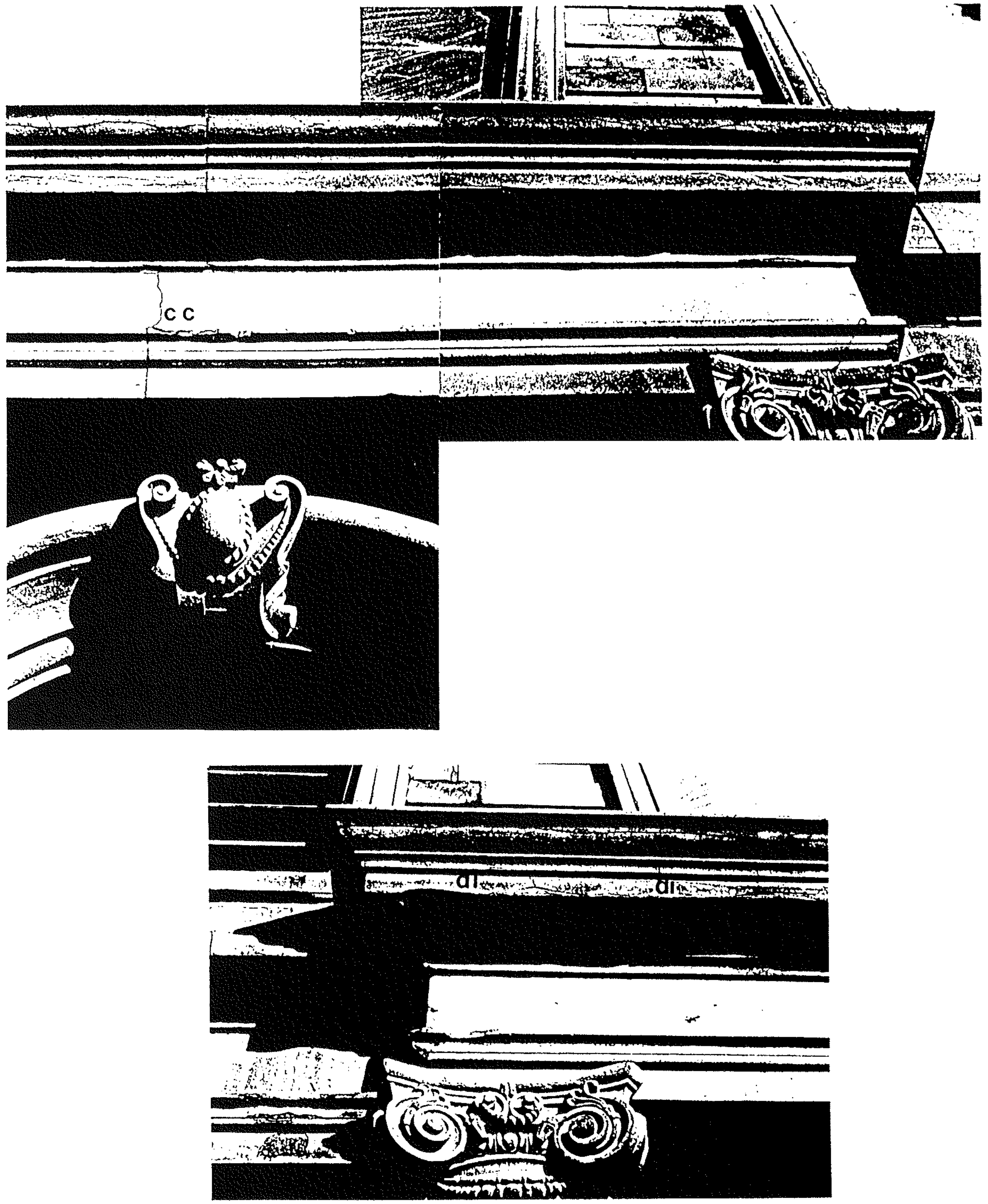


Figure 42. Stone repair: photographic montage.

for the bedding planes to be correctly oriented. Because of this potential problem anyone seeking stone for restoration work is well advised to check and double check that the bed depth or thickness of the quarried strata are sufficiently large to allow for the supply of sawn stone of the desired vertical dimensions.

Obtaining the Stone

When obtaining stone for restoration work the ideal situation is for the experienced restorer or conservator to go to the quarries and select the material for the specific project. At the same time the restorer presents

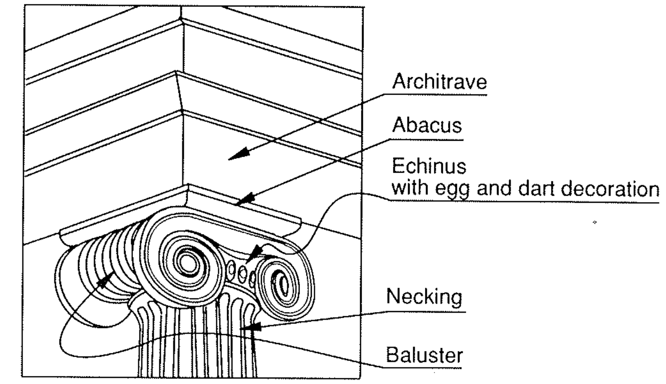


Figure 43a. Architectural details.

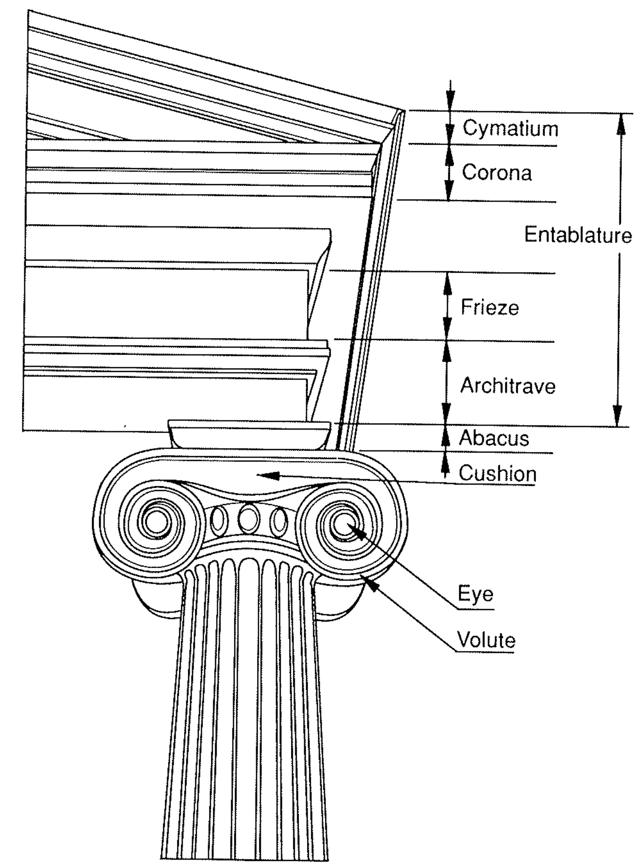


Figure 43b. Architectural details *continued*.

