PRESERVATION
Tech Notes
U.S. Department of the Interior
National Park Service
Cultural Resources
Heritage Preservation Services

TEMPORARY PROTECTION

NUMBER 3

Protecting a Historic Structure during Adjacent Construction

Chad Randl
Technical Preservation Services
National Park Service

IDENTIFYING AND AVOIDING RISKS FROM ADJACENT CONSTRUCTION

Valued for their ability to convey the past through existing materials and features, historic buildings must also survive in an ever-changing present. That change is often characterized by new building construction and demolition activities on neighboring sites. Whether it is the modest renovation of an existing building or the demolition of an existing structure and construction of a new high rise, physical damage to an adjacent historic building may occur. It is important for both the historic property owner and those responsible for the neighboring work to give careful consideration to the potential risks. Early planning offers the opportunity to identify these risks and to determine successful ways to avoid them.

Problem

The forces that contribute to the deterioration of a historic building, from atmospheric pollutants to the footsteps of visitors, often take decades and even centuries to exact their toll. Demolition activities and new construction on neighboring sites, however, can cause immediate harm to the physical integrity of a historic structure. In the instant it takes an improperly planned excavation blast to crack the foundation of an adjacent historic structure, or for a steel beam to be dropped from a construction crane onto its roof, significant damage may occur. Additionally, adjacent construction work can expose the neighboring historic building to concentrations of dust, vibration and fire hazards that would normally be experienced only over the course of many years.

These concerns are often overlooked when a project is undertaken next to historic resources. In some situations, the historic property manager may be unaware of the nature and extent of work at an neighboring site. In other cases, the new construction team is not familiar with the particularly fragile character of the neighboring historic structure or decides to repair any damage after the fact rather than avoiding it from the beginning.

Solution

Effective planning and protective measures initiated before construction takes place can prevent most of the damage that may occur to adjacent historic buildings. Depending upon the nature of the project, protective measures may be limited to documenting and monitoring the historic structure or may encompass a broader plan that includes encasing windows, indepen-

When historic structures are exposed to adjacent construction or demolition work, a protective plan including documentation, monitoring and specific safeguards should be implemented to prevent damage and loss of historic fabric.

dent review of excavation procedures and a range of other precautions. Cooperation between all parties can help to ensure that construction activity continues without interruption and that the neighboring historic building is preserved unharmed.

The information provided in this *Tech Note* can serve as a basis for discussions between the historic property manager and the developer of the adjacent site aimed at ensuring the protection of the historic building in a cost-effective manner. This guidance is also applicable where new construction is undertaken on the same site as the historic structure.

Although adjacent construction work often poses a more immediate threat than the incremental impacts of weather or pollution, the best defense for both situations is that buildings be in good condition. A well maintained structure with tight mortar joints, strong connections between interior and exterior walls, solid foundations and sound plaster is at less risk from neighboring activity than a neglected structure.

Providing adequate protection involves the following steps: 1. consultation between the historic building owner and development team to identify potential risks, negotiate changes and agree upon protective measures; 2. documentation of the condition of the historic building prior to adjacent work; 3. implementation of protective measures at both the construction site and the historic site; and 4. regular monitoring during construction to identify damage, to evaluate the efficacy of protective measures already in place, and to identify and implement additional corrective steps.

Consultation

Early consultation between the historic property owner and the developer of the neighboring construction site is the first and often most important step. Establishing such contact has many advantages. Consultation provides the foundation for a mutually beneficial relationship that is cooperative rather than adversarial. The process gives the historic site owner an opportunity to become familiar with the scope of the impending project and for the development team to understand the historic structure's vulnerabilities. Consultation permits all parties a chance to propose, discuss, and negotiate changes to the construction plan that reduce the risk of damaging adjacent historic resources. The ultimate goal is to draft a protection plan acceptable to both parties.

Resolving concerns before construction is underway can save time and money, as well as the need to repair damaged historic fabric. It is crucial that such discussions take place during the paper stage of the project, before final decisions are made. If not, the developer may conclude that changes would be cost prohibitive and that it is preferable to repair damage after it takes place. Early consultation also provides information that can be used to assess whether the level of insurance coverage is sufficient to meet the specific project risks.

