# That Hollow Feeling

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A city sidewalk might not be as simple as it appears – it depends on your perspective. Many pedestrians do not expect that the common sidewalk they walk on might be hollow. But hollow sidewalks are common in many older cities; the sidewalk was the early loading dock through which the building was stocked with supplies via a sidewalk hatch. In these older buildings, the basement extends beyond the footprint of the building and under the city sidewalks. The "vault" space under the sidewalk ends with a concrete or masonry wall that retains the soil beneath the street. And frequently, the sidewalk over the vault, the only barrier preventing people and vehicles from falling into the basement, is badly deteriorated and unsafe (*Figure 1*).

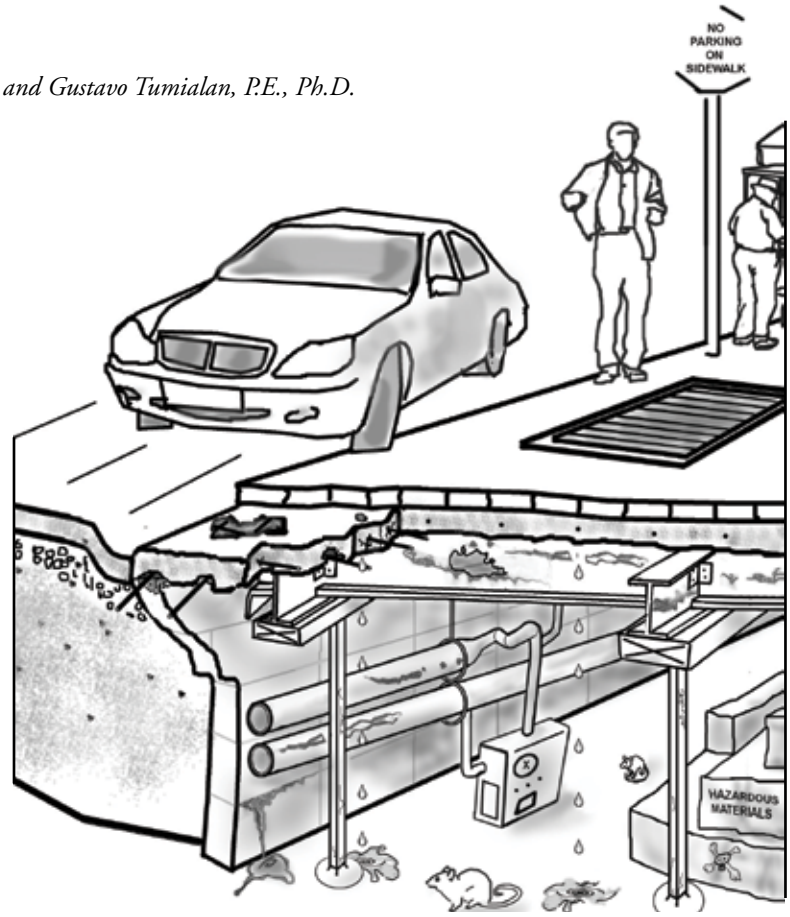


*Figure 1: Frequently, the sidewalk over the vault, the only barrier preventing people and vehicles from falling into the basement, is badly deteriorated and unsafe.*

## What is the Problem?

Deteriorated structural sidewalks that cover vaults are a growing safety concern. Occasionally, a careful observer might see a sign "Warning: Hollow Sidewalk," probably partially hidden by a delivery truck that just parked with two wheels on the sidewalk. Structural engineers who have seen their share of sidewalk covers from underneath are very wary when they see such a scene. They are also never surprised when they learn that a heavy vehicle has punched its wheel through a sidewalk somewhere in the city. Veteran engineers may even recall situations where the sidewalk cover fully collapsed and destroyed a maze of pipes and rusting structural elements that were in the way. In severe instances, after the cover fails, the (now) laterally unsupported curb-line foundation can also cave in, taking with it a part of the driving lane. A scenario with cars driving right into the newly formed sink hole in the street is then not too farfetched. Not pretty!

What are the causes of this urban collapse risk? Several contributors are common.

The first is related to the loading; many sidewalk vault covers were never designed for vehicle loads. Many of them were in fact built prior to development of modern code provisions, and were intended for pedestrians only. However, in the fast-pace environment of today's life, it is not uncommon to see delivery trucks, various mechanical equipment and machinery, contractor pickup trucks, cranes, or even fire trucks, trying to steal that one more inch of space closer to their destination – this effectively places the same load demands on the sidewalk as those that occur on a road bridge. Other heavy loads occur as building owners place large planters at the entranceways, or when contractors erect scaffolding right on the hollow sidewalk. When exposed to these "unexpected" (for them) loads, many sidewalk vaults do not collapse, but when the structural condition is marginal, some local damage will develop and accumulate, leaving the sidewalk weaker for the next "overload" event. Small sink holes and topside cracks reflecting through pavers or topping are usually a good indicator that the vault structure requires attention.

