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Subsurface Utility Engineering: An Initial Step in Project Development

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The accurate location of underground structures is a serious problem in construction. Subsurface Utility Engineering (SUE) is an emerging solution to this subsurface structures problem. SUE is a process that incorporates new and existing technologies to accurately locate underground facilities during early development of a project. This paper discusses the current locating practices and the benefits that can be obtained through the application of SUE. It will be evident that SUE can reduce unexpected utility conflicts, construction delays, contractor claims, utility relocations, project redesigns, and the time required to design projects. In summary, when the SUE process is applied, contractors' risk is reduced, and a cost savings of $7-$10, or possibly $15, for every $1 spent on SUE is realized.

Key Words: Subsurface Utility Engineering (SUE), Quality Levels "A," "B," "C," and "D," Designating and Locating, Surface Geophysical Methods, Subsurface Utility Characterization, Utility Location Disclaimer Note

Introduction

The development of a typical construction project involves the phases of planning, design, and construction. Typical underground-structure damage-prevention practices are currently applied during the construction phase of the project. Every state currently has some sort of a one-call system that function during this construction phase. Unfortunately for contractors, the application of typical underground-structure damage-prevention practices during the construction phase does little to reduce the risk of hitting an underground structure. A better solution to the subsurface structures problem would be to place emphasis on the design phase of the project, and to engineer risk out of the project.

Background

Costs Incurred

Contractors' risk is usually compounded by the low-bid contracting procedures currently used by most project owners. Not included among the bid costs are the extra costs for the problems created by the incorrectly shown, omitted, or unknown locations of underground structures. Often, the owner and contractor seek arbitration or even litigation due to these problems created by the incorrectly shown, omitted, or unknown locations of underground structures. Interference with utility lines, communication cables, tanks, and old foundations are only a few of the examples of the results caused by misinformation or lack of information, further increasing the cost of construction projects. Traditionally, the contractor has been forced to be at risk for the location of the subsurface structures. However, the courts are beginning to recognize that contractors are being unfairly placed at risk, and in recent cases, have placed the responsibility for showing the correct locations of utilities onto the owners.

Lack of incentive causes deaths

The traditional approach to many projects where the owner is funded by the taxpayer or ratepayer is to pass the cost of doing business to the general public. These types of projects have little or no incentive to employ, let alone use, strategies that will reduce the project's costs. Tragically, these costs are sometimes the lives of construction workers, or the general public in the form of an innocent bystander killed in a gas-line explosion. The chances of property loss, injury, and even death are real in construction due to the obvious danger involved when striking gas or high-pressure petroleum lines. These dangers and the resulting incidents are more real than most people are aware. Bernold (1994) reported that excavating equipment hitting buried utility lines causes an average of one death per day in the United States.

Project delays and costs

Other underground risks are not so obvious. Project delays and cost increases happen due to conflicts with existing utilities and structures that are uncovered during construction operations. Of course, these conflicts become the source of change orders to the scope of the project, and claims for delays. These conflicts set back the revenues derived from income-producing projects and commercial developments. A simple reason for these risks and resulting conflicts is existing records used by the owners and their engineers are not sufficient enough in detail or complete enough for design purposes.

Existing Records of Owner's Underground Structures

A brief overview of the status of underground structures records is appropriate to describe the nature of the subsurface structures problem facing the construction industry. The design of a project is normally based on existing records that frequently are incorrect, incomplete, out of date, or inadequate for actual design and construction purposes. There may be many reasons why this is true. Some are listed as follows:

> Working drawings were not accurate in the first place, or the design drawings were used for record keeping.
>
> Some as-builts may be correct, but others are not correct due to human error during the record keeping.
>
> No as-builts or record drawings were ever made.
>
> The records created by multiple utility owners at the same site, who have been installing underground structures for decades, have never been placed in a single central file, or are lost, or are incomplete.

> The references on the record drawings are lost and cannot be recreated. For example, a reference might specify a certain distance to a building that is no longer there.

Traditional Design Practices

The designers of construction projects understand the nature of incomplete subsurface records, and they attempt to protect themselves and limit their liability by including a disclaimer on the project's plans. The wording of this disclaimer varies, but a typical paraphrasing is as follows:

> The utilities shown on these plans were taken from the records of utility companies. The actual location of utility lines and other features may be different. It is the responsibility of the contractor to identify, verify, and safely locate all utilities and features for this project at the time of construction.

Designers make little or no effort to field-locate utilities and underground features during the design process. At best, they rely on past experience in an area. Information on the project's plans is left at the risk of the contractor. During the design phase, utility owners mark their locations under one-call procedures. When conflict problems arise during construction, the question of whether or not the mark was correct arises, and there is usually insufficient evidence to assign location responsibility.

