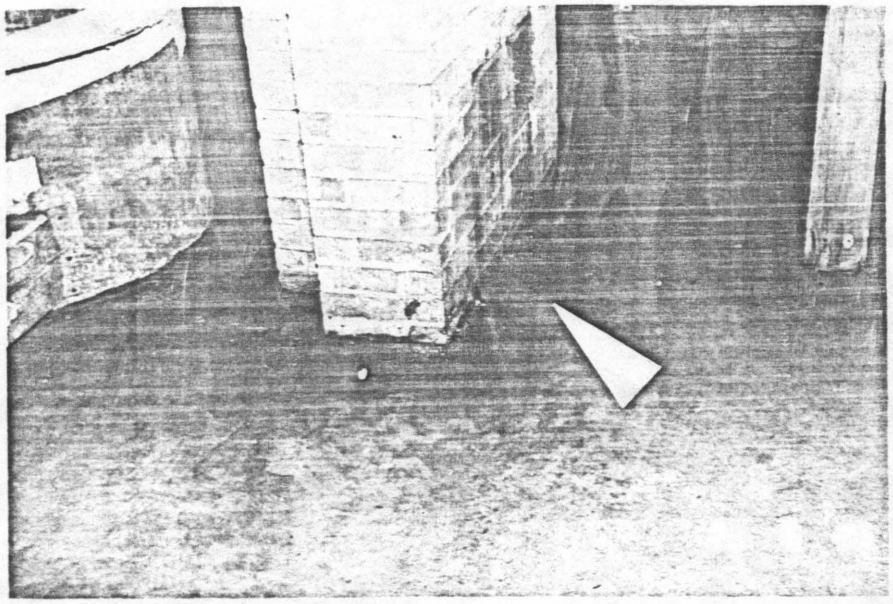


PHOTO #12

WATER-STAINED SLAB

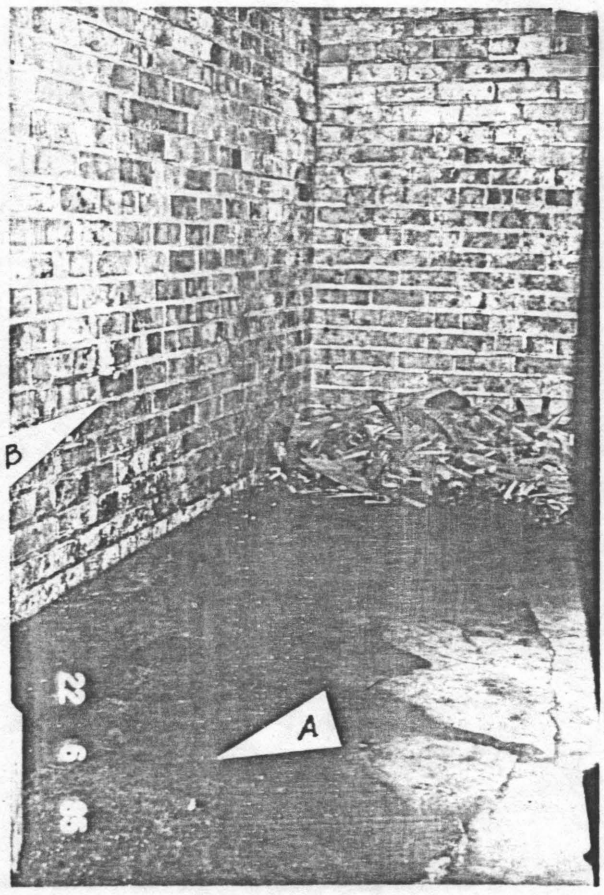


PHOTO #13

A: VERY DAMP SLAB ON NORTH WALL

B: SALTS DEPOSITED ON WALL FROM RISING DAMP

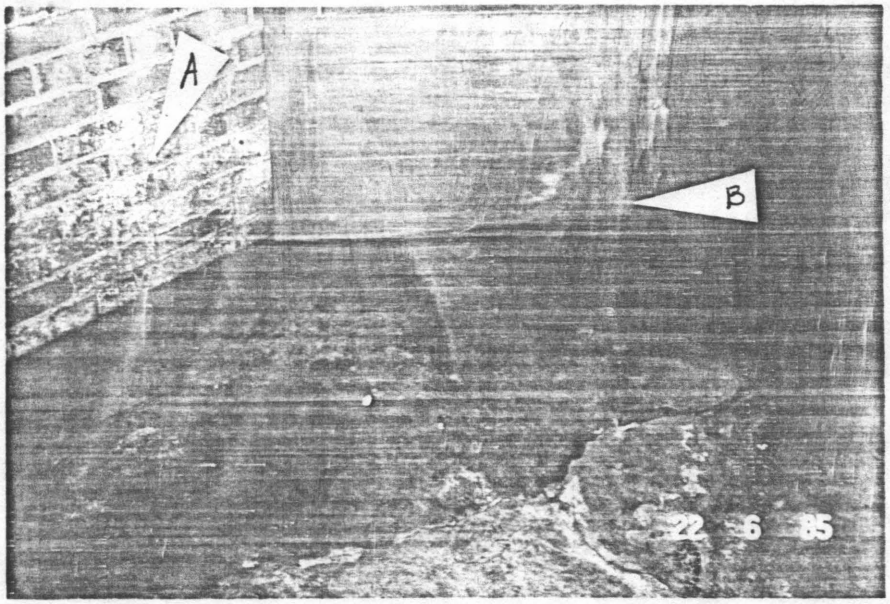


PHOTO #14

A: SALTS

B: ROTTED DOOR FRAME

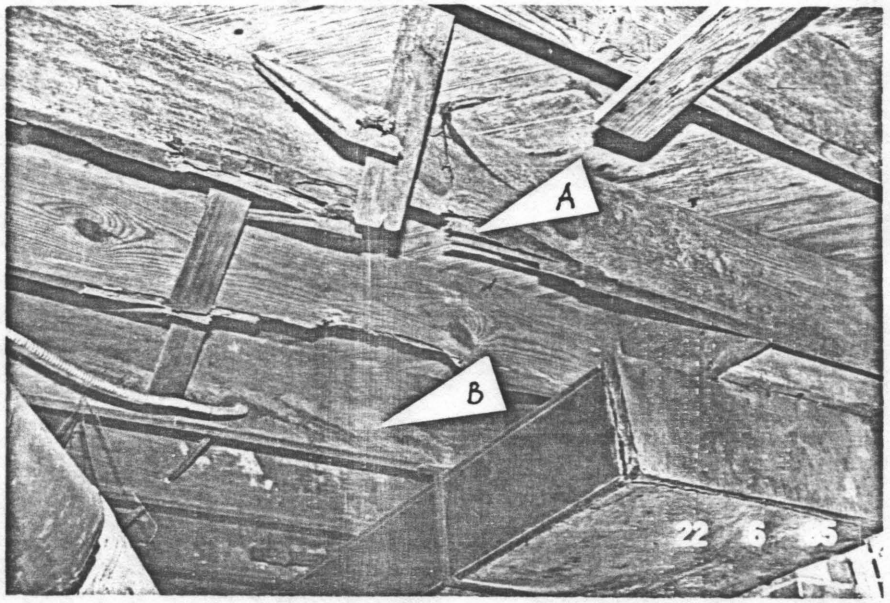


PHOTO #15

A: ROTTED WOOD JOIST

B: STAINED WOOD: WATCH FOR ROT

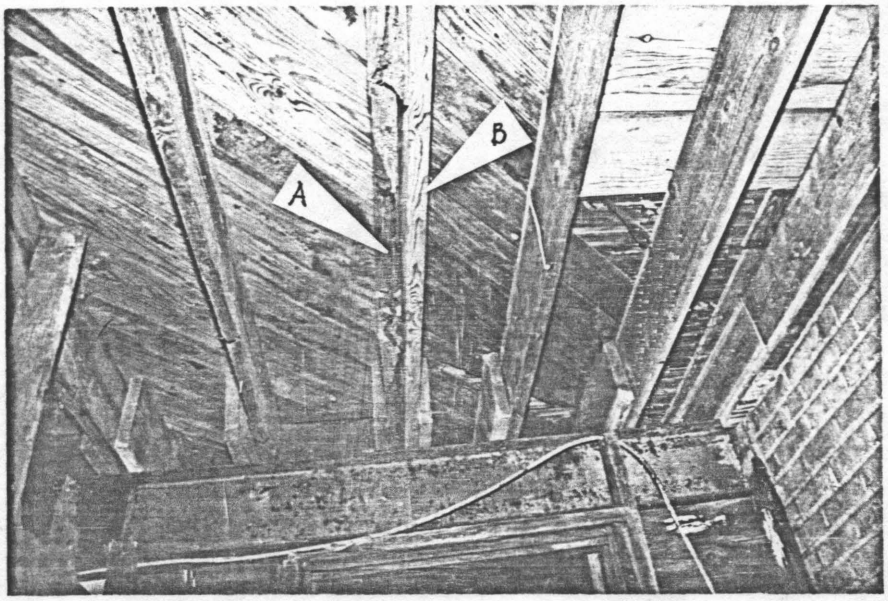


PHOTO #16

A: ROTTED JOIST

B: NEW COMPANION MEMBER IN PLACE

OUTER ISLAND

1. Psychrometer Readings: West room: 87% RH
East room: 87% RH

Discussion: these readings are high. We recommend installing exhaust fans.

2. Moisture Readings:

West room:	Wall surface:	20-35
	Thru mortar:	30-50+
	Floor slab (surface):	17-25
East room:	Wall surface:	23-28
	Thru mortar:	43-50+
	Floor slab (int.):	37

Discussion: these readings were all rather high, especially the readings taken through the mortar joints. (Which indicated a high degree of moisture within the masonry walls.)

3. Additional Observations (Photodocumentation):
Photo #17 shows a rather typical situation in the basement: damp slab around the perimeter walls, failing whitewash due to damp walls forcing the coatings off, exfoliating brick and stone, and deteriorating mortar. Photo #18 is a detail of the situation at the sill. The sill brick are showing signs of pronounced exfoliation. Since the sill is so deteriorated, it is very possible that the moisture damage in this area is due to water penetration in and around the window opening (loose fit or rotten framing) rather than through the masonry wall. Photo #19 shows damage to the fiberboard ceiling in the east basement room. Since this damage occurred close to an interior wall, we are most likely dealing with water which has come from another source than through the exterior walls (such as a roof or interior plumbing leak), or water which has wicked up through theinterior wall and into the joists above. Photo #20 was taken from the east elevation, looking at the first floor line between the first floor and basement windows. There are several items of interest in this photo. First, is the existence of a crack between windows. Cracks of this nature arise from slight shifting of the wall between these two openings. The situation may be moisture-related, however additional research is required. This condition will permit introduction of additional moisture, and should be corrected. However, before any repairs such as repointing are undertaken, we must treat the cause. The second condition showing up in this photo is the condition of the window frame--which is showing signs of rotting at the base (to the

right). This situation should be corrected, as this permits another avenue for moisture to enter the building. The third condition indicated is the condition of the brick itself: pitted and scored. The extreme weathering effects of wind, rain and ice are the likely causes. The description on pages 14-15 confirms the fact that this situation is not critical. Photo #21 (taken on the west elevation) shows a similar condition. Photo #22 is a detail of a typical exterior wall. The joint work appears satisfactory (the mortar is not cracking), and even shows signs of having been repointed fairly recently (due to the unevenness of the joints). Photo #23 was taken at the base of the tower, and shows a section of the plastered (stucco) finish broken away. Since the substrait is brick, it is likely that rising damp has forced this section of the plaster finish loose. Photo #24 shows a condition which is not moisture-related, but one which we feel deserves special attention: the modification of the attic windows. First of all, the windows are not historic. Second, the pointing and "toothing" of brick at the sides was handled rather poorly: it is too obvious, even from quite a distance from the building, that an intrusion has been made. We strongly suggest adherence to the guidelines contained in the enclosed Preservation Brief on repointing (Appendix E).

4. Conclusions / Recommendations:
First of all, we recommend gutters and downspouts as outlined above, as well as considerations for regrading if necessary. Next, we strongly recommend a perimeter drainage system.

Deterioration in basement walls should be monitored monthly, using calibrated measuring devices on the surface of the brick and in the mortar joints. The surface of deterioration should be measured back from a line projected from sound masonry, and the difference recorded. (We are exploring the existence of such a device, and will forward our findings.) Loss of more than 1/3 the total depth of the wall material (brick or masonry), or more than 1/3 of the depth of the mortar under individual masonry units, would necessitate replacement of deteriorated masonry units, and/or partial repointing, following the guidelines in Appendix D.

Crack monitors, such as those illustrated in Appendix F, should be installed over all cracks such as those appearung in Photos #21 and 22. Monthly monitoring should be done, and any movement should be noted and reported to this office for action.

Follow the guidelines for masonry replacement and repointing given in the Sand Island study. There are several instances where individual brick should be replaced: the window sills

and portions of the interior masonry wall in the basement. Wholescale replacement of the foundation is not necessary. The structure (contrary to our initial reactions) is not in danger of collapse. Deterioration such as we are experiencing in the basement walls of the Outer Island lighthouse takes quite a number of years; the deterioration is slow. Also there were no indications (such as gaping cracks in walls) of structural problems of that magnitude.

To quote Baird M. Smith in his NPS booklet Moisture Problems in Historic Masonry Walls: "It is best to be cautious in treating moisture problems in historic buildings. Such structures have become adapted to the physical environment. While obvious maintenance-related problems, such as damaged down-spouts, clogged drains, and damaged roof flashings should receive immediate attention, reckless intervention in other situations can upset the sensitive balance between environmental forces and building responses. The addition of excessive heat, extensive structural modifications, extreme humidification, or rapid drying have been found to damage historic buildings."

All window openings should be checked for cracks, loose-fitting members, lack of adequate weather stripping, or rotted members such as showing up in photo #20. Repairs should be made thusly; epoxy repairs of window frames is advised, rather than replacement of historic fabric. A second Preservation Brief on this technique is enclosed (Appendix E).

The fiber board ceiling should be taken down and the wood joists observed for presence of moisture, and rot. This ceiling should not be put back up until the joists have had a chance to dry out. (Replace the ceiling only after the perimeter drainage system has been in-place and functioning for several months).

We recommend not coating or re-coating the interior face of the basement walls for the reasons outlined earlier. We also recommend not re-stuccoing the base of the tower until the drainage system is in.

Second Floor Bedroom: This situation needs further investigation. We recommend that the summer lighthouse keepers make a thorough investigation during a heavy rainfall, preferrably one accompanied by high winds. Portions of the ceiling and wall studs in the vicinity of the water damage should be exposed for ease of inspection. Running water or excessive dampness should be noted. Findings should be transmitted to this office, and we will

prepare a recommendation based on these findings.

Again, quoting Baird M. Smith: "Rain penetration is not normally a problem in older masonry buildings. In walls over three brick wythes in thickness or with cavities, penetration is very unlikely. There must be evidence of interior staining before penetration can be suspected. In the rare cases of severe penetration, few treatments have been found to be successful without undesirable side effects. As a general rule, when rain penetration occurs in masonry, it penetrates the mortar joint, not the masonry unit. With that in mind, treatments must focus on the joints.

"When rain penetration occurs, it can be attributed to defective or weathered pointing and treatment requires the rather sizeable job of repointing. Care should be exercised in matching the strength of the pointing mix to that of the existing mortar and the masonry. After a passage of time, if the repointing has not been effective in stopping the rain penetration, then more drastic measures could be taken, but only in cases where the rain penetration is so severe that staining or damage still occurs...."

In response to this, a thorough investigation should be undertaken to determine exactly where the water is coming from. We are getting staining, as mentioned, but we haven't ruled out the possibility of other avenues such as roof leaks, improper flashing, missing trim, or openings in window frames, etc. These items should be dealt with immediately.

