Earth, air and water

Principles

2.2 Co-operation among specialties
2.3 Work in order
2.4 Work at right pace
3.3 Informed reconnaissance/ inspection
3.4 Archaeology (site & structure) for reconnaissance
4.5 Respect for setting/context in community
4.6 Minimal conjecture/informed invention
5.4 Archaeology (site & structure) for rescue of artifacts
5.8 Moving as last resort
6.2 Maximum retention
7.7 Gentle cleaning

References

For background on soil and topographic considerations in conservation, see CHAP66, CURT79, FLAD78, THOM81 and TREA80. For more general issues of environmental context, seeKING77, LANG80, TECH86 and WEAV87. For health, safety and environmental hazards of conservation activities, see FEIL82, FERG86, FLAD78, HIGG85 and MCCA85.

How the ground affects the building

The type of soil, depth of water table, and slope of ground surrounding a building all combine to influence the building itself, its stability and the condition of its materials over time. Many forms of deterioration can be traced to poor foundations, and these in turn to inadequate strength in soils or a high water table. In rocky areas of the Canadian Shield or the limestone plains of southeastern Ontario, even small buildings may rest directly on solid rock; though the foundations may be solid to start, high moisture and even running water beneath the building will hasten deterioration above.

Where a building (urban or rural) sits on soil, the level of surrounding ground will often be different from the original condition, usually higher, on account of waste disposal and growth and accumulation of vegetation. Where this change in grade has altered drainage or covered previously exposed features, then corrective measures should be taken, both to reveal historic details and to preserve historic materials.

Regrading to historic contours

❖ Remove earth buildup at foundation walls, taking the level down to or close to the original level, which may be visible as a change in materials — for instance, the line between masonry walls above original grade and stone rubble at and below grade.

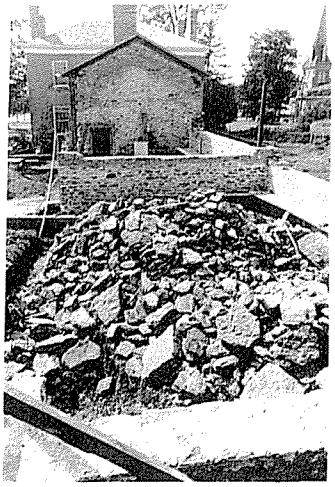
❖ Where historic contours cannot be achieved because of subsequent alterations, ensure that soil surrounding the foundation is well drained and that water drains away from the building.

The perils of backhoe archaeology

❖ Do not dig on a property before determining the likelihood of archaeological finds. Do a thorough archaeological investigation before any ground is disturbed and, where there is a strong possibility of finding buried artifacts, ensure that someone with archaeological qualifications is at hand (see ARCHAEOLOGICAL INVESTIGATION AND REPORTING, and SURPRISES).

❖ Take the same precautions as you would for buried utilities. Dig by hand rather than machine anywhere there is likelihood of disturbing buried objects.

If water-table conditions change outside, it may be necessary to undertake major drainage repairs to prevent problems inside (below).



EXTERIOR CLEANING

For information about masonry cleaning precautions, see HIGG85. Contact a municipal environmental official or the Ministry of the Environment about questionable areas that may be regulated by legislation; see the appendix, "Codes and regulations for conservation work in Ontario".

Environmental impacts on buildings

- Many causes of building faults are environmental, that is, under very little if any immediate control (see FAULT DIAGNOSIS). Preventative measures may be taken against some of these, however, and periodic inspection and maintenance of heritage properties should take these into account — ensuring that rainwater disposal is functioning well to avoid buildup of acidic precipitation against vulnerable surfaces, and so on.
- Human use can wear floor and stairway surfaces beyond safe limits, especially in buildings now in public use that were formerly domestic. Vulnerable wooden surfaces should be covered or foot traffic rerouted away from them, and similar measures taken for any areas subject to heavy use.
- The use of salt on exterior walks and drives, and its splashing against exposed walls, comprise a major cause of deterioration. Common salt should not be used as a de-icer anywhere near a building; instead, use calcium chloride (more expensive, but non-corrosive) or clean sand. Sand should be the *only* de-icer used near any important landscape feature with vulnerable vegetation.

Conservation's own environmental impacts

- Be more than careful with any conservation treatment that uses toxic chemicals. Check first with environmental officials if there is no information readily available about safe use and disposal. For example, ammonium hydroxide may be useful for cleaning masonry, but cannot be allowed to run off the building face into the ground — a temporary gutter must be placed around the base of the surface being treated (and the cleaning solution recycled and disposed with special care).
- Manage the movement of people and materials with care. Precautions that should be part of any construction project — location of waste disposal dumpsters, truck access to the site, workers' safety on scaffolding, and so on — take on added importance in conservation work because of the sometimes restricted site.

Graphic demonstrations of chemical erosion from environmental sources that could have been prevented by closer attention to maintenance — bird droppings (opposite) and de-icing salt (right).

Vegetation

Principles

2.4 Work at right pace
2.5 Appropriate skills
3.2 Thorough and documented research
3.3 Informed reconnaissance/inspection
3.5 Specifics of uniqueness (pattern, ensemble, detail)
4.4 Respect for uniqueness (pattern, ensemble, detail)
4.5 Respect for setting/context in community
4.6 Minimal conjecture/informed invention
5.2 Fitting use of existing spaces
9.2 Faithful maintenance

References

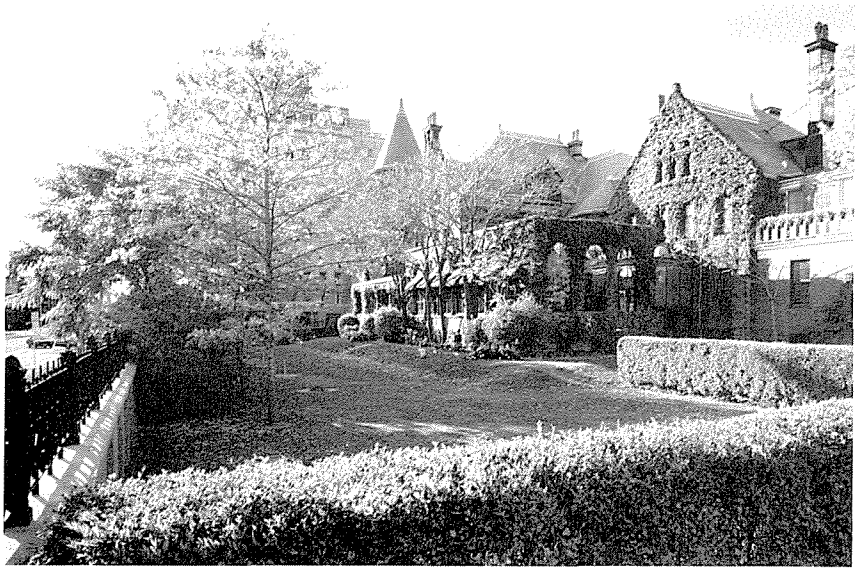
Background material on the evolution of some of Ontario's green landscapes can be found in GENT84, HILT86 and LANG78. See MADD85 and NEWC79 for more general information on landscape conservation. The problems of vegetation and buildings are treated in JOHN84, MELV73 and STAH84.

Garden restoration is a specialized field whose technical information resides mostly in specialized journals, though see VONB84 for a good historical survey of what types of landscaping would be appropriate for specific contexts.

Vegetation and buildings

Trees, bushes, vines, hedges and lawns are both assets and liabilities when close to buildings. Most people prefer the contrast between "natural" plant materials and buildings to the absence of greenery. Charm is not a negligible factor in arguing for conservation, and much of the attraction of many old structures consists in their being clad in ivy or creepers, shaded by towering trees, or hemmed in by dense and often colourful foundation planting. Indeed, historic views of homes of the late 19th and early 20th centuries, particularly in the Queen Anne style, often show climbing vines which were as much a part of the overall look and feel of the style as the trellises on which they grew. Shade trees have always been highly regarded companions to buildings, but shrubbery as foundation planting is a more recent taste.

Under many conditions vegetation can draw excess moisture away from a building and shade roof and walls from sun, wind and rain, thereby moderating extremes of weather on those surfaces. But under other conditions it may hold moisture near the building by restricting ventilation. Some planting coexists peacefully with architecture, but some may cause great damage. In all cases, regular attention is needed to detect small problems before they become serious.



Clinging vegetation can be a very attractive part of the character of an older building — but it must be checked constantly, and removed if it is causing damage to the materials or structure of the building.

- Use or maintain trees that offer summertime shade to building surfaces and openings, but keep them far enough from the building to avoid root damage to foundations and walls.
- Keep eavestroughs and drains free of leaves and roots. Carefully trim vegetation around windows and doorways.
- Vines must not be permitted to extend rootlets into the walls, especially into masonry and mortar. Creepers that root in adjacent soil are generally satisfactory, *but avoid or remove any common ivy* (only the variety known as Boston ivy does not extend its hyphae into building cracks). Because the leaves of creepers shade walls, they also keep the walls humid, and this condition must be monitored constantly to prevent deterioration. Clinging vegetation is contentious among conservation professionals (one claim is that climbers help neutralize acidity in rainfall and thereby help protect walls from deterioration).
- Watch the building carefully through periodic inspections; if problems of moisture penetration or physical damage can be traced to vegetation, trim or remove it.
- Ensure that trellises and other woodwork supporting climbing plants are not overloaded by the weight of greenery. Make sure that birds do not nest in the shelter of climbing plants close to building walls.