Tradition and past practices have caused an assumption that there will always be problems with underground conflicts, especially with utilities. An accepted belief is that the conflicts are inevitable and the resulting change orders cannot be avoided. For this reason, project owners have had little incentive to require designers to do a better job of locating.

Quality Levels

For a designer or constructor to understand the concept of SUE, it is first necessary to comprehend the quality levels established for subsurface information used for locating underground structures. The normally accepted definitions are as follows:

> *Quality Level "D"*. Quality Level "D" (or QL "D") is the most basic level of subsurface locating information. All QL "D" information is derived from a review of available existing records and utility as-built records. The application of this level is for planning purposes such as route selection and utility relocation costs. Quality level "D" information does provide one with the overall concept of potential underground structure location, but, for design purposes, is limited in terms of the detail, accuracy, and comprehensiveness required to eliminate the risks and dangers of conflict with underground structures.

> *Quality Level "C"*. Quality Level "C" (or QL "C") information is the most common type used for design purposes. This level involves adding to and adjusting Quality Level "D" as-built information with an above-ground inventory of all visible features and evidences of utilities or foundations. Level "C" information is still not accurate enough to prevent conflicts. Studies have shown that with accepted tolerance standards of two feet or less, there is still a 15 to 30 percent error and omission rate.

Quality Level "B". Quality Level "B" (or QL "B") involves the actual use of technology that supplements Quality Level "D," as-built information, with "designating." Designating requires the use of surface geophysical techniques and methods to determine the existence and horizontal location in two dimensions of underground structures and utility features. This designating, or horizontal mapping information, permits sound decisions to be made during the design phase of a project on the placement of foundation footings, drainage systems, and any subsurface feature that conflicts with existing utilities and underground structures. Adjustments in design and layout can be made that yield cost savings by eliminating utility line relocations and moving the excavation work away from existing utilities and underground features. Information in this level should not be used for vertical design basis or when close or minimum horizontal tolerances are required.

Quality level "A". Quality level "A" (or QL "A") represents the highest accuracy level of presenting subsurface features by adding actual "locating" to Quality Level "B" information. Information can now be mapped horizontally and vertically in three dimensions. Locations are determined by nondestructive excavation methods at critical conflict points to expose the underground features. Exact determinations of horizontal and vertical positions are now made in three dimensions. The resulting highly accurate information is used to design the project to avoid most underground conflicts, thus avoiding utility line relocation or nearby excavation, providing condition assessment, construction, and maintenance information.

Subsurface Utility Engineering (SUE)

Subsurface Utility Engineering (SUE) is a newly developed engineering process that incorporates new and existing technologies to accurately identify and map underground facilities during the early development and design stages of a project. The main components of SUE are:

Designation - the use of geophysical investigating techniques and methods (as indicated in Table 1) to determine the existence and horizontal position of underground utilities and structures. A designation may indicate the existence of two or more utility lines, thus requiring location to determine exactly what is there. It is necessary to proceed to the location step to make this determination.

Location - the use of nondestructive digging equipment at critical points along a subsurface project's path or location to determine the exact and precise horizontal and vertical position of buried utilities and other subsurface objects.

Data Management - the use of the above designation and location information by designers and engineers for examining project options and for planning ahead to eliminate conflicts before they occur. The information can be obtained by surface geophysical surveys and then entering the information into a computer-based data management system.

Though many of the technology techniques and methods already exist for locating underground structures, until now there has been no one process to ensure that accurate, in-depth, and complete information can be available prior to bid time. Applying this invaluable preliminary tool known as SUE during the design phase of a project will generate benefits (costs, timeliness, and safety) for both the owner and the contractor. The designers can then feel confident about the accuracy of the subsurface information on the plans they provide.

Geophysical Methods Used for Locating Subsurface Features

Many surface geophysical methods and equipment are available to the SUE practitioner to locate underground features. Traditional methods used by utility owners are to mark locations for contractors at the time of construction. These methods will remain in use, however, they do not provide sufficient damage prevention. The geophysical methods shown in Table 1 should be employed with Subsurface Utility Engineering.