OUTER ISLAND

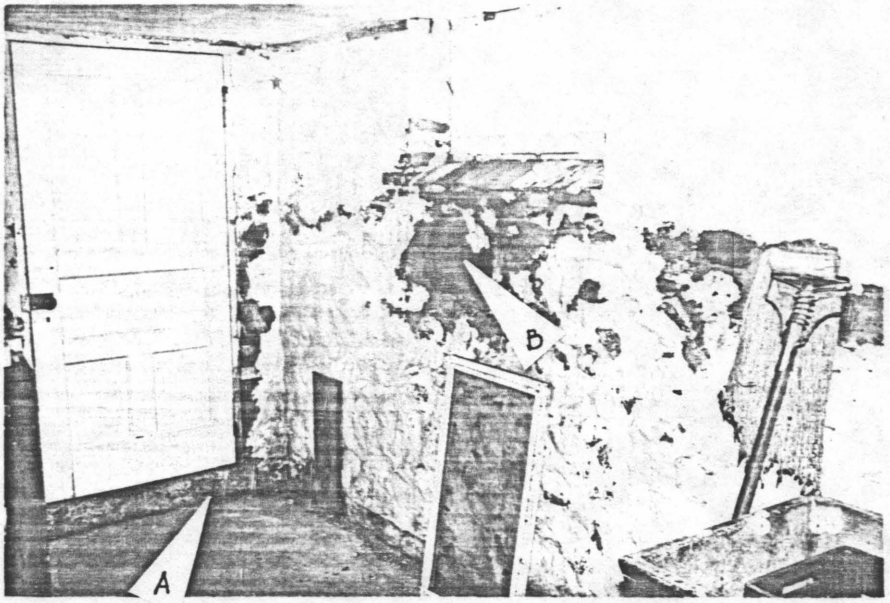


PHOTO #17

A: DAMP SLAB AT JUNCTION OF WALL AND SLAB (TYPICAL)

B: DETERIORATION OF WALL UNDER SILL

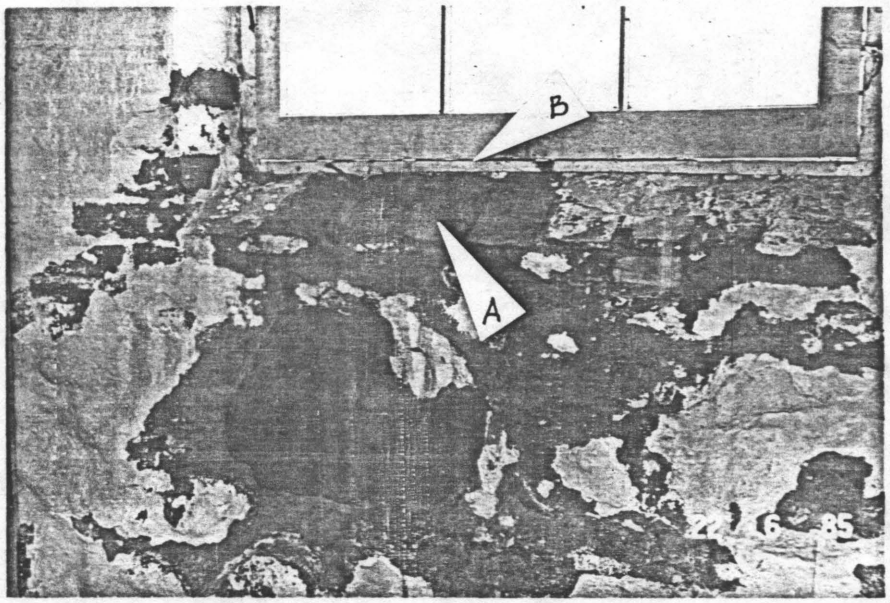


PHOTO #18

A: BRICK SILL SHOWING EXFOLIATION

B: POSSIBLE SOURCE OF MOISTURE (LEAKY WINDOW)

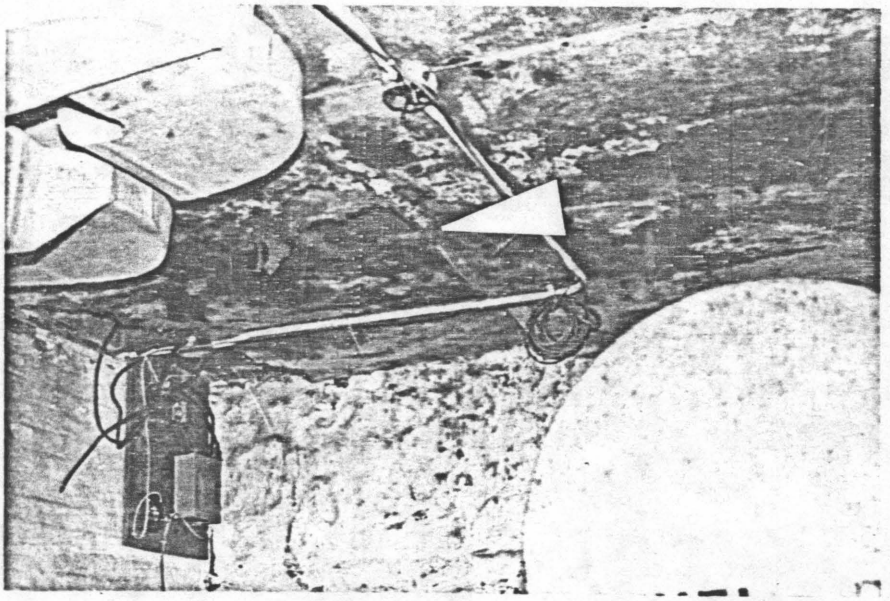


PHOTO #19

NOTE DETERIORATED FIBER BOARD CEILING

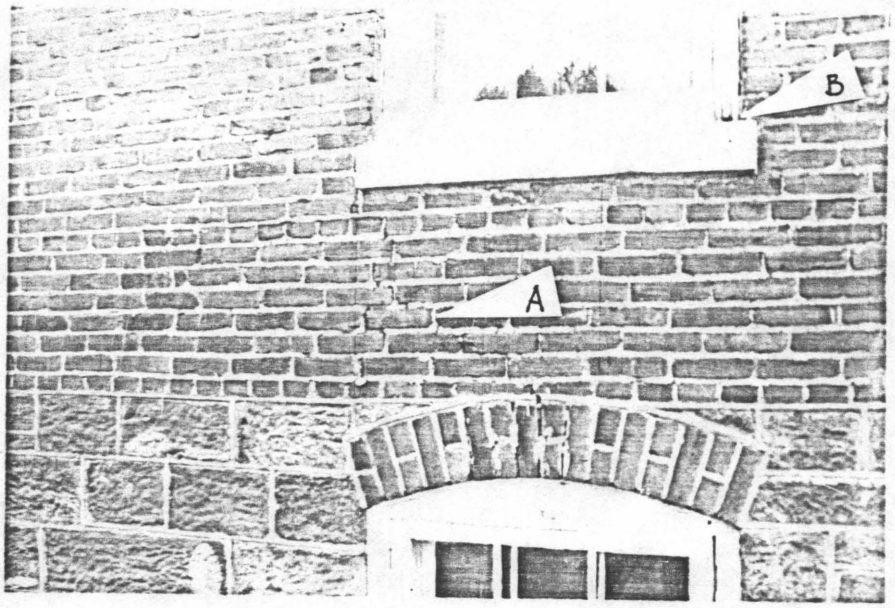


PHOTO #20

A: CRACK IN WALL BETWEEN WINDOWS

B: DETERIORATED WINDOW FRAME: POSSIBLE SOURCE OF WATER INTRUSION

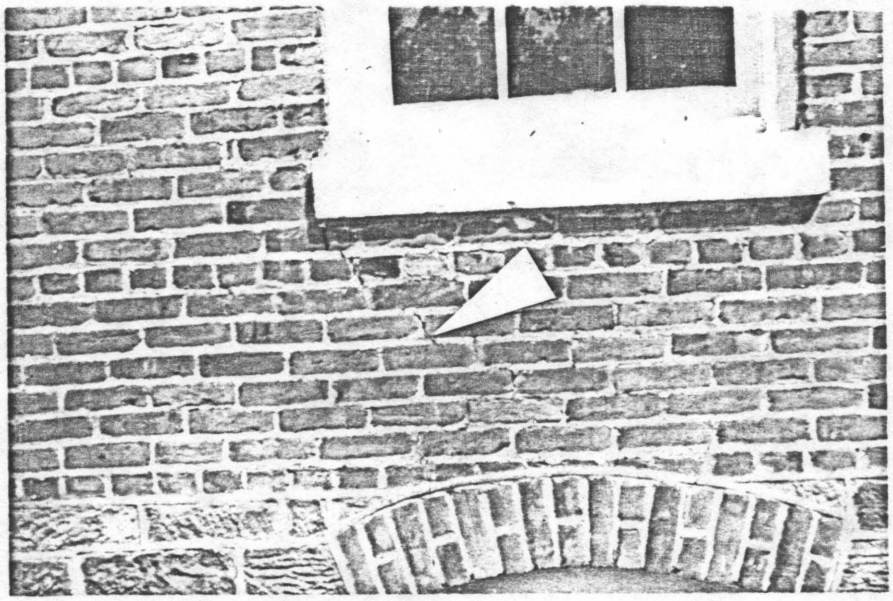


PHOTO #21

CRACK IN WALL BETWEEN WINDOWS

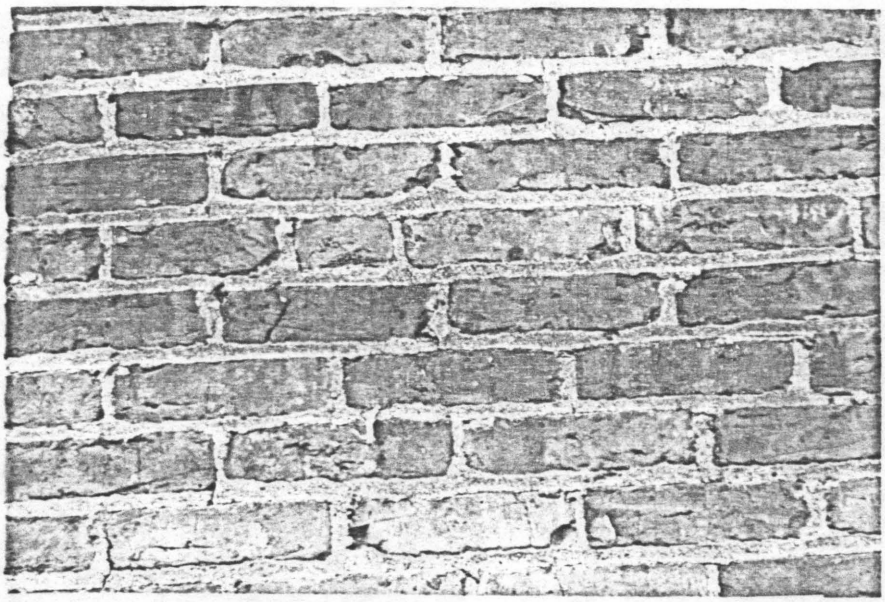


PHOTO #22

CLOSE-UP OF BRICK: NOTE PITTED SURFACE. POINTING LOOKS RELATIVELY NEW.

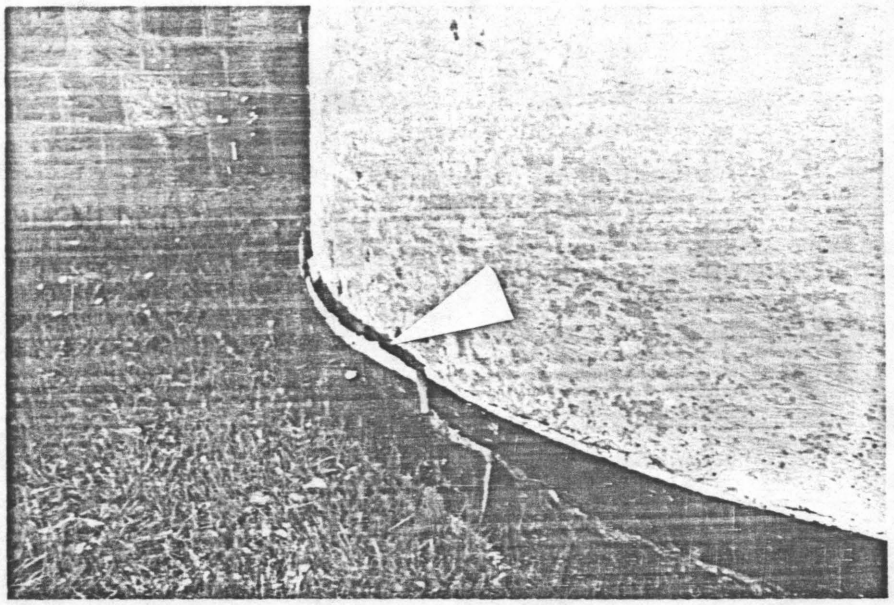


PHOTO #23

CRACKED STUCCO AT BASE OF TOWER



PHOTO #24

NON-HISTORIC WINDOWS, POOR JOB OF POINTING

DEVIL'S ISLAND

A. East Residence

1. Psychrometer Readings: 90% RH

Discussion: again, exhaust fans are recommended.

2. Moisture Readings: Walls: 15-18
Floor slab: 28-35

Discussion: The walls in the east residence were relatively dry. There was some moisture observed at the junction of the wall and slab. The slab in the southern portion of the basement was the dampest. This concrete was considerably older than that found in the north room.

3. Additional Observations (Photoducumentation):
Photo #25 shows the condition of the floor slab in the southern portion of the basement. These walls also show indications of rising damp, as evidenced by the deposition of salts on the brick. Photo #26 was taken looking up the west basement stair. There is evidence of movement in the stairs themselves, as seen by the cracking. Although the stairs do not affect the structural capacity of the building, they will need to be repaired eventually. Photo #27 illustrates, again, poor repointing techniques.

4. Conclusions / Recommendations:
Gutters and downspouts should be checked, and serious consideration should be given to the site drainage around both of the Devil's Island quarters. Some settling of grade was noticed around both buildings, especially the west building. Since the grade is relatively flat around these two structures, consideration should be given to creating a series of swales around the buildings to divert water away from the them.

Again, we recommend perimeter drainage systems for both buildings. And we recommend monthly analyses of wood framing members and masonry walls. The condition at the east building, especially as related to masonry foundation walls, is not as serious as at Sand or Outer Islands, however, the situation should be monitored.

Crack monitors should be installed over the stair cracks, the crack near the basement window on the west wall (and any other cracks in the exterior masonry walls), and monitored.

All windows and other openings through exterior basement walls should be properly sealed and weatherstripped.