Removing destructive vegetation

- To remove ivy, sever the vine from its roots and remove all vegetation within reach of the ground. The remainder will dry out and shrink and can then be readily removed. Do not pull living vegetation from a wall, lest bits of the wall come with it.
- Roots of not-yet-mature trees near building foundations may invade drains or push foundations so hard that cracks appear in the building. Mature trees are unlikely to alter what is probably a stable situation. Underpinning the structure to remove obvious stress will be expensive.

THE FLORENCE CHARTER

There is an international statement of conservation principles for historic gardens: the Florence Charter of 1982, promulgated by the International Council on Monuments and Sites (ICOMOS). It parallels the Venice Charter (see Appendix 6). It recognizes the living and changing nature of gardens and landscapes and seeks to preserve their spirit and form in overall design and in detail, distinguishing clearly the historic garden as a surviving artifact of the past from what it calls "reminiscence", a conjectural reconstruction that is *not* deemed historic.

Removing the trees requires poisoning the roots and waiting until ground conditions become stable, which may take several months.

❖ After removing vegetation with significant root systems, postpone permanent structural alterations until the foundations are stable.

Garden restoration

Restoring gardens is a very specialized area of expertise; even with early written accounts of a property and the research of palaeobotanists, much restoration may be conjectural.

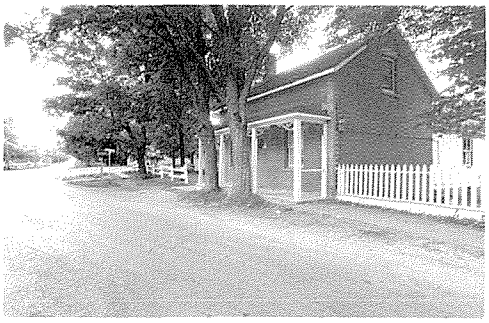
❖ No restored or re-created landscape should be presented as "authentic" without full research and documentation. Historic photographs are especially valuable.

Use period drawings or engravings cautiously, especially those in the many county atlases of the 1860s to 1880s; many views were edited to reveal buildings on their sites or to enhance hoped-for growth of recent plantings.

❖ Gardens and landscapes should be sympathetic to the architecture they surround. For visual clues to help create modern gardens in the proper spirit, historical atlases can indeed be useful.

❖ Dense foundation planting around dwellings was not 19th-century taste; it is thus not an authentic "historic" treatment for early residences (certainly not before the "Craftsman" style of the 20th century) and should not be used or represented as an earlier form of landscaping.

In the rare cases where there is photographic evidence for a historic landscape, it is especially important to note how the garden was integrated with the building — or not.



The small trees planted to match the central columns of the porch have now grown to shade the entire house, a rare effect which adds great visual interest to the house and to the street.

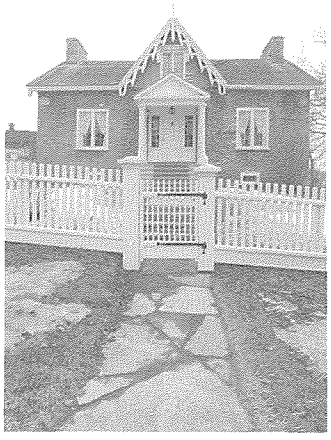
Spatial definition and hard landscaping

Principles

2.1 Co-ordinated work
2.5 Appropriate skills
3.2 Thorough and documented research
3.3 Informed reconnaissance/ inspection
3.4 Archaeology (site & structure) for reconnaissance
3.5 Specifics of uniqueness (pattern, ensemble, detail)
4.4 Respect for uniqueness (pattern, ensemble, detail)
4.5 Respect for setting/context in community
4.6 Minimal conjecture/informed invention
5.2 Fitting use of existing spaces
5.4 Archaeology (site & structure) for rescue of artifacts
5.8 Moving as last resort
6.2 Maximum retention
8.6 Aided access
9.2 Faithful maintenance
9.4 Conservation commemorated

References

For general background on appropriateness of treatments, see the references to the topics under *Environment* and *Design*. For paving and other horizontal surfaces, see BALL83, CHAM76, DAVE80/86, FEIL82, RESE85 and VONB84. For walls and other masonry structures see BROO77, CONS82, DAVE80/86, GRIM84, OEHR80, POWY29 and WILL83.



Fences, lawns, gates, paving, symmetry, formal axes — all enhance the formal approach to a building, even adding a touch of modest ceremony.

The value of surroundings

The space around a building is both its visual setting and its physical means of access. When a building is completed and first used these twin functions mesh well, but often the demands of one overwhelm the other with time and changes in use. The surroundings of a building lie between the public space of the street and the private spaces inside. In Ontario, if there is any barrier between public and private worlds, it is almost always a fence that may inhibit physical access but invites the eye to look past it to grounds and the building beyond. This intervening space is in private custody but public view — "semi-private". It must be respected, for the way in which we appreciate architecture depends on how we view it, across a greensward or close up against a sidewalk.

The "picture-postcard" view includes the space that sets the building apart from its neighbours and from the viewer. This space, with its topography, greenery, furnishings and lighting, is as important to the heritage value of the architecture as the structural foundations on which the building rests.

The surfaces of this space, particularly its hard surfaces, are also part of the architectural experience of the place as a whole. Traditional paving materials and patterns — of wood, stone, asphalt, brick, concrete, even gravel — have demarcated areas functionally but they also provided visual and tactile delight in their colours and patterns. Though limited in number, they have been used with great inventiveness in many combinations.

Many elements within these spaces and along these paths — walls, terraces, sculptures, monuments — are vital to the heritage value of a property. Their conservation may present the problems of entire buildings on a much smaller but no less serious scale.

Outdoor "rooms", public use and access

- Recover and maintain as much as possible the historic approaches to and through a property. Use historic documents and photographs to determine earlier configurations. For instance, do not presume that a classical building necessarily sat in a classically geometrical landscape.
- In exploring the archaeology of a property's grounds, look for traces of former pathways, terraces, walls and ornamental structures.
- Try to maintain the traditional sense and character of front yards, side yards, and back yards characteristic of Ontario residences and institutions. The public view across a lawn is an essential part of "massing", acting as a visual base of green that sets off the principal façade.
- Do not block principal ("postcard") viewing angles with intrusive new elements in the landscape; instead, use any new elements to help define the historic spatial character.

Conserving paved areas

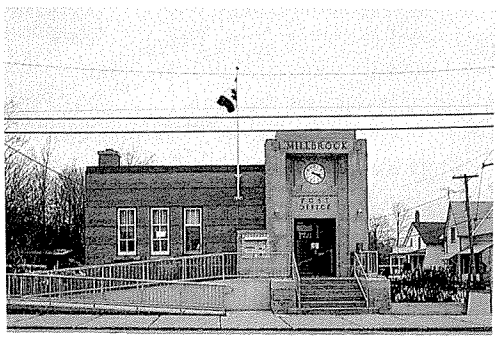
- Ensure that paved areas are properly drained; there should be no standing water after rainfalls. Ensure that surfaces have no abrupt breaks, unless intended to be full steps. Repair or replace broken or heaved units and fill potholes promptly. Keep moss and lawns well trimmed, but do not remove greenery where that has become a comfortable part of the pattern of paving units such as flagstones.
- Maintain and conserve existing surfaces; repair or replace only deteriorated units (individual bricks or stones).
- New paving surfaces should harmonize in colour and visible texture with adjacent buildings. When using paving units, avoid standardized treatments that have no local historical precedents, such as interlocking pastel-coloured concrete tiles in "modern geometric" patterns. Paving units that *do* have extensive Ontario precedents are non-interlocking brick, flagstones, asphalt blocks, wooden blocks on end and granite setts.
- Do not destroy steps or parterres to install ramps for aided access; add ramps alongside rather than over top, in order to provide a suitably shallow slope and to avoid making the steps themselves additionally hazardous.
- To make aided access discreet, convenient and safe, change the adjacent grade level and slope, where possible, rather than

build a ramp structure. Make sure that added slopes and ramps are safe. Use proper lighting. Combine safety and visual continuity by choosing railings compatible in form, material and colour to the delicacy or robustness of the existing building and non-slip surfaces in harmony with other outdoor surfaces (see PROGRAMMING AND USING SPACE).

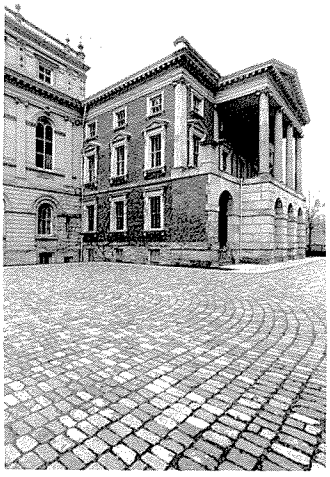
Walls, fences and monuments

- ❖ Keep walls, fences and other boundary features in their historic locations and configurations.
- ❖ Keep retaining walls in good repair, with special care for water drainage around and beneath them. Ensure that the uphill side does not trap water and ice against the wall (see FOUNDATIONS).
- ❖ If openings are required in walls or fences, make them in the pattern of materials and techniques typical of historic practices for gates, gateposts, and so on. New openings in walls should not masquerade as "old", but should correspond to earlier practice in proportion and material. For walls, follow good practice guidelines for appropriate materials (see MASONRY and STUCCO, CONCRETE AND COMPOSITES).
- ❖ Maintain historic lamp standards and lighting fixtures where they survive; consider reproducing missing lamp standards from historic photographs and documents. Though numerous cast-aluminum reproductions of cast-iron originals are available, use only those that match closely the size and proportions of the originals as shown in documentary sources. Use incandescent luminaires to correspond to historic colours of light (see PAINT, COLOUR AND LIGHT).
- ❖ Some patterns of cedar-rail fencing are meant to be relocated, to periodically redefine pastures or livestock runs. Replace deteriorated posts or rails in kind and do not permanently fasten them with metal connectors that may hasten decay of the wood. Pay close attention to how the pieces go together when taking apart and reassembling these fences — local variations in assembly may be subtle indicators of regional cultural heritage.
- ❖ Most deterioration of freestanding sculptures and monuments begins with ill-advised repairs to "correct" much less serious decay. Do not use supposed "high-tech" repairs without thorough independent testing and consultation with experts. *Epoxies that inadvertently block or redirect moisture movement within the repaired materials may cause extreme deterioration within months.*
- ❖ Use chemical "aging" treatments for metals with *extreme* care, and only when existing and repaired material look too different to be perceived as the same material.

