Mitigation of Damage to Buildings Adjacent to Construction Sites in Urban Environments

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This paper is the third article in a three-part series on planning and managing building response to adjacent construction. The first article, *Monitoring Building Response to Adjacent Construction*, was published in the November 2008 issue of STRUCTURE® magazine. The second article, *Planning to Minimize Damage to Buildings Adjacent to Construction Sites in Urban Environments*, was published in February 2010.

Construction of buildings in congested urban settings often results in damage to existing structures located on adjacent sites. The underlying cause of damage is typically lack of planning and proper care before or during construction, or unpredictability of existing conditions. However, even the most careful planning and implementation can result in damage when adjacent existing buildings are fragile structures that can be especially susceptible to ground movement (due to excavation and dewatering) or vibrations (due to demolition, pile driving, and other construction activities).

Once the damage occurs, it is in all parties' best interests to resolve claims quickly and amicably. Some of the processes associated with evaluation, immediate response, and long-term remediation of damage are described in this article.

Managing Building Response and Remedial Actions (React)

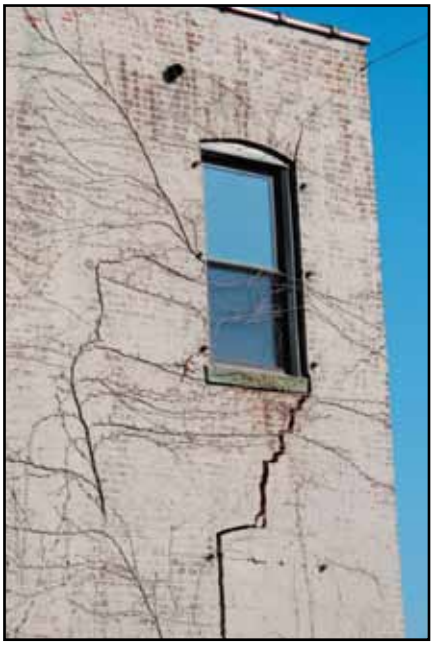
Even though consultant involvement can be a result of proactive thinking by the adjacent building owner in the planning or initial stages of construction, engineers and attorneys are most often brought in only after damage (real or perceived) has occurred. The engineer is tasked with determination of what if any damage occurred, when it occurred, why it occurred, and how to manage and repair it.

In most cases, damage to adjacent structures occurs due to change in support conditions (vertical or lateral) for the structure, due to excessive vibrations, or due to physically inflicted distress, such as impact (e.g. during demolition). However, depending on project specifics, level of organization, and control, the actual cause may be traced to many different origins. Damage may occur even in well organized projects; for example, when unexpected field or subterranean conditions are encountered. Regardless of the number of soil borings taken prior to construction, specific soil and foundation conditions cannot be predicted with certainty. Also, lack of control or supervision during operations is often likely to result in undesired outcomes for adjacent buildings; improper excavation, dewatering, or underpinning operations can be a cause of significant building damage. On the design side, poor predictive models of behavior, as well as incorrect assumptions, will also often result in damage. For example, if it is assumed the adjacent building is supported on steel piles bearing on rock, when in fact it is supported on wood piles bearing on a shallower, somewhat loose sand stratum, vibrations associated with driving of sheet piling can and likely will result in soil consolidation and settlement. Had the right assumption been made, or if foundation conditions were verified by limited exploration through test pits, a different approach to the earth retention system may have been selected with the explicit intent to mitigate damage.

Engineering Field Investigation

When damage is alleged, typically the first question to answer is whether damage has in fact occurred. Buildings adjacent to construction sites can respond to movement, vibration, or lack of vertical or lateral support; these events typically result in some level of tenant discomfort, which may or may not be related to damage. Even if there is no damage, engineers should evaluate available information and determine whether construction processes should be modified to accommodate relief of tenant discomfort, or to avoid potential for damage in the future.

If there is damage, the question to answer is whether the damage is in fact due to activities associated with adjacent construction. A well-planned and executed preconstruction survey can serve as the first evaluation by simply comparing the alleged damage with the documented pre-existing conditions. If this comparison is not available or insufficient, engineers essentially start playing the role of detective.



A photo of a building with severe masonry distress due to settlement caused by adjacent construction.