DEVIL'S ISLAND

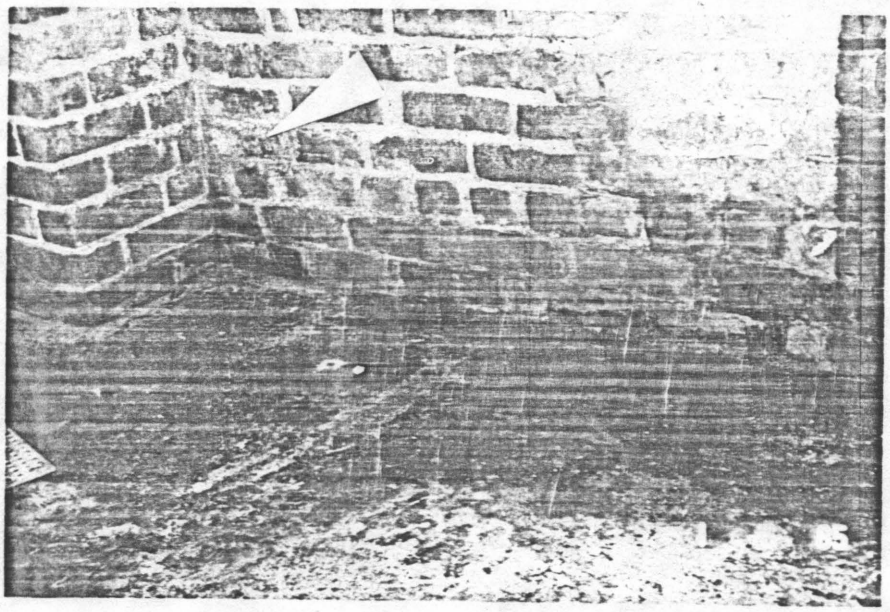


PHOTO #25

NOTE PRESENCE OF SALTS

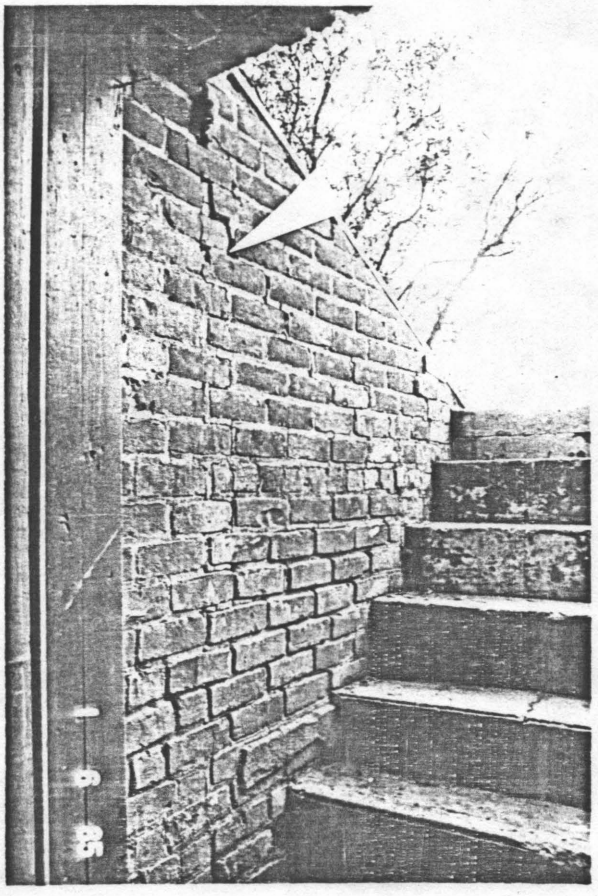


PHOTO #26

SIDE WALLS OF STAIRS ARE CRACKING

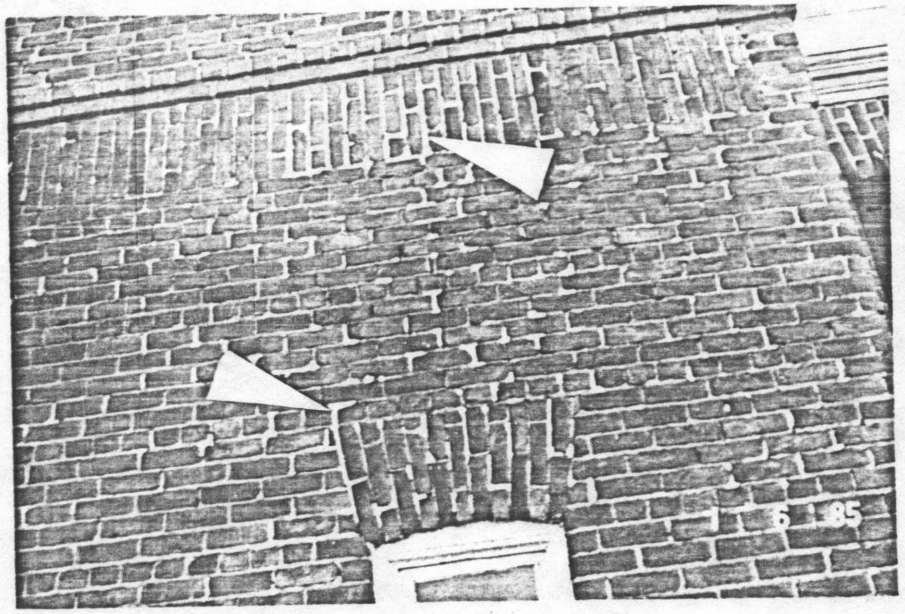


PHOTO #27

POOR POINTING

B. West Residence:

1. Psychrometer Readings: East room: 90% RH
West room: 93% RH

Discussion: we recommend the use of exhaust fans.

2. Moisture Readings:

East room walls:	14-18
East room (thru slab):	40
West room walls:	15-22
West room slab (surf.):	25-28
West room (thru slab):	43-49

Discussion: The readings on the walls were low, indicating a drier condition. As well, the west room floor slab was found to be relatively dry. The floor slab in the west room was damper, and had heaved at the north-west. This slab was considerably older than the slab in the east room.

3. Additional Observations (Photoducumentation):
Photo #28 was taken in the west room of the basement. Note the damp slab toward the back of the picture. Photo #29 was also taken in this same room, this time looking north-west at the portion of the slab which had heaved. Note the opening in the wall (basement vent). Photo #30 is a close-up of a wall in the west room showing evidence of salts on the face of the brick, indicating rising damp. Photo #31 was taken on the exterior of the building adjacent to the portion of the slab which had heaved inside (Photo #29). Note the unevenness of the grade, and the apparent settling around the downspout extension. Photo #32 also shows this settling of grade at the foundation wall. As well, this photo shows some uncareful repointing.

4. Conclusions / Recommendations:
(See East Residence). Specific recommendations for this building include: analysis of the drain line leading from the north-west downspout (the one showing in Photo #31) for possible leaks, and replacing the west room slab (only after the perimeter drainage systems are in place, and repairs--if any--to the downspout drain line are made).

DEVIL'S ISLAND



PHOTO #28

DAMP SLAB IN WEST AREA OF BASEMENT

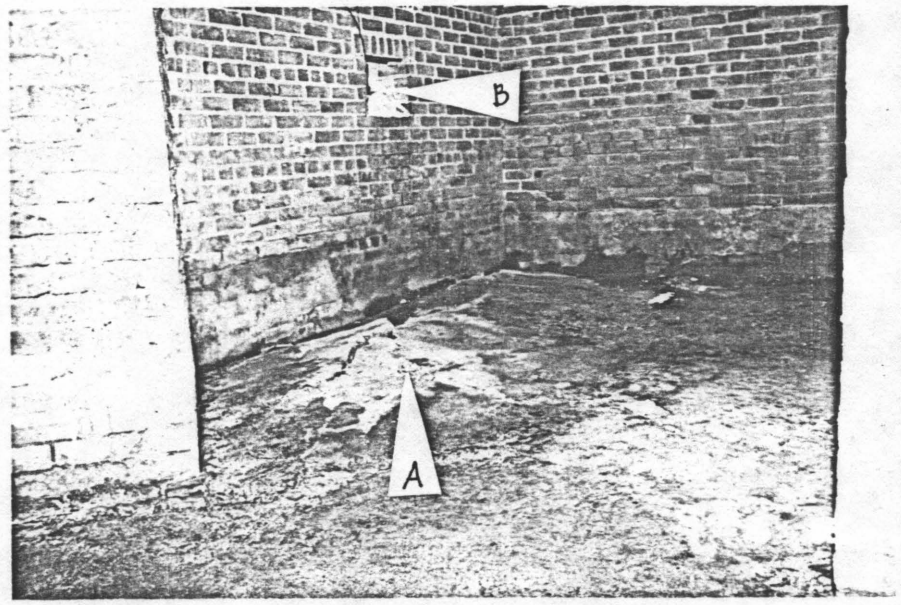


PHOTO #29

A: SLAB HAS HEAVED DUE TO FREEZE-THAW

B: NOTE VENT IN WALL

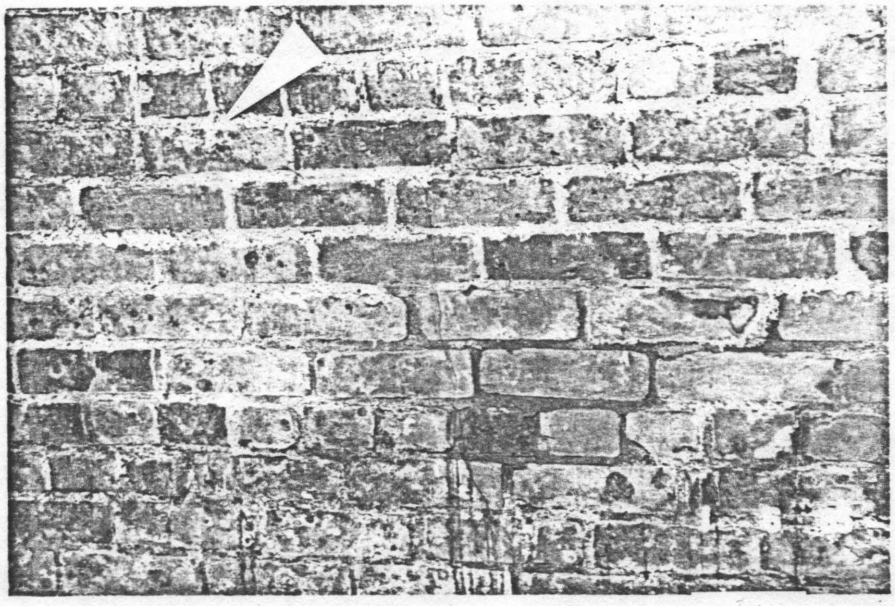


PHOTO #30

WALL EXPERIENCING RISING DAMP: NOTE SALTS

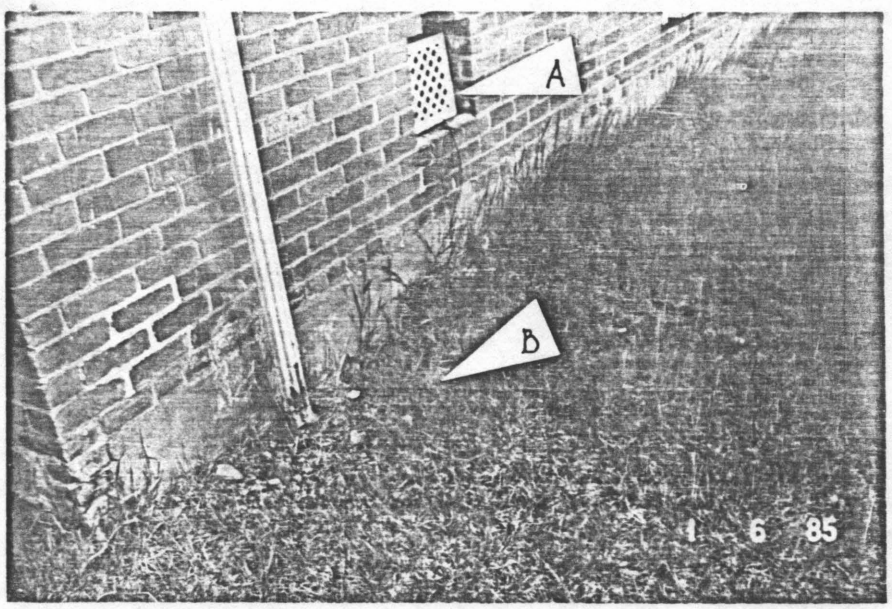


PHOTO #31

A: NOTE WALL VENT

B: GRADE HAS SETTLED IN AREA OF DOWNSPOUT (POSSIBLE BAD CONNECTION OR DRAIN LINE)

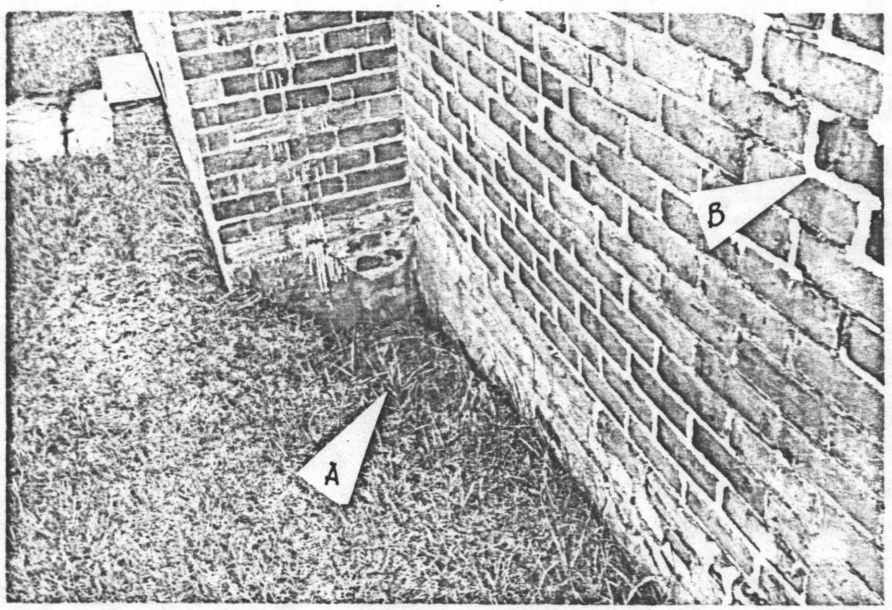


PHOTO #32

A: GRADE HAS SETTLED

B: POOR REPOINTING

SUMMARY OF RECOMMENDATIONS

A. SAND ISLAND
   1. Check guttering system.
   2. Monthly inspection of masonry walls and wood members, replacement if necessary.
   3. Check all openings into basement for proper seal.
   4. Check grade and regrade if necessary.
   5. Install perimeter drainage system.

B. RASPBERRY ISLAND
   1. Check guttering system.
   2. Monitor masonry walls for rising damp.
   3. Check all openings into basement for proper seal.
   4. Monitor wood framing members.

C. MICHIGAN ISLAND: 1858 Lighthouse
   1. Install gutters and downspouts.
   2. Monthly inspection of wood members: remove interior sheathing.
   3. Remove or encapsulate asbestos on piping.
   4. Monthly inspection of stone walls.
   5. Check all openings into basement for proper seal.
   6. Regrade site if necessary.
   7. Install perimeter drainage system.

D. MICHIGAN ISLAND: Keeper's Quarters
   1. Check guttering system.
   2. Check site for proper drainage.
   3. Remove or encapsulate asbestos on piping.
   4. Monthly inspection/repair of wood framing members.
   5. Check all openings into basement for proper seal.

E. OUTER ISLAND
   1. Install gutters / downspouts.
   2. Check site for proper drainage.
   3. Install perimeter drainage system.
   4. Install crack monitors over all cracks: monitor monthly.
   5. Monitor surface deterioration of masonry walls.
   6. Selective repair of masonry walls.
   7. Check all openings into basement for proper seal.
   8. Remove fiber board ceiling and inspect wood members.
   9. Investigate water penetration in second floor bedroom.

F. DEVIL'S ISLAND: East and West Residences
   1. Check guttering system.
   2. Correct site drainage.
   3. Install perimeter drainage system.
   4. Monthly inspection of wood framing members and masonry walls.
   5. Install crack monitors and monitor movement (if any).

6. Check all openings into basement for proper seal.

G. DEVIL'S ISLAND: West Residence

1. Check drainage system for damage.

SUGGESTED PRIORITIES

1. All buildings: check gutters and downspouts; monthly inspection of masonry walls, wood framing members and crack monitors; check all openings into basement for proper seal; repair of masonry and/or wood members;

1a. Investigate moisture penetration, second floor Outer Island lighthouse.

1b. Removal of fiber board ceiling, Outer Island lighthouse.

1c. Selective removal of interior wood sheathing, 1858 Michigan Island lighthouse.

1d. Removal or encapsulation of asbestos on piping in two Michigan Island buildings.

2. Site surveys of all buildings to determine existing contours; regrading if necessary.

3. Michigan Island: design and installation of perimeter drainage systems at both buildings.

4. Outer Island: design and installation of perimeter drainage system.

5. Perimeter drainage system design/installation at: Sand Island lighthouse, and Devil's Island residences.

APPENDIX A: RELATIVE HUMIDITY (PSYCHROMETER READINGS)

Relative humidity readings above 80% are quite high, and could jeopardize both wod framing members and ferrous metals. The high relative humidity readings recorded are the result of the presence of high concentrations of moisture in the basement walls and slabs.

APPENDIX B: MOISTURE READINGS AND MASONRY DETERIORATION

Moisture readings were taken with a device which measures electrical resistance. The instrument contains two metal probes which are placed on the surface of the item to be measured. With the use of concrete nails, which are driven into the surface of the masonry, mortar joints, or concrete slab, the resistance can be measured within the material. As the amount of water in the material increases, so does the electrical conductance of the material. Generally speaking, readings of the following values may be assumed to have the following connotations: 0-15: dry to slightly damp; 16-25: damp; 26-40: wet; above 40: very wet).