The owner of a historic property cannot in most cases compel the support and cooperation of the development team. If, after consultation has been attempted, the level of protection provided is not sufficient, the aid of local building officials should be sought. Local building officials, through the permitting process, can often insist that changes be made to development plans to ensure that adjacent properties are protected. Local building codes may also provide safeguards by establishing certain conditions such as maximum vibration levels.

Other parties can also participate in and contribute to the consultation process. The support of neighborhood committees, local non-profit preservation organizations, independent engineers and the historic district commission (if applicable) may be enlisted to ensure that protection concerns are fully addressed. The developer will benefit from the assembly of a team, including or representing the general contractor, architect, structural engineer, construction manager, and subcontractors, who can be present at consultation meetings and play a continuing role in balancing protection efforts with development interests.

Preconstruction meetings should address several issues. Most important, the parties should reach an understanding about what steps will be taken to protect the historic structure (*see figure 1*). Responsibility for implementing the agreed upon protections should be established among the developer, the general contractor and relevant subcontractors, and the historic property owner. Such decisions should be listed in performance specifications that accompany agreements between the contractor and the developer. A walk-through of the historic building by the development team is also advisable. Finally, schedules for major work such as excavation, and requirements for materials delivery, site storage, and other use of the premises by the con-

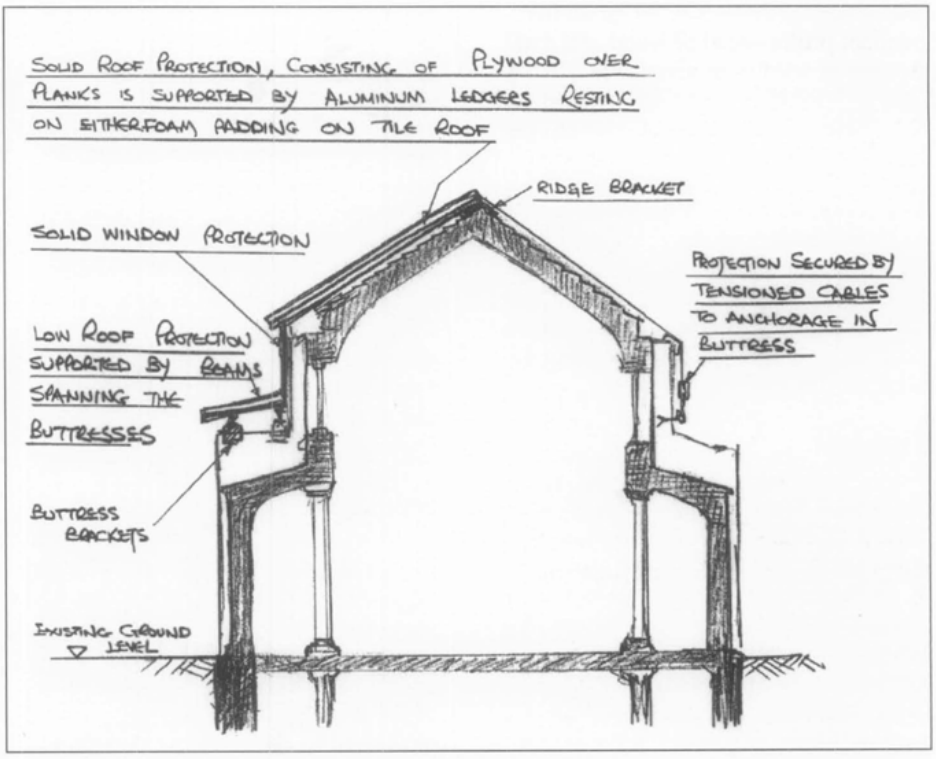

Figure 1. Before new construction was undertaken to the left of this church, a subcontractor was hired to design a protective system for the tile roof and clerestory windows. Drawing: Alan Shalders, Universal Builders Supply, Inc.

tractor should be discussed and arranged to minimize disruptions to the historic site.

Documentation

A crucial step following consultation with the developer is to document the existing condition of the historic structure. Such an investigation provides a "baseline" from which changes to the building during the adjacent construction can be identified, monitored and assessed. Like the consultation process, thorough documentation benefits both the historic property owner and the developer. For the former, it may be used to substantiate claims that damage occurred as a result of the neighboring construction work by illustrating the previously sound condition of the historic building. If the damage existed prior to construction work, the record can show that it was not caused by the developer's negligence. In the case of future litigation, the documentation record can serve as evidence along with the testimony of the professional who undertook the assessment.

