Biodegradation of Untreated Wood Foundation Piles In Existing Buildings

Remedial Options - Part 3 of 3

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Parts 1 and 2 of this series of articles can be found in the June 2007 and September 2007 issues of STRUCTURE® magazine.

Untreated wood piles supporting buildings in cities historically built on urban fill are subject to increased biological deterioration due to localized groundwater drawdown, predominantly caused by man-made construction. Groundwater depletion, along with the growing uncertainty relative to realistic projected overall service life of piles (regardless of whether continually submerged or not), has become a significant economic problem and/or concern among building owners in historic cities.

Preventive Methods

Monitoring Programs

There are certain situations where building repairs are not immediately warranted or even possible. For instance, budgetary constraints may prevent immediate action, and repairs are postponed until settlement trends in the building are better understood. Similarly, remediation may not be the first choice if the discovered damage is not significant enough to warrant immediate repairs. Or, if it is known that a potential for (additional) pile decay exists due to proximity to known groundwater depletion areas, regardless if the building shows signs of settlement and/or piles can be exposed for assessment, an alternative initial approach may be chosen.

One of the available options to manage building safety prior to repair is to establish deflection and/or crack monitoring programs. A deflection monitoring program consists of regular monitoring of global movement (usually downward) of numerous discrete points. Assistance of a registered land surveyor is typically needed to set up a deflection monitoring program. Supplemental to global-movement monitoring, crack gauges can be installed across existing building cracks (*Figure 1*), if present, to observe any additional widening or shearing of the cracks that may be indicative of building settlement.

The goal of the deflection monitoring program is to understand settlement trends and to enable timely response to mitigate damage. In certain situations, this may yield the expected results. However, settlement is not necessarily directly correlated to the present condition of the piles, and, once settlement becomes evident, the pile damage can already be beyond the point that would allow preventive measures.

An alternative or additional approach to evaluating pile-damage risks is to continually monitor groundwater elevations in the vicinity of the building. The most direct approach is to install monitoring wells either in the building basement, in previously excavated test pits, or directly adjacent to the building. The monitoring well is essentially a perforated pipe installed vertically in the ground to below the expected groundwater table elevation. The pipe is surrounded by crushed rock or other permeable material, and the groundwater is allowed to enter the pipe through the perforations (*Figure 2*). The wells are monitored from the ground, allowing for accurate and timely observation of the groundwater table and implementation of remedial actions, if necessary. Multiple wells can allow for monitoring of groundwater trends and potential identification of drawdown sources.

It is important that wells be regularly maintained and inspected to prevent clogging or other malfunctions.

Figure 1: Crack gauge is placed across an existing crack to monitor future movement.

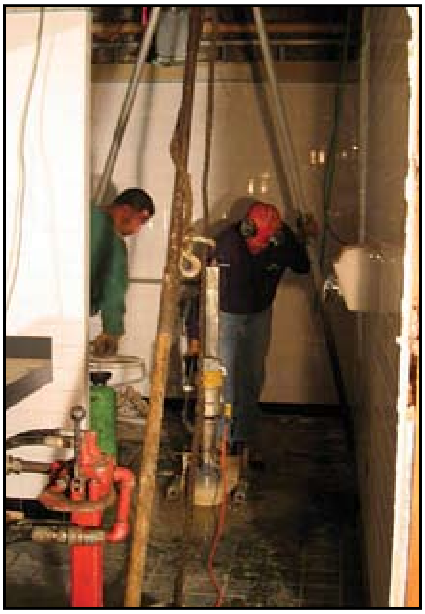

Figure 2: Installation of an observation well on the building interior.

Recharge of Groundwater

If pile decay is minor or non-existent, if no significant settlement exists, and if preventing or retarding further pile deterioration is economically viable, several methods are available to maintain groundwater level above the tops of existing piles.

