TECH BRIEF

Vacuum Testing of Manholes

Understanding the limits of the methodology

By Michael R. Miller

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Photos courtesy Cherne Industries Inc.

The use of vacuum testing is now the primary standard by which manholes are tested and accepted.

During the past five years, the precast concrete industry has seen a dramatic change in testing of installed products, especially manholes. The use of vacuum (negative air pressure) testing has gained ground almost everywhere and is now the primary standard by which manholes are tested and accepted. This broad adoption means that more inspections are being performed in a wider variety of conditions. As these conditions vary and include more extremes, both installers and inspectors find that vacuum testing, like all test methods, has its limitations and cautions.

Water pressure effects in hydrostatic manhole testing

The relationship between the height of a water column and the pressure it exerts is direct and linear. If you have a column of water 23 feet tall, you have a pressure of 10 psi at the bottom, 5 psi at the midpoint and 0 psi at the surface. If the column is 46 feet tall, you have a pressure of 20 psi at the bottom, 10 psi at the mid-point, and 0 psi at the surface. Thus, when a 15-foot-deep manhole is filled with water for an exfiltration (leakage) test, the bottom of the manhole is pressurized to 6.5 psi, the midpoint to 3.25 psi and the surface to 0 psi.

Based on this linear relationship, it is easy to see how water testing provides unequal testing pressures throughout the manhole structure. Because of the increased pressure, water leaks have a greater impact as they occur lower in the manhole. Conversely, because the water pressure is zero, it is impossible to test the top end of the manhole without pressurizing it. However, pressure inside a sealed manhole can create problems quickly. By sealing a standard 48-inch-ID manhole and pressurizing it to 5 psi, 9,050 pounds of uplift is generated. Such uplift is usually sufficient to separate a section joint, releasing the pressure but severely damaging the manhole assembly. If a section joint doesn't release, then the pressure buildup can create a significant safety hazard to workers in the area. Thus low-pressure air testing is not recommended.

Vacuum effects in manhole testing

Vacuum testing establishes a differential pressure between the inside and outside of the manhole. By pumping atmospheric air out of the manhole

(thereby reducing internal pressure), you create exactly the same set of differential conditions as if we had increased pressure outside the structure. Neither the manhole sections nor the joints can tell any difference.

Because this test is performed with a gas whose pressure does not vary with height, the applied pressure differential is uniform throughout the manhole structure. If there is a 5-psi differential at the bottom of the manhole, there is also a 5-psi differential at the top. This results in equal testing of the entire manhole stack with joints at the top tested at the same differential as those at the bottom.

Dynamic effects on the manhole components are more dramatic with vacuum testing than with water exfiltration testing. Because the assembly is sealed, the test force is distributed throughout the manhole. Each joint is pulled tighter together as the 9,050 pounds of compressive force is added to the weight of the stack. Rubber and sealant materials are compressed further in joints. Rubber connectors are stretched inward. Plugged pipes are strained into the manhole. As such, an 8-inch (ID) PVC pipe is pulled inward with at least 280 pounds of force, requiring substantial blocking to resist this force.

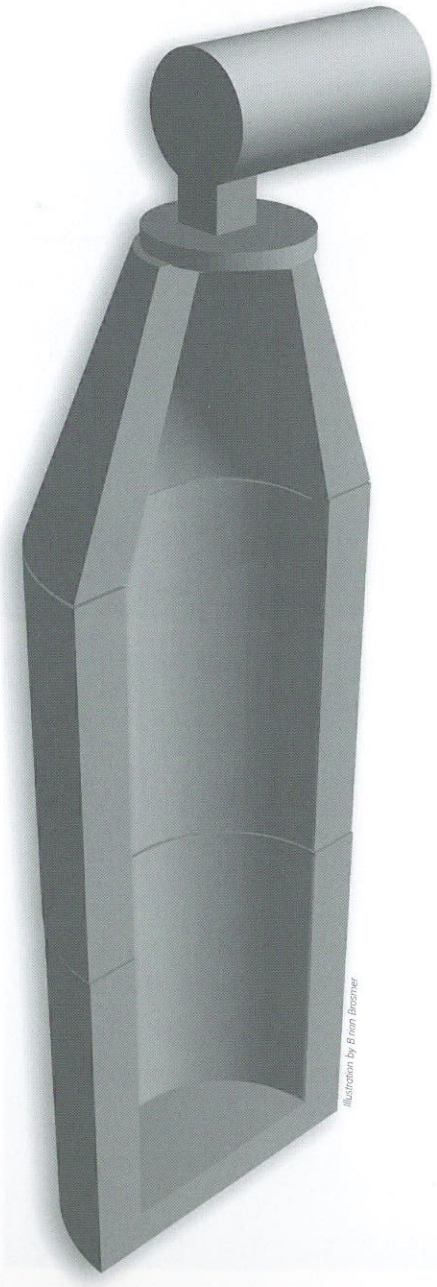
Water, air and soil are drawn into minute cracks and pores in the concrete. Some of these seal as they fill with fines. Leaks can be easily identified by damp areas inside the manhole. If the manhole is not backfilled, repairs can be made on the exterior by applying slurry to areas where leaks are detected or suspected. The slurry then can be pulled into the wall by the pressure differential and then it seals the leak. Other patching or repair techniques can be easily used as well.