Both parties should ensure that the documentation is objective and accurate. Joint surveys, in which both the developer and the historic property owner participate or sign off on noted conditions, are most likely to ensure that the resulting data are not in dispute. When the developer pays for the assessment, it is advisable that an independent professional be hired and that the survey results be accessible.

Information obtained through documentation can also be used in formulating a protection plan for the historic building. By characterizing existing damage and exposing potential weaknesses, the documentation process identifies areas of the structure that may require additional protection as well as appropriate locations for monitoring equipment. Features that should receive particular attention during visual inspections would also be highlighted. Although a formal building condition survey including analysis, repair proposals and cost estimates is not necessary, the property owner may find that the disruptive period during adjacent work provides an opportune time for a thorough survey program.

Documentation of existing conditions should take the form of written descriptions, 35mm color photographs and/or a videotape recording. Photographs should show both the interior and exterior of the building, with close-up images of cracks, staining, indications of settlement or other fragile conditions. A complete interior and exterior crack survey should be undertaken to identify and characterize existing cracks *(see figure 2)*. Their locations can then be plotted on a drawing of each wall or ceiling surface. While identifying every hairline crack may be impractical in a large building or one that exhibits a great deal of preexisting damage, the more thorough the documented record, the better. The condition of features such as arches, chimney stacks and parapet walls determined by the engineer to be particularly susceptible to distress should also be recorded even when no damage is apparent.

Common Risks and Protective Measures

Each instance of new construction or demolition next to an existing historic structure will involve varying risks to that structure. The proximity of the historic site to the project and the scope of the project are two of the most significant variables. Construction of a high rise building with deep foundations is more likely to affect a neighboring structure than the rehabilitation of a nearby rowhouse. However, the converse may be true if the rowhouse is directly adjacent to and sharing a wall with the historic structure. Other factors influencing the degree of likely impact include the age, construction type and structural integrity of the historic building, as well as the depth and makeup of its foundation and its surrounding soil types.

Owners should also anticipate the effect increased dust, vibration and fire risk will have upon interior architectural features and furnishings. For the most sensitive objects, such as chandeliers, paintings and glassware, temporary removal to an off-site location may be the safest course. Those features that cannot be easily removed, including plaster ceiling medallions and cornices, can be cushioned and buttressed by padded wood supports. Additional information concerning the safeguarding of interior features can be found in the preceding *Tech Note* in this series, "Temporary Protection, Number 2. Specifying Temporary Protection of Historic Interiors During Construction and Repair."

The remainder of this section addresses some of the more common dangers to historic structures when new construction or demolition activities occur nearby. The description of each potential impact is accompanied by suggested approaches for reducing or eliminating those risks.