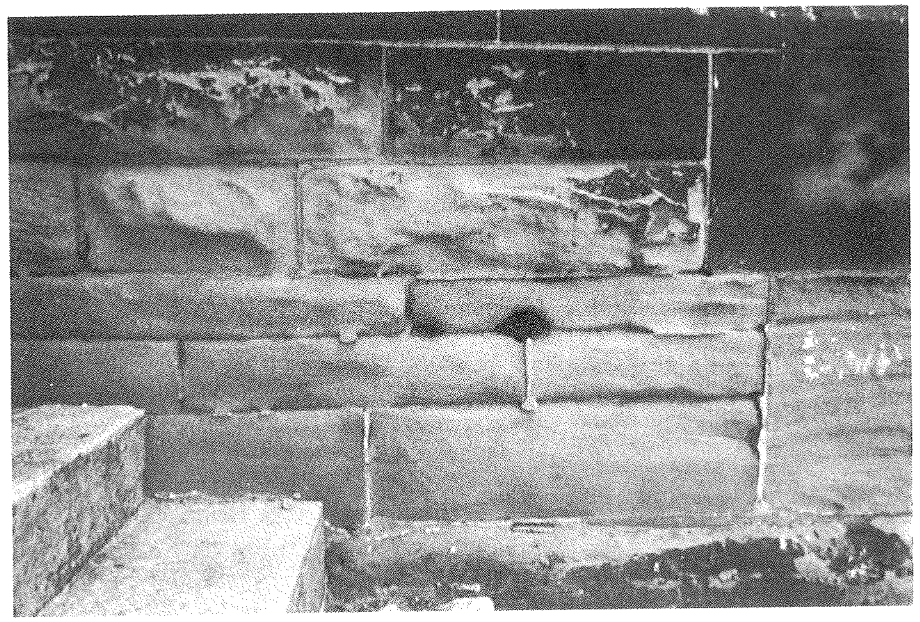
the quarry with dimensioned drawings with the bedding plane orientations clearly marked for all units individually. On the basis of this information, the quarry can supply accurate estimates for price and delivery times. Even in cases where the restorer is working through an intermediate stone dealer it is still advisable for the restorer to follow all these procedures. The restorer should also quote all the appropriate ASTM stone standards in the specifications for the job in order to ensure that the stone is of the requisite quality.

The Use of Substitutes

In cases where deicing salts have caused severe damage to sandstones used for paving, staircase treads and at the bases of buildings adjacent to the sidewalk it may be necessary to consider using a limestone for replacement work. Limestones are often much more resistant than sandstones to attacks by salts. But on no account should sandstones be replaced by limestones where the runoff from the limestone will cause carbonates to be redeposited in the adjacent sandstone units. The original sandstones can be destroyed as a result of such substitutions, particularly in polluted environments. The substitution of more durable stones in conditions of extreme weathering and pollutant exposure is prudent but it is recommended that acid-resistant stones of igneous or metamorphic origin should be employed instead of limestones. As an example of this process, a fine grained granite of similar color to a disintegrating original sandstone was used for restoration work on the base of the National Assembly Building in Quebec.

Avoiding Bedding Plane Problems

The restorer must pay careful attention to the correct orientation of bedding planes in original work and in new work. Obviously if the original units are in good condition and showing no signs of problems despite incorrect orientation of the bedding planes, then they should be left alone. If, however, definite face bedding problems are occurring the offending unit should be carefully cut out and, if possible, turned so that the orientation is corrected. This will not often be possible and the unit may have to be totally replaced. In my experience bedding plane problems generally occur in certain sandstones which tend to split very readily on planes where thin clay layers occur. Some of the Quebec limestones of the Trenton and Chazy formations also tend to split along fine horizontal crack lines. In some sandstones the inexperienced practitioner may be confused by "contour scaling" or the loss of the crustal layer through oxidation crust formation and other causes. Although at first gance this phenomenon may be confused with face bedding problems, further inspection will immediately reveal that the losses are not parallel to one plane but also proceed at right angles to that plane.



Deicing salt damage in sandstone next to staircase.

Stone Veneers and Double Walls

In cases where veneers of stonework or outer wythes have become detached from backing masonry or inner wythes, it is first necessary to establish their stability. If it is clear that stonework of the outer wythe is actually moving outward and could become unsafe, then there are a number of possible approaches to the restoration of the masonry. It is essential that the cause of the problem be established so that it can be remedied first. I have known of a number of cases where thick stone walls had their inner and outer wythes moving apart and major structural cracking and bulging occurring. In nearly all of these cases the problems were the

Contour scaling in red sandstone.