Water-recharge systems typically include cutoff walls or coffer dams placed adjacent to or surrounding the existing foundations, to impede groundwater flow to drawdown sites. Water from the tap or from collection of rainwater can then be supplied to effectively maintain water levels by locally replenishing and controlling groundwater in the vicinity of building foundations. Recharge systems with sensors can be utilized to automatically start water replenishment when the table drops below a predetermined level (*Figure 3, see page 16*). Similar to observation wells, the recharge systems need to be regularly maintained. Care should be used in selecting the recharge source. In one project investigated, storm-water piping was tapped for recharge, but intermixing of sewage occurred, causing extreme odor problems in the recharged building. In another project, boiler-leakage penetrated the recharge system, causing a peculiar high-temperature soil and groundwater environment around several pile caps in the building, potentially suitable for unusual bacterial action. Care must also be taken in design and construction of the cutoff structure to provide tight containment.

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Figure 3: An automated device controlling groundwater table – the recharge system "kicks in" when water elevation drops below a predetermined level.

Other Preventive Methods

As mentioned above, groundwater depletion is predominantly caused by leakage into sewers, deep basements, construction sites, tunnels, and other subgrade structures. One potentially effective method to control localized drawdown is installation of siphons that equalize groundwater levels on opposite sides of dam-like buried structures and other drawdown sites, therefore theoretically allowing for the groundwater to remain at pre-construction levels. Without constant monitoring, inspection, and adjustments, however, these systems are not reliable and may prove to be ineffective.

In addition to man-made structures, groundwater table is also affected by the constantly shrinking green areas in urban environments. Without these "natural rechargers," the majority of rainwater does not end up in the soil, but it is collected on the streets and transported away by the storm-drainage system. Building owners can try to limit the effect of this phenomenon by directing gutters and downspouts on their property into the soil adjacent to the building. Also, in sensitive groundwater-depletion areas, it may be advisable to replace the impermeable asphalt on driveways and other surfaces with gravel or other, more permeable materials.

All of the above preventive methods are of a limited or only temporary value if the damage is expected to be at a level where groundwater exposure no longer helps (the decay mechanism is irreversible), or when the predominant decay mechanism is not tied to groundwater depletion (e.g. when piles are submerged, but have been exposed over 200 years to slow-consuming bacterial or soft-rot action).

Remedial Methods

When piles cannot be relied upon to support the building loads, the only viable option is foundation repair or underpinning. There are several currently available repair approaches.

Replacement or Strengthening

The most common repair involves replacement of the deteriorated portion of the piles with a new load-bearing component. Typically, the load path is maintained by inserting either a steel or concrete component between the pile cap and the "healthy" portion of the pile below (*Figure 4*). Since connection between the remaining pile and the inserted element is difficult to establish, the inserted elements are typically encased in concrete or other flowable materials to provide bracing.

This method requires engineering assessment and design. The "insert" elements must be designed to match or exceed the actual load demands on the pile, the tunneling or other excavation support must be adequate, and the pile-cutoff point for the repair, based on the lowest expected groundwater table in the future, must be carefully evaluated.

Access to the piles is provided either through pit or tunnel excavation. To minimize disruption to tenants and building operations, tunneling is the preferred approach if the building has a used full-height basement. In sub-basement or crawl-space situations, excavation pits may be the preferred method. In either case, pile replacement is a lengthy and expensive process, involving tremendous hand-digging and requiring close supervision for worker and building safety.

Abandonment and Replacement

An alternative to reusing the unaffected or "healthy" portions of existing piles is installation of a completely independent foundation system that "circumvents" existing piles. There are several effective and commercially available foundation systems that provide direct support to foundation walls or pile caps; the load path from the building is transferred from the wood piles to the new components. The new system is usually also of a deep-foundation variety: mini piles, jacked-in-place or helical piers, jet grouting, etc.

These approaches do not require providing direct access to the piles, but they still require significant construction effort. Installation of standard mini piles requires detailed

Figure 4: Steel pipes are inserted to fully replace the deteriorated portion of the pile. The void is later filled with concrete.