Readings above 26 indicate a relatively high degree of moisture present in floor slabs and walls. Damage occurrs in slabs when the slab freezes and heaves. Also, the concrete will deteriorate when salt crystals form. In walls, a high degree of moisture indicates the possible action of salt crystallization within masonry units (stone or brick) or the mortar joints. Salts are formed when a chemical reaction takes place between moisture and elements present in either the mortar or the masonry units themselves. When crystallization occurs, an expansion within the masonry / mortar occurs, breaking apart either. In masonry, "exfoliation" occurs (this can be seen as crubmling brick or stone--which appears soft, and usually powders away from the wall). In mortar joints, the mortar is broken down and crumbles away. High condentrations of moisture in walls is also susceptible to freezing. Most basement walls--being well below the frost line--are not experiencing this type of deterioration.

APPENDIX C: WOOD ROT

The fresh surface growths of decay fungi are usually fluffy or cottony--seldom powdery like the surface growths of molds. They may appear as fan-shaped patches, strands, or root-like structures, usually white or brown. Sometimes fruiting bodies are produced that take the form of toadstools, brackets of crusts. The early stages of decay are often accompanied by a discoloration of the wood. Many fungi produce incipient decay that differs only slightly from the normal color of the wood, or gives a somewhat water-soaked appearance to the wood. Typical or late stages of decay are easily recognized, because the wood has then undergone definite changes in color and properties.

The rotted wood may be white or brown in color. Brown, crumbly rot, in the dry condition, is sometimes called "dry rot," but the term is incorrect because wood must be damp in order to decay, although it may become dry subsequently. In addition to a visual inspection, the wood members can be tested by "knocking" on them to detect hollow-sounding areas. Areas most affected would be those which would have come in contact with rising damp within the walls. Look for evidence of rising damp, and if the high tide mark has approached the wood sill or any of the joists or other framing members above, it is likely that the wood members have been taking on moisture from the surrounding walls and will begin to decay.

---Exerpts from the Wood Handbook, U.S. Dept. of Agriculture Handbook No. 72, 1955. Page 382.

U.S. Department
of the Interior
Heritage Conservation
and Recreation Service
Technical Preservation
Services Division

Preservation Briefs: 2

Repointing Mortar Joints in Historic Brick Buildings

Robert C. Mack, AIA
de Teel Patterson Tiller
James S. Askins

Repointing is the process of removing deteriorated mortar from the joints of a masonry wall and replacing it with new mortar. Properly done, repointing restores the visual and physical integrity of the masonry. Improperly done, repointing not only detracts from the appearance of the building, but may, in fact, cause physical damage to the masonry units themselves.

The purpose of this brief is to provide general guidance on appropriate materials and methods for repointing historic brick buildings and is intended to benefit building owners, architects, and contractors alike. Because of its general nature, this publication should not be considered a specification for repointing. Rather, it should serve as a guide to prepare such specifications; to develop sensitivity to the particular needs of historic masonry; and to assist historic building owners in working cooperatively with contractors and architects.

Identifying the Problem

The decision to repoint is most often related to some obvious sign of deterioration (figure 1) such as disintegrating mortar, cracks in mortar joints, loose bricks, damp walls, or damaged plasterwork. It is, however, erroneous to assume that repointing alone will solve all these problems. Therefore, the true cause of the deterioration should be determined before beginning any repointing work. Leaking roofs or gutters, differential settlement of the building, capillary action causing rising damp, or extreme weather exposure should all be recognized as sources of deterioration and should be dealt with immediately. Without such action, mortar deterioration will continue and any repointing work will have been a waste of time and money.

Budgeting and Scheduling

It is important to recognize that repointing will probably be both expensive and time-consuming due to the extent of handwork and special materials required; however, it should also be emphasized that it is not only possible, but preferable to repoint *only* those areas that require work rather than an entire wall, as is often specified. Recognizing this at the outset may prevent many restoration/rehabilitation jobs from becoming prohibitively expensive.

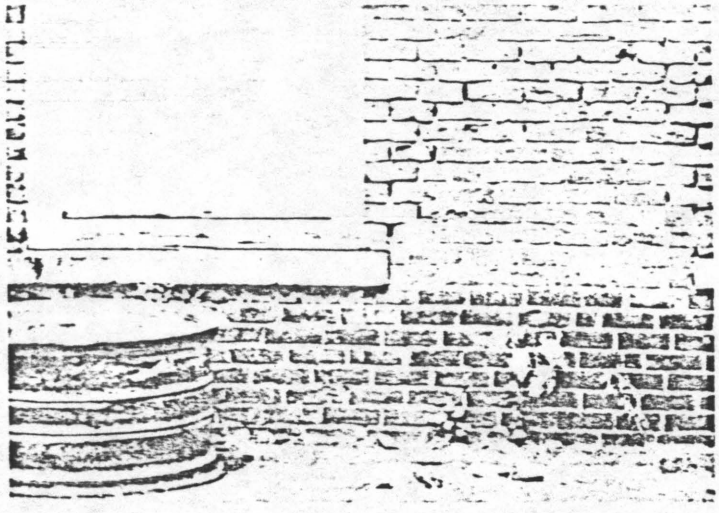


Figure 1. *All buildings and building materials are in a constant process of deterioration, such as the brick masonry seen here. Through repointing, the deteriorated mortar joints which might otherwise lead to serious damage, can be renewed and thus preserve the historic character and integrity of the brickwork. Photo: Baird M. Smith.*

In scheduling, seasonal aspects need to be considered first. Generally speaking, repointing should only be undertaken when the wall temperatures are between 40° and 95° (F) to prevent freezing or excessive evaporation of the water in the mortar. During hot weather, repointing should ideally be done on the shady side of the building in order to slow the drying process of the mortar.

The relationship of repointing to other proposed work on the building must also be recognized. For example, if paint removal or cleaning are anticipated and if the mortar joints are basically in sound condition and only need selective repointing, it is generally better to postpone repointing until after completion of these activities. However, if the mortar has badly eroded, thus allowing moisture to penetrate deeply into the wall, repointing should be accomplished before cleaning. Related work such as structural or roof repairs should be scheduled so that they do not interfere with repointing and so that all work can take maximum advantage of scaffolding.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Visual Examination

All repointing work on historic masonry buildings should be preceded by an analysis of the mortar and by an examination of the bricks and the techniques used in the original construction of the wall. For most projects, a simple visual analysis of the historic mortar is sufficient to allow an appropriate match for the new mortar. The exact physical and chemical properties of the historic mortar are not of major significance as long as the new mortar:

- matches the historic mortar in color, texture, and detailing;
- is softer (measured in compressive strength) than the brick;
- is as soft, or softer (measured in compressive strength) than the historic mortar.

A simple method of analyzing the historic mortar to aid in developing an appropriate repointing mortar for many restoration jobs and most rehabilitation work follows[1]:

1) Remove three or four unweathered samples of the mortar to be matched from several locations on the building (set the largest sample aside—this will be used later for comparison with the repointing mortar). It is important to recognize that many historic buildings have been repointed a number of times and that on any given wall surface there may be a variety of mortars. Therefore, it is important to remove as many samples as are representative to obtain a "mean" mortar sample.
2) Break the remaining samples apart with a wooden mallet until they are separated into their constituent parts. There should be a good handful of the material.
3) Carefully blow away the powdery material (the lime or cement matrix which bound the mortar together).
4) With a low power (10 power) magnifying glass, examine the remaining sand and other materials such as oyster shells.
5) Note and record the wide range of color as well as the varying sizes of the individual grains of sand or shell.

Historic sand colors may range from white to grey to yellow within a given mortar sample. Furthermore, the varying sizes of the grains of sand or other materials such as shell play an important role in the texture of the repointing mortar. Historic sand was not screened or graded by size as it is today. Therefore, when specifying sand for repointing mortar, consideration may need to be given to obtaining sand from several sources and then combining them in order to approximate the range of sand colors and grain sizes in the historic mortar sample. The role of the sand in the overall appearance of the replacement mortar should not be underestimated!

Pointing styles and the methods of producing them should be examined (figure 2). It is important to look at both the horizontal and the vertical joints to determine the order in which they were tooled and whether they were the same style. Some late-19th- and 20th-century buildings, for example, have horizontal joints that were tooled while the vertical joints were finished flush and stained to match the bricks, thus creating the illusion of horizontal bands. It is significant to note that pointing styles often differed from one facade to another. Front walls often received greater attention to mortar detailing than side and rear walls.

Bricks should also be examined so that any replacement will match the historic brick. Within a wall there may be a surprising range of colors, textures, and sizes, particularly with hand-made brick. Replacement should match the full range of the historic brick rather than a single brick. Although many bricks can be matched from existing stock, they must often be custom-ordered, a lengthy process that can seriously affect the project budget and schedule. Here, there should be a note of caution! The use of recycled brick from demolished buildings for replacement brick often results in an excellent color and texture match; however, it is important to remember that historic brick was manufactured in varying grades, ranging from high-fired exterior brick to low-fired interior "bat" or "clinker" brick. This low-fired brick was never intended to be exposed to the weather, and, when used for replacement brick on an exterior wall, will deteriorate at a rapid rate, often needing replacement within a year or two. Great care, therefore, should be taken in choosing the proper type of recycled brick.

Properties of Mortar

In general, mortars for repointing should be softer (measured in compressive strength) than the masonry units and no harder than the historic mortar. This is necessary to prevent damage to the masonry units. It is a common error to assume that hardness or high strength is a measure of durability. Stresses within a wall caused by expansion, contraction, moisture migration, or settlement must be accommodated in some manner; in a masonry wall, these stresses should be relieved by the mortar rather than by the bricks. A mortar that is stronger or harder than the bricks will not "give," thus causing the stresses to be relieved through the bricks—resulting in cracking and spalling (figure 3). Stresses can also break the bond between the mortar and the brick, permitting water to penetrate the resulting hairline cracks.

Constituents of Mortar

Sand: Sand is the largest constituent of mortar and the material that gives mortar its characteristic color and texture. When viewed under a magnifying glass or low-power binocular microscope, particles of sand generally have either rounded edges, such as found in beach or river sand, or sharp, angular edges, found in crushed or manufactured sand. For repointing mortar, rounded or natural sand is preferred for two reasons. First, it is usually similar to the sand in the historic mortar, thus providing a better visual match. Second, it has better "working" qualities or plasticity and can thus be forced into the joint more easily, forming a good contact with the historic mortar and the surface of the bricks. Although manufactured sand is frequently the only type readily available, it is worth the search to locate a sufficient quantity of rounded or natural salt-free sand for repointing.

[1] Two detailed methods for performing a mortar analysis are presented by E. Blaine Cliver in "Tests for the Analysis of Mortar Samples" in the *Bulletin* of the Association for Preservation Technology, vol. 6 (no. 1, 1974); and Morgan W. Phillips in "Brief Notes on the Subjects of Analyzing Paints and Mortar and the Recording of Moulding Profiles: The Trouble with Paint and Mortar Analysis" in the *Bulletin* of the Association for Preservation Technology, vol. 10 (no. 2, 1978).

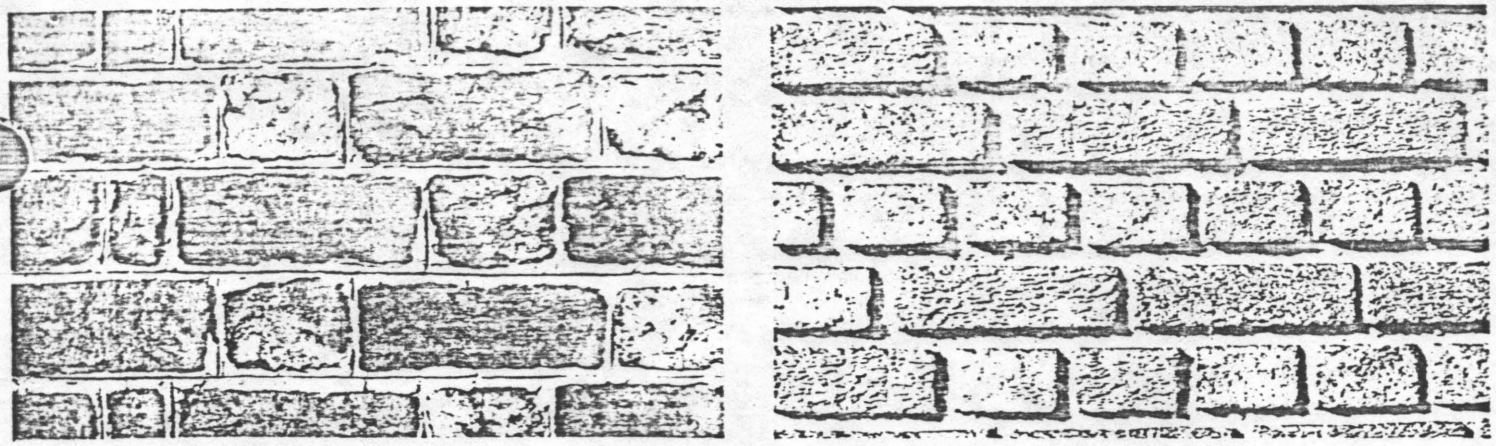


Figure 2. *Joint styles and bonding patterns give a rich, divergent, and varied character to historic masonry walls as is apparent in these two examples. The sample on the left is an 18th century (c. 1720) Flemish bond struck with a grapevine joint; the example on the right, an early 20th century English bond with a raked joint. Successfully recreating the historically correct joint size and profile is of paramount importance in the appropriate repointing of historic brick walls. Photos: Calder Loth.*

Lime or Portland Cement: The two commonly used binders for mortar are lime and portland cement. Of the two, lime produces a mortar that meets nearly all the requirements for a good mortar for historic buildings, while portland cement produces a mortar that does not perform as well. High lime mortar is soft, porous, and changes little in volume during temperature fluctuations. In addition, lime mortar is slightly water soluble and thus is able to re-seal any hairline cracks that may develop during the life of the mortar. Portland cement, on the other hand, can be extremely hard, is resistant to movement of water, shrinks upon setting, and undergoes relatively large thermal movements. The use of a high lime mortar, therefore, is recommended for nearly all repointing projects. *However, the addition of 5 percent white portland cement for not more than 20 percent of the lime will usually improve workability or plasticity without adversely affecting the desirable qualities of the lime mortar.* Workability or plasticity of the mortar is important to ensure that the new mortar forms a good bond with the original mortar and the bricks.

Water: Water should be clean and relatively free of salts or acids.

Historic Additives: In addition to the color of the sand, the texture of the mortar is of critical importance in duplicating historic mortar. While modern mortars are finely ground and present a uniform texture and color, historic mortars were not as well ground. They may contain lumps of oyster shell, partially burned lime, animal hair, or particles of clay. The visual characteristics of these additives should be duplicated through the use of similar materials in the repointing mortar.

Matching Color and Texture of Mortar

In matching the repointing mortar, the new mortar should match the unweathered interior portions of the historic mortar. The simplest way to check the match is to make a small sample of the proposed mix and allow it to cure; this sample is then broken open and the broken surface is compared with the broken surface of the largest "saved" sample of historic mortar.

If it is not possible to obtain a proper color match through the use of natural materials because locally available sands are not a close match to the original sand, it may be necessary to use a modern mortar pigment, and, in fact, some historic mortars did use such additives. In the late 19th century, some mortars were colored with pigments to match or contrast with the brick. Red, brown, and black pigments were commonly used. Pigments are available as separate ingredients or already mixed with mortar; however, the premixed mortars normally are not suited for use on repointing projects because of their high portland cement content. Only chemically pure mineral oxides, which are alkali-proof and sun-fast, should be used in order to prevent bleaching and fading.

Material Specifications

Modern materials specified for use in repointing mortar should conform to specifications of the American Society for Testing Materials (ASTM) or comparable federal specifications.

Sand should conform to ASTM C-144 to assure proper gradation and freedom from impurities. Sand color, size, and texture should match the original as closely as possible to provide the proper color match without other additives. Samples of sand proposed for use should be submitted for approval prior to beginning work.

Lime should conform to ASTM C-207, Type S, Hydrated Lime for Masonry Purposes. This lime is designed to assure high plasticity and water retention with a safe degree of strength. The use of quicklime, which must be slaked and soaked, does not necessarily provide better results.

Cement should conform to ASTM C-150, Type II (white non-staining) portland cement. It should not have more than 0.60 percent alkali to help avoid efflorescence.