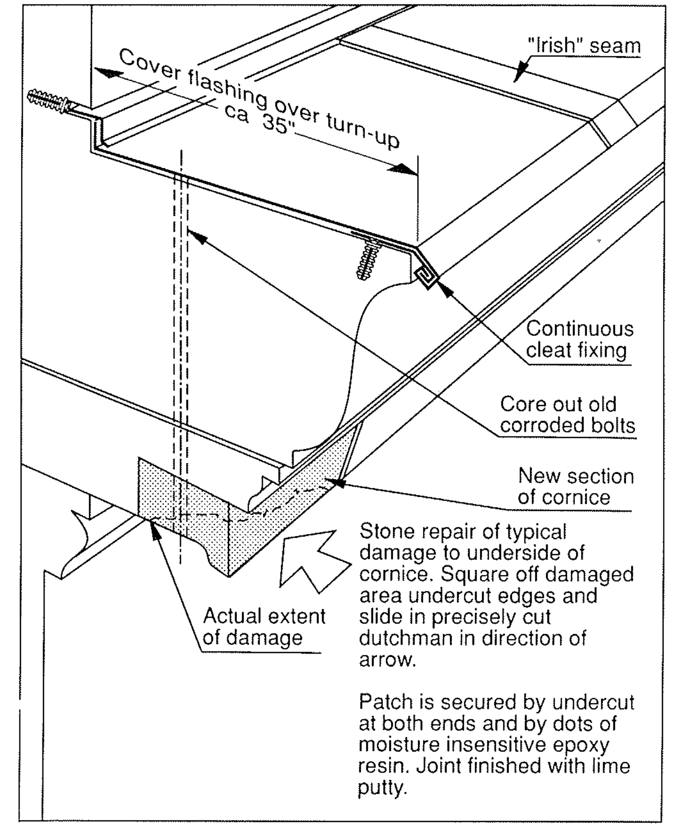


Figure 44a. Detail of flashing of main cornice: Vieux Palais de Justice, Montreal, Quebec.

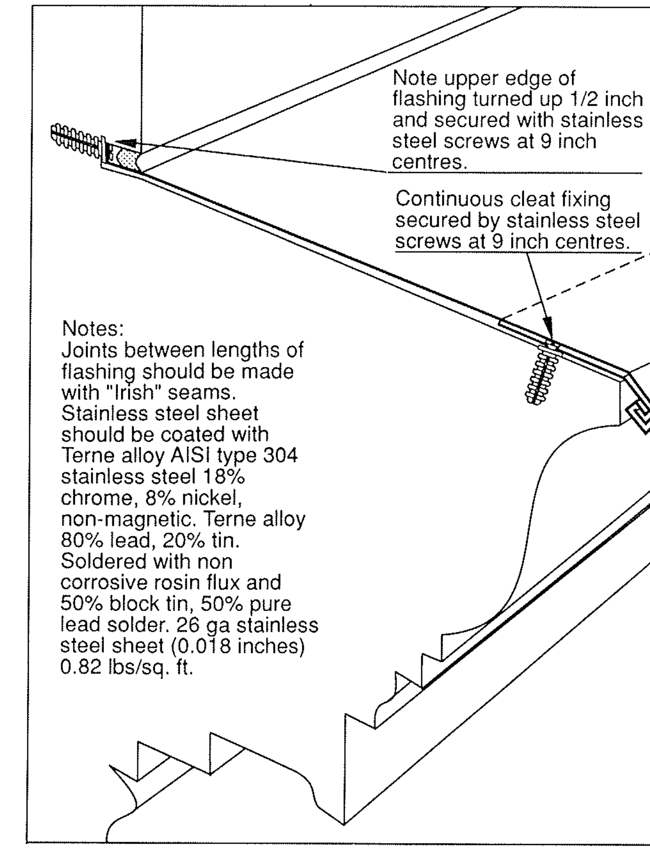
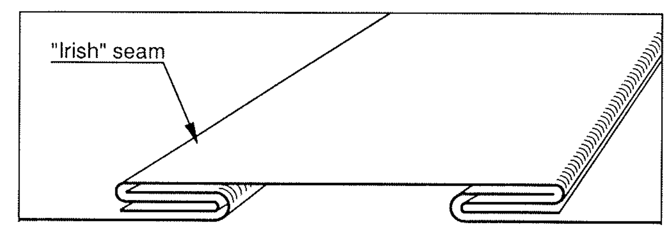


Figure 44c. New stainless steel flashing on belt course.



Seams at the ends of sheets of flashing should be secured with so called "Irish" seams which allow for expansion and contraction and do not involve any perforation of the sheet.

Figure 44b. Detail of flashing of main cornice.

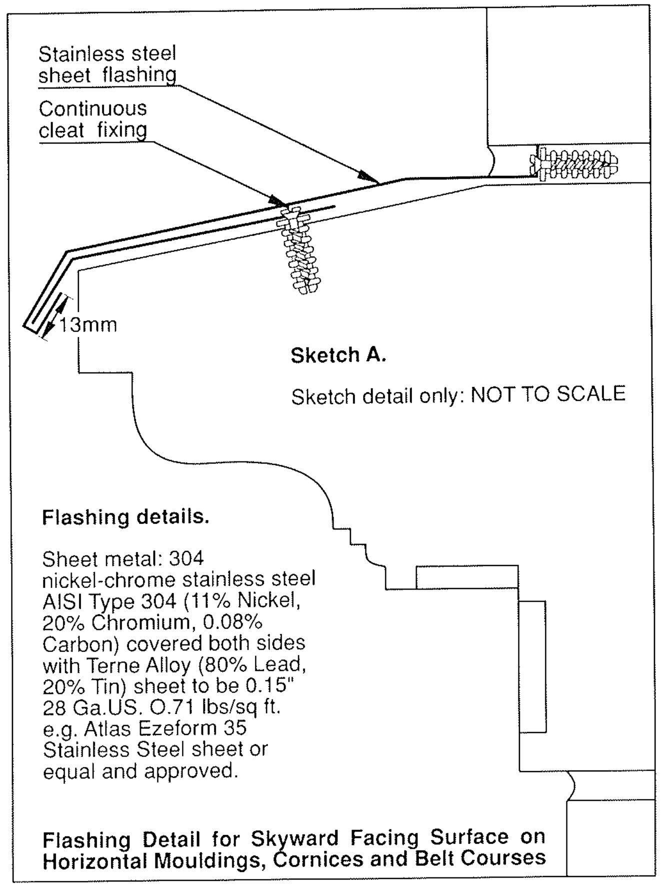
result of acid precipitation penetrating into the interior of the wall via open joints and defective flashings or roofing. The excessive quantities of water had removed most of the lime from the mortar leaving only wet sand. Obviously in all such cases the sources of unwanted water must first be eliminated by repointing joints and replacing flashings and roof finishes.