See also CEMETERIES AND PRESERVED RUINS.



Traditional hard-paved surfaces include industrial brick and granite setts, which are much more durable and fitting to historic architecture and districts than the standard interlocking concrete pavers often used erroneously as "heritage" paving (right and below). Ramps are often necessary additions to historic buildings, but they cannot be designed and built by formula. They need to be fitted carefully to the individual character of the building and its setting — one solution won't automatically be correct for other cases (bottom right).



Cemeteries and preserved ruins

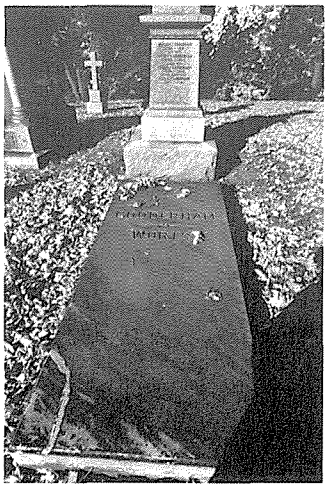
Principles

2.1 Co-ordinated work
2.2 Co-operation among specialties
2.3 Work in order
2.4 Work at right pace
2.5 Appropriate skills
3.4 Archaeology (site & structure) for reconnaissance
5.4 Archaeology (site & structure) for rescue of artifacts
5.5 Minimal emergency action/ stabilization to buy time
5.8 Moving as last resort
6.2 Maximum retention
6.5 Safe working conditions
7.1 Traditional repair (proven technology)
7.4 Cautious high-tech repair
7.6 Maintainable repairs
9.4 Conservation commemorated

References

On cemeteries, see BROO77, CONS82, DAVE80/86, GRIM84, HANK74, NETH81, OEHR80, POWY29 and WILL83.

On the reinforcement and temporary protection of ruined structures, see especially BAXT86, JONE86, KEMP81 and PICH84/84a. On their permanent conservation, see FEIL82, FITC82, FROI86, POWY29 and THOM81.



Monuments on the ground are especially vulnerable to ice damage — water must be made to drain away quickly before it penetrates the surface.

Cemeteries

Grave markers and monuments are exceptionally valuable cultural artifacts, revealing artistic and social concerns of our predecessors in landscapes that are often of exceptional charm. But cemeteries pose very difficult conservation problems, materially and procedurally.

Grave markers sculpted from the relatively soft stone used throughout the 19th century are extremely vulnerable to atmospheric agents of erosion, especially to acidic precipitation — driving rain and snowdrifts push acidic moisture into the pores of limestone and sandstone, where it chemically and physically degrades the stone. Though most good building and sculptural stone develops a hard and durable surface patina with age and weather, microscopic cracks may allow moisture to penetrate; ice and salt crystals then simply pop the skin off the stone. Even granite is vulnerable to this process of decay. Weather erodes most surfaces over long periods, but the more rapid decay of the vulnerable lettering on grave markers lends deteriorated cemeteries particular poignancy. Occasionally very old wooden markers and iron fences survive — even more delicate and difficult to preserve *in situ*.

All conservation work in cemeteries must be preceded by careful inventory and analysis, as is true for any other conservation project. But additional legal concerns must be dealt with under the provincial Cemeteries Act: municipal permissions, notification of descendants, and so on. In the case of burial grounds not currently cared for, it may be difficult to find funds and people to take responsibility for conservation and maintenance. These matters must be addressed during research, inspection and planning, before any major work begins.

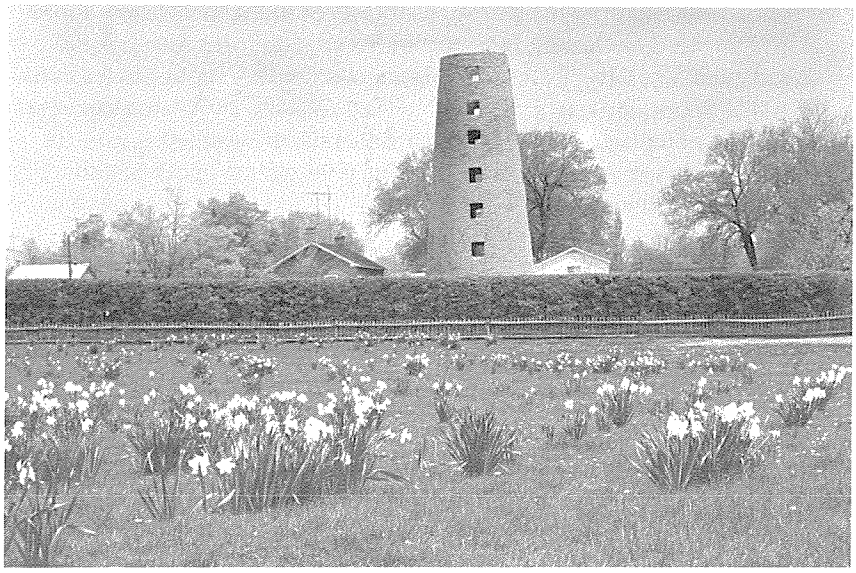
- Concentrate efforts on maintenance and on stabilization and arrest of further deterioration — don't try to restore an earlier, fresher appearance to monuments and markers. Keep vegetation carefully cropped and settings well maintained.
- Ensure that landscaping and drainage problems are corrected before conserving individual monuments. Water must be drained away from the bases of monuments, ideally by subtly adjusting grade and slope rather than by raising monuments on new plinths. Fill in rather than dig. In damp areas, maintain a gravel border surrounding the monument to drain moisture and to keep vegetation (and lawnmowers) from damaging the stone.
- Do not use concrete plinths to "protect" monuments; destructive salts may migrate into the stone from the plinth as the cement in the concrete cures. And the many small cracks often found in concrete will draw water up from damp ground and let damaging salts attack the stone.
- Retain and conserve monuments and grave markers in their original locations, upright, unless so far deteriorated that they would be quickly obliterated or destroyed by remaining in place (either through continuing degradation by the elements or at the hands of vandals). In cases of severe weakness, consider adding subtle, non-rusting reinforcements of treated timber or metal.
- If stones already laid flat for some time are sound and not deteriorating, leave them lying but protect their perimeters from damp and vegetation (see above). Consider removal of markers to protected "commemorative walls" or interior galleries only when there is no other way to protect them from further decay. And *never* embed the markers in concrete.
- Use "high-tech" stone consolidants and epoxy repairs with *extreme* caution, and only after thorough independent testing and consultation with experts in stone conservation. Ensure that any compound used in repair has the same or perfectly compatible chemical and physical properties.

See VEGETATION and MASONRY.

The uses of ruins, *in situ*

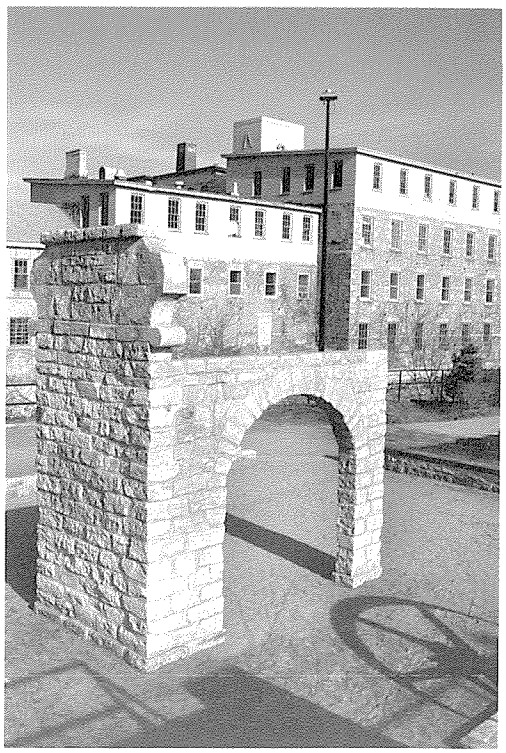
Ruins have popular romantic appeal, but they are not heritage resources in the same sense as buildings in use — they are preservations of destruction more than reminders of a living community. The original building's use and heritage are only incidental to the fantasy evoked by the "ghost walls" that have survived while the real life has disappeared. Ruins may be much like the myth of "nature", inexplicable and mysterious. They are museum objects — fragments of a once-whole building — taken out of context for display and enjoyment (even though still on their original site). There remains only a portion of heritage value in a preserved ruin.

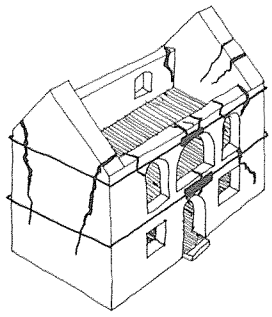
Ruins have romantic appeal as "memorials" of historic activities, and more pragmatic use as "punctuation" in designs for public parkland.