Another contributing collapse mechanism is the deterioration of the sidewalk covers and the structure that supports them from below. The only thing pedestrians and delivery truck drivers see are

*Figure 2: Segmental masonry brick arches supported by steel beams and stone masonry walls.*

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*Figure 3: Concrete beams and slabs forming the vault cover. Note the shored beam and leaching on the slab underside caused by moisture migrating from the top.*

flat-pavement sidewalks; perhaps with some patches and unevenness, but still appearing safe to walk (or drive) onto. As it turns out, this is often not the case when the sidewalk is in fact a "bridge" deck and not supported by ground. Most likely, there are several layers of pavement (with patches, weak spots, even holes) that hide the real nature of the structure below: potentially corroded steel beams, deteriorated concrete, semi-collapsed temporary shoring systems, deteriorated walls and columns, etc. An experienced engineer has seen them all.

## How are Vaults Constructed and What is Happening to Them?

To fully appreciate the magnitude of the structural concern, one must first understand various types of sidewalk construction, as well as consider what type of (frequently undocumented) deterioration occurs during their service life.

Many sidewalk vaults in older buildings consist of granite sidewalk slabs that span between the curb-line foundation wall (typically re-taining earth) and the beams and piers that support the exterior wall of the building. The granite plates are typically 6 to 8 inches thick and time has proven them to be sufficient to carry pedestrians and small vehicles. But, accumulated deterioration due to weather and traffic exposure, as well as various modifications/penetrations made in and through the covers, can weaken the slabs during their long service life. Typically, however, granite covers do perform well; regular inspections of slabs for cracking and soundness should prevent any safety issues. On the other hand, since these systems generally have no waterproofing, their supports are subject to deterioration. Metal structural elements and lime mortars in older stone and brick foundation walls are especially susceptible, and should be subject to close annual inspection.

Another traditional sidewalk cover is iron grating infilled with glass-block cubes that allow some light to enter the basement space. The iron grating usually only covers a portion of the sidewalk width. This system is very prone to water penetration, and, therefore, is subject to metal corrosion. In addition, grating systems are often found covered over by maintenance paving, which can conceal the threat of deteriorated materials. Therefore, any inspection of sidewalk vaults should be done from both the outside and inside of the vault space.

*Figure 4: Shoring of a deteriorated vault structure.*

Some sidewalk-vault structures consist of brick or terra-cotta arches, supported by steel beams concealed in the arches (*Figure 2*). This construction includes concrete toppings (typically 4 inches thick), or thin brick pavers (typically in the range of 2 inches thick), which tend to crack or dislodge due to heavy traffic above. Due to the arch configuration, these vault covers are generally capable of supporting high loads. However, their susceptibility to water penetration often results in heavily corroded steel beams and masonry arch deterioration due to freezing and thawing cycles, therefore rendering the entire system very weak and unreliable.

Newer systems are very similar to modern bridge decks, and include concrete slabs on metal deck supported by steel beams. Other typical systems include concrete beams and infill slabs. These vault types typically also have a topping for pedestrian traffic. Just like any other systems, if not constructed properly and with forethought, these structures can also deteriorate very quickly if water is allowed to enter the system (*Figure 3*). Just like modern bridge decks, there is frequently no waterproofing membrane to protect structural components from water ingress, which when laden with deicing salts, can cause very early demise of steel beams and reinforcing steel embedded in concrete. It is not unusual to observe many concrete elements inside of vaults whose steel reinforcement was gone due to deterioration. And even when there is waterproofing placed between the underside of the walking surface and the top of the "structural" deck, the termination of the waterproofing against the curb and the rising wall of the building is very susceptible to leakage failure and is difficult to maintain.

In many of the vault spaces there are remnants of past attempts to "shore up" the deteriorating decks, rather than evidence of leakage maintenance and/or structural repair. The shoring often involves timber or metal posts and other types of structural elements (*Figure 4*). These conditions are difficult to evaluate, because very frequently there is no documentation showing who installed the shoring, for what reason, and when. In addition, the shoring elements (plywood, timber) often cover the underside of the actual structure, rendering observation of structural conditions impossible. Shoring of the structure also frequently gives a false impression of safety to building inhabitants and to the untrained inspector.

## Repair Alternatives

Despite potential long-term shortcomings, temporary shoring is a rational short-term alternative. Shoring alleviates the most immediate structural concerns, while allowing time for development of other solutions. But, it requires continued inspection and reevaluation of the system. In other words, with shoring, the immediate safety concern may be addressed, but the cause and root of the problem (most frequently this is water penetration) is not removed. Therefore, additional deterioration can be expected.