Once the cause of the bond failure has been eliminated the wythes can be stabilized either by the injection of a liquid grout into the core of the wall to replace the deteriorated mortar, or by drilling holes with diamond-tipped coring bits through the outer wythe into a stable core or masonry backing and then inserting stainless steel tubular injection anchors set in cementitious grout or threaded stainless steel rods which are set in a moisture insensitive epoxy resin-based grout. Various combinations of these techniques may also be used. I use AISI Type 316 stainless steel for such conservation work because of its very high corrosion resistance. In locations where the problems have clearly been caused by acid recipitation and air pollution it is a false economy to use anything other than such corrosion-resistant material despite its expense.

Any subsequent restoration necessitated by the failure of less durable materials will immediately cost a great deal more than was saved by their use.

Dismantling and Rebuilding

In extreme cases of bulging wythes and in other cases where stonemasonry is unstable, the stonework may have to be carefully taken down and totally rebuilt. Such rebuilding should be preceded by numbering and recording so that the stonework can be restored exactly



Continuous Cleats:
Same metal and thickness as sheet metal specified above. Make cleats at least 38mm wide and folded into stainless steel flashings 13mm as shown. Any seams in the sheet metal flashing are to be formed as double locked cross welts. The upper edge of the flashing is to be secured with No. 8 stainless steel screws set in lead plugs at 450mm centres.

The cleat is to be secured with No. 8 s.s. screws set in lead plugs at 300mm centres. The upper edge of the flashing is to be covered with a neatly struck fillet of 1:1:6 mortar finished with a slightly concave profile. (all parts by volume white non-staining Portland Cement: hydrated lime: sand)

Figure 45. Flashing details.

as it was. Temporary numbering in chalk is placed on the faces of the stone units for photographic recording. When the stonework is dismantled the permanent numbers are painted onto faces which will be hidden in the rebuilding. I normally use exterior quality latex paints for this numbering. A system of temporary and permanent numbering avoids the difficult problem of removing paint from the finished faces of the stone units. Special attention should be paid to recording the thickness of joints so that they can be reproduced. Without this precaution the masonry can never be accurately rebuilt. I usually specify the use of timber or plywood templates or profile boards which are cut to match the vertical profiles of the masonry at various critical points.

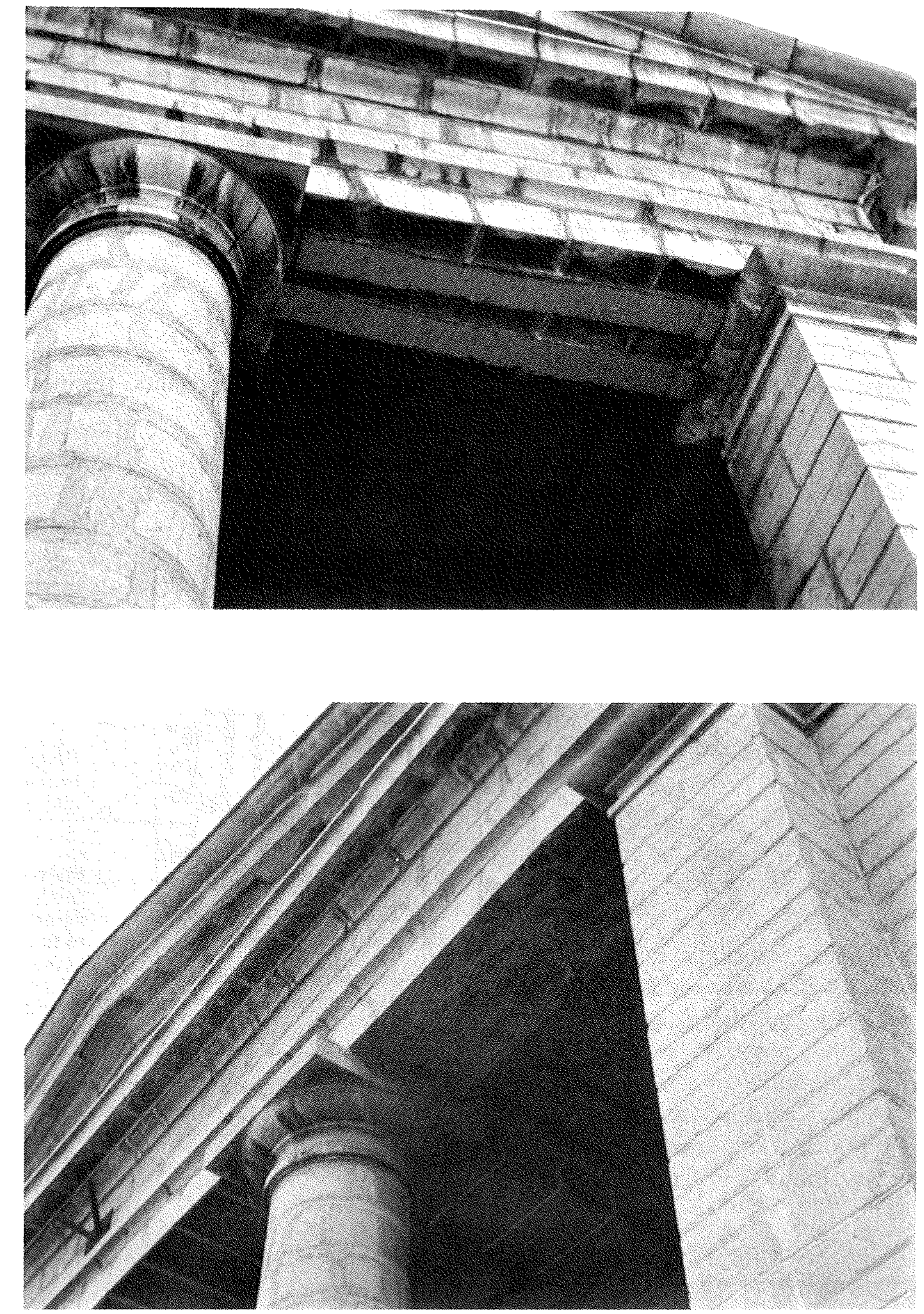
When the stonework is being rebuilt the blocks should be set on soaked hardwood wedges so that they are in their correct positions and so that the mortar has time to cure without the blocks settling out of position. When the mortar has cured, the wedges will have shrunk and can be removed. The resulting holes can be filled with mortar.