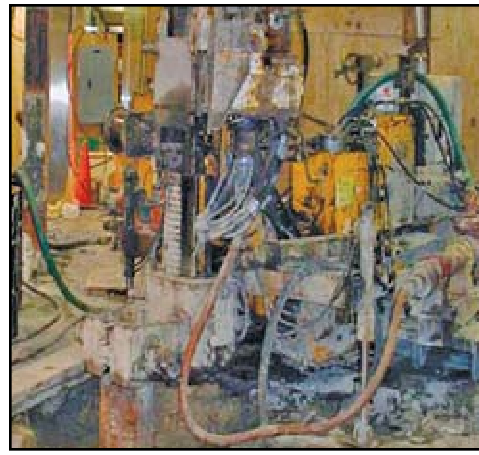

Figure 5: Mini-pile installation can be messy and disruptive.

engineering design of the connection (load transfer) between the building components and the new pile foundations. Often, pile-cap modifications or construction of new cap components are required. Invariably, operations are extremely disruptive, especially in inhabited and finished spaces (*Figure 5*). The pile-installation equipment, although portable, is generally limited to spaces where ceiling height exceeds 10 ft.

In addition to the conventional mini-pile approach, several lighter-duty proprietary systems employing a similar approach have become available in recent years. Push-pier and helical pile systems are simple, pile-based systems that rely on simple connections to the existing building foundations. Special shelf brackets can be tucked under the pile cap to pick-up building loads (*Figure 6*), or special bolted-plate connections can be mounted to the foundation walls.

The push-pier systems consist of segmental steel pipes pushed into the ground with hand-operated hydraulic devices, until a predetermined resistance is reached; the system is then "proofed" to a certain load resistance. The operator relies on the weight of the building as a reaction during pile installation. Even though the piles "push" against the building, no upward jacking should be expected.

Similarly, helical piles are "screwed" into the soils until a torque associated with a pre-calibrated vertical load resistance is reached (*Figure 7*). Both of these systems are less obstructive than mini piles, but their load rating is limited and therefore they are preferred in situations where the load demands are not very large.

Before specifying these proprietary systems, manufacturer's claims relative to code compliance, durability, installation, and long-term performance should be evaluated. Engineering guidance is recommended, especially in situations where only one-sided access to the foundation walls is available, or when individual columns require underpinning. For

Figure 6: Push-pier pile is installed with a steel bracket tucked in under the foundation pile cap.

Figure 7: Helical pile is installed adjacent to the existing footing.

example, if the piles are all applied to one side of the foundation wall, the eccentricity associated with the installation may result in an undesired moment on the wall. This can create distress, particularly in masonry wall situations.

Jet grouting is based on the idea of modifying the properties of the soil layer (fill) that cannot be relied upon to adequately support the weight of the structure above. Typically, the piles were originally installed to pass through weak soil layers, and to transfer loads into the bearing strata below. Jet grouting is a method that essentially places concrete columns in the soil through drilling and rotational spraying of grout as the grout pipe is withdrawn from the soil. The ensuing sub-grade concrete columns are then relied upon to transfer the building loads directly into the bearing strata. This method has successfully been used in large underpinning projects, but several constraints render its application limited in low-rise structures commonly founded on untreated wood piles. Similar to mini piles, the jet-grouting operation is disruptive and space consuming. Also, some organic soil layers are not conducive to jet-grout placement, and the existing wood piles can "shadow" grout placement (the piles get in the way of the grout spray), limiting its effectiveness. In situations where the wood piles are already badly deteriorated, grout spray may further damage the wood material and cause further distress and settlement, prior to solidification of grout.

Several other, unproven methods are currently under consideration for pile repair. For instance, experiments are under way involving in-situ chemical modification of wood material's physical properties. One potential approach considers instant petrification of wood, where the wood material, decayed or not, is essentially turned into stone through an accelerated chemical process. Ideally, the soils and therefore the piles would be treated from the ground, without the need for expensive pits or tunneling. Such approaches are still in the infancy phase and far from realization. Even if such technology is developed, issues like leaching of chemicals into the groundwater, as well as installation quality control and assurance, would need to be resolved.

Conclusions

Several methods for prevention and remediation of building settlement from wood-pile decay exist today. An accurate estimate of the remaining service life of wood piles, combined with a timely reestablishment of groundwater levels through recharging, could potentially result in postponement or elimination of inherently-expensive underpinning repairs and result in significant cost savings. On the other hand, inaccurate assertion that wood piles are in good condition, or failure to recognize potential service-life limits associated with various degradation mechanisms, can result in extensive settlement and, potentially, in a structural failure.

Affected individuals, academicians, as well as governmental and other agencies need to become actively involved and work on strategies to limit and control this significant and growing economic problem.▪

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