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Fracturing Under Buildings and other delicate work

Subsurface contamination originates wherever it was deposited and migrates to wherever it may be as a result of the physics of flow. Often, buildings or other structures overlay the contaminated soils/bedrock – and indeed may be, in part, the source or cause of the contamination. Consequently, remedial efforts need to be deployed in or around structures. Over the years, FRx has faced such challenges at several sites. This memo describes the three such cases so that the insights and lessons can offer an approach for additional sites.

When a fracture is nucleated near or under a building, the load of the building needs to be considered as a component of the in situ stress, which is the principal factor that controls the propagation path and resulting form of the fracture. (Throughout this discussion the word "building" means all structures that exert a geotechnical load, whether natural – such as large trees – or anthropogenic and also whether fixed or mobile – such as heavy construction equipment.) Fractures propagate perpendicular to the least principal stress. If the load of a building is significant, i.e. is not the least stress, then the preferred propagation of the fracture will not cut across the direction of the load – the fracture will not propagate under the building load. Another way to think about these phenomena is that the weight of the building tends to pinch the fracture shut. Of course, deeper and smaller fractures have lesser interaction with the surface.

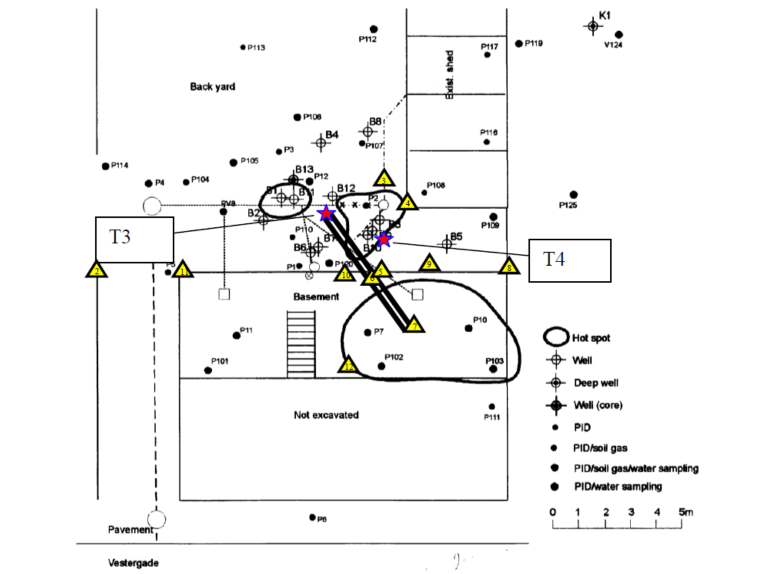
In instances where the building load is not overwhelmingly significant, the fracture may propagate underneath – depending upon other potentially controlling factors – with insignificant or noticeable effect. In some cases, hydraulic fractures have elevated light structures, such as the frame kiosk used at many fuel dispensing facilities, uniformly upward a few millimeters with no effect upon the building, attached utilities, or even the attendant within. In other instances, a portion of the building is elevated. Since structural design allows some deformation – either intentionally so as to accommodate any deterioration of support or effectively through flexure of internal joints – no damage results. Indeed, textbooks of beam design often include a problem that invokes a deformation limit imposed by the flexure of plaster (1/360th the length of span.)

Haslev, Denmark

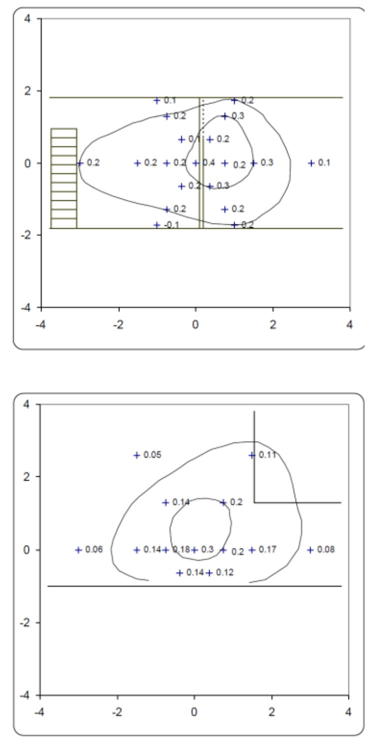
A small dry-cleaning operation has been in business in a red-brick, two-story building near the center of this Danish village. Inadvertent actions contaminated the underlying glacial till with chlorinated solvents. Mass removal could be effected if sufficient air flow could be established for soil vapor extraction. Hence, hydraulic fractures were created in the source areas.

Red brick buildings along Vestergad Street, Haslev, date from the 19th century and currently are used for shops and residences. Neither structural nor cosmetic damage were allowed.

The building housing the dry cleaner, as well as its neighbors, was deemed to be sound and valuable structures, so concern existed about possible damage due to surfical displacements that might be caused by the fractures. Structural analysis established a threshold of maximum allow able movement. A two-pronged approach was adopted to address these issues. First, relatively small fractures were planned so as to minimize any impact on the building. Second, elevation of the building, an outlying garage and other selected points in the back garden were monitored by a squad of surveying students (under the auspices of their rigorous professor, a master surveyor) from a near-by technical school; no changes in elevations of the permanent structures were detected.