Refinishing, Inserts, Repairs, or Consolidation?

Where stones have been dissolved by water or acidic solutions they may simply be reduced in thickness or may have lost binding material to such an extent that they are liable to crumble and fail under load. In the former case the restorer must judge whether the surface loss in any way endangers the continued survival of the stone. If it is merely an aesthetic problem, the stone should be left as it is. Where the remaining surface has a totally unacceptable appearance, it may be redressed or retooled if the original unit is thick enough. If redressing produces too large a setback, the stone block can be carefully cut free and can be advanced and reset. Redressing is not a technique for use in all situations but should be reserved for cases of severe surface deterioration in otherwise sound blocks. Any new stone units which are set into old salt-infested stonework must be isolated from that work by having their back surfaces coated with an appropriate waterproof coating such as a sanded bitumen paint. The coatings should be kept away from surfaces which will be exposed and it is generally recommended that they are stopped about one inch short of the face to avoid staining problems.

When stones naturally containing ferrous compounds are placed in masonry in contact with large volumes of fresh concrete it is also necessary to coat their backs or the face of the concrete in order to prevent reactions with the strong alkalis in the concrete. Indiana limestone is a good example of a stone which suffers from "alkali staining" in just this way. The rust-colored stains are, in fact, formed by ferric hydroxide resulting from a reaction between calcium hydroxide in the concrete and iron ions in the stone.

When fragments of a stone block have spalled off or where critical drip edges have weathered away, it may be necessary to insert a patch into the original stone. The hole in the stone is carefully squared off, with the sides undercut to assist in holding the patch in place. The patching may then be carried out with a piece of matching stone which is carefully cut to match the hole and set in position with dots of a moisture-insensitive epoxy resin. The small gap between the patch and the



Stabilized and restored voussoired stone beam; before and after views, 1840's Gatehouse, Kingston Penitentiary, Ontario.

original stone is then "pointed" or filled with a lime putty or similar mortar to match the stone. As in wood conservation such patches are known as "Dutchmen."

Plastic Repair or Dentistry?

Small chips and spalls may also be patched with "plastic" repairs. A plastic repair is usually a mortar/synthetic resin composite mixed with stone dust and other materials to form a stable patch matching the original in color and texture and which can be placed in position and shaped. It will then cure and harden in place adhering to the prepared surface at the desired location. The adhesion of the patch is additionally ensured by the insertion of threaded stainless steel rods, teflon, or nylon rods or other noncorroding reinforcement into the old stone and through the patch. Any resins used in such mortar repairs must be nonreemulsifiable which

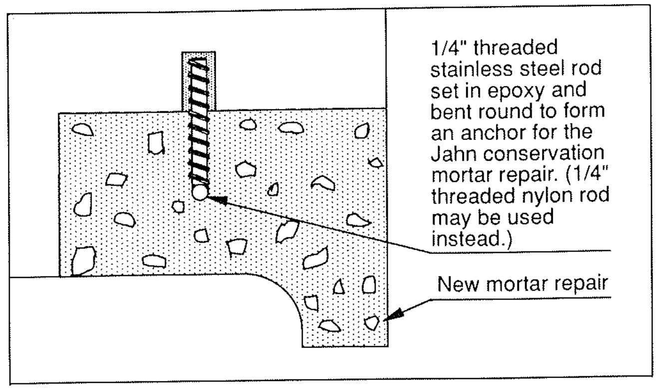


Figure 46. Mortar repair: detail of new patch.

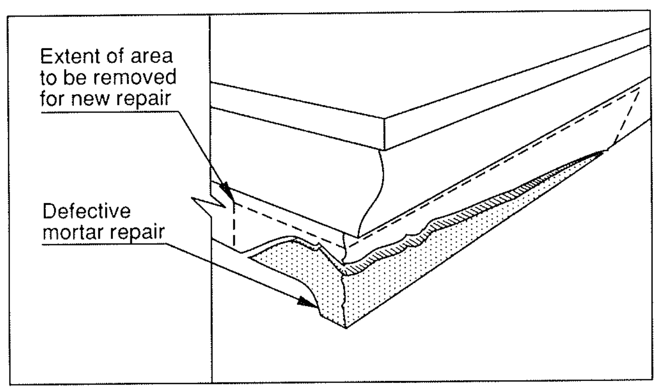


Figure 47. Mortar repair: Vieux de Palais Justice, Montreal, Quebec.

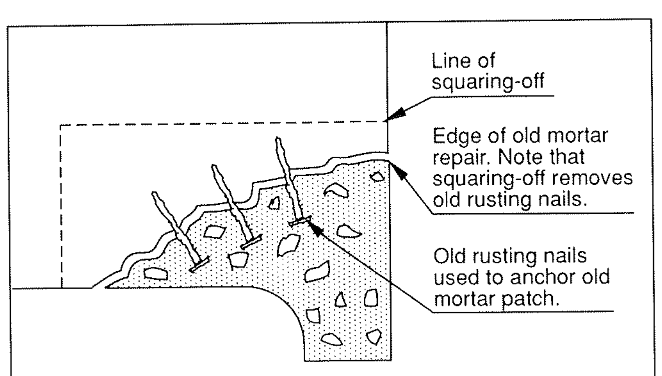


Figure 48. Mortar repair: detail of old patch.

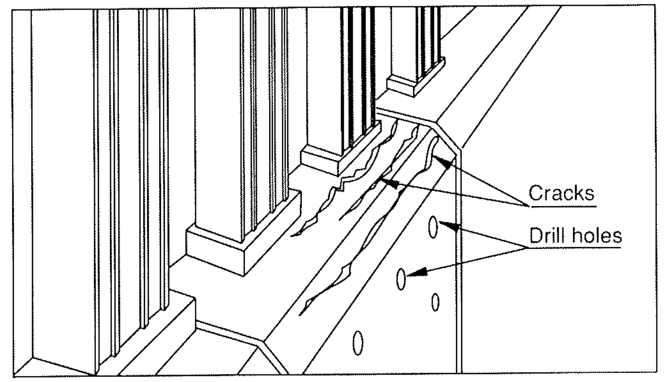


Figure 49a. Stone repairs: perspective view of damaged stone.