Soil pressure load effects in manhole testing

While it is easy to illustrate differential external pressures using a water column, soil pressure loads are not as easily determined or calculated, and are greatly dependent upon the composition of backfill materials, their placement and compaction techniques. The variation in these materials and methods means that the actual loads on the manhole are often difficult to determine accurately, even with the best engineering resources. Therefore, it is necessary to acknowledge this and to understand how to adjust test requirements to prevent overloading of the structure during the test.

Vacuum testing is best performed before backfilling. For deep excavations, the precast manhole can be tested in graduated lifts as the structure is assembled.

CONDITION	EXTERNAL PRESSURE	TEST VACUUM REDUCTION	EFFECT ON TEST
Unbackfilled	N/A	None	None
Backfilled	Known water column height (WCH)	1" Hg per foot WCH	Test at MH base unaffected
Backfilled	Known soil pressure load (SPL)	1" Hg per 60 psf SPL	Test at MH base unaffected
Backfilled	Known WCH and SPL	The greater of the two adjustments	Test at MH base unaffected
Backfilled	Unknown WCH and SPL	1" Hg per foot manhole depth	Cannot be determined



Accumulated loads during vacuum testing

From the preceding paragraphs we see that the accumulated loads (existing and applied) on the manhole during the test vary greatly, depending upon the conditions of the individual manhole. Knowing what these loads are – and compensating for them – is critical to ensuring that the test conditions do not inadvertently exceed the installed limits of the manhole.

When these limits are exceeded, failure of any part of the assembly can occur, sometimes with disastrous consequences. Excessive accumulated loads during vacuum testing are capable of compromising a well-made, properly installed manhole and can affect the long-term, watertight performance of the structure. Needless to say, repairing a backfilled manhole is difficult and often requires that the structure be re-excavated.

Compensating for existing external pressures and loads

This problem can be solved in either of two ways. The best method is to conduct manhole vacuum testing prior to backfilling. Deep manholes can be tested in graduated lifts, as the structure is assembled and before each lift is backfilled. Testing before backfill effectively prevents buildup of external pressure and makes repairs to the manhole stack simpler and more effective. It is important that proper equipment and techniques be available to permit the rapid and safe testing of open manholes. Then installation and testing crews need not be required to choose between proper or safe vacuum test practices.

An alternative practice is to reduce the amount of vacuum used so that the total differential pressure at its greatest point (the manhole base) does not exceed the capacity of the structure or its components. It is best if both hydrostatic head (water column height) and soil pressure loads are known. Measuring water column height is easily accomplished by using a standpipe next to the manhole. Estimating soil loads is much more difficult, and this information is usually not available in the field at the time of testing. The table at the top of this page offers guidelines.

Using these guidelines will ensure that the loads applied to the manhole by the vacuum test and existing external loads remain within suitable limits.

There is no doubt on the direction the market is headed – there will be continued growth in vacuum testing. Areas that have water testing likely will continue to switch, and areas with no testing likely will begin to adopt vacuum testing. Customers will insist on proof of their installed systems. It is critical that specifiers and installers have an understanding of the important technical issues involved in manhole testing so that they are prepared to respond and provide leadership to project owners.

For more information on vacuum testing of manholes, please use the search engine at www.precast.org to locate a manufacturer.