Water should be potable—clean and free from acids, alkalies, or large amounts of organic materials.

Historic Additives will require writing new specifications for each project. If possible, suggested sources for special materials should be included. For example, crushed oyster shells frequently can be obtained in a variety of sizes from poultry supply dealers.

Mortar Mix: Specifying the proportions for the repointing mortar for a specific job is often a perplexing task for the architect, engineer, contractor, or preservation

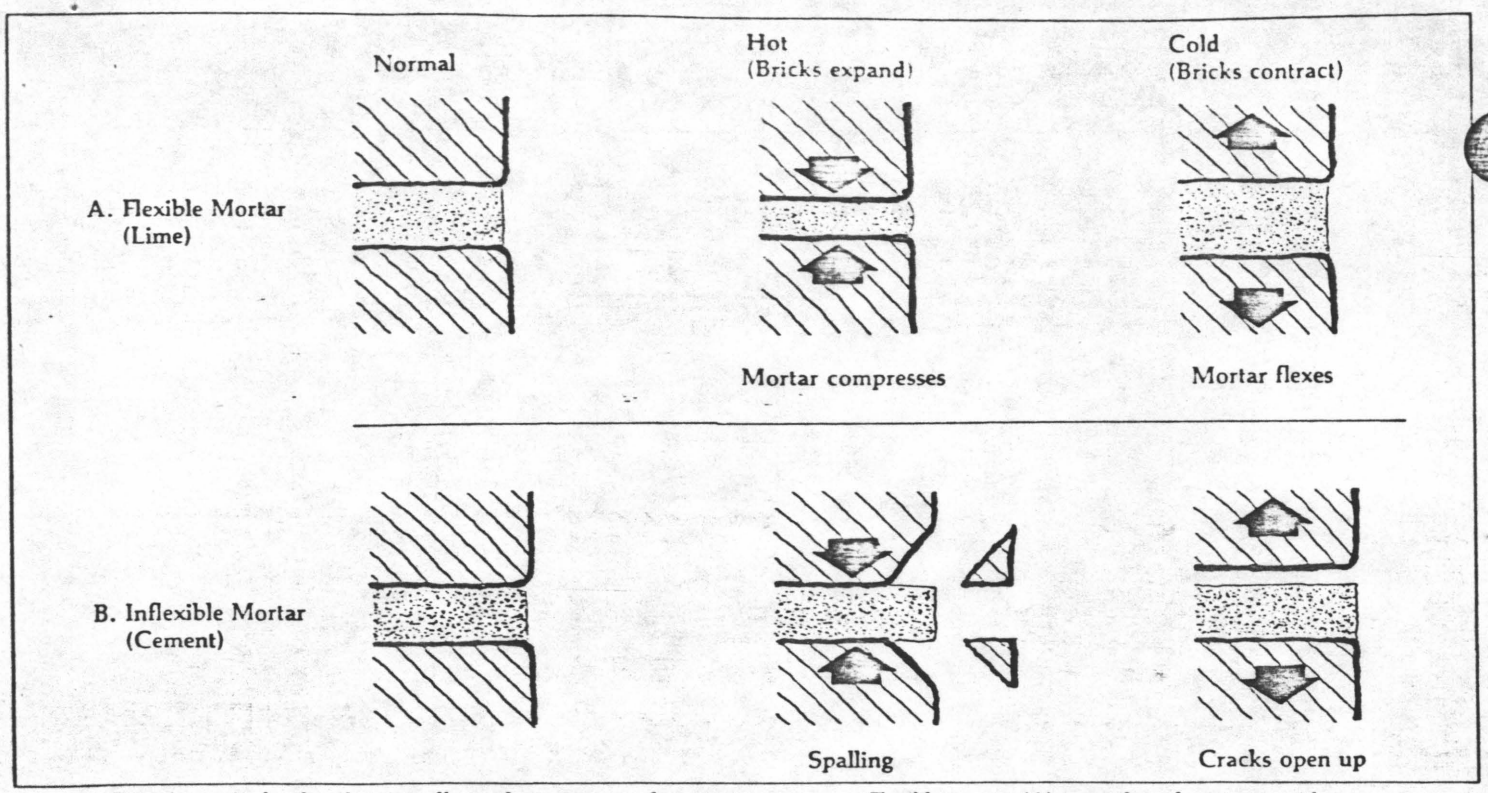


Figure 3. *Diagrammatic sketches showing effects of temperature change upon masonry. Flexible mortar (A) expands and contracts with temperature changes. Bricks bonded by inflexible mortar (B) tend to spall at the edges (the area of greatest stress) in hot weather and separate from the mortar when it is cold. This latter condition opens cracks, permitting the entry of water and causing additional deterioration. Adapted from* Maintenance of Old Buildings, *Document D10; National Swedish Institute for Building Research, Stockholm, 1975.*

consultant alike. The following guidelines can assist in writing specifications:

- Material proportions should be given in volumes, that is, 4 parts of lime to 12 parts of sand, rather than 2 bags of lime to 6 cubic feet of sand. This will avoid any confusion on the job site when substitution of sources occur with differing packaging sizes.
- Repointing mortar for most historic buildings should ideally be composed only of lime and sand. A proportion of 1 part of lime to 2 parts of sand is a useful starting point.
- ASTM C-150, Type II (white non-staining) portland cement may be added to the repointing mortar to increase workability or to achieve whiteness in color; however, no more than 20 percent of the total volume of the lime and portland cement—combined—should be portland cement. Above 20 percent, the portland cement increases the hardness of the repointing mortar to a potentially damaging degree.
- For surfaces of extreme weather such as parapet walls or water tables, a harder mortar (6 parts of sand, to 3 parts of lime, to 2 parts of white portland cement) may be more desirable.

Execution of the Work

The Test Panel: In choosing a contractor or mason, perhaps the best way to award the contract and for the contractor or mason to demonstrate his or her work in a repointing job is the test panel: a small demonstration section of joint preparation and repointing actually done on the historic masonry. The test panel should be carefully selected to include all types of masonry, joint styles, and types of problems to be encountered on the job. Usually a 3-foot by 6-foot area located in an inconspicuous yet readily accessible place is sufficient.

Joint Preparation: Old mortar should generally be removed to a minimum depth of 2½ times the width of the joint to ensure an adequate bond and to prevent mortar "popouts." For most brick joints, this will require removal of the mortar to a depth of approximately ½–1 inch. Any loose or disintegrated mortar beyond this minimum depth should be removed (figure 4). The use of power tools such as saws with carbide blades or impact hammers for the removal of mortar almost always results in damage to the bricks by breaking the edges and by overcutting on the head, or vertical, joints (figure 5). Damage to the bricks not only affects their visual character but can also lead to accelerated weather damage. Where joints are uniform and fairly wide, it may be possible to use a grinder to assist the removal of mortar; however, final preparation of the joint should be done by hand.

Test panels are quite helpful, but they cannot adequately assess the potential effect of using a grinder since such panels are not prepared under actual working conditions. If there is any chance of damaging the masonry, hand-methods should be used exclusively. Although slower, these methods are easier to control and less likely to cause irreversible damage to the bricks. Mortar should be removed cleanly from the bricks, leaving square corners at the back of the cut. Before filling, the joints should be rinsed with a jet of water to remove all loose particles and dust. At the time of filling, the joints should be damp but with no standing water present.

Mortar Preparation: Mortar should be mixed carefully to obtain uniformity of visual and physical characteristics.

Dry ingredients should be measured by volume and thoroughly mixed before the addition of any water. Half the water should be added, followed by mixing for approximately 5 minutes. The remaining water should then be added in small portions until a mortar of the desired consistency is reached. The total volume of water necessary may vary from batch to batch, depending on weather conditions. Mortar should be used within 30 minutes of final mixing, and "re-tempering," or adding *more* water after the initial mix is prepared, should not be permitted.

Modern Additives: In general, modern chemical additives are unnecessary and may, in fact, have detrimental effects. The use of antifreeze compounds is not recommended. They are not very effective with high lime mortars and may introduce salts, which will later cause efflorescence. A better practice is to warm the sand and water, and to protect the completed work from freezing. The use of air-entraining additives to resist frost action and enhance plasticity, are also discouraged, since the air has a detrimental effect on both bond and strength of the mortar. In areas of extreme exposure requiring high-strength mortars (see formula for "extreme weather exposure" under *Mortar Mix* section), air-entrainment of 10–16 percent may, however, be desirable. Bonding agents that increase the bond of the new mortar to the old should also be avoided. If the joint is properly prepared, there will be a good bond between the new mortar and the adjacent surfaces; chemical agents do not significantly improve this bond and are not a substitute for proper joint preparation. In addition, some of the agent will inevitably become smeared on the surface of the masonry and removal is very difficult.

Filling the Joint: Where existing mortar has been removed to a depth of greater than 1 inch, these deeper areas should be filled first, compacting the new mortar in several layers. The back of the entire joint should be filled successively by applying approximately ¼ inch of mortar, packing it well into the back corners. This application may extend for several feet. As soon as the mortar has reached thumb-print hardness, another ¼ inch layer of mortar—approximately the same thickness—may be applied. Several layers will be needed to fill the joint flush with the outer surface of the brick. It is important to allow each layer time to harden before the next layer is applied; most of the mortar shrinkage occurs during the hardening process and layering thus minimizes overall shrinkage.

The rate of hardening can be controlled by dampening the brick and the old mortar before beginning to fill the joint, but free water or excessive dampness in the joint should be avoided. Too much water will delay the tooling or cause excess shrinkage; too little water will be absorbed from the mortar before it is properly set, thus reducing bond strength.

When the final layer of mortar is thumb-print hard, the joint should be tooled to match the historic joint. Proper timing of the tooling is important for uniform color and appearance. If tooled when too soft, the color will be lighter than expected, and hairline cracks may occur; if tooled when too hard, there may be dark streaks called "tool burning," and good closure of the mortar against the brick will not be achieved.

If the old bricks have worn, rounded edges, it is usually best to recess the final mortar slightly from the face of the bricks. This treatment will help avoid a joint visually wider than the actual joint width; it will also avoid creation of a large, thin featheredge which is easily damaged, thus admitting water (figures 6 and 7).

After tooling, it is frequently necessary to remove excess mortar from the edge of the joint by brushing with a bristle brush.

"Aging" the Mortar: Even with the best efforts at matching the existing mortar color, texture, and materials, there will usually be a visible difference between the old work and the new, partly because the new mortar has been matched to the unweathered portions of the historic mortar. If the mortars have been properly matched, the best treatment for surface color differences is to let the mortars age naturally. Another reason for a slight mismatch may be that the sand is more exposed in old mortar due to the slight erosion of the lime or cement. Several methods of treatment have been attempted in an effort to overcome these differences. As with all work, however, any proposed treatment should be carefully tested prior to implementation.

Efforts to stain the new mortar to produce a color match should, in most cases, be avoided. Although such a process may provide an initial match, the old and new mortars may weather at different rates, leading to visual differences after a few seasons. In addition, the mixtures used to stain the mortar may be harmful to the masonry, for example, introducing salts into the masonry which can lead to efflorescence.

Cleaning: If repointing work is carefully executed, there will be little need for cleaning other than the small

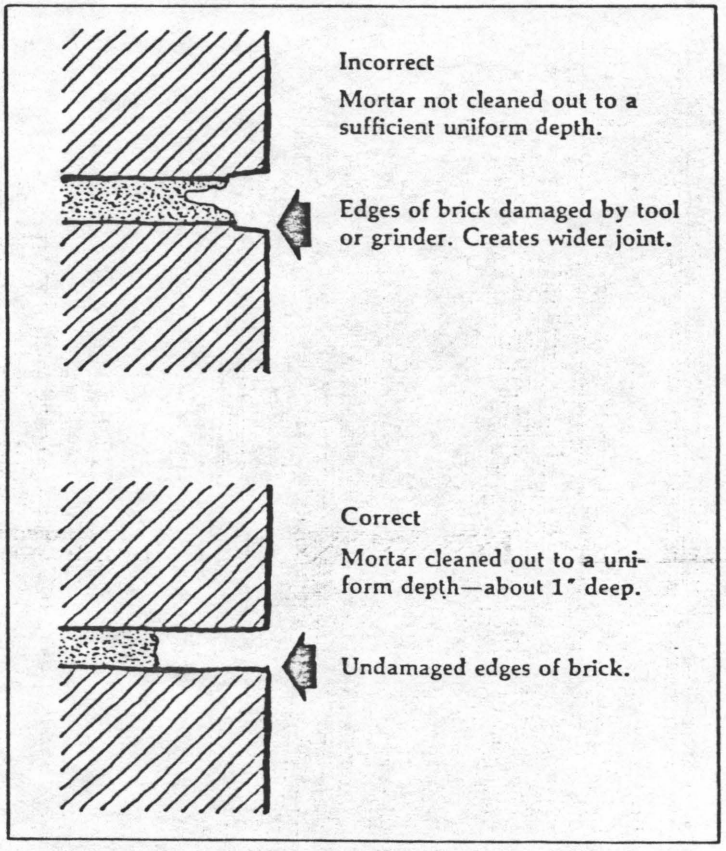


Figure 4. *Comparison of incorrect and correct preparation of mortar joints for repointing. Drawing: Robert C. Mack and David W. Look.*

amount of mortar brushed from the edge of the joint following tooling. This type of cleaning is best accomplished with a stiff bristle brush after the mortar has dried, but before it is fully hardened (1-2 hours). Mortar that has hardened can usually be removed with a wooden paddle or, if necessary, a chisel.

Further cleaning is best accomplished with plain water and bristle brushes. If chemicals must be used, their selection should be made with extreme caution. Improper cleaning can lead to deterioration of the masonry units, deterioration of the mortar, mortar smear, and efflorescence. New mortar joints are especially susceptible to damage because they do not become fully cured for several months. Chemical cleaners, particularly acids, should be used only once and should be flushed freely with plain water to remove all traces of the chemicals.

Several precautions should be taken if freshly repointed mortar joints are being cleaned. First, the mortar should be fully hardened before cleaning—30 days is usually sufficient, depending on weather and exposure (as mentioned above, the mortar will continue to cure even after the mortar has hardened). Test panels should be prepared to evaluate the effects of different cleaning methods. Only stiff natural bristle brushes should be used, except on glazed or polished surfaces. Here, only soft cloths should be used. Further information concerning masonry cleaning is presented in Preservation Briefs 1 "The Cleaning and Waterproof Coating of Masonry Buildings."

New construction "bloom" or efflorescence occasionally appears within the first few months of repointing and usually disappears through the normal process of weathering. If the efflorescence is not removed by natural processes, the safest way to remove it is by dry brushing with stiff natural or nylon bristle brushes and water. Hydrochloric (muriatic) acid, is generally ineffective and should be avoided in the removal of efflorescence. In fact this chemical may deposit additional salts, which, in turn, can lead to additional efflorescence.