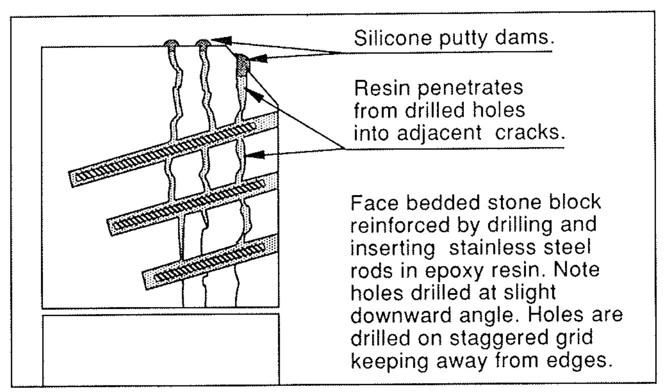


Figure 49b. Stone repairs: section.

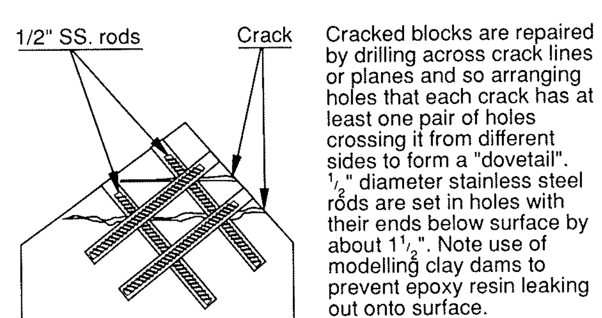


Figure 49c. Stone repair: section of typical coping block.

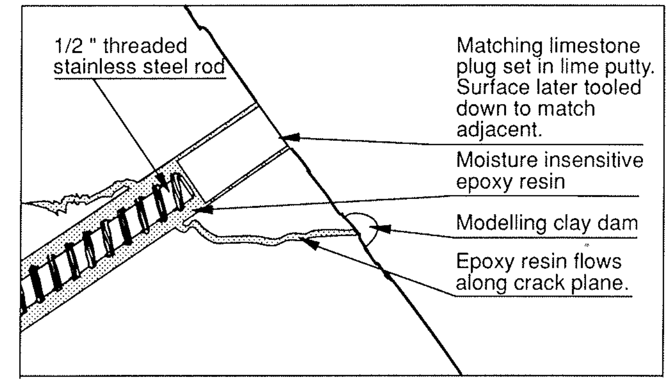


Figure 49d. Stone repair: enlargement of section.

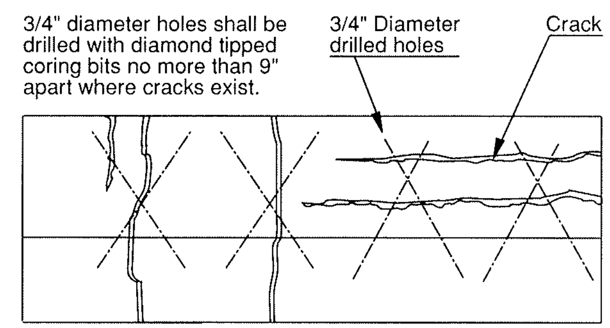


Figure 49e. Stone repair: side view of typical coping block.

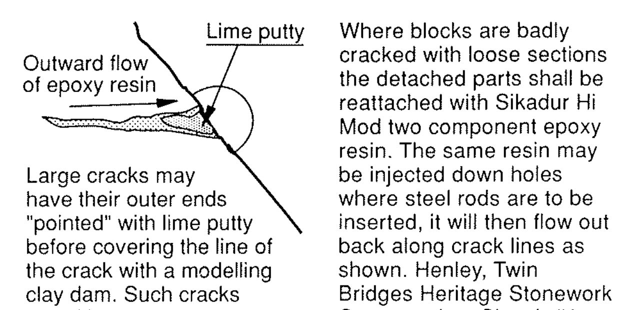


Figure 49f. Stone repair: enlargement of crack.

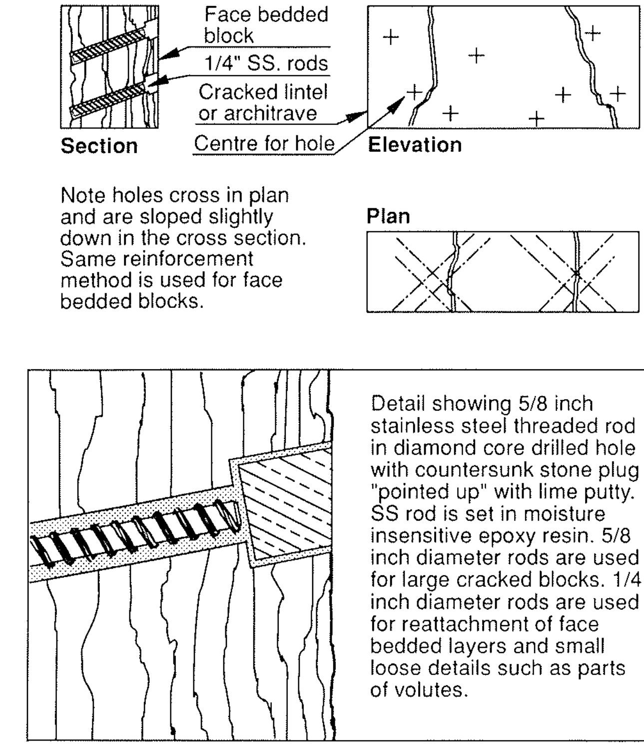


Figure 50. Repair of cracked stone lintels and architraves.

means that when moisture passes through the patch, as it inevitably will, it will not reemulsify the resin and remove it.

Even when synthetic resins are used in such patches, experienced restorers avoid forming thin "feather" edges in the patches because these tend to be brittle and easily break away. Most restorers prefer to leave stones alone when the surface losses are non-threatening, first because restoration is unnecessary but second because the weathered surface of the stone is a part of its history, character, and authenticity.