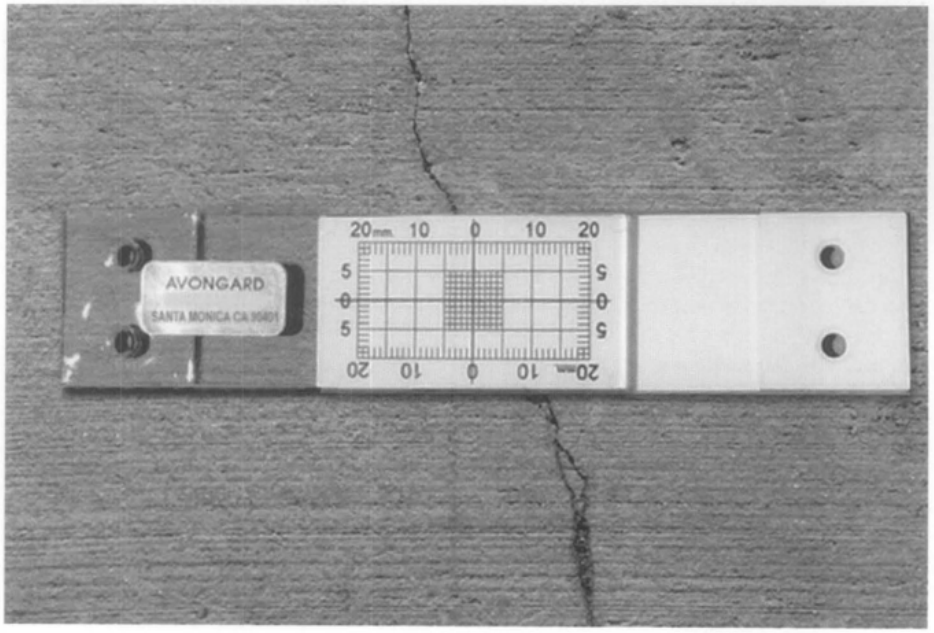

Figure 2. With advanced notice of adjacent construction activity, a crack monitor can be used to determine whether existing cracks in the historic building are stable or still experiencing movement. Compared with measurements taken during the monitoring phase, such information can help determine if subsequent movement resulted from work on the neighboring site. Photo: Avongard Products U.S.A., Ltd.

Vibration

Demolition and new foundation work are common sources of vibrations that can affect adjacent structures. The tools and methods used in demolition, such as impact hammers, wrecking balls, pavement breakers and implosion blasting, produce vibrations that may be transmitted to the historic structure. Similarly, techniques used to prepare new foundations (pile driving and blasting) create potentially dangerous vibrations. Vibrations may also be caused by increased truck traffic accompanying new construction or demolition work. In all cases, the force of the vibrations reaching the adjacent historic structure depends upon the activity generating the vibrations, the distance between the source and the existing structure, and the type of soil or pavement found between the two.

Historic structures may be particularly vulnerable to the effects of vibrations generated at an adjacent site. Deferred maintenance and past alterations may have produced structural weak points that are susceptible to damage. Historic finishes, such as plaster walls and ceilings, lack the flexibility to accommodate abnormal movement, while shallow foundations (common in historic buildings) may lack the rigidity to resist vibration induced movement.

Mitigating the effects of vibrations should begin during the consultation process when acceptable levels can be set and alternative processes explored. Hand demolition is an appropriate substitute when conventional demolition activities may cause excessive vibrations. If pile driving is likely to damage adjacent structures, the contractor may be able to employ non-displacement piles that are inserted in bored holes rather than driven. Lower vibration levels can also be achieved by "jacking-in" or pressing the piles into the ground. Locating delivery entry and exit points farther from the historic site may reduce vibrations caused by increased vehicular traffic. Once construction is under way, continual crack and vibration monitoring provides an effective warning system, indicating that established safe thresholds have been crossed.

Movement

Excavation and foundation work can also cause ground displacement and movement of an adjacent historic building. New construction almost invariably calls for digging a foundation that is much deeper than the foundations of neighboring historic buildings. This is especially true for projects that include underground parking facilities. A historic structure, with a shallow masonry or stone foundation and wall footings, may experience corresponding displacement that can result in major structural damage.

Efforts to control movement should begin during the consultation phase. Whether the developer's engineer selects underpinning or strengthened excavation walls with tie backs as the means to resist movement of the adjacent structure, the historic building team should retain its own engineer to review the plans *(see figure 3)*. The consulting engineer should ensure that the selected approach addresses the unique characteristics and vulnerabilities of the historic structure and that even incidental movement is restricted.

Water

A well functioning water drainage system is essential to the protection of any historic structure. This system can easily be rendered ineffective by neighboring construction or demolition work. Debris originating at the construction site often finds its way to the gutters, downspouts and drains of an adjacent building. Drainage mechanisms may also become inoperable when excavation workers inadvertently seal off or collapse old pipes running from neighboring buildings. If blocked pipes cannot remove water from both above and below the surface of an historic site, excessive moisture levels or flooding may result.

Regular visual inspections (part of the monitoring program described later) are one of the best means of thwarting increased moisture levels. The inspection procedure should include checking gutters, valleys and exposed drains for any obstructions. Also, indications of dampness or water damage in the basement and where gutters and downspouts meet other building surfaces should be noted.