Scrub Coats: A variety of new and purportedly useful repointing techniques for historic buildings are being offered by contractors which, appear to have limited usefulness in historic preservation. These techniques are identified under a variety of names that include: slurr coats, slurry coating, and, most commonly, scrub coating. All involve the brushing of a thinned, low-aggregate coat of mortar over the entire masonry surface which, when dry, is scrubbed off the brick with a brush, presumably leaving a residue in the mortar joint. These techniques have become increasingly appealing as they are quick, inexpensive in comparison to traditional repointing costs, and do not require particularly skilled labor or craftsmanship. Their greatest attraction lies in repointing large masonry surfaces such as highrise structures, but their benefit to historic masonry is essentially cosmetic. A certain amount of crack sealing in the mortar joint does occur, and for these limited applications it is a useful technique; however, these techniques should not be confused with, or substituted for, repointing. It is not the same process. Slurr coats and slurry and scrub coatings, tend to mask joint detailing or tooling, have a life expectancy of only a few years, and are extremely difficult to clean from the surface of the brick without leaving a residue, called "veiling." While of some limited use in specific instances, these new techniques are not



Figure 5. *The damage to these bricks was caused by using a power saw with a carbide blade to rake out the mortar joints. Note the overcutting of the joint into the brick above the vertical joint. Careful hand work is required to prevent such damage to the brick during joint preparation. Photo: John Myers.*

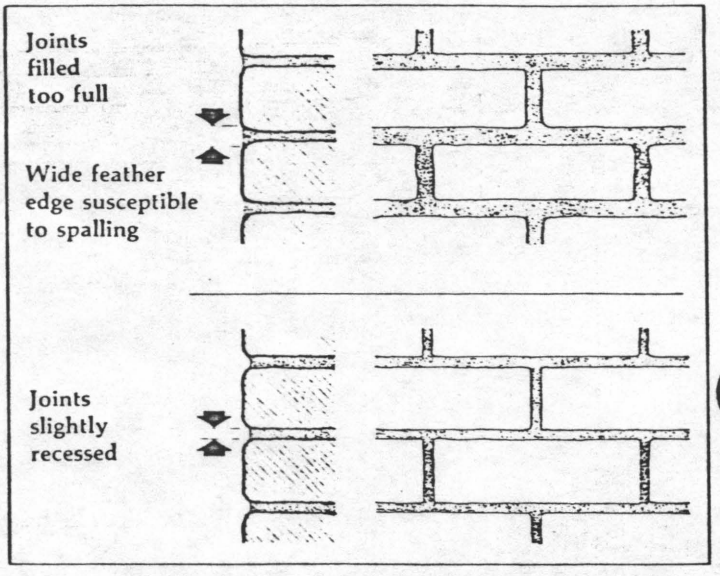


Figure 6. *Comparison of visual effect of full mortar joints vs slightly recessed joints. Filling joints too full hides the actual joint thickness and changes the character of the original brickwork.*

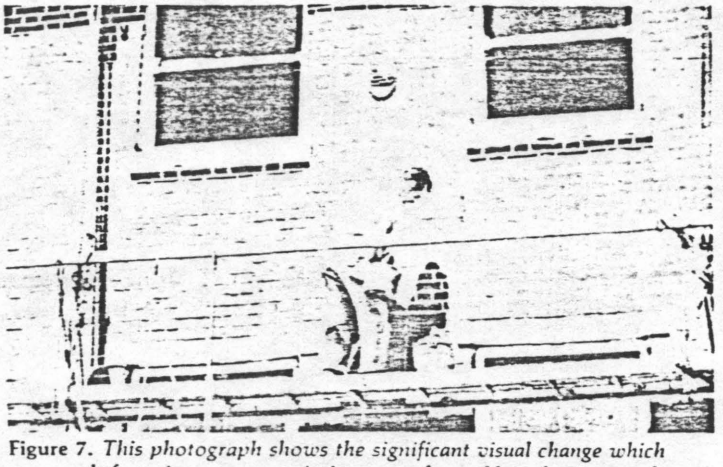


Figure 7. *This photograph shows the significant visual change which can result from improper repointing procedures. Note the increased thickness of the joints, the color variation, and the difference in the method of tooling—all noticeable even from a distance. Photo: Lee H. Nelson.*

appropriate for historic buildings and should therefore not be considered when a lasting and durable repointing job is desired.

Summary

For the Owner/Administrator: The owner or administrator of an historic building must constantly remember that repointing is likely to be a lengthy and expensive process. The owner will need to allow adequate time for evaluation by a qualified preservationist, for preparation of plans and specifications for the work, and for a lengthy work period with scaffolding in place. Schedules for both repointing work and other activities will thus require careful coordination to avoid unanticipated conflicts. The owner must avoid the tendency to rush the work or economize if the building is to retain its visual integrity and the job is to be durable.

For the Architect/Consultant: The architect/consultant must assist the owner in planning for logistical problems relating to research and construction. The consultant must also realize that older buildings have special problems usually not encountered with modern building materials or techniques of construction. Therefore, extra research will be required, and nonstandard materials and procedures will need to be used in evaluating the work of potential contractors to ensure that they are qualified to work on projects of the type anticipated. The consultant must also be prepared to spend more time than is customary in modern construction to inspect the work.

For the Contractor/Craftsman: The contractor or craftsman must keep in mind that a repointing project for a historic building will be slower and more expensive per unit cost than work on a modern building. The contractor must understand the reasons for these special requirements, and must convey them to the workers at all levels. Understanding the nature of the project and the potential problems will not only allow the contractor to submit a more accurate bid, but will also provide for the use of nonstandard methods in performing work.

Conclusion

First and foremost, a good repointing job is meant to last, often in the range of 50–100 years. Shortcuts and poor craftsmanship not only result in a job that looks bad, but also in one that will require future repointing more frequently than if the job had been done correctly in the first place. The mortar joint in a historic brick building has often been called the wall's "first line of defense." Good repointing practices guarantee the long life of the mortar joint, the wall, and the historic structure. However, while careful preservation, restoration, and maintenance will guarantee the long life of the freshly repointed mortar joints, it is important to remember that these mortar joints will probably require repointing some time in the future. It is the nature of mortar joints to deteriorate. Nevertheless, if the historic mortar joints proved durable for many years, then careful repointing should have an equally long life, ultimately contributing to the preservation of the historic brick building.

This brief was first written by Robert C. Mack, AIA, in 1976. It has been revised and updated in 1980 by Robert C. Mack, de Teel Patterson Tiller, Architectural Historian, Heritage Conservation and Recreation Service (HCRS), Department of the Interior; and James S. Askins, Preservation Craftsman, National Park Service, Department of the Interior. Other HCRS staff members who contributed materially to the development of this revised brief are Kay D. Weeks, Technical Writer-Editor, and James A. Caufield, Historical Architect.

September 1980

This publication has been prepared pursuant to Executive Order 11593, "Protection and Enhancement of the Cultural Environment," which directs the Secretary of the Interior to "develop and make available to Federal agencies and State and local governments information concerning professional methods and techniques for preserving, improving, restoring and maintaining historic properties."

Preservation Briefs 2 has been developed under the technical editorship of Lee H. Nelson, AIA, Chief, Technical Preservation Services, Heritage Conservation and Recreation Service, U.S. Department of the Interior, Washington, D.C. 20243. Comments on the usefulness of this information are welcome and can be sent to Mr. Nelson at the above address.

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U.S. Department
of the Interior
Technical Preservation
Services Division

Preservation Briefs: 9

The Repair of Historic Wooden Windows

John H. Myers

The windows on many historic buildings are an important aspect of the architectural character of those buildings. Their design, craftsmanship, or other qualities may make them worthy of preservation. This is self-evident for ornamental windows, but it can be equally true for warehouses or factories where the windows may be the most dominant visual element of an otherwise plain building (see figure 1). Evaluating the significance of these windows and planning for their repair or replacement can be a complex process involving both objective and subjective considerations. The *Secretary of the Interior's Standards for Rehabilitation*, and the accompanying guidelines, call for respecting the significance of original materials and features, repairing and retaining them wherever possible, and when necessary, replacing them in kind. This Brief is based on the issues of significance and repair which are implicit in the standards, but the primary emphasis is on the technical issues of planning for the repair of windows including evaluation of their physical condition, techniques of repair, and design considerations when replacement is necessary.

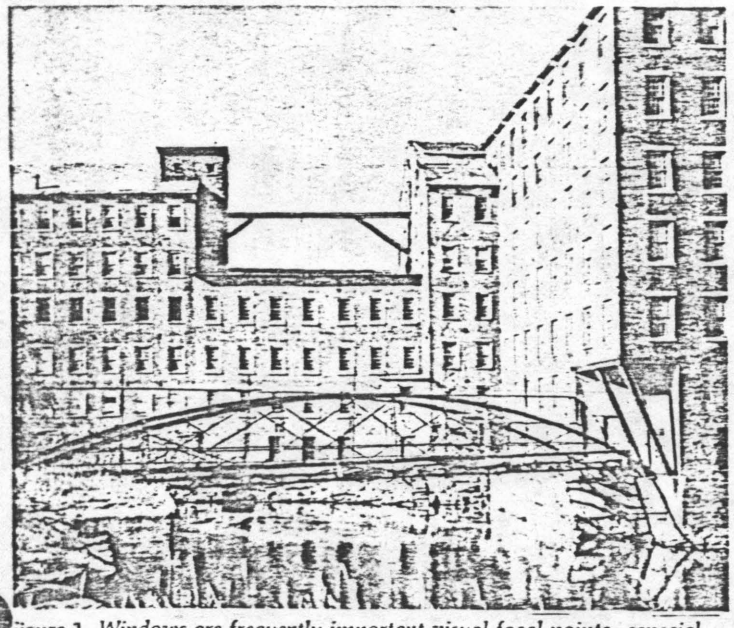


Figure 1. *Windows are frequently important visual focal points, especially on simple facades such as this mill building. Replacement of the multi-pane windows here with larger panes could dramatically change the appearance of the building. The areas of missing windows convey the impression of such a change. Photo: John T. Lowe*

Much of the technical section presents repair techniques as an instructional guide for the do-it-yourselfer. The information will be useful, however, for the architect, contractor, or developer on large-scale projects. It presents a methodology for approaching the evaluation and repair of existing windows, and considerations for replacement, from which the professional can develop alternatives and specify appropriate materials and procedures.

Architectural or Historical Significance

Evaluating the architectural or historical significance of windows is the first step in planning for window treatments, and a general understanding of the function and history of windows is vital to making a proper evaluation. As a part of this evaluation, one must consider four basic window functions: admitting light to the interior spaces, providing fresh air and ventilation to the interior, providing a visual link to the outside world, and enhancing the appearance of a building. No single factor can be disregarded when planning window treatments; for example, attempting to conserve energy by closing up or reducing the size of window openings may result in the use of *more* energy by increasing electric lighting loads and decreasing passive solar heat gains.

Historically, the first windows in early American houses were casement windows: that is, they were hinged at the side and opened outward. In the beginning of the eighteenth century single- and double-hung windows were introduced. Subsequently many styles of these vertical sliding sash windows have come to be associated with specific building periods or architectural styles, and this is an important consideration in determining the significance of windows, especially on a local or regional basis. Site-specific, regionally oriented architectural comparisons should be made to determine the significance of windows in question. Although such comparisons may focus on specific window types and their details, the ultimate determination of significance should be made within the context of the whole building, wherein the windows are one architectural element (see figure 2).

After all of the factors have been evaluated, *windows should be considered significant to a building if they:* 1) are original, 2) reflect the original design intent for the building, 3) reflect period or regional styles or building practices, 4) reflect changes to the building resulting from major periods or events, or 5) are examples of exceptional craftsmanship or design. Once this evaluation of significance has been completed, it is possible to pro-

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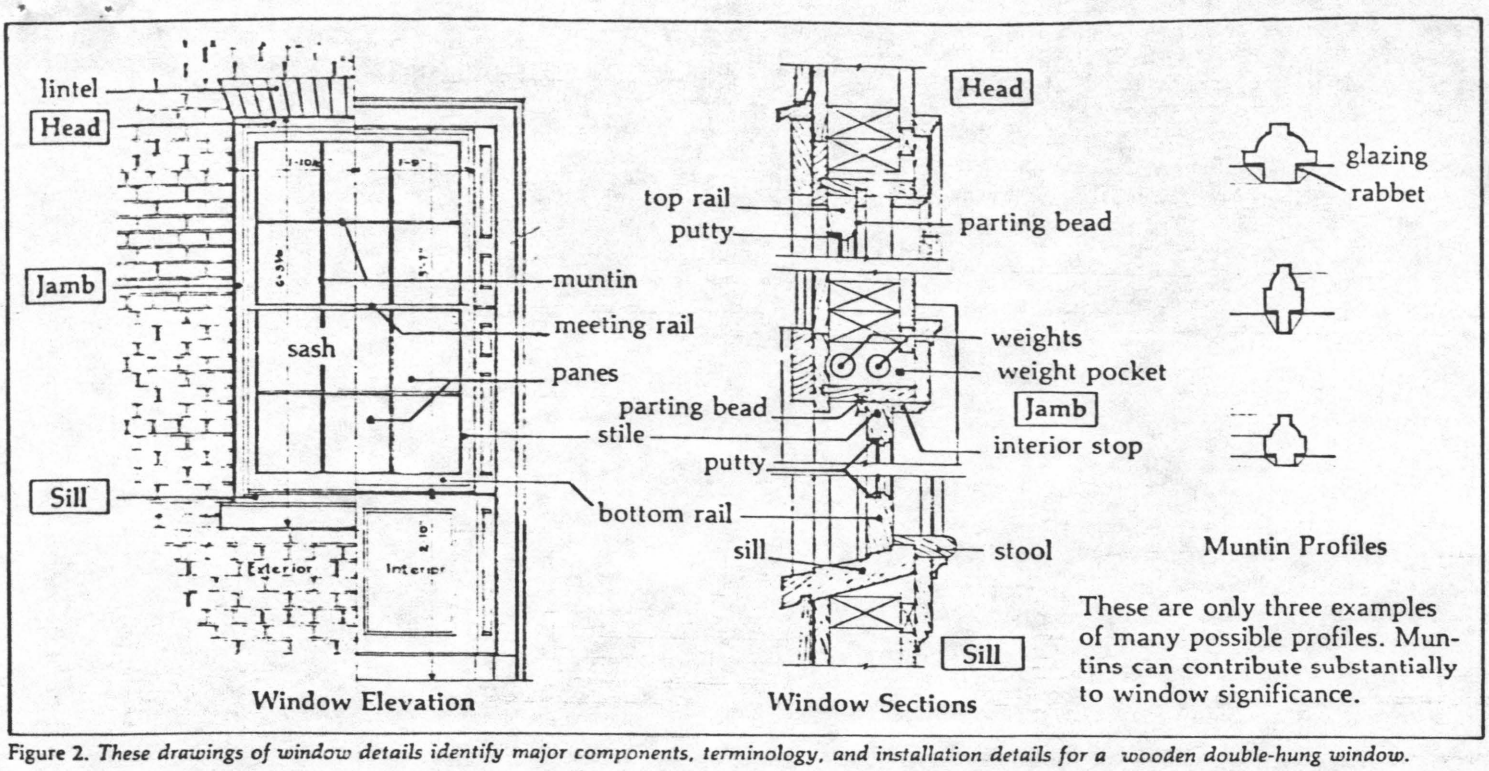


Figure 2. *These drawings of window details identify major components, terminology, and installation details for a wooden double-hung window.*

ceed with planning appropriate treatments, beginning with an investigation of the physical condition of the windows.

Physical Evaluation

The key to successful planning for window treatments is a careful evaluation of existing physical conditions on a unit-by-unit basis. A graphic or photographic system may be devised to record existing conditions and illustrate the scope of any necessary repairs. Another effective tool is a window schedule which lists all of the parts of each window unit. Spaces by each part allow notes on existing conditions and repair instructions. When such a schedule is completed, it indicates the precise tasks to be performed in the repair of each unit and becomes a part of the specifications. In any evaluation, one should note at a minimum, 1) window location, 2) condition of the paint, 3) condition of the frame and sill, 4) condition of the sash (rails, stiles and muntins), 5) glazing problems, 6) hardware, and 7) the overall condition of the window (excellent, fair, poor, and so forth).

Many factors such as poor design, moisture, vandalism, insect attack, and lack of maintenance can contribute to window deterioration, but moisture is the primary contributing factor in wooden window decay. All window units should be inspected to see if water is entering around the edges of the frame and, if so, the joints or seams should be caulked to eliminate this danger. The glazing putty should be checked for cracked, loose, or missing sections which allow water to saturate the wood, especially at the joints. The back putty on the interior side of the pane should also be inspected, because it creates a seal which prevents condensation from running down into the joinery. The sill should be examined to insure that it slopes downward away from the building and allows water to drain off. In addition, it may be advisable to cut a dripline along the underside of the sill. This almost invisible treatment will insure proper water run-off, particularly if the bottom of the sill is flat. Any conditions, including poor original design, which permit water to come in contact with the wood or to puddle on the sill must be corrected as they contribute to deterioration of the window.

One clue to the location of areas of excessive moisture is the condition of the paint; therefore, each window should be examined for areas of paint failure. Since excessive moisture is detrimental to the paint bond, areas of paint blistering, cracking, flaking, and peeling usually identify points of water penetration, moisture saturation, and potential deterioration. Failure of the paint should not, however, be mistakenly interpreted as a sign that the wood is in poor condition and hence, irreparable. Wood is frequently in sound physical condition beneath unsightly paint. After noting areas of paint failure, the next step is to inspect the condition of the wood, particularly at the points identified during the paint examination.