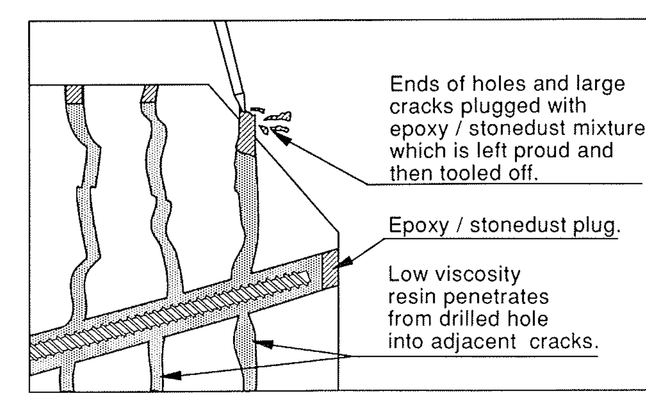


Figure 51. Stone repairs: section enlargement.

Consolidants

Where the loss of binding or cementing materials is causing the stone to crumble, the use of stone consolidants may be considered. Although sandstones, limestones, and some architectural ceramics may be treated with stone consolidants, sandstones with calcareous and argilaceous binders are perhaps the stones most frequently subject to binder or cement loss. The latter have been successfully consolidated with alkali silicates or with various types of alkoxysilanes and synthetic resins such as ethyl silicate, triethoxymethylsilane, or trimethoxymethylsilane. Although these two types of products are the most common, acrylic copolymers, epoxies, polyurethanes, and microcrystalline waxes have had some recorded successes in specific applications. For normal use on the exterior of buildings products of German origin of both types are available in North America. Bagrat silicates and ProSoCo's Conservare alkoxysilanes are the two major product ranges with proven long-term good performances. Consolidation with epoxy/solvent systems rather than pure low viscosity resins is the subject of apparently successful laboratory tests at the Getty Conservation Institute (personal communication). The lack of the frequently problematic darkening and reverse flow of the resin to the surface has been achieved by various means including solvent-saturated atmospheres in plastic film enclosures.

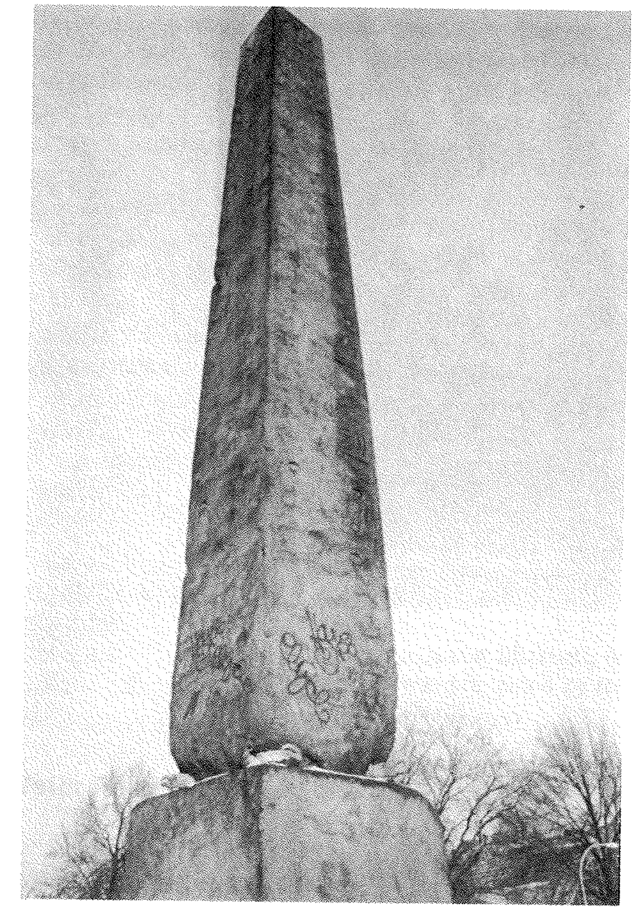
The history of the development of stone consolidants is marked with a long series of failures which have involved subsequent total losses of treated surfaces, severe discoloration, heavy soiling caused by the sticky nature of the treated surface, and many other problems caused particularly by entrapped moisture.

Early attempts to use resins with solvents were continuously dogged by the problem of the resin returning to the surface with the solvent as the latter evaporated. This typically caused darkening of the surface and sometimes an unpleasantly glossy, slick surface because of the resin concentration.

Consolidants will not function as grouts, void fillers, or means of reattaching flaking, exfoliating, or spalling surface layers. Spot use of moisture-insensitive epoxy resins may be appropriate for such purposes.

There have been many failures of historic stones which have been found to have been associated with earlier treatments with paraffin wax and/or beeswax. The "Caffal Process" or "Obelisk Process" which was still in use in the 1920s was based on the use of hot paraffin wax. This process was used on many New York landmarks, including "Cleopatra's Needle" in Central Park, and contributed to the deterioration of the stones.

This core from some historic concrete has been coated with an epoxy resin which has consolidated the concrete but has radically changed its appearance making it darker, yellow and glossy.



Cleopatra's Needle, Central Park, New York, showing deteriorated face.