Table 1

Surface geophysical methods available for subsurface feature locations

Title of Method	Description of Method
Radiofrequency Electromagnetics ELF, VLF, LF ranges	Inexpensive and highly useful for metallic lines, or accessible utilities that can have conductors or transmitters inserted into them.
Magnetics - Flux gate	Inexpensive and most useful for utility lines and appurtenances that exhibit a strong magnetic field at ground surface.
Elastic wave introduction into a non-compressible fluid	Inexpensive and moderately useful for water lines with sufficient access points (typically fire hydrants) and low ambient noise.
Terrain Conductivity	Moderately inexpensive and useful in non-utility congested areas, or areas of high ambient conductivity. Most useful in the detection of tanks and drums.
Impulse Radar (Ground Penetrating Radar)	Moderately expensive and highly interpretative. Useless in areas of high conductivity such as marine clays, or for small targets such as small diameter lines.
Seismic Reflection and Refraction	Expensive and highly interpretative. Its usefulness under field conditions is extremely limited due to signal/noise ratio problems.
Thermal Imagery	Moderately expensive and interpretative. It is sometimes useful for poorly insulated steam systems or other high heat-flux systems.
Radioisotope Tracing	Moderately inexpensive to highly expensive. Useful for utilities already impregnated with radioactive isotopes.
Microgravitational	Expensive. This method is limited to identifying utilities of large differential in mass from their surrounding environment.

(Source: Anspach, J. H., Proceedings of the American Society of Civil Engineers 1995 Conference)

Costs and Benefits of SUE

To understand the cost reduction potential of SUE, one must be aware of the costs and benefits. On projects where SUE is used, its cost is typically 10 percent of the total preliminary engineering costs. This translates to approximately 1 percent of the total project cost. The benefits are several.

Costs

The cost of obtaining information at the Quality “A” Level for mapping, surveying, designating, and locating can vary in a range from a high of $1000 per test hole to a low of $300 per test hole. The range difference is due to the degree of difficulty involved depending on the type of surface penetrated and the nature of the site soil conditions. The cost of Quality Level B information, mapping, surveying, and designating, is less than Quality Level A. As a general rule, designating information costs approximately $1 per linear foot of underground structure feature. For example, a building site with 1,500 feet of underground utility lines, a 20-foot buried tank, and 300 feet of adjacent foundations would generally have less than $2,000 in designation cost.

Benefits

SUE reduces utility line relocations, unexpected utility conflicts, cut utility lines, conflicts with abandoned buried tanks, and increases the accuracy of environmental site assessment. These benefits combined with subsequent reduction in bid prices, reduction of construction delays, reduced contractor claims, and lower redesign costs may result in a savings of fifteen dollars for every one dollar spent on SUE for a typical project. Several documented examples of the benefits achieved from using SUE are presented as follows:

> On a major highway project in Richmond, VA, the SUE provider for the Virginia Department of Transportation (VDOT) dug 156 test holes at locations where Quality Level B information indicated highway/utility conflicts. Using this newly obtained Quality Level A information, VDOT’s roadway and hydraulic engineering designers were able to determine that conflicts would occur at 75 of the sites. As a result, design revisions and changes were made, and 61 of the potential conflicts were eliminated. Making these design changes avoided $731,425 worth of utility adjustments. The cost of excavating the test holes was only $93,553, resulting in a savings of $637,872.
>
> Columbus Southern Power Company employed SUE during the design phase of a 138KV electric underground duct 1.2 miles long through downtown Columbus, Ohio. The cost of SUE totaled slightly less than $100,000. After interviewing the successful bidder for construction of the electric duct, it was determined that the bid price had been reduced by $400,000 due to the accuracy and completeness of the underground utility information. In addition, there were no utility relocations, no contractor claims, no utility damages, and no change orders during the project. Lastly, the project was completed ahead of schedule.
>
> The Federal Highway Administration (FHWA) sponsored research on SUE, and has experience with the application of SUE on its projects. Based on its research and experience, the FHWA estimates that the proper use of SUE could result in nationwide cost savings exceeding $100,000,000 per year for highway work alone.
>
> Permit requirements for a new cogeneration facility in Bayonne, New Jersey, included an environmental assessment of the site which was an old industrial location. SUE techniques were used as a part of the environmental site assessment to fully identify, characterize, and

map all existing utilities with a high degree of accuracy. SUE was then employed to conduct a site geophysical survey as part of the environmental site investigation. A total of 37 significant inconsistencies in the subsurface conditions were documented. Investigation of the inconsistencies proved that almost all were environmentally harmless as a result of differing compositions of fill that had been used at the site over the years. Based on the complete site environmental characterization as supplemented by SUE, the environmental permit was approved on first submittal. A significant reduction in scheduled construction time could then be achieved.

The advantages of SUE extend beyond those of decreasing the risks of conflicts, and decreasing the compromising of utility lines as a result of construction. Significant cost savings result to the taxpayer, the ratepayer, and the owner on projects that employ SUE. Stevens (1993) approximated the basic categories of project expenditures in Table 2.

Table 2

Basic categories of project expenditures

Category	**Cost**
Administrative Costs	20%
Engineering Costs	10%
Construction Costs	45%
Cost "Overruns"	15%
Utility Relocation Costs	10%

When compared to projects not utilizing SUE, a total cost savings of 10% to 15% on a typical project can be realized as reported by Stevens (1994). The cost savings may be realized in several forms