Each window should be examined for operational soundness beginning with the lower portions of the frame and sash. Exterior rainwater and interior condensation can flow downward along the window, entering and collecting at points where the flow is blocked. The sill, joints between the sill and jamb, corners of the bottom rails and muntin joints are typical points where water collects and deterioration begins (see figure 3). The operation of the window (continuous opening and closing over the years and seasonal temperature changes) weakens the joints, causing movement and slight separation. This process makes the joints more vulnerable to water which is readily absorbed into the end-grain of the wood. If severe deterioration exists in these areas, it will usually be apparent on visual inspection, but other less severely deteriorated areas of the wood may be tested by two traditional methods using a small ice pick.

An ice pick or an awl may be used to test wood for soundness. The technique is simply to jab the pick into a wetted wood surface at an angle and pry up a small sec-

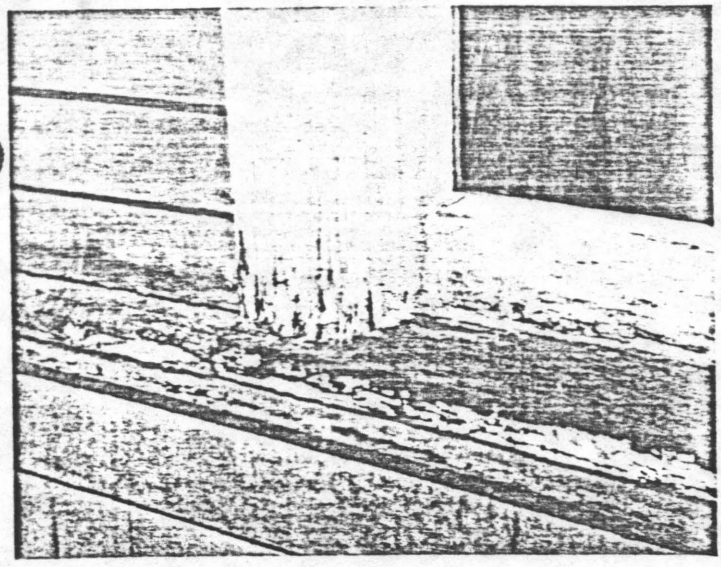


Figure 3. *Deterioration of poorly maintained windows usually begins on horizontal surfaces and at joints where water can collect and saturate the wood. The problem areas are clearly indicated by paint failure due to moisture. Photo: Baird M. Smith, AIA*

tion of the wood. Sound wood will separate in long fibrous splinters, but decayed wood will lift up in short irregular pieces due to the breakdown of fiber strength.

Another method of testing for soundness consists of pushing a sharp object into the wood, perpendicular to the surface. If deterioration has begun from the hidden side of a member and the core is badly decayed, the visible surface may appear to be sound wood. Pressure on the probe can force it through an apparently sound skin to penetrate deeply into decayed wood. This technique is especially useful for checking sills where visual access to the underside is restricted.

Following the inspection and analysis of the results, the scope of the necessary repairs will be evident and a plan for the rehabilitation can be formulated. Generally the actions necessary to return a window to "like new" condition will fall into three broad categories: 1) routine maintenance procedures, 2) structural stabilization, and 3) parts replacement. These categories will be discussed in the following sections and will be referred to respectively as Repair Class I, Repair Class II, and Repair Class III. Each successive repair class represents an increasing level of difficulty, expense, and work time. Note that most of the points mentioned in Repair Class I are routine maintenance items and should be provided in a regular maintenance program for any building. The neglect of these routine items can contribute to many common window problems.

Before undertaking any of the repairs mentioned in the following sections all sources of moisture penetration should be identified and eliminated, and all existing decay fungi destroyed in order to arrest the deterioration process. Many commercially available fungicides and wood preservatives are toxic, so it is extremely important to follow the manufacturer's recommendations for application, and store all chemical materials away from children and animals. After fungicidal and preservative treatment the windows may be stabilized, retained, and restored with every expectation for a long service life.

Repair Class I: Routine Maintenance

Repairs to wooden windows are usually labor intensive and relatively uncomplicated. On small scale projects this allows the do-it-yourselfer to save money by repairing all or part of the windows. On larger projects it presents the opportunity for time and money which might otherwise be spent on the removal and replacement of existing windows, to be spent on repairs, subsequently saving all or part of the material cost of new window units. Regardless of the actual costs, or who performs the work, the evaluation process described earlier will provide the knowledge from which to specify an appropriate work program, establish the work element priorities, and identify the level of skill needed by the labor force.

The routine maintenance required to upgrade a window to "like new" condition normally includes the following steps: 1) some degree of interior and exterior paint removal, 2) removal and repair of sash (including reglazing where necessary), 3) repairs to the frame, 4) weatherstripping and reinstallation of the sash, and 5) repainting. These operations are illustrated for a typical double-hung wooden window (see figures 4a-f), but they may be adapted to other window types and styles as applicable.

Historic windows have usually acquired many layers of paint over time. Removal of excess layers or peeling and flaking paint will facilitate operation of the window and restore the clarity of the original detailing. Some degree of paint removal is also necessary as a first step in the proper surface preparation for subsequent refinishing (if paint color analysis is desired, it should be conducted prior to the onset of the paint removal). There are several safe and effective techniques for removing paint from wood, depending on the amount of paint to be removed. Several techniques such as scraping, chemical stripping, and the use of a hot air gun are discussed in "Preservation Briefs: 10 Paint Removal from Historic Woodwork" (see Additional Reading section at end).

Paint removal should begin on the interior frames, being careful to remove the paint from the interior stop and the parting bead, particularly along the seam where these stops meet the jamb. This can be accomplished by running a utility knife along the length of the seam, breaking the paint bond. It will then be much easier to remove the stop, the parting bead and the sash. The interior stop may be initially loosened from the sash side to avoid visible scarring of the wood and then gradually pried loose using a pair of putty knives, working up and down the stop in small increments (see figure 4b). With the stop removed, the lower or interior sash may be withdrawn. The sash cords should be detached from the sides of the sash and their ends may be pinned with a nail or tied in a knot to prevent them from falling into the weight pocket.

Removal of the upper sash on double-hung units is similar but the parting bead which holds it in place is set into a groove in the center of the stile and is thinner and more delicate than the interior stop. After removing any paint along the seam, the parting bead should be carefully pried out and worked free in the same manner as the interior stop. The upper sash can be removed in the same manner as the lower one and both sash taken to a convenient work area (in order to remove the sash the interior stop and parting bead need only be removed from one side of the window). Window openings can be covered with polyethylene sheets or plywood sheathing while the sash are out for repair.

The sash can be stripped of paint using appropriate techniques, but if any heat treatment is used (see figure 4c), the glass should be removed or protected from the sudden temperature change which can cause breakage. An

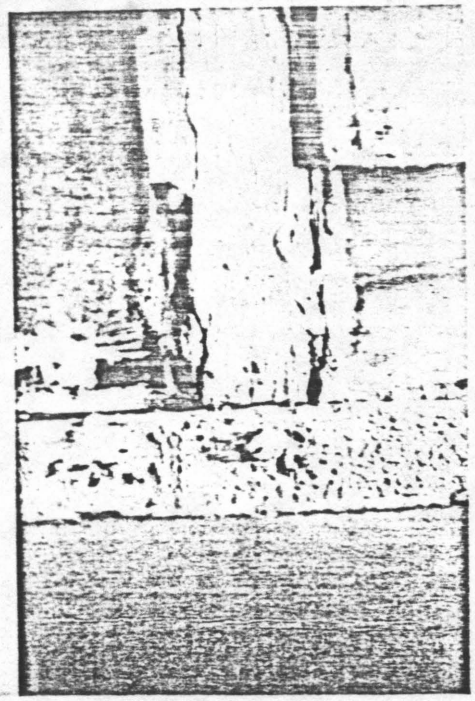


Figure 4a. *The following series of photographs of the repair of a historic double-hung window use a unit which is structurally sound but has many layers of paint, some cracked and missing putty, slight separation at the joints, broken sash cords, and one cracked pane. Photo: John H. Myers*

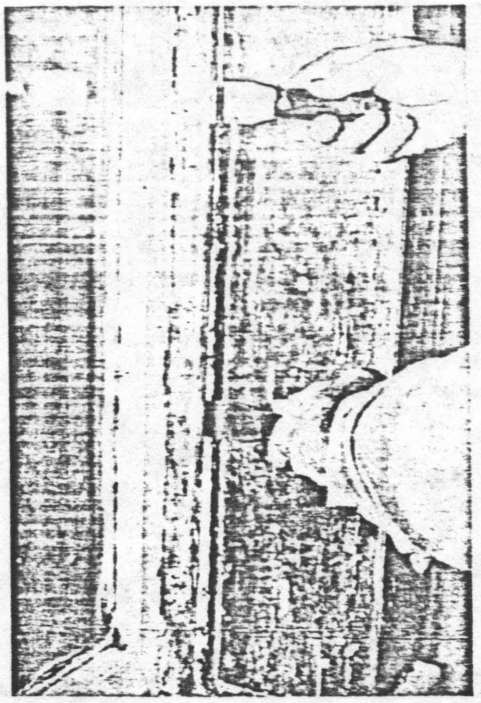


Figure 4b. *After removing paint from the seam between the interior stop and the jamb, the stop can be pried out and gradually worked loose using a pair of putty knives as shown. To avoid visible scarring of the wood, the sash can be raised and the stop pried loose initially from the outer side. Photo: John H. Myers*



Figure 4c. *Sash can be removed and repaired in a convenient work area. Paint is being removed from this sash with a hot air gun while an asbestos sheet protects the glass from sudden temperature change. Photo: John H. Myers*

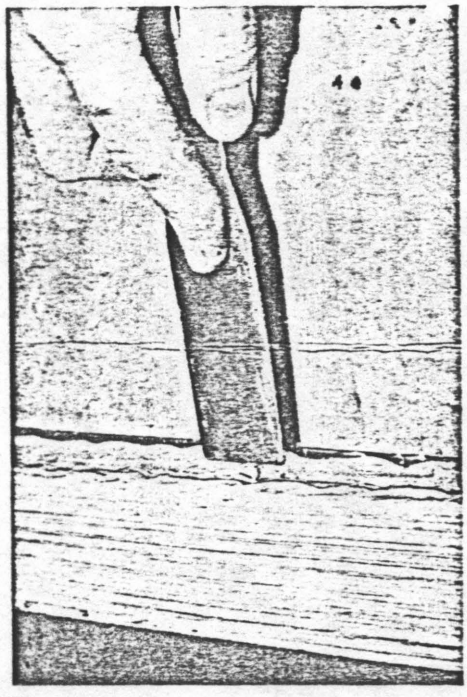


Figure 4d. *Reglazing or replacement of the putty requires that the existing putty be removed manually, the glazing points be extracted, the glass removed, and the back putty scraped out. To reglaze, a bed of putty is laid around the perimeter of the rabbet, the pane is pressed into place, glazing points are inserted to hold the pane (shown), and a final seal of putty is beveled around the edge of the glass. Photo: John H. Myers*

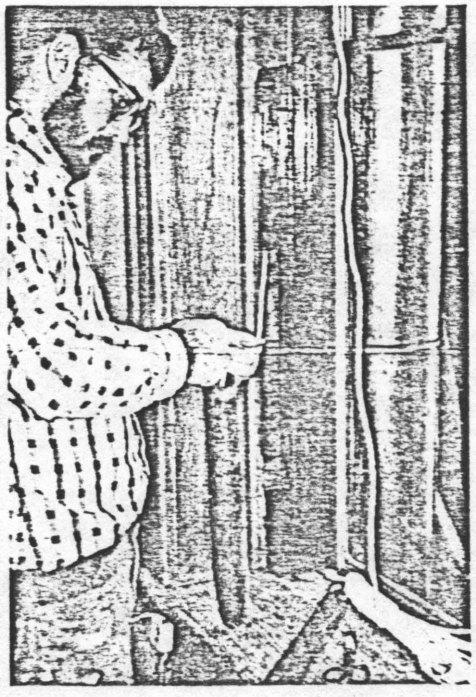


Figure 4e. *A common repair is the replacement of broken sash cords with new cords (shown) or with chains. The weight pocket is often accessible through a removable plate in the jamb, or by removing the interior trim. Photo: John H. Myers*

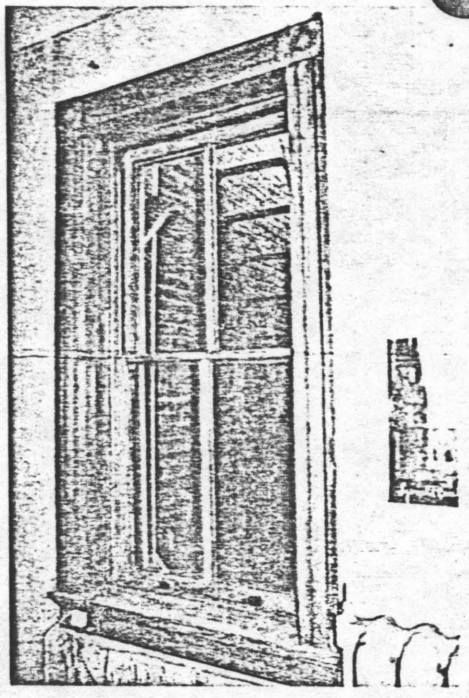


Figure 4f. *Following the relatively simple repairs, the window is weathertight, like new in appearance, and serviceable for many years to come. Both the historic material and the detailing and craftsmanship of this original window have been preserved. Photo: John H. Myers*

overlay of aluminum foil on gypsum board or asbestos can protect the glass from such rapid temperature change. It is important to protect the glass because it may be historic and often adds character to the window. Deteriorated putty should be removed manually, taking care not to damage the wood along the rabbet. If the glass is to be removed, the glazing points which hold the glass in place can be extracted and the panes numbered and removed for cleaning and reuse in the same openings. With the glass panes out, the remaining putty can be removed and the sash can be sanded, patched, and primed with a preservative primer. Hardened putty in the rabbets may be softened by heating with a soldering iron at the point of removal. Putty remaining on the glass may be softened by soaking the panes in linseed oil, and then removed with less risk of breaking the glass. Before reinstalling the glass, a bead of glazing compound or linseed oil putty should be laid around the rabbet to cushion and seal the glass. Glazing compound should only be used on wood which has been brushed with linseed oil and primed with an oil based primer or paint. The pane is then pressed into place and the glazing points are pushed into the wood around the perimeter of the pane (see figure 4d). The final glazing compound or putty is applied and beveled to complete the seal. The sash can be refinished as desired on the inside and painted on the outside as soon as a "skin" has formed on the putty, usually in 2 or 3 days. Exterior paint should cover the beveled glazing compound or putty and lap over onto the glass slightly to complete a weathertight seal. After the proper curing times have elapsed for paint and putty, the sash will be ready for reinstallation.

While the sash are out of the frame, the condition of the wood in the jamb and sill can be evaluated. Repair and refinishing of the frame may proceed concurrently with repairs to the sash, taking advantage of the curing times for the paints and putty used on the sash. One of the most common work items is the replacement of the sash cords with new rope cords or with chains (see figure 4e). The weight pocket is frequently accessible through a door on the face of the frame near the sill, but if no door exists, the trim on the interior face may be removed for access. Sash weights may be increased for easier window operation by elderly or handicapped persons. Additional repairs to the frame and sash may include consolidation or replacement of deteriorated wood. Techniques for these repairs are discussed in the following sections.

The operations just discussed summarize the efforts necessary to restore a window with minor deterioration to "like new" condition (see figure 4f). The techniques can be applied by an unskilled person with minimal training and experience. To demonstrate the practicality of this approach, and photograph it, a Technical Preservation Services staff member repaired a wooden double-hung, two over two window which had been in service over ninety years. The wood was structurally sound but the window had one broken pane, many layers of paint, broken sash cords and inadequate, worn-out weatherstripping. The staff member found that the frame could be stripped of paint and the sash removed quite easily. Paint, putty and glass removal required about one hour for each sash, and the reglazing of both sash was accomplished in about one hour. Weatherstripping of the sash and frame, replacement of the sash cords and reinstallation of the sash, parting bead, and stop required an hour and a half. These times refer only to individual operations; the entire process took several days due to the drying and curing times for putty, primer, and paint, however, work on other window units could have been in progress during these lag times.