Salts and Their Removal

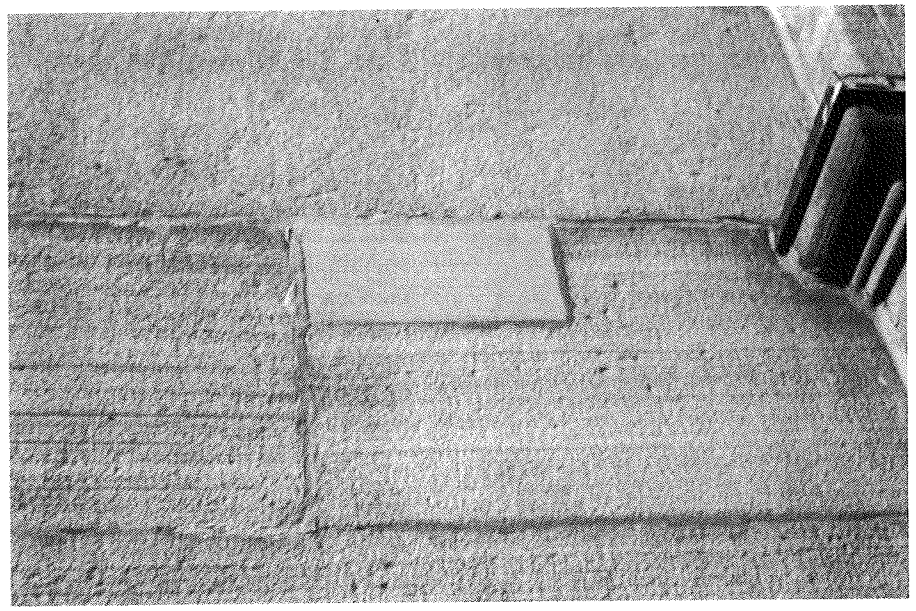
Harmful accumulations of water-soluble salts are best dealt with by poulticing techniques which use "inert" powders which may be mixed with water to form a stiff paste with about the consistency of runny peanut butter or stiff cream. The stiff paste is applied to a lighly wetted surface and then left to dry. In excessively dry or sunny conditions, the evaporation of moisture from the surface of the poultice may be helpfully retarded by covering the poultice with a sheet of polyethylene. The moisture from the poultice soaks into the stone, dissolves the salts, and returns to the surface with them in solution. When the moisture evaporates into the atmosphere, the poultice dries out and the salts are left behind in the temporary surface provided by the poultice, which is then removed. The process may be repeated a number of times to complete the removal of the salts. Suitable poultice materials include diatomaceous earth (available, for example, as Celite which is manufactured by Johns Manville); fullers earth, and kaolinite.

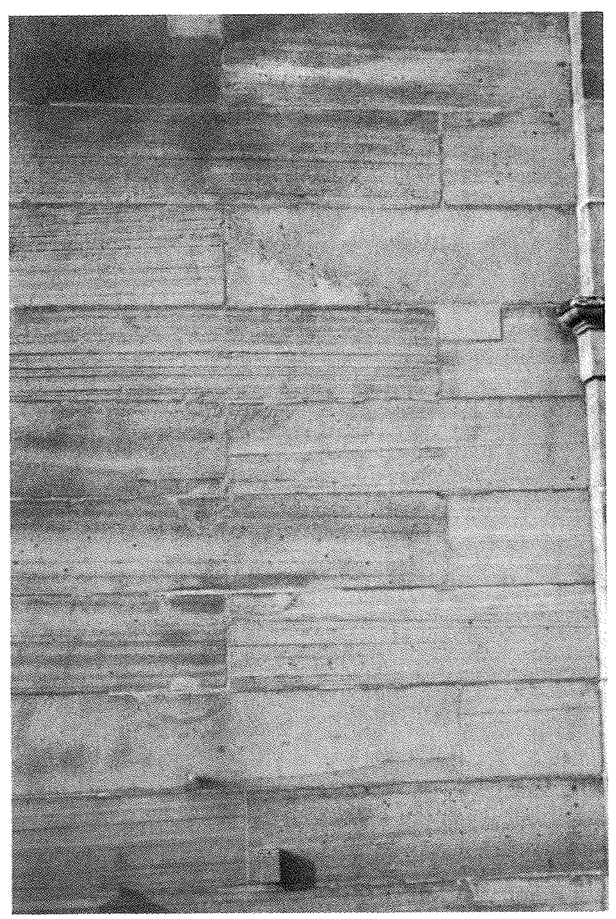
Corroded Metal Elements

Where iron or steel cramps or dowels have corroded and shattered surrounding stonework through the expansion of their corrosion products, it is essential to remove the corroded remains and sulfur settings where these exist. A new cramp or dowel of a noncorroding metal such as an appropriate type of stainless steel may then be substituted for the original.

I have found that the easiest way to remove such corroded remains which may be jammed into the stone, is to drill them out with water-cooled diamond-tipped coring bits. Problems with mortars and repointing raise many major issues which are discussed in Chapter 7.

Poultice of diatomaceous earth and water being used to remove salts.





Repairs of cramp shattered stonework, Oswego, NY.

Median Monument, Queen Elizabeth highway bridge. St. Catherine's, Ontario. Further surface exfoliation was prevented by treating the stone surface with a water repellent.

Water Repellents

A final problem concerns stones which are excessively permeable or which have extensive networks of such small diameter pores or capillaries that they are subject to moisture-related problems. The water or moisture may be eliminated at its source or in some cases the stone surface may be treated with a water repellent or hydrophobic substance.

Water repellents, like stone consolidants, have a long history of unfortunate failures behind them. In situation where there are concentrations of water-soluble salts trapped behind the coating of water repellent, the latter may actually cause the destruction of the stone. In practice, only if and when all other methods for keeping water out of stonemasonry have been tried and found unsatisfactory, then there may be a case for the use of a water repellent. I have been consulted on a large number of cases of stone surface failures which have been traced to the use of silicone and less commonly metallic stearate water repellents. There have, of course, been thousands of examples of treatments with water repellents which have caused no problems but scientific research and field observations have suggested that in a large percentage of these cases there was, in fact, no need for the treatment in the first place. It should be clear, however, that water repellents have proved their value in certain specific applications, particularly where rain and spray are being driven through thin and permeable stonework in very exposed locations. Where such stonework is by the sea and the interior surfaces are powdering and crumbling, then the repellent should be applied to the exterior surface only. Stone window mullions and tracery are particularly prone to this problem.

I worked on a case where an oligomeric alkylalkoxysilane from the Conservare range of products was used to protect the surfaces of some vintage bridge pylons and median monuments built of dolomite. Fast moving trucks and cars constantly bombarded the surfaces of the stone with high velocity sprays of polluted water from puddles, causing deep penetration of pollutants and consequent damage. The additional feature of the alkali resistance of the selected repellent makes it an almost essential conservation material in this case because it will not be affected by the alkalis in fresh mortar or concrete used in the restoration work. Conservators generally agree that most water-repellent treatments are carried out unnecessarily and have added what may have been a substantial cost for no particular benefit. Most water repellents break down after a number of years and cease to function. Unfortunately, they do not break down evenly and can cause unsightly blotches and patches on surfaces as they deteriorate. Having broken down, water repellents then require replacement but difficulties of access usually prevent this essential maintenance.