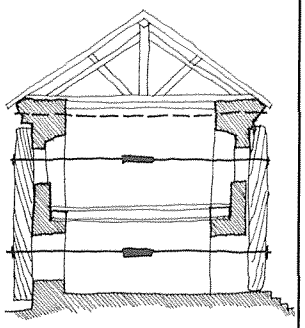
Deliberate "ruinification" of a building is *not* heritage conservation. But in the wake of inadvertent and tragic destruction, conserving the remains of a heritage resource in ruined form may be appropriate if the material and structure are suitable and if the use and maintenance of the conserved ruin are assured for the long term.

- ❖ Inspect and diagnose the existing building thoroughly before undertaking any irreversible work. Follow the procedures in INSPECTION, FAULT DIAGNOSIS and PHASING AND SCHEDULING thoroughly and in strict order.
- ❖ Ensure that every surface that may be subject to weathering is able to survive such weathering; remove or provide suitable protection for former interior finishes.
- ❖ Make sure that surviving features are structurally stable, by underpinning and consolidating foundations, regrading to shed water away from the ruins, reinforcing unsupported walls either internally or with external bracing, and protecting all wall surfaces from moisture penetration, especially parapets and other horizontal surfaces.

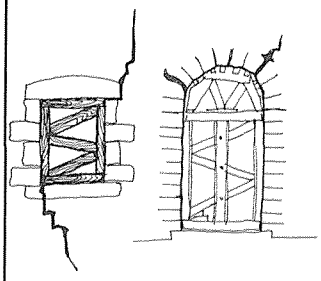




STRAPPING AN UNSTABLE BUILDING



TEMPORARILY REINFORCING OPENINGS



Temporary stabilization

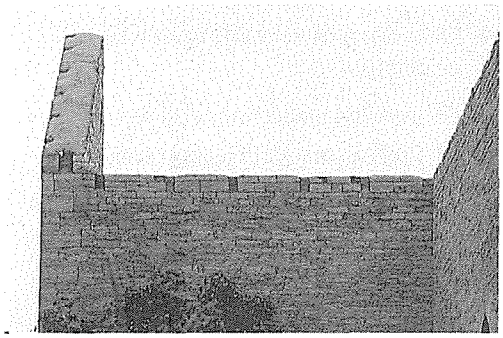
- If there is any instability in any portion of a partly destroyed building, exercise extreme caution in permitting access or stabilization work; if necessary, do recording work remotely, with binoculars, cameras, photogrammetry and thermography, as required.
- Undertake no remedial action without the advice of a qualified engineer *with experience in older structures.*
- Properly anchor or found temporary braces and props; place no additional loads on the structure itself, except to relieve existing stresses and restore equilibrium. Pad all props, straps, cables and beams with balks of timber to protect the building's surfaces.
- Make sure that props do not puncture or damage the fabric of the building; where possible place braces in window openings to stabilize both sides of a wall in all directions. Temporarily reinforce window openings by filling them in with heavy timber props or concrete blocks.

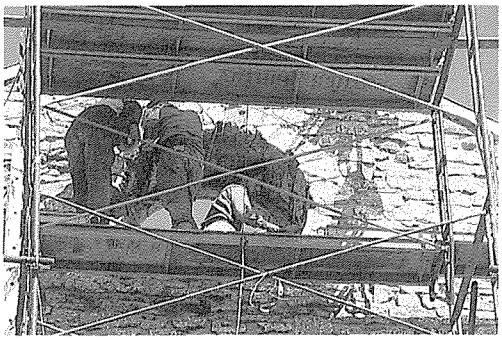
Permanent preservation and maintenance

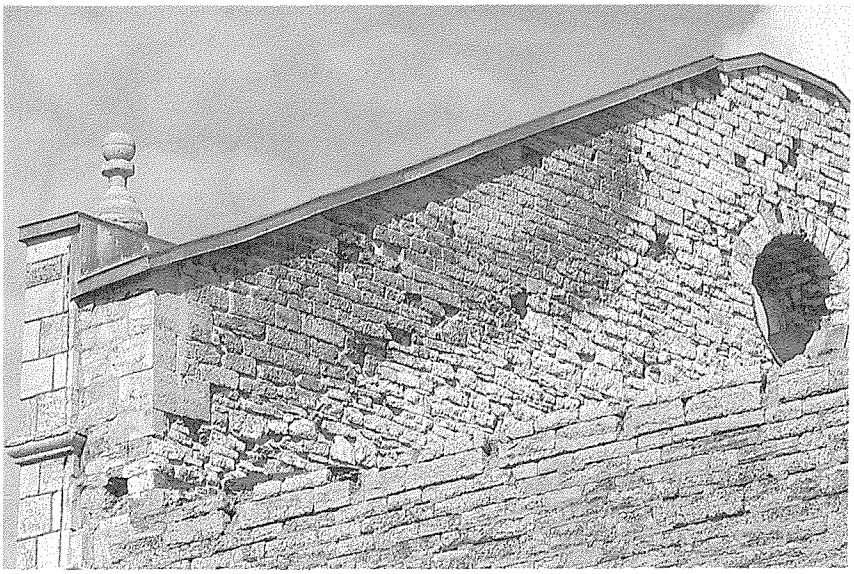
Former buildings or structures can be permanently stabilized in such a way as to hide the means of their stabilization or to expose them conspicuously. Either approach is satisfactory on its own, but half-measures are likely to be unsatisfactory both functionally and aesthetically. Original materials and construction may determine which approach is best. Thick walls of brick or stone can be stabilized, reinforced, and made weather-resistant by hidden or subtle means. But it is difficult to preserve structures of timber or combinations of several materials without putting a great deal of the preservation treatment on display as well.

- If a ruin is to be treated in a conventionally "romantic" manner (see above) make all traces of structural stabilization and weatherproofing inconspicuous or hidden. Vertical buttresses should be of the same material as surviving walls, but subtly distinguished from them. There should be no obviously new horizontal projections of parapets or sills.
- Drainage of water away from the ruin must be inconspicuous; use subtle regrading and gravel bedding around the perimeter rather than constructing a plinth.
- If a ruin is to be treated as a sculptural artifact, with little regard for the evocation of "atmosphere", make techniques of stabilization and protection clearly visible, even to the point of erecting a structure or armature to support the ruins, shelter and protect them from weathering, and even allow for viewing at upper levels. In this case, elevation on an artificial platform or plinth would be perfectly in character with the rest of the treatment.
- Design all horizontal surfaces to shed water completely and to keep moisture from entering hidden spaces inside a wall. But since no treatment will be perfectly waterproof, provide ventilation to enable moisture to evaporate rather than be trapped in a way that would cause freeze/thaw damage.
- Design and construct protective details that are adjustable and repairable. Accommodate expansion/contraction and freeze/thaw cycles — and the consequent structural movements. Unheated structural remains will have to bear daily temperature extremes well beyond those endured by normal buildings.
- Inspect vulnerable surfaces frequently — especially horizontal areas — and make repairs as soon as signs of deterioration appear there or in the walls below. Ruins require very special care: they lack the constant maintenance routine that a lived-in building receives, and their surfaces are often vulnerable to weathering from all sides. Keep vegetation under careful control.

It is difficult to adequately protect ruin walls of stone or brick from water penetration. Designs must incorporate parapet or coping details that both shed water and allow trapped moisture to migrate or evaporate without causing damage to the wall, especially in its core. Any conservation treatment must be backed up by regular inspection and maintenance. In this case, the earlier asphalt and concrete caps did not keep water out of the walls, but rather trapped it inside. The newer metal caps intrude somewhat on the "romantic" image of the ruin, but they mean to do a better job of protecting the material and structure.







Stabilization during repairs

Principles

2.1 Co-ordinated work
2.3 Work in order
2.5 Appropriate skills
2.6 Second opinions when in doubt
5.1 Priorities of features, priorities of work
5.9 Façadism as last resort
6.5 Safe working conditions
7.1 Traditional repair (proven technology)
7.4 Cautious high-tech repair

References

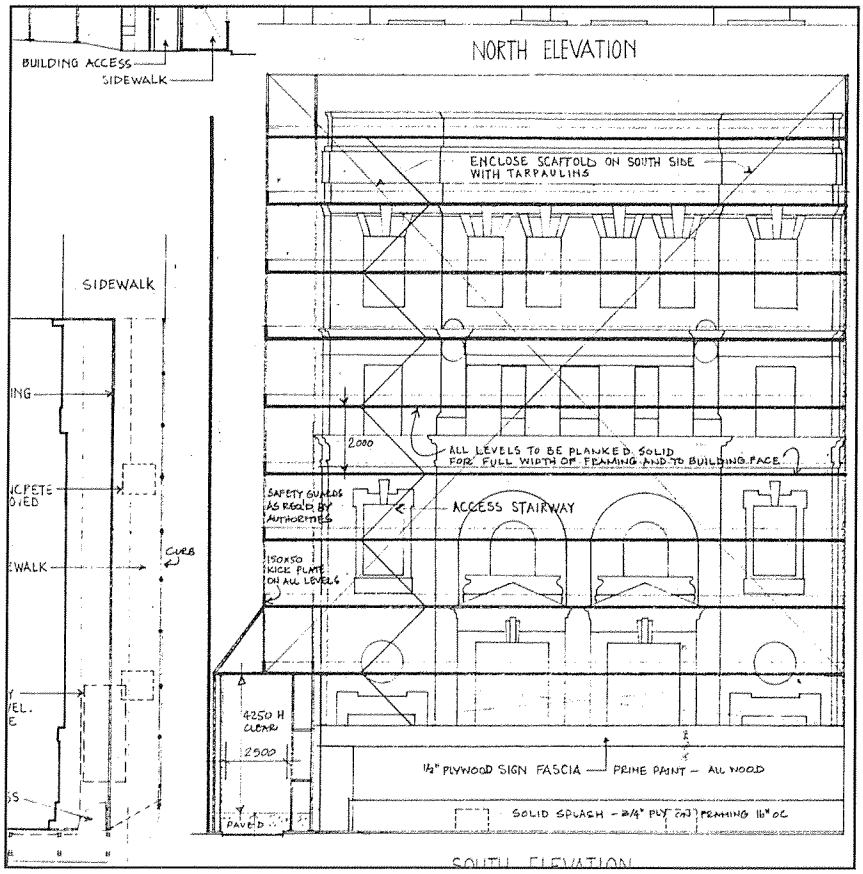
For general references on the maintenance of safe conditions in the course of conservation work, see FEIL82, FERG86, FITC86, FROI86, HODG07, INSA72 and LEVI78. Specific attention to stabilization and reinforcement of weakened or damaged structures during repairs is given in BAXT86, CURT79, JONE86, MACG71 and PICH84/84a.