However, depending on timing of damage discovery, available clues pointing to causation may be limited. For example, if the building next door is already erected, many clues related to excavation or underpinning methods, and whether they were adequate, are going to be concealed and unavailable.

Once on site, the first task for the "detective" engineer is to determine and independently evaluate the visible signs of damage. Building size, location, orientation, type, and details will to a large extent govern the amount and type of observable damage. Also, construction methods, type, and sequence will be associated with certain types of damage. A savvy engineer would look for certain types of damage common to specific construction types. For example, buildings with bearing masonry wall construction exhibit visible stepped brick cracking when subjected to differential settlement. Additionally, if racked window and door frames, cracked or displaced lintels and sills, or in some cases visible sloping floor- and roof-lines are observed, the likely culprit is differential settlement. Other typical damage to look for includes sloped and cracked slabs on grade (due to consolidation or settlement of soils below them), bowing exterior walls or loss of bearing for joists in wall pockets

(due to vertical settlement or lack of lateral support), impact damage, and damage to waterproofing systems (e.g. if the adjacent building sharing a party wall was demolished).

Discomfort and damage reported by owners and tenants may not necessarily confirm that the distress occurred due to adjacent construction, or how recently it occurred. Once the first vibration or loud noise occurs, people tend to start looking for damage and notice "new" cracks and other distress, which in fact could have been there for a long time. The engineer should attempt to discern between a "fresh" distress and one that has been around since the last interior renovation. Unfortunately, not all cracks can be read like an open book. But, the engineer should be able to classify observed damage based on the likelihood of it occurring due to activities next door. Cracking from settlement should be easily distinguishable from cracking due to lintel corrosion or drying of mortar, for example. On the other hand, some vibration-induced damage may not be easily classified or dated.

Immediate Shoring and Stabilization

Before establishing cause of damage, the engineer often must provide immediate recommendations for stabilization and shoring in case any component of the structure is unstable or potentially unsafe. Stabilization efforts can be comprehensive and may vary from pinning back a dislodged individual ornamental terra-cotta façade component, to providing floor-to-floor shoring in a distressed masonry bearing wall building. Floor shoring becomes especially critical if floor-framing support provided by the bearing masonry wall is compromised due to lateral wall movement (joists are in danger of slipping out of the pockets). In some situations, for example where lateral stability of the party wall is further reduced due to demolition of the building on one side of it, the floor-to-floor shoring may need to be supplemented with temporary lateral wall support. This can be provided by a "raker and waler" (or another) system from the construction side, or with connection details that tie floor framing to exterior walls, hence preventing lateral movement in long-term. Available exterior shoring options will typically vary depending on the construction stage at the adjacent site. In general, engineers have to be extremely careful to identify all potential safety issues; for example, if façade components are visually assessed as potentially unstable, either immediate up-close investigation should be performed (followed by remediation as needed), or pedestrian protection should be provided. In extreme situations, buildings may have to be evacuated.

Engineering Evaluation

Once immediate safety concerns are addressed, the cause of damage and potential for further damage should be evaluated, followed by development of a remedial work plan. Evaluation of damage alone may not be sufficient to determine cause and allocate responsibility for it. It needs to be put in context. Differential settlement damage could be a result of long-term soil consolidation, or it could be a result of improper bracing for excavation adjacent to the building in question, or both, or something entirely different. To correlate damage to activities next door, the "detective" engineer needs to understand the methods of construction at the adjacent construction site, the chronology and sequence of events, soil and site constraints, etc.

Assuming access to the construction site is provided, the engineer could observe activities, construction process, and detailing at the adjacent site. If access is not provided, or if the structure is already out of the ground, the engineer will have to rely on records. This includes design documents, the geotechnical report, shop drawings, underpinning and excavation drawings, and photographs. In general, accessing detailed information from the developer may be difficult, and it will depend on the level of cooperation or communication between parties, as well as the organizational structure of the project. There are also situations where there is not a direct line of communication, regardless of the relationships. One example is when the engineer is working to determine damage causation on behalf of the insurance company, after the fact, when the offending party may not be reachable or even known.

If construction documents are not readily available, the building department records can often be used to glean information regarding general layout of the construction site and location and depth of the adjacent structure, even though they would typically not describe the construction excavation methods. Photos and verbal reports, often produced by tenants of adjacent buildings, can also help identify the type of activities at the adjacent construction site.