Construction site runoff from cement mixing and cleaning and dust suppression activities should not flow toward the historic property. Although placing screens and wire cages over exposed areas of the drainage system may provide some protection from obstructions, such installations need to be inspected just as frequently. Low-pressure water washes can occasionally be used to flush the system of dirt and debris. To reduce the possibility that drainpipes will be blocked at the adjacent construction site, all concealed pipes should be traced from their origins at the historic structure and the

Figure 3. Concrete pier underpinning to an existing building may be necessary when adjacent construction occurs. In this example, pits are hand dug beneath the foundation of the historic building to provide space for wood forms. After concrete is poured into the forms, the space between the top of the pier and the bottom of the original foundation is packed with a quicksetting grout. The historic building owner should retain an independent engineer to ensure that the underpinning plan adequately protects the historic structure. Photo: Professor Arpad Horvath, Department of Civil and Environmental Engineering, University of California, Berkeley.

information passed on to the appropriate contractors. Final landscaping and grading patterns on adjacent construction sites should be examined to ensure that rainwater is not routed towards the historic building.

In some cases, the lack of water beneath an historic structure can lead to damage. Buildings located in areas with a high water table were often constructed upon timber piles. When groundwater or storm water is removed from a neighboring site during foundation excavations (a process known as "dewatering"), the groundwater level beneath the historic site may also drop. Previously submerged timber piles that are exposed to air can quickly begin to undergo dryrot. If there is reason to suspect that the structure was built on such a foundation, the property manager should work with the neighboring construction team to maintain the existing water table. This can be done using watertight excavation support systems such as slurry walls which ensure that most of the water pumped out of the construction site does not come from adjacent properties. Dewatering of soft clay ground may also result in settlement of a neighboring building, as ground water pressure is reduced and the soil consolidates.

Fire and Security Concerns

The heightened possibility of fire accompanies many demolition and new construction activities. Temporary heating devices, torches, sparks, molten metal and undersized electrical utility panels are some of the most common sources of fire at construction sites. Additionally, the improper storage of fuels, cloth rags and brushes also presents opportunities for fire to ignite and spread. The *Tech Note*, "Specifying Temporary Protection of Historic Interiors during Construction and Repair," provides detailed information on reducing the likelihood of fire in situations involving work near historic structures.

The security of a historic building can be threatened when adjacent construction provides opportunities for illegal entry. Newly constructed floor levels at the building site may make the neighboring historic structure's ledges, windows and rooftops accessible to trespassers. Window openings on the historic building should be fastened and all doors from the roof to the interior should be locked. Where a historic structure is protected by an intruder alarm system, that system should be upgraded to protect rooms that are rendered accessible from the outside. In cases where the historic structure does not directly abut new construction or demolition activity, attention should still be paid to the possibility that incidents of vandalism and theft will carry over to the historic site.

Physical Impact

Construction or demolition can cause direct physical damage to neighboring historic features and materials. Cranes, hoists and workers on upper floors of a construction site can drop building supplies and tools onto an adjacent historic structure. Misdirected debris chutes and backing vehicles may also leave their mark.

Generally, to counter these occurrences, protective barriers are placed over any area of the historic structure deemed at risk. If the new construction will rise above the historic building, plywood sheets should be placed over the roof to distribute the force of dropped materials *(see figure 4)*. Plywood covers should also be placed over decorative roof embellishments such as finials and balustrades. Alternately, horizontal netting can be rigged to shield vulnerable rooftop features.

Facades that are directly exposed to adjacent construction sites should receive close attention. To avoid damage, windows should be covered with plywood. Layers of cushioning materials can be placed between the plywood covering and particularly fragile windows, such as stained glass. If entire wall surfaces are vulnerable, scaffolding should be erected against the facade and debris netting placed on the outside of the scaffolding. Plastic sheeting can provide added protection in areas where acidic cleaning solutions may splash onto historic facades, windows and other surfaces.

The best means of protecting a historic structure from physical impact, however, is often to have adequate horizontal and vertical netting and barriers in place at the construction site. When adjacent buildings are adequately considered in the construction site netting and scaffolding plans, protective measures at the historic site can be less intrusive, and the likelihood of damage reduced even further.

Additional Dangers

Other byproducts of new construction and demolition, such as dirt and dust, can also pose threats to an adjacent historic structure. Dust suppression measures including the installation of fabric enclosure systems should first be employed at the building site *(see figure 5)*. Despite these efforts, historic building owners will undoubtedly have to deal with raised levels of dust infiltration. Accordingly, vulnerable interi-

Figure 4. Dropped equipment, tools, and materials all present risks when new construction rises above neighboring historic structures. In this case, the historic slate roof was completely covered with sheets of exterior grade plywood. Photo: National Park Service files.