Scaffolding

Even the smallest building conservation projects require scaffolding as a work platform for everything from initial inspection to final painting and cleaning up. Scaffolding at its most basic is a plank between two stepladders (a single ladder is not a suitable working platform), but work beyond that rather short reach requires steel-tube scaffolds with platforms of wooden planks or steel grating.

Full-scale scaffolding is usually separate from specifications for conservation work and normally the responsibility of the contractor, not the client or consultant. Nevertheless, its uses may go beyond serving as a platform for the contractor. Owners should try to take advantage of these opportunities. Normally, scaffolding has to be erected for exterior work to the full height of the building, sometimes for interior spaces as well. Because of its expense and the time needed to erect and move it, it may loom large in budgets and schedules.

❖ Ensure that scaffolding is provided, erected and maintained by experienced crews under safe conditions.



❖ Provide scaffolding of sufficent strength and stablility to meet the most strenuous demands of the project (usually heavy-material lifts and movements). Scaffolding must satisfy applicable standards and regulations for loading and height. Construction hoists must not exceed the scaffolding's capacities.

❖ Make sure that all scaffolding is well founded and braced, that its weight is not concentrated at points where it will subside or damage building or site, and that building surfaces are protected from stains or impacts by timber balks. Provide safety and weather protection as needed — railings and platform guards for work at any great height; windscreens, tarpaulins and even roofing for bad-weather work.

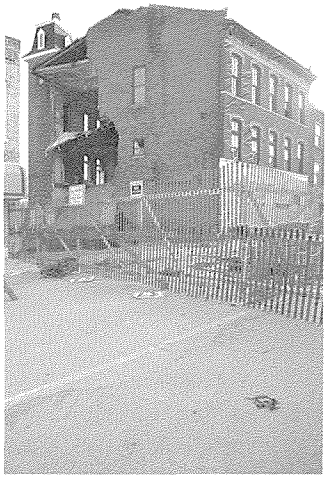
❖ Make the most of scaffolding when it is available:

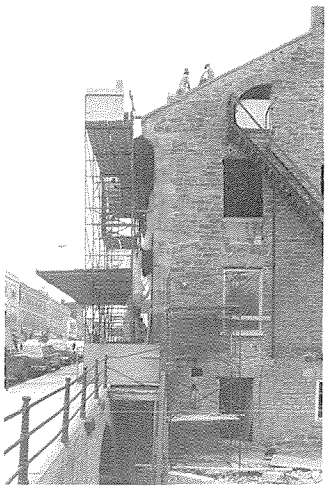
- ❒ Detailed inspections and recording
- ❒ Preliminary stabilization and temporary repairs; strapping and shoring
- ❒ Protection of windows and delicate features
- ❒ Photographic recording, measurement and photogrammetry of details
- ❒ Removal of features for workshop repairs
- ❒ Cleaning up vegetation, unblocking drainage
- ❒ Roof, chimney and drainage repairs
- ❒ Masonry repair and repointing
- ❒ Repairs of wall surfaces and woodwork
- ❒ Installation of new services
- ❒ Cleaning, painting, refinishing
- ❒ Reinstallation of repaired components
- ❒ Final inspections

❖ Where height is not prohibitive, have work and scaffolding move sideways around the building or space rather than dismantling and re-erecting it repeatedly (to save time and assure consistently solid assembly).

❖ Cherry-pickers and mobile construction hoists are ideal for early inspections and recording, but use them only within their specified limits of loading and movement.

It is absolutely essential to take immediate steps to stabilize a structure in the wake of a flood, explosion or other calamity, to keep the building's own weight from causing further deterioration. It is no less important to keep the structure stable during repair and conservation work that may alter the distribution of loads (below). And it is vital that the working conditions are kept safe, by providing temporary handrails, safety barriers, secure outdoor storage, and so on (bottom).

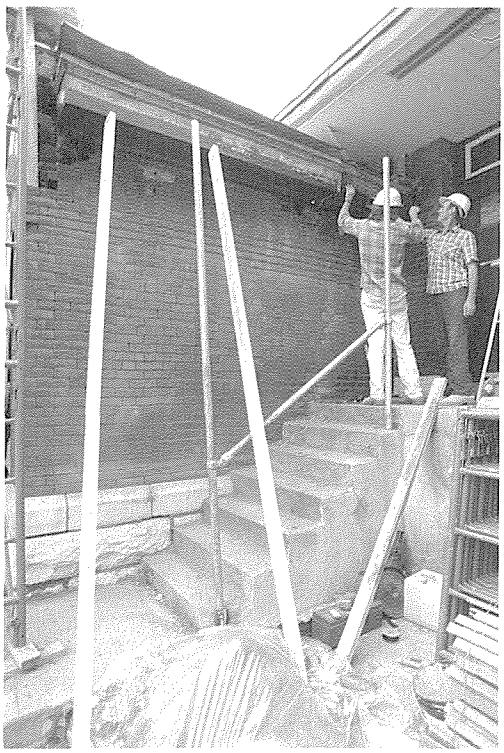




Temporary reinforcement

In cases of advanced deterioration or damage from some recent disaster, it may be necessary to stabilize a structure temporarily with straps, struts, jacks and the like. Only an expert engineer experienced in dealing with old buildings can supervise this work. The structure must be stabilized against the forces of gravity and deterioration, and must bear the strains of conservation work and equipment for months, even years. These loads may be heavier than those of the structure's previous or ultimate uses. As for scaffolding, temporary reinforcements are normally the contractor's responsibility, except on very small projects (without contractors) or very large ones (with special engineering requirements).

- Properly anchor or found temporary braces and props; place no additional loads on the structure itself, except to relieve existing stresses and restore equilibrium. Pad all props, straps, cables and beams with balks of timber to protect the building's surfaces. Treat timbers with preservatives if they are to withstand dampness for any lengthy period, but note that preservatives may stain the building itself.



- Make sure that all braces — timber props, steel beams, lally columns, hydraulic jacks, and so on — do not puncture or damage the fabric of the building. Place braces in window openings where possible to stabilize both sides of a wall in all directions (first removing windowframes for workshop repairs). Temporarily reinforce window openings by filling them in with heavy timber props or concrete blocks.
- Do not brace the building against itself with props or cables, unless the bracing part of the structure is sound. Be sure not to compromise any *previous* repairs to the structure, especially those involving post-tensioning; these may fail abruptly if not anticipated.

Site workshops and services

- Provide sheltered and serviced areas in or adjacent to the project for workshop, office and storage use:
  - Work areas for repairs to windows, fixtures and so on to be reinstalled in building
  - Secure storage for plans, specifications, project records
  - Secure storage for tools, equipment, samples, hardware, etc.
  - Space for clerk of works or site supervisors to consult plans and specifications, maintain and update project records
- Provide sufficient space on site for material storage and waste-disposal dumpsters. Connect and maintain site services — water and electricity especially — properly throughout the work.
- Make doubly sure that the site is secured against vandalism and theft from the very beginning of the work. And keep the site as neat as possible — keep vegetation trimmed and the inevitable mess out of public view. The conservation project must try to be as good a neighbour as the building was before and will be afterward.

Foundations

Principles

2.3 Work in order
2.5 Appropriate skills
3.4 Archaeology (site & structure) for reconnaissance
5.1 Priorities of features, priorities of work
5.4 Archaeology (site & structure) for rescue of artifacts
5.9 Façadism as last resort
6.5 Safe working conditions
7.1 Traditional repair (proven technology)
7.4 Cautious high-tech repair
7.6 Maintainable repairs
8.2 Added value (high quality) in new work
8.4 Independent additions

References

For foundation conditions and problems in residences and other small buildings, see CUNN84, DAVE80/86, FITC86, HOLM75, HUTC80, KIRK84, KITC83, LYNC82a, MELV73, REMP80 and SMIT85. For large buildings, see BAXT86, DIBN85, FEIL82, FITC82, FROI86, LYNC82a, SMIT85 and STAH84.

Moisture damage in foundations is a primary cause of decay in buildings of every size; in addition to the references above, see GRIM84, OXLE83 and TRIL72/73.

Moving buildings creates special problems for both old building and new foundation; see CURT79. For cautions on the problems of insulation, waterproofing, vapour barriers, and "aggressive" energy-conservation retrofits in small buildings, see HERI87a/87b.