Repair Class II: Stabilization

The preceding description of a window repair job focused on a unit which was operationally sound. Many windows will show some additional degree of physical deterioration, especially in the vulnerable areas mentioned earlier, but even badly damaged windows can be repaired using simple processes. Partially decayed wood can be waterproofed, patched, built-up, or consolidated and then painted to achieve a sound condition, good appearance, and greatly extended life. Three techniques for repairing partially decayed or weathered wood are discussed in this section, and all three can be accomplished using products available at most hardware stores.

One established technique for repairing wood which is split, checked or shows signs of rot, is to: 1) dry the wood, 2) treat decayed areas with a fungicide, 3) waterproof with two or three applications of boiled linseed oil (applications every 24 hours), 4) fill cracks and holes with putty, and 5) after a "skin" forms on the putty, paint the surface. Care should be taken with the use of fungicide which is toxic. Follow the manufacturers' directions and use only on areas which will be painted. When using any technique of building up or patching a flat surface, the finished surface should be sloped slightly to carry water away from the window and not allow it to puddle. Caulking of the joints between the sill and the jamb will help reduce further water penetration.

When sills or other members exhibit surface weathering they may also be built-up using wood putties or homemade mixtures such as sawdust and resorcinol glue, or whiting and varnish. These mixtures can be built up in successive layers, then sanded, primed, and painted. The same caution about proper slope for flat surfaces applies to this technique.

Wood may also be strengthened and stabilized by consolidation, using semi-rigid epoxies which saturate the porous decayed wood and then harden. The surface of the consolidated wood can then be filled with a semi-rigid epoxy patching compound, sanded and painted (see figure 5). Epoxy patching compounds can be used to build up

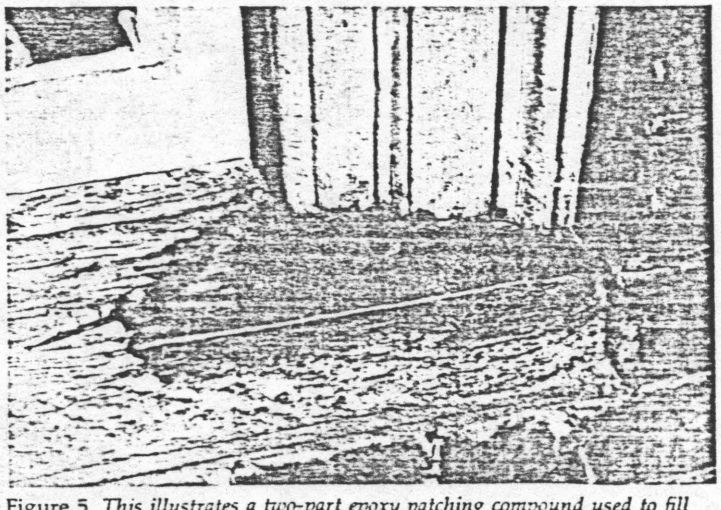


Figure 5. *This illustrates a two-part epoxy patching compound used to fill the surface of a weathered sill and rebuild the missing edge. When the epoxy cures, it can be sanded smooth and painted to achieve a durable and waterproof repair. Photo: John H. Myers*

missing sections or decayed ends of members. Profiles can be duplicated using hand molds, which are created by pressing a ball of patching compound over a sound section of the profile which has been rubbed with butcher's wax. This can be a very efficient technique where there are many typical repairs to be done. Technical Preservation Services has published *Epoxies for Wood Repairs in Historic Buildings* (see Additional Reading section at end), which discusses the theory and techniques of epoxy repairs. The process has been widely used and proven in marine applications; and proprietary products are available at hardware and marine supply stores. Although epoxy materials may be comparatively expensive, they hold the promise of being among the most durable and long lasting materials available for wood repair.

Any of the three techniques discussed can stabilize and restore the appearance of the window unit. There are times, however, when the degree of deterioration is so advanced that stabilization is impractical, and the only way to retain some of the original fabric is to replace damaged parts.

Repair Class III: Splices and Parts Replacement

When parts of the frame or sash are so badly deteriorated that they cannot be stabilized there are methods which permit the retention of some of the existing or original fabric. These methods involve replacing the deteriorated parts with new matching pieces, or splicing new wood into existing members. The techniques require more skill and are more expensive than any of the previously discussed alternatives. It is necessary to remove the sash and/or the affected parts of the frame and have a carpenter or woodworking mill reproduce the damaged or missing parts. Most millwork firms can duplicate parts, such as muntins, bottom rails, or sills, which can then be incorporated into the existing window, but it may be necessary to shop around because there are several factors controlling the practicality of this approach. Some woodworking mills do not like to repair old sash because nails or other foreign objects in the sash can damage expensive knives (which cost far more than their profits on small repair jobs); others do not have cutting knives to duplicate muntin profiles. Some firms prefer to concentrate on larger jobs with more profit potential, and some may not have a craftsman who can duplicate the parts. A little searching should locate a firm which will do the job, and at a reasonable price. If such a firm does not exist locally, there are firms which undertake this kind of repair and ship nationwide. It is possible, however, for the advanced do-it-yourselfer or craftsman with a table saw to duplicate moulding profiles using techniques discussed by Gordie Whittington in "Simplified Methods for Reproducing Wood Mouldings," *Bulletin* of the Association for Preservation Technology, Vol. III, No. 4, 1971, or illustrated more recently in *The Old House*, Time-Life Books, Alexandria, Virginia, 1979.

The repairs discussed in this section involve window frames which may be in very deteriorated condition, possibly requiring removal; therefore, caution is in order. The actual construction of wooden window frames and sash is not complicated. Pegged mortise and tenon units can be disassembled easily, *if* the units are out of the building. The installation or connection of some frames to the surrounding structure, especially masonry walls, can complicate the work immeasurably, and may even require dismantling of the wall. It may be useful, therefore, to take the following approach to frame repair: 1) conduct regular maintenance of sound frames to achieve the longest life possible, 2) make necessary repairs in place wherever possible, using stabilization and splicing techniques, and 3) if removal is necessary, thoroughly investigate the structural detailing and seek appropriate professional consultation.

Another alternative may be considered if parts replacement is required, and that is sash replacement. If extensive replacement of parts is necessary and the job becomes prohibitively expensive it may be more practical to purchase new sash which can be installed into the existing frames. Such sash are available as exact custom reproductions, reasonable facsimiles (custom windows with similar profiles), and contemporary wooden sash which are similar in appearance. There are companies which still manufacture high quality wooden sash which would duplicate most historic sash. A few calls to local building suppliers may provide a source of appropriate replacement sash, but if not, check with local historical associations, the state historic preservation office, or preservation related magazines and supply catalogs for information.

If a rehabilitation project has a large number of windows such as a commercial building or an industrial complex, there may be less of a problem arriving at a solution. Once the evaluation of the windows is completed and the scope of the work is known, there may be a potential economy of scale. Woodworking mills may be interested in the work from a large project; new sash in volume may be considerably less expensive per unit; crews can be assembled and trained on site to perform all of the window repairs; and a few extensive repairs can be absorbed (without undue burden) into the total budget for a large number of sound windows. While it may be expensive for the average historic home owner to pay seventy dollars or more for a mill to grind a custom knife to duplicate four or five bad muntins, that cost becomes negligible on large commercial projects which may have several hundred windows.

Most windows should not require the extensive repairs discussed in this section. The ones which do are usually in buildings which have been abandoned for long periods or have totally lacked maintenance for years. It is necessary to thoroughly investigate the alternatives for windows which do require extensive repairs to arrive at a solution which retains historic significance and is also economically feasible. Even for projects requiring repairs identified in this section, if the percentage of parts replacement per window is low, or the number of windows requiring repair is small, repair can still be a cost effective solution.

Weatherization

A window which is repaired should be made as energy efficient as possible by the use of appropriate weatherstripping to reduce air infiltration. A wide variety of products are available to assist in this task. Felt may be fastened to the top, bottom, and meeting rails, but may have the disadvantage of absorbing and holding moisture, particularly at the bottom rail. Rolled vinyl strips may also be tacked into place in appropriate locations to reduce infiltration. Metal strips or new plastic spring strips may be used on the rails and, if space permits, in

the channels between the sash and jamb. Weatherstripping is a historic treatment, but old weatherstripping (felt) is not likely to perform very satisfactorily. Appropriate contemporary weatherstripping should be considered an integral part of the repair process for windows. The use of [illegible] locks installed on the meeting rail will insure that the [illegible]sh are kept tightly closed so that the weatherstripping will function more effectively to reduce infiltration. Although such locks will not always be historically accurate, they will usually be viewed as an acceptable contemporary modification in the interest of improved thermal performance.

Many styles of storm windows are available to improve the thermal performance of existing windows. The use of exterior storm windows should be investigated whenever feasible because they are thermally efficient, cost-effective, reversible, and allow the retention of original windows (see "Preservation Briefs: 3"). Storm window frames may be made of wood, aluminum, vinyl, or plastic; however, the use of unfinished aluminum storms should be avoided. The visual impact of storms may be minimized by selecting colors which match existing trim color. Arched top storms are available for windows with special shapes. Although interior storm windows appear to offer an attractive option for achieving double glazing with minimal visual impact, the potential for damaging condensation problems must be addressed. Moisture which becomes trapped between the layers of glazing can condense on the colder, outer prime window, potentially leading to deterioration. The correct approach to using interior storms is to create a seal on the interior storm while allowing some ventilation around the prime window. In actual practice, the creation of such a durable, airtight [illegible] is difficult.

Window Replacement

Although the retention of original or existing windows is always desirable and this Brief is intended to encourage that goal, there is a point when the condition of a window may clearly indicate replacement. The decision process for selecting replacement windows should *not* begin with a survey of contemporary window products which are available as replacements, but should begin with a look at the windows which are being replaced. Attempt to understand the contribution of the window(s) to the appearance of the facade including: 1) the pattern of the openings and their size; 2) proportions of the frame and sash; 3) configuration of window panes; 4) muntin profiles; 5) type of wood; 6) paint color; 7) characteristics of the glass; and 8) associated details such as arched tops, hoods, or other decorative elements. Develop an understanding of how the window reflects the period, style, or regional characteristics of the building, or represents technological development.

Armed with an awareness of the significance of the existing window, begin to search for a replacement which retains as much of the character of the historic window as possible. There are many sources of suitable new windows. Continue looking until an acceptable replacement can be found. Check building supply firms, local woodworking mills, carpenters, preservation oriented magazines, or catalogs or suppliers of old building materials, for product information. Local historical associations and state historic preservation offices may be good sources of information on products which have been used successfully in preservation projects.

Consider energy efficiency as one of the factors for replacements, but do not let it dominate the issue. Energy conservation is no excuse for the wholesale destruction of historic windows which can be made thermally efficient by historically and aesthetically acceptable means. In fact, a historic wooden window with a high quality storm window added should thermally outperform a new double-glazed metal window which does not have thermal breaks (insulation between the inner and outer frames intended to break the path of heat flow). This occurs because the wood has far better insulating value than the metal, and in addition many historic windows have high ratios of wood to glass, thus reducing the area of highest heat transfer. One measure of heat transfer is the U-value, the number of Btu's per hour transferred through a square foot of material. When comparing thermal performance, the lower the U-value the better the performance. According to *ASHRAE 1977 Fundamentals*, the U-values for single glazed wooden windows range from 0.88 to 0.99. The addition of a storm window should reduce these figures to a range of 0.44 to 0.49. A non-thermal break, double-glazed metal window has a U-value of about 0.6.

Conclusion

Technical Preservation Services recommends the retention and repair of original windows whenever possible. We believe that the repair and weatherization of existing wooden windows is more practical than most people realize, and that many windows are unfortunately replaced because of a lack of awareness of techniques for evaluation, repair, and weatherization. Wooden windows which are repaired and properly maintained will have greatly extended service lives while contributing to the historic character of the building. Thus, an important element of a building's significance will have been preserved for the future.

Additional Reading

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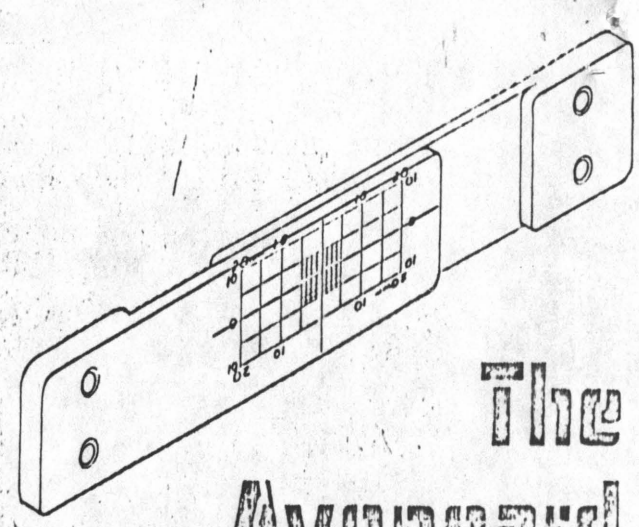
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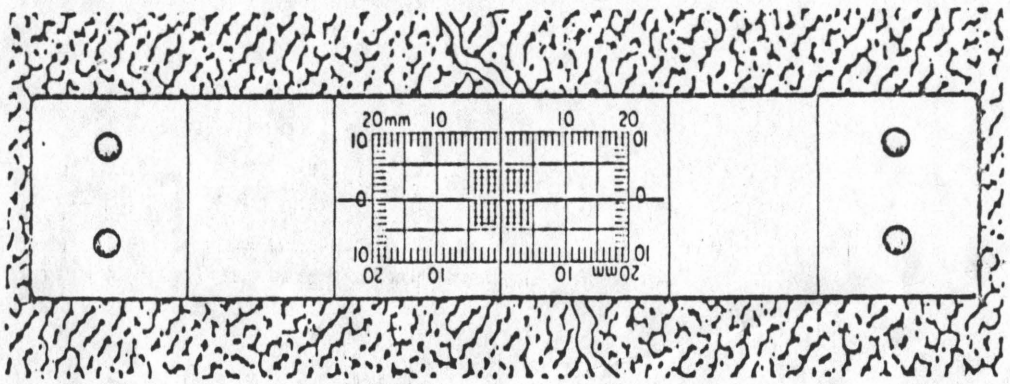
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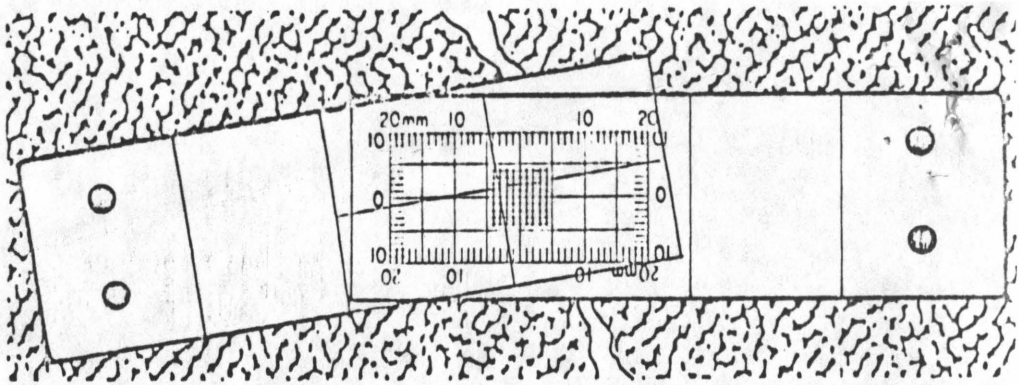


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Crack movement is seen by the appearance of the crossed cursor lines as illustrated above.

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To simplify mounting, the plates are preset at zero with transparent tape. After installation, the tape is cut at the top and bottom, allowing the plates to move independently of one another. The reliance on the skill of the person mounting the Monitor is thereby kept to a minimum.

The Calibrated Crack Monitor is weather resistant and can be used on internal or external walls. It can also be REUSED by simply removing the bolts or screws with which it is mounted. Care must be taken to tape the plates together with the cursor lines set at zero on the grid. Then the gauge can be reinstalled at a new location. Alternatively, the Monitor can be quickly and easily mounted using epoxy cement or putty.

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