Total or partial replacement of the vault structure is usually the best solution, but it can be shockingly expensive. The sidewalk covers can be replaced with a more-durable system, supported by a new permanent support structure below (*Figure 5*). Partial replacement of

*Figure 5: Support for new cover vault consisting of metal deck and steel framing.*

the cover is also an alternative, but it requires integration between the existing and new covers (*Figure 6*). A common and comprehensive waterproofing system should be installed, and/or the entire deck and support systems must be made robustly resistant to water ingress. The problems with comprehensive cover and structure replacements include access solutions (around the existing equipment, tenants, etc), rerouting of pedestrian traffic, temporary support of the retaining wall during construction, temporary or permanent relocation of utilities, etc. Relocation of utilities typically deserves special attention, since the vault spaces often house very congested utility lines (*Figure 7*). Utility relocation and even identification of active versus abandoned components, can result in additional expenses, potentially requiring special permits and coordination with the building departments.

*Figure 6: New steel structural support for partial replacement of a vault cover. Note that the original structure consists of concrete beams and slabs.*

An alternative approach for providing durable and almost infinitely strong sidewalks is filling the vault space with concrete or flowfill (type of concrete made with fly ash and a foaming agent). This is a viable alternative when the vault space is not needed or valuable. Generally, this solution involves providing for a barrier between the basement space and the vault space (such as a steel-reinforced CMU wall), that will serve as a form for concrete or flowfill placement. Concrete is then placed to fully "plug" the vault space, all the way to the underside of the existing cover. This approach is the most direct, and it does not require removal of existing covers. Commonly, implementation of this system requires rerouting of utility piping and relocation of other mechanical equipment.

Building codes commonly specify a uniform live load of 250 pounds per square foot (psf), or a concentrated wheel live load of 8,000 pounds to be considered in design of sidewalks that are subject to trucking. To put this in perspective, a large group of people standing shoulder to shoulder can rarely exceed a live load of 100 psf. More significant, though, is that neither the uniform-load criterion nor the point-load criterion adequately reflect some of the modern large-wheel loads; the actual demand placed by one wheel of a fire truck can exceed 10,000 pounds.

So, an engineer with a task of designing or retrofitting a sidewalk-cover structure struggles with setting a safe load criterion. Is 100 psf adequate when evaluating an existing sidewalk-cover structure? Posting a warning on building walls may legally protect the building owners against liability, but it will not necessarily stop the trucks from driving onto the sidewalk should the opportunity present itself. Is 250 psf the right number? That will probably work for smaller trucks, but will a fire truck ever drive up onto the sidewalk? Is the 8,000 lbs wheel load enough? Should the cover be designed for regular fire-truck loading and consider loads due to truck or crane outriggers?

In most cases, engineers faced with this problem will have to consider likelihood of certain types of traffic, and then make decisions based on the feasibility of particular solutions. Of course, it is much easier to design a vault cover from scratch to be truck-proof than to upgrade an existing vault for increased loads. Analysis and retrofit of existing vaults is also frequently bogged down with access difficulties and lack of information on the existing structure. Building finishes, stored items, existing installations, and sometimes even shoring do not allow adequate inspection and observation of the existing systems, drawings are seldom available, etc.

*Figure 7: Vault space congested with utility lines.*

In the end, engineering solutions will sometimes be expensive, controversial (undesired by the owners), and disruptive. But, the engineer's ultimate goal is to protect public safety.

## Public Safety

The number of slowly deteriorating and unattended sidewalk vaults in many larger cities is alarming. Currently, in some states, there are no city ordinances or official code regulations requiring building owners to inspect and maintain their vaults and the associated covers on a regular basis. Many vaults are almost a no-man's land, frequently disclaimed by building owners and forgotten by city officials. The owners' negligence is surprising, given that the liability, should something happen, is typically assigned to owners or operators of the buildings – they "own" the sidewalk. Even when there are accidents reported in the news, many owners think it a freak occurrence that cannot happen to them.

Given the continually progressive nature of the deterioration problem, the number of neglected vaults (and buildings), and the overload occurrences, the frequency of accidents are bound to increase! To prevent this, city officials and governing code regulators should work towards developing a set of stringent inspection and repair guidelines, similar to city ordinances or local laws requiring façade or fire escape inspection on a regular basis (e.g. 5 year cycles). Another simple tool would be to require the curbs adjacent to all sidewalk vaults to be painted a certain color, as a universal warning to heavy vehicles and as a reminder to building owners of their hidden risk. Overall, minimizing the risks, whether through preventing access, providing adequate maintenance and repair, strengthening, or a combination of all of the above, is in the best interest of public safety.▪

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