Foundations and building systems

Every building is a system — each part is connected. Thanks to gravity, the foundation is at the bottom (literally) of almost every building problem. Most buildings move, shift and settle in the few years after construction as the ground gets used to the new weights placed on it. Even foundations on bedrock may move as compressive forces squeeze their materials against the rock. In general, old-building foundations are thus far more stable and secure than those of new buildings. Over time they have attained equilibrium.

Earth movements and ground water can unsettle this equilibrium. Several parts of Ontario, especially in the east, are potential earthquake zones, but there are no seismic retrofit requirements for buildings in the province, as there are, for instance, in California. Man-made earth movements are far more serious concerns, especially in the mining areas of northern Ontario and near gravel quarries and heavy industries. Adjacent construction and excavation may also unsettle once stable foundations. Vibration makes loose soil act like a liquid, and foundations have been known to settle unevenly under such conditions, long after they should have stabilized.

Variations in ground water are far more widespread than ground movements; all but the largest buildings are founded on soil whose load-carrying capacities change with moisture content. As urban and agricultural areas expand, and forests shrink, the water table tends to drop, soil dries out, and the ground compresses under the weight of a building. Installation of storm sewers in small towns has often led to sudden foundation settlement in century-old buildings.

With such external influences, it is almost impossible to take corrective action until the environment itself stabilizes. In many cases, settlement will be uniform and will not cause much harm, apart from small cracks and misalignment of doors and windows. The flexibility inherent in small frame structures allows them to remain sturdy, even though some of their finishes may suffer.

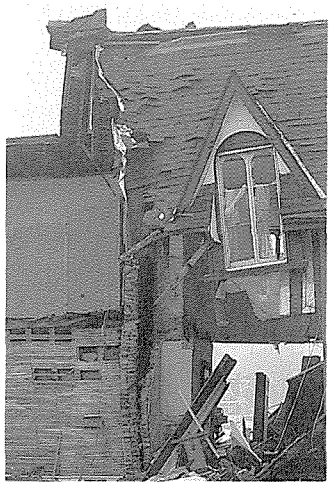
Changes in the use of a building can also destabilize both structure and foundation, especially when loads exceed the capacity of the original design. There is always a large "safety" factor in any structure, and old buildings may have far more generous margins than closely calculated new construction, but even these have limits. When left undisturbed by major renovations or changes of use, foundations should remain stable. But they may require reinforcement or underpinning if loading is to be changed dramatically.

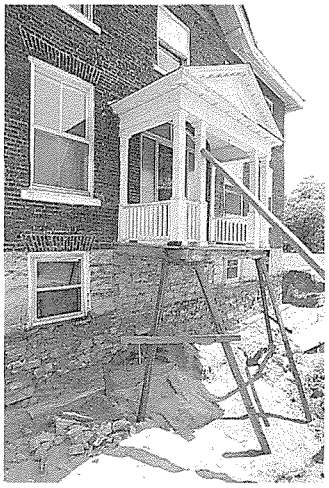
- Ensure that foundations are dry and that they show no signs of recent movement. Even timber foundations (common in bedrock areas) may be perfectly sound and suitable for continued use *if they remain dry*. Make sure that new additions or energy conservation measures do not cause *new* dampness in foundations.
- Where portions of the foundation are to be more heavily loaded as a consequence of alteration and adaptation, consider using structural means within the building to transfer the loads more evenly across other parts of the foundation, rather than reinforcing only parts of the foundation.
- If at all possible, finish conservation work after earlier alterations in the foundations have stabilized. As much as possible, make repairs to interior finishes and carpentry in ways that can accommodate subsequent movements and adjustments.

Foundations on the outside

- Do no excavating until archaeological concerns have been addressed (see SURPRISES and EARTH, AIR AND WATER).
- Remove (carefully) roots and other vegetation near or beneath foundations. Make sure that all downspouts drain well away from the building.
- If there is evidence of dampness (ranging from loose interior plaster or salt or rust stains on outside walls near the ground to running water during storms), drain the perimeter of the foundation. Inspect and repair existing drainage. Keep potentially moist ground at least 20 cm (8") below the level of the bottom of ground-floor joists and wall plates of timber-framed buildings. Inspect regularly to make sure of this separation.

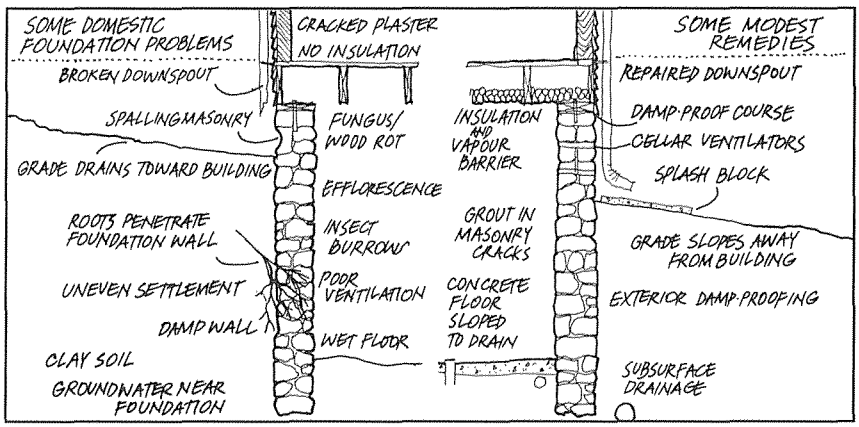
The stability of foundations depends on the stability of the soil's moisture. The vibration of heavy equipment or a catastrophic explosion may cause damp soil on any slope to shift and let the building collapse (top); it may be necessary to excavate and provide permanent drainage to prevent such a calamity (middle).





- Since causes may be difficult to diagnose, have an experienced professional investigate dampness before undertaking repairs, with special care to determine if the dampness is external or internal in origin.
- If foundation dampness is the result of a high water table, dig out a trench around the perimeter and fill it with granular material to permit water to drain away from the walls. Waterproofing an existing foundation is difficult and expensive, though where water-table conditions have changed, exterior waterproofing may become necessary. *Beware of sealing the wall in a way that will trap warm humid air from the interior and let it condense inside a cold foundation wall.* Provide weep-holes, drains and ventilation to let water drain out or evaporate. In winter, high interior humidity in a waterproofed foundation may cause damp and condensation from the inside, so that properly installed and maintained vapour barriers and drainage are doubly important.
- In extreme cases, dampness may migrate up inside walls to create damp conditions in structure and woodwork above grade. In such cases, if drying and draining the perimeter prove ineffective, consider installing a damp-proof course in the exterior walls to block moisture migration upward. Ensure that such a course is complete and does not concentrate the problem in one place.
- Once the causes of damp conditions are dealt with, ensure that stone, brick and mortar in foundation walls are sound. When repointing, use a mortar formulation similar to what exists, keeping Portland-cement content to a minimum. Ensure that rubble-core foundations (both walls and piers) remain sound, adding grout carefully as necessary to re-establish their original strength.
- In the case of differential settlement, it may benecessary to underpin, but only after the cause, internal or external, has been determined. Underpinning by any method is expensive and creates disequilibrium that takes time to stabilize. Repair any drainage problems first. If the soil on which the foundation rests has itself weakened, then the underpinning should spread the load out onto a wider base or transfer the load to a more solid base. If the problem arises from existing or potential overloading in the building, consider redirecting the additional load more broadly within the structural frame.
- Avoid covering foundation walls with stucco or insulation; once the basic problems of moisture and movement have been treated, repoint foundation walls to match their historic appearance.

See SUPERSTRUCTURE and MASONRY.



Basements and crawlspaces

- When excavating basements and crawlspaces for additional headroom, make sure that foundations retain their load-carrying capacity either by underpinning or maintaining a plinth around all foundation elements.
- Inspect, and reinforce where needed, any foundation or basement structural elements weakened by sloppy utility installations or structural changes.
- When a previously uninsulated basement is insulated, condensation and dampness from inside may create more havoc in the foundation than water from outside. Make sure that vapour barriers and insulation do not cause condensation within the walls themselves. Though there may be little threat from freeze/thaw cycles below the frost line, there may be uncomfortable dampness and a high likelihood of damage to interior finishes, both old and new.

Superstructure: frames, walls and floors

Principles

2.1 Co-ordinated work
2.3 Work in order
2.5 Appropriate skills
2.6 Second opinions when in doubt
5.1 Priorities of features, priorities of work
5.9 Façadism as last resort
6.2 Maximum retention
6.5 Safe working conditions
7.1 Traditional repair (proven technology)
7.2 Replacement in kind/ recycled materials
7.3 Reversible repair
7.4 Cautious high-tech repair
7.6 Maintainable repairs
8.1 Distinctive new work
8.2 Added value (high quality) in new work
8.4 Independent additions
9.2 Faithful maintenance

References

Good general reference sources for small-building foundations include BIX85, BOWY80, CUNN84, DAVE80/86, FINE86, FITC86, HOLM75, HUTC80, KITC83, LITC82, MELV73, RADF83, READ82, REMP80, TRIL72/73 and VILA81. For large buildings, see BAXT86, FEIL82, FROI86, STAH84 and TRIL72/73.

Structural problems and repairs in timber are treated in GOOD80, MACG73, MULL81 and WOOD86. Structural problems and repairs in masonry are treated in BEAL87, CONS82, GRIM84, LYNC82a, MACG71, SMIT85, WEIS82 and WILL83.