Figure 5. The historic building on the left is partially protected from debris and dust generated by the renovation of the structure to the right. Such temporary enclosure systems consist of a polyethylene or other fabric shell stretched between an aluminum frame. Photo: Walton Technology, Inc.

or objects and artifacts should be covered or temporarily moved to another location. Windows can be taped shut or temporarily sealed with clear polyethylene sheets. Additional mats or carpets near entrances can help reduce the amount of dirt tracked inside. An accelerated maintenance program that includes thorough and frequent cleaning and HVAC filter replacement, is an effective means of addressing the degraded environment surrounding a construction site. To lessen the chance of airborne asbestos infiltration, the exhaust from sealed work areas must be properly filtered and vented away from historic buildings.

The owner of a historic property should anticipate the increased rodent and pest presence that accompanies major demolition activity. Newly opened holes in old foundations are easy escape routes that should be promptly sealed. The construction or demolition site rodent control plan should include provisions for protecting adjacent historic resources. Concurrently, the historic property owner should consider securing a contract with an independent extermination company. Plans should include both preventive measures to reduce conditions favorable to infestation as well as a system of eradication such as rodenticide and traps.

Monitoring

A monitoring program should be established during the consultation and documentation phases and continued until adjacent work is finished. It is undertaken to detect, gauge, record and interpret structural movement, the effects of vibration and other changes to the historic building that result from neighboring construction or demolition work. Data collected during the monitoring program can serve as a baseline for any subsequent movement or changes to site drainage patterns that arise within the first years after construction is completed. Ultimately, monitoring shows the degree to which steps taken to protect an historic structure from adjacent construction are sufficient and successful.

Because of liability concerns, those responsible for a new development will often arrange to monitor an adjacent structure. As with a documentation program, the historic property owner may want to hire an independent engineer to review both the monitoring process and the measurements that result.

The extent of the monitoring program and the tools used will depend upon the scope of the adjacent activity. A basic plan to address concerns over vibration levels may include a single seismograph placed on the structure's basement floor. More comprehensive measurements can be obtained by locating sensors at several points throughout the structure and the ground immediately adjacent to the historic building foundation *(see figure 6).*

Whether acceptable vibration levels are mandated by law or left to the discretion of a project engineer, thresholds should take into account surrounding soils, the makeup and condition of the adjacent foundation and the particular vulnerabilities of the historic resource. Construction projects that involve major excavation work next to historic structures should include a program of test blasting before work begins. Testing various charges, delays and blast design configurations will aid in developing a controlled program that limits blast induced damage to a neighboring property.

Structural movement as described in the preceding section is detected and recorded using a number of different tools. Electronic monitors that feed precise movement measurements to laptop computers can be placed across existing cracks *(see figure 7).* When budgets are tight or a large number of cracks are involved, inexpensive telltales made from two sheets of overlaid plastic with a grid can be used to track changes.

Optical survey instruments provide another means of detecting vertical and lateral movement within a historic building. Control points are established and marked by targets or reflectors on the historic structure facade and interior walls before adjacent construction begins. The location of each of these markers is precisely measured at regular intervals. Engineers then use the resulting information to determine whether the markers have shifted from their original positions and, if so, the rate and direction of movement.

A program of visual inspections undertaken by a qualified conservator or engineer is an important adjunct to technical monitoring procedures. Inspectors should look for newly opened cracks, other signs of settlement and movement, and evidence of increased dampness or water infiltration. Additionally, visual inspections should ensure that temporary protective coverings are secure, that dust and dirt are not accumulating in the historic building, and that fire and hazardous material protection provisions are being upheld. A checklist can be drawn up during the consulting and documentation phases for use during

Figure 6. A seismograph records vibrations transmitted at the ground level of an historic building. The instrument is wired to a light and siren designed to warn the excavation crew that vibration levels are approaching preset limits. Additional sensors are often installed in the basement and on sensitive features such as stained glass windows. Photo: Wilson, Ihrig & Associates, Inc.

each visual inspection. Such a systematic written record may also prove useful if disputes arise over the timing of and responsibility for damage.