Hydraulic fractures were created near and under the house to address contaminant hotspots at Vestergade 10. Solid stars indicate injection wells. Solid heavy lines bracket the pathway of the inclined well. Triangles indicate location of surface and building deformation survey points that documented the stability of structures. (Additional survey locations for general uplift measurements are not shown here but can be seen in uplift maps. Hot spots, other wells and borings, and sampling locations indicated by the legend.



Uplift above Fractures T3 and T4. Uplift measured at locations indicated by + and recorded in cm. Axes indicate north / south and east / west distances in meters from center of uplift array. Contours shown for 0.1, 0.2, and 0.3 cm of uplift. Perimeters of the cellar, steps, house, and outbuilding indicated by light straight lines.

While one source area could be accessed readily from the back garden (yard,) the hottest source lay directly under the building. (See insert, above) These fractures were nucleated from inclined borings drilled under the building walls from the back garden. The surveyors also made elevation measurements of the ground surface surrounding the injection well by observation of several graduated rods placed on a hexagonal array. These data, known as uplift, depict the form of the underlying fracture and are shown in a second insert, right. The uplift for fracture T3 is particularly compelling, showing that the fracture distributed across the length and breadth of the footprint of the basement but that propagation was arrested by the weight of the masonry walls of the building. In contrast, the fracture T4 propagated underneath the southwest corner of an outbuilding – a garden shed of light frame construction. Indeed the surveyors detected upward movement of 0.85 mm at the corner of the shed. (Examination revealed no damage or any visually perceptible change.)

Because the work at Haslev was funded, in part, by the Danish Ministry of the Environment, the full technical reports for this project are available – in Danish. Any English language version made available by FRx must be considered an unofficial draft.

Linemaster Switch

The Linemaster Superfund site resulted from discharge of chlorinated solvents into glacial till underlying the site, which in turn impacted the deeper aquifers that provided potable water to the adjacent community. Hydraulic fractures were created in the till unit to facilitate dewatering and mass removal via vapor extraction. Since the source area was adjacent to the principal manufacturing building, fractures needed to be created close to it. However, the building housed precision high-speed machine tools that had been carefully leveled; deformation of the building risked adverse disruption of ongoing manufacturing.

The building consisted of a multi-story, brick structure built upon a deep and wide concrete foundation. Interior steel trusses and floors were commensurate with heavy manufacturing. In aggregate, the building exerted considerable load on the supporting soil, and fractures were not expected to penetrate beneath it. Still, surveying methods were employed and verified the building to be immobile within 0.25 mm.

This air-handler, which was constructed on a 4-inch thick concrete pad, was elevated by fractures created at a depth of seven feet. Hydraulic fractures were created from a boring located at the lower, rightmost corner of this photograph – at the base of the yellow hoist unit. The staffs were used to measure uplift while the buckets protected tiltmeters.

A portion of the heating and ventilating system was constructed exterior to the building, however, was dislodged by fractures nucleated underneath it. This unit was located nearly on top of one of the desired fracture locations. It was attached to the building at the second story level by a rectangular sheet-metal duct about 4 feet x 2 feet in cross-section and 1 foot in length. The property owner and factory operator were forewarned that the unit might be dislodged. They concurred that the value of the heating and ventilating equipment paled in comparison to the cost of subsurface remediation and approved the planned fracturing work.

During creation of the fracture, the air-handler was lifted about a centimeter on one corner. The shift at the base was magnified by the distance to the second floor, and the deformation of the sheet metal connection to the building cause a few loud, bass-drum booms during the fracturing process. On the next day, an HVAC repairman cut away the damaged connector duct and installed a replacement with a few hours of labor. This is the only site were FRx predicted structural damaged.

As a superfund site, the technical reports for this project are part of the public record.

Coastal Plain – New Jersey

In 2000, hydraulic fractures were created at a gasoline station in New Jersey for the purpose of improving the in situ distribution of ISCO (in situ chemical oxidation) treatments. Some of the work was performed by cutting through the concrete floor of the building. Uplift was monitored by surveying techniques. This building, which was of light construction, was elevated by the fractures. No damage was realized in the structure or large plate-glass windows. Operation of the facility was not disrupted by the work, although pedestrian control did present challenges.

Conclusions

Hydraulic fractures can be created underneath buildings and structures. Only the weight of the structure has an impact on the fracture. The propagation and final form of a fracture are controlled by the in situ stress; the degree of stress imposed by the building or structure, whether fixed or mobile or natural or anthropogenic, determines the extent of influence exerted by the fracture.

If the load established by a structure is sufficiently large or the fracture is sufficiently deep or small, a fracture may have no effect on surface features. If in situ stress does permit propagation beneath the load imposed by a structure, the effect may be in either undetectable or may otherwise be accommodated by the structure. Only in extreme circumstances will damage be probable or even possible.

In event of concern about integrity of structures overlying fractures or potential propagation path of fractures, multiple avenues of approach are available. Since the magnitude of impact increases with size (volume), smaller fractures should be considered as part of the design; multiple small fractures may provide equal or better remedial performance without the threat of structural impact. Certainly, placement of structures can be monitored during creation of underlying fractures. The fracturing process occurs over the time span of tens of minutes, so fracturing can be terminated safely if untoward movement of a structure is noted. Vertical movement of structures can be measured by surveying techniques while angular deformations (relative to vertical) can be detected with great resolution by tiltmeters.