See the following about specific structural matters: early metal structures, GAYL80 and JAND83; structural elements of commercial façades, MEAD86; fire ratings of outmoded structural types, NIBS80.

Types and materials

The following deals with frames, walls and floors as structural elements. Finishes (and the finishing of exposed structural elements) are dealt with separately as exterior or interior features. Normally, the structure is concealed beneath exterior or interior finishes. Excepting barns, churches, and industrial or engineering structures, exposing the structure is a very recent fashion. In Ontario, even exterior masonry walls are often finishes over a frame rather than part of the main structure.

All walls bear at least their own weight, and often a portion of the loads of the floors and roof above. Nevertheless, most buildings in Ontario from small to large are constructed as a structural frame with a relatively light cladding rather than according to the more traditional European practice of bearing-wall construction. Log construction is essentially a case of bearing walls supporting a small and relatively light roof structure. In many areas, a masonry or clapboard exterior on a house with rather thick walls probably covers an older log structure. Cladding fashionably upgraded of appearance and protected the logs from weathering (as well as stopping drafts).

Most other bearing-wall structures are of stone masonry with timber floors and roofs. Such bearing walls consist of two faces of relatively well-cut stone (sometimes one face is brick) with a core of rubble, sometimes bonded by mortar. Most bearing-wall structures in Ontario are churches; massive walls support elaborate and heavy roof structures.

Brick exteriors are often just cladding; plentiful supplies of timber and sawn lumber for framing made the load-bearing brick walls of European practice obsolete, even in urban areas, where some early building regulations required brick exteriors to prevent the spread of fires. Brick veneer allowed for much larger openings than brick bearing walls and was far more suitable for the complex forms demanded by late-19th-century picturesqueness. Nevertheless, idiosyncratic examples of double- or even triple-thick brick bearing walls seem to occur everywhere. The modern practice of backing a brick face with concrete block did not become common until the 1920s.

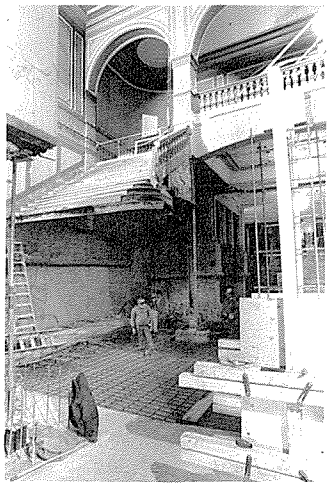
Timber frames have come in several varieties. The traditional mortise-and-tenon framing of relatively heavy timber beams and joists arrived from Europe and the United States with each wave of immigration, with subtle variations in practice from group to group. But cheap sawn lumber and machine-made nails made platform- and balloon-framing an instant success by the mid-19th century, pushing traditional heavy-timber construction out of domestic and commercial use. Most such lightweight framing uses "sticks" of small dimensions for wall studs and floor joists, with wooden laths, floorboards and occasional diagonal braces or bridging to make the entire assembly solid. Much more rare was the use of post-and-beam construction, with rigidly braced joints. Where sawn lumber was especially plentiful and cheap, there were occasional structural oddities made of sawn planks stacked up like bricks.

Wrought iron as a structural material, used for engineered structures such as bridges and gas-holders and some framing in large public buildings, was a rarity in 19th-century Ontario. Steel supplanted wrought iron late in the century. Steel's strength permitted much of the eclectic stone and masonry constructions of commerce and public building to be "draped" on a hidden framework that carried most of the load. Steel-reinforced concrete frames appeared soon afterward; some pioneering bridges displayed the new technique and material openly, but in most buildings the concrete frame was concealed behind other materials.

Repairs in general

The basic approaches to conserving heritage structures are to repair in kind wherever possible and to make any repairs easily accessible for inspection and reversible (where necessary). Replacements should be the same material as the original, even the same species of wood where possible, to avoid future deterioration where two incompatible materials abut. Chemical incompatibilities and unanticipated structural movements are likely to continue to trouble the structure if repairs do not fit properly with what exists.

- ❖ Inspect and record the structural system very carefully and add to that record



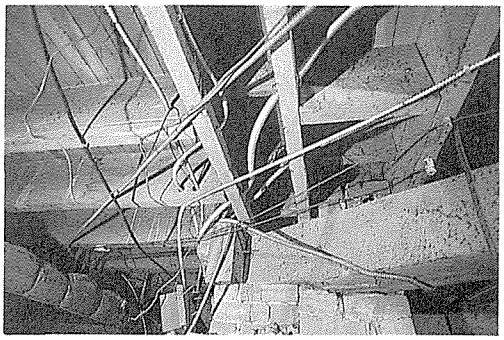
While most structures are supported from beneath, there are many instances of structures suspended from above or cantilevered from one side. Every structure must be fully understood, with the help of expert advice as required, before it can be repaired or altered.

throughout conservation work as elements, especially joints, become visible.

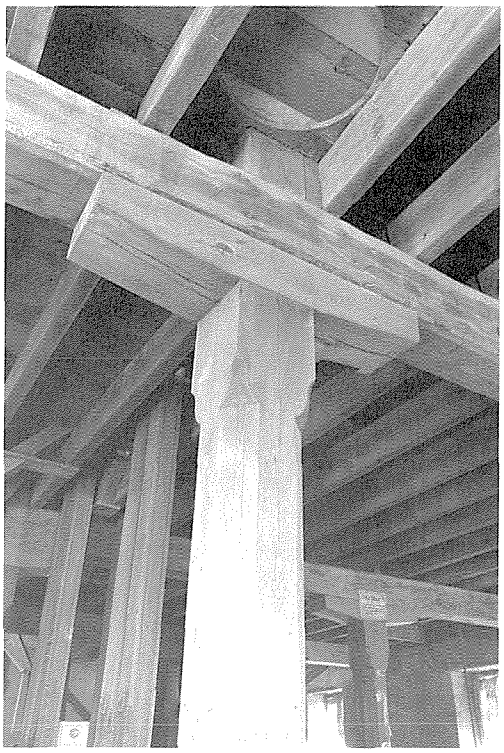
- Correct any apparent structural problem before continuing other conservation work; correct conditions that may seem only indirectly related to matters at hand as well as more obvious deficiencies. Work up from foundation to roof. Remember, every part of a building is connected.
- Do not remove or alter load-bearing structures until the consequences of the change are clearly understood. Do not allow loads to shift so as to overload other parts of the walls or frame. Make no new openings unless the rearrangement of loads is fully resolved.
- Use professional architectural and engineering advice in case of any doubts about structural safety or adequacy. Make sure that such consultants are familiar with and sensitive to the problems of conserving existing structures.
- Do not add major new loads (heavy dead loads such as mechanical equipment or large numbers of bookshelves or heavy live loads such as public assembly spaces) without ensuring that the capacity of the existing structure is sufficient. Reinforcement should be minimal and unobtrusive — if a new use requires a completely new structure, then it may not be appropriate for that building.

Timber repairs

- Use non-destructive testing techniques; use probes gently, especially on smaller timbers. Ensure that all posts and joists are securely seated and that the seats themselves are sound. Note every member that has been cut to permit utility installations in the past and reinforce these. Do not cut any more holes, unless they are fully reinforced.
- Correct the causes of timber weakness and decay before undertaking permanent structural repairs. Ensure that any fungus and insect infestations are halted. Remove sections of wood that have lost their strength due to dampness or rot. *Make sure that all remaining wood is sound and dry.* Do not use chemicals or techniques (for cleaning, caulking, insulation, etc.) that will leave residues harmful to the wood in the long term. Make sure that periodic inspection and maintenance catch deterioration before it becomes severe.
- Generally, repair structural weaknesses with splices, braces or flitch plates that can be adjusted or replaced, rather than with epoxies whose bonding properties and chemical characteristics may or may not be satisfactory over the long term. Do not use epoxies for structural wood repairs in any areas where humidity and temperature vary beyond the typically narrow range of normal interiors. Epoxy-laden wood does not absorb moisture and thus does not expand and contract like untreated wood. Whether or not epoxies are satisfactory consolidants for badly deteriorated materials, they are inappropriate for parts of an existing structural system exposed to the elements.
- Floors may sag over time under heavy loading. If beams or joists are deformed but do not bounce back after loads are removed, and are otherwise sound and able to support the required loading, do not try to jack them level or bend them straight — use shims or other supplementary means to level flooring. Sometimes beams and joists may be bouncy but structurally sound; these may require stiffening, extra vertical supports, or lighter use altogether.
- All timber repairs should allow for movement within a small range to accommodate wood's expansion and contraction with changes in humidity. As much as possible, stabilize humidity and ventilate structural members to allow absorbed moisture to escape — especially vital for sealed and vapour-protected areas. Allow for variation of moisture content *within* heavier members that lie between spaces with different humidities.
- Where reinforcing cannot achieve long-term stability, replace timbers with wood of similar dimensions, species and moisture content. New timber is seldom properly seasoned or kiln-dried, and may shrink or twist — connectors and joints should be adjustable to accommodate such movements. Ideally, store replacement



Most small brick buildings, whether domestic or not, have wooden frames supporting their brick skins (above). Their frames are often weakened over the years, sometimes severely, by numerous cuts and holes for utilities, and may require repair and reinforcement (right). Heavy timber structures require massive reinforcement at joints to resist loads and vibrations, and in traditional practice these are simply but elegantly detailed in iron or wood (below right).