To further evaluate damage and likelihood for further damage, all available monitoring data, soil data, and site data should be considered and used to analyze the observed distress. If monitoring data from the adjacent site are not available or do not exist, a new monitoring program may need to be established. Depending on the situation, these additional programs may include installation of extensometers to monitor ground strains, installation of deflection monitoring points (DMPs) at various locations on the building exterior and interior

to measure vertical and horizontal deflections and angular distortion, laser surveying, installation of tilt meters to measure verticality, and seismographs to measure vibrations. Monitoring building behavior in real time allows for timely reaction and remediation, often before the "real" damage has occurred. For example, if vibration levels are quickly deemed sufficient to cause building damage or soil subsidence, the construction methodology can be promptly altered to mitigate problems.

In addition to monitoring, a more-thorough condition appraisal may be needed to understand all the effects of adjacent construction. This may include up-close access to the building façade or localized removal of building finishes in order to observe critical structural details (for example where joists bear on masonry walls). These investigative actions, as well as monitoring, can be expensive; therefore, insurance carriers should be promptly involved.

If monitoring information is not clearly pointing to the underlying cause of damage, other engineering tools and analytical models can be employed to help estimate the nature and magnitude of the problem so that it can be addressed more effectively. For example, if a tendency of soil to move laterally is analytically predicted due to a particular configuration of excavation, appropriate bracing can be provided.

In situations where the effects of construction activities cannot be easily assessed, it may be advisable to notify the developers to cease operations until the investigation is completed. Advising the building department of an ongoing situation should be used if all other forms of communication fail.

Remediation

Permanent repairs for damage incurred at the adjacent property are typically handled at the end of the construction process. Most damage can be repaired in a reasonable and conventional fashion. Some building responses, however, can result in irreparable damage, at least from a cost standpoint. A good example is sloping floors. In most older buildings, some differential settlement is likely. Even if the amount of new settlement due to construction activities next door is distinctly discernable from pre-existing damage, jacking up framing to level floors is impractical, cost-prohibitive, and in some cases can cause more damage than good.

Other damage can be repaired. Cracked or otherwise distressed brick walls should be stitched, partially rebuilt, or repointed. Generally, distressed structures can be permanently stabilized and strengthened with bracing, shoring, and re-attachment. In cases where further movement and damage is probable, underpinning, re-underpinning, or other soil stabilization techniques (e.g. jet grouting), as well as further monitoring, may be required. Slabs-on-grade and other foundation elements can be drilled and grout pumped to fill voids left by subsiding soils. For certain types of construction, jacking of columns may be a viable solution to negate some effects of excessive settlement. In other cases, leveling floors with insertion of a light-weight grout of variable thickness can provide a viable solution. If the lateral-load-resisting system or any other structural system of the building is rendered inadequate or was compromised by adjacent construction, retrofit may be needed. An example of this situation is when one of the buildings sharing a party wall is demolished, the building on the other side of the party wall may be left inadequate to resist lateral loads on its own. The solution in that case could involve installation of moment frames or braced frames within the building interior or on the exterior to enhance lateral stability.

Exterior building wall is braced to prevent further lateral movement of the wall.

Other repairs may be required by the building code. For example, in some municipalities, if a structure on one side of the masonry bearing party wall is removed, the developer is obliged to provide permanent attachment of the remaining wall to the floor framing on the other side. Also, any visible and obvious damage to the waterproofing system, roofing, or façade, may need to be repaired by the construction project owner to protect the adjacent building. Enforcement of the repairs mandated by the code, however, may be difficult.

Conclusions

Interpretation of construction-related damage to buildings in congested urban environments is often in the eye of the beholder. Some engineers are equipped to impartially determine the extent and cause of the conditions of concern, as well as the means to repair it. Unfortunately, lack of planning typically results in reactive measures, and responsibility for those, despite even the clearest engineering interpretations, usually does not get sorted out easily or amicably. This is due, in part, to ambiguity of building codes and common laws regarding allocation of responsibility, to developers and their contractors who undertake construction without proper regard to their neighbors, and to uninformed building owners. As a result, adjacent-building owners can be misled into believing that problems are not real or will go away, are not compensated fairly for incurred damage, or are forced into litigation or costly repairs they cannot afford. In the meantime, the building stock irreversibly accumulates damage.▪

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