Conclusion

Protecting a historic building from adjacent construction or demolition activity requires thoughtful planning and cooperation between the developer and the historic property owner. Thorough pre-construction documentation of the historic structure ensures a common understanding of present conditions and suggests appropriate damage prevention measures that can be taken at both the historic site and the construction site. A routine program of visual inspection and vibration and movement monitoring helps insure early detection of the effects neighboring construction work is having on the historic building. Early consideration of these issues, before damage takes place or worsens, can allow for the adoption of safeguards that protect the developer's schedule and budget and the physical integrity of the historic structure.

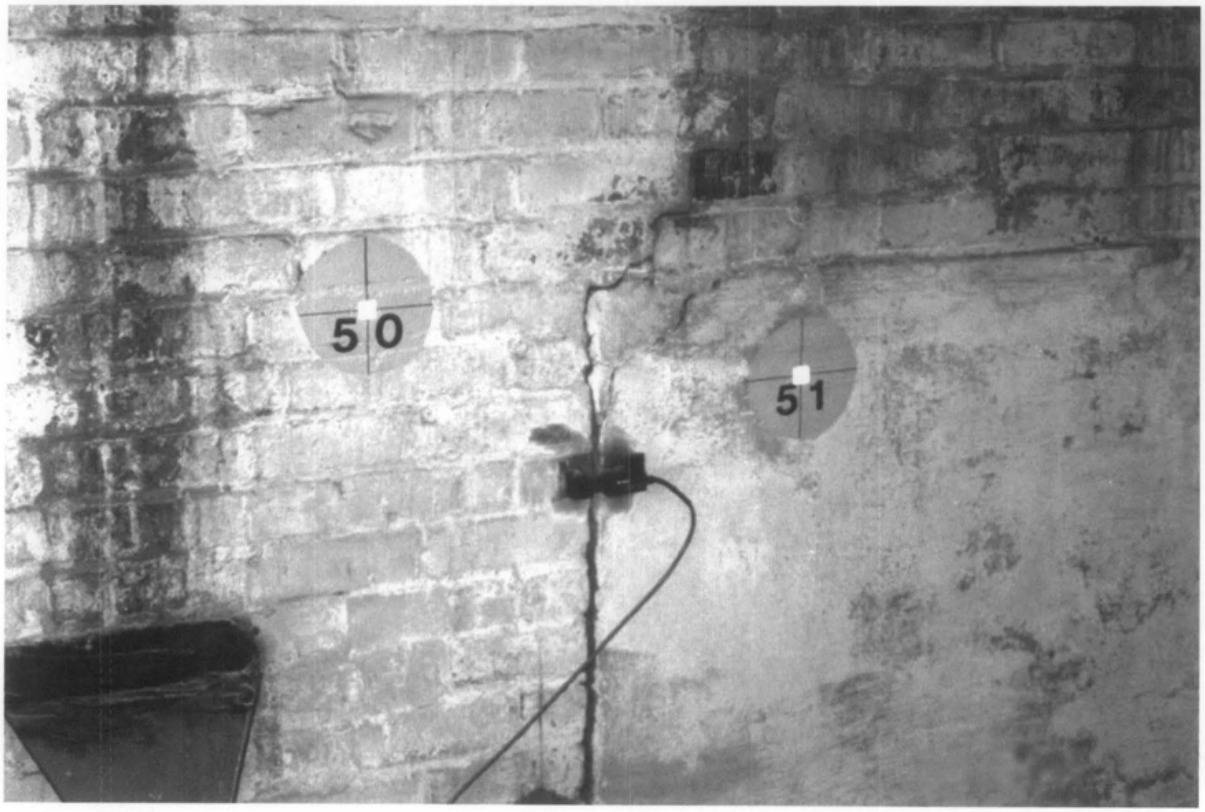

Figure 7. Electronic crack monitor and survey targets are shown installed on an existing wall. The crack monitor feeds movement data to a laptop computer. The targets are aligned and measured with optical survey equipment to determine the degree and direction of movement. Photo: McMullan and Associates, Inc.

Checklist for Historic Property Owner and Historic Site

- ☐ Consult with developer, and other parties to determine extent of work and identify necessary protective measures
- ☐ Conduct survey of existing conditions, including 35 mm photographs, crack inventory and description of other damage
- ☐ Include historic building in construction site fire plan
- ☐ Secure windows and rooftop doors that are made accessible by new construction
- ☐ Remove particularly fragile interior objects and furnishings from site
- ☐ Install temporary supports beneath fragile features that are not moved
- ☐ Place plywood coverings on openings that face construction area
- ☐ If adjacent construction rises above historic site, protect roof with plywood covering, encase rooftop embellishments
- ☐ If construction is directly adjacent, cover historic facade to protect against mortar and acidic cleaning solution
- ☐ Install temporary floor coverings at entrance and seal windows facing construction site to limit dust infiltration
- ☐ Remove dust from interior surfaces on accelerated schedule
- ☐ Clean HVAC system & filters on accelerated schedule
- ☐ Clear obstructions from gutters and drainage system regularly
- ☐ Establish monitoring program, including:
  1) Seismographs to ensure that effects of blasting, pile driving and other work are at acceptable levels
  2) Crack monitors and optical survey methods to detect movement
  3) Schedule of regular visual inspection

Checklist for Development Team and Construction Site

- ☐ Consult with historic property owner and other relevant parties to identify necessary protective measures
- ☐ Review and sign off on pre-construction condition survey of adjacent property
- ☐ Arrange delivery locations and times to limit disruption and possible damage to neighboring historic structure
- ☐ Explore excavation and demolition methods that produce low vibration levels
- ☐ Limit movement of adjacent building with sufficient underpinning or reinforced excavation walls
- ☐ Reduce changes to adjacent ground water level during dewatering
- ☐ Ensure water runoff is not directed toward historic structure
- ☐ Install appropriate debris nets to prevent dropped materials from impacting historic building
- ☐ Direct debris chutes away from historic structure
- ☐ Install fabric enclosure system to reduce spread of construction dust
- ☐ Include adjacent historic building fire plan and ensure fuels, rags and brushes are stored appropriately and not directly adjacent to historic site
- ☐ If asbestos or lead remediation is involved, ensure exhaust from sealed building is filtered and vented away from historic site and that lead chips are gathered and removed
- ☐ Include adjacent historic structure in rodent control program and seal openings in demolished foundation
- ☐ Participate in monitoring program at historic site to ensure that vibration levels or indications of movement are within established thresholds

This PRESERVATION TECH NOTE was prepared by the National Park Service. Charles E. Fisher, Heritage Preservation Services, serves as the Technical Editor. Special thanks go to Deborah Slaton and Michael J. Scheffler, P.E., of Wiss, Janney, Elstner Associates, Inc., Sharon Park, Kay Weeks and Michael Auer of the National Park Service's Heritage Preservation Services, and Marie Ennis of Einhorn Yaffee Prescott for their review and comments. Thanks also go to Denis McMullan, McMullan and Associates; Richard Ortega, PE, Ortega Consulting; Dorothy Richter, Hager-Richter Geoscience, Inc.; George Siekkinen and Gregory Mixon, National Trust for Historic Preservation; Suzanne Pentz, Keast & Hood Co.; Mark Richards, Moretrench American Corporation; Dr. Edward J. Cording, Department of Civil and Environmental Engineering, University of Illinois; Mark Gaudschaal, Schnabel Foundation Co.; William Stivale; Robert M. Powers, Powers and Associates; Martin P. Azola, Azola and Associates; and Margaret Gardiner and Mary Knapp at Merchant's House Museum, for their assistance. Tim Buehner, National Park Service, and Camille Martone provided initial research for this publication.

PRESERVATION TECH NOTES are designed to provide practical information on traditional practices and innovative techniques for successfully maintaining and preserving cultural resources. All techniques and practices described herein conform to established National Park Service policies, procedures and standards. This Tech Note was prepared pursuant to the National Historic Preservation Act which direct the Secretary of the Interior to develop and make available to government agencies and individuals information concerning professional methods and techniques for the preservation of historic properties.

Comments on the usefulness of this information are welcomed and should be addressed to PRESERVATION TECH NOTES, Technical Preservation Services NC200, National Center for Cultural Resources, National Park Service, 1849 C Street, NW, Washington, DC 20240.

ISSN: 0741-9023 PTN 42 July 2001