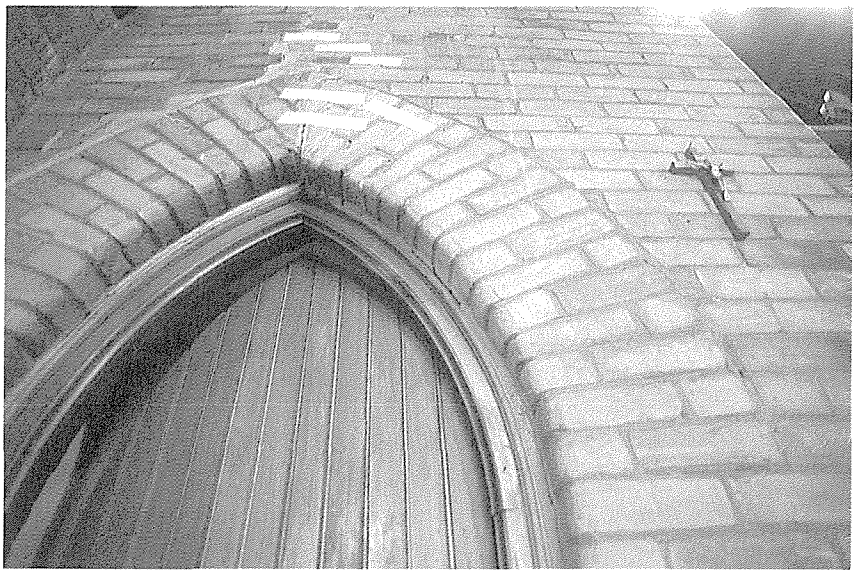
Solid masonry structures may shift in time and reveal cracks that must be watched carefully for recent movements. In this case, the shifting was traced to weakened exterior walls, whose buttresses required rebuilding to regain their ability to hold up the roof (opposite).

timbers where they will be used long enough to bring their moisture content to the same level as the existing structure.

- Use fastening devices appropriate to the existing structure; if increased loads require more strength, use external connectors that spread the load uniformly. Ensure that any chemical preservative in new wood cannot migrate and cause staining or chemical deterioration of other building components.
- If replacing deteriorated timbers with other structural materials, ensure that every connection is able to resolve differential movement without disturbing other parts of the structure.

Masonry repairs

- Record and monitor all cracks and discontinuities in masonry walls, both between units and in the surfaces of individual units. Look especially for missing mortar and other evidence of weakness in the core of a load-bearing masonry wall. If water has for a long time been able to penetrate the core, do not be surprised to find that the core may have been washed out altogether, creating severe stresses in the surface masonry.
- Do all foundation repairs before permanent work on walls — most cracks in masonry walls are based on foundation problems. And repair framing that bears on masonry before making final repairs to the walls themselves. Where weakness or decay in floor systems has altered the loading on supporting walls, redistribute the loading properly before fixing the walls.
- Use mortars softer and weaker than the masonry units they hold. Stresses and small movements in walls must be resolved in the assembly as a whole and must not be transferred to individual units through hard mortars (see MASONRY).
- Grouting of masonry walls requires skilled and experienced workers and careful supervision. Make sure that any pressure-grouting of rubble cores is not so powerful as to dislodge the masonry units themselves. Grouts should be as carefully



mixed as mortars, with very little Portland cement.

- For masonry veneers connected to the structure with metal ties, make the ties secure — they often rust through in places, leaving the brick only barely attached to the structure. Allow for thermal expansion or contraction in any reinforcements and connections. Locate new ties at masonry joints, *not* at holes drilled through the masonry itself.
- Replace rusted metal ties. Use only rust-free metal reinforcements or connectors. Stainless steel, though expensive, is far preferable to galvanized metal. Hot-dipped galvanized nails and ties may be adequate where risk of moisture entrapment is very low. Vapour and liquid moisture may penetrate walls, no matter how well sealed. When iron connectors rust they expand, shifting and cracking masonry before letting go altogether.
- Replacement units should be as strong and durable as what they replace. Replace in kind — do not substitute sandstones and limestones for one another. Ensure that stone is worked and laid with its bedding planes horizontal, to minimize moisture penetration and consequent spalling. Mortar should be mixed to match existing work both physically and chemically, and its pointing should follow the existing pattern. Replacement bricks should be of equivalent hardness, smoothness and porosity, to provide similar structural strength and durability. Ideally, they should come from the same yard as those they replace.

Traditionally exposed structures

Because they will be on view, repairs to exposed structures must respect much more rigorously the heritage character of the building. Churches are most sensitive because their structures are adorned and decorated. Barns, mills and factories are expected to be more robust and can accept far more robust repair work.

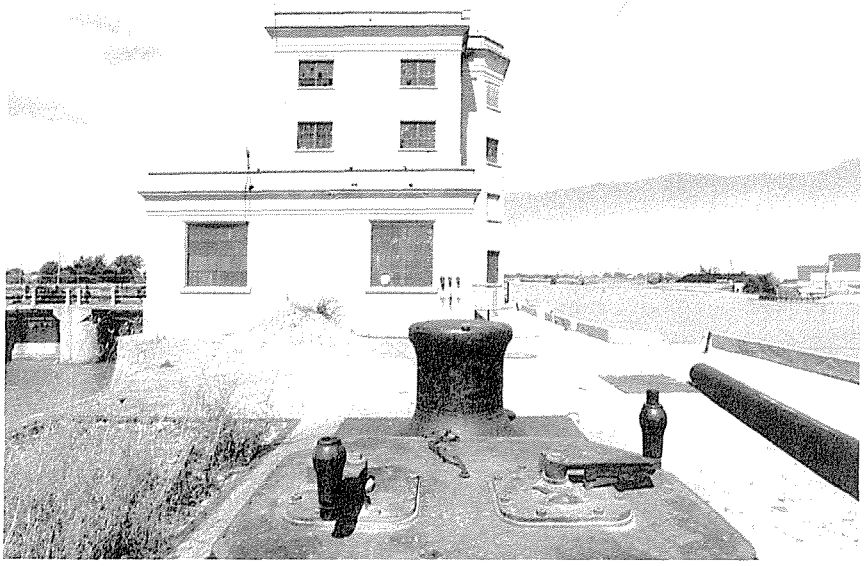
The size and complexity of these structures will usually require the aid of architectural and engineering consultants familiar with historic construction practices.

- Heavy timber structures (barns, mills and the like) require careful inspection to ensure that vibrations and movements have not displaced any members or joints. If they remain in heavy use, inspect them frequently; use simple strain gauges to measure movement.
- These structures may also require reinforcement where cuts in the structure permitted insertion of services or shafts. The seating of beams on stone walls is especially vulnerable to loosening from vibration. Many heavy timber structures have already been reinforced with iron or steel tie rods, and more such reinforcement may be needed to keep outer walls from spreading under load and vibration.
- The open trusses of many church interiors are among the most impressive of architectural feats, even at the modest scale of most Ontario churches. Take very special care to maintain their dignity while repairing any decay. Once all causes of deterioration have been treated (often foundation and buttress failures due to the weight of the roof), make repairs such as the insertion of flitch plates as much as possible on the hidden upper side of timbers. If the church is kept heated throughout the winter, the interior environment may prove sufficiently stable to consider epoxy repairs. Tie rods have often proved necessary to keep side walls and buttresses from spreading under the roof's weight, and these may be preferable to the more drastic reinforcement and enlargement of the buttresses themselves or the addition of new truss elements.

See WOOD AND PLASTER.

Concrete, iron and steel

Though concrete, iron and steel are thought of as especially modern building materials, older structures made of them require major conservation work if they are to survive. Most conspicuous are engineering structures such as bridges, vulnerable to weathering and to chemical corrosion from road salt. But the engineering achievements seen in the impressive trusses of arenas and armouries deserve conservation no less than the stylish architectural clothing of the exteriors. The size



Because exposed structures have such distinctive visual impact, whether sacred or secular, they require and deserve special care in repair and reinforcement (opposite). Wrought iron and other metal frameworks can be reinforced to a certain point without much effect on their appearance, but their use (in this case the maximum loading of the bridge) may have to be regulated to avoid the problems of more radical reinforcement (above, top). Reinforced concrete has become an extremely common structural type, but it is seldom exposed, apart from engineering structures, because of the difficulty of making minor repairs without marring its appearance (above).

and complexity of *these* structures require structural experts familiar with the historic background of modern construction practices.

- Steel structures must be protected from weathering, by paint or by enclosure. Regular maintenance is essential; corrosion and rust must be arrested immediately on discovery.
- Reinforcement for increased loading on existing steel structures should be as discreet as possible. Use materials and techniques similar to those of the existing structure — use several small members rather than fewer larger members. Where possible, resolve the distribution of forces by reinforcement in tension, by cables or rods rather than beams or girders. Use the lightest-weight technique. If replacement is necessary, replace in kind.
- Major concrete repairs are quite difficult to carry out in a manner that restores both structural integrity and original appearance. Exposed reinforced concrete degrades under attack from salts, allowing moisture to get at the reinforcing bars, which corrode, rust and expand, popping off more concrete, exposing more steel, and so on. Proprietary compounds to fill cracks must be used in a program of regular maintenance. If deterioration goes too far, the only reasonable conservation treatment may be replication in new concrete.
- "Plastic" repairs of concrete forms should match the existing contours, aggregate, colour and strength of material as closely as possible (concrete is one material that is hard to match *too* closely). Patches must be keyed into the remaining concrete to provide a contiguous surface against water and water-borne salts. Paints or silicone-based coatings do not prevent water penetration for long and must be constantly renewed. It is better to design elements that let water drain quickly away without being trapped.

See METALWORK and STUCCO, CONCRETE AND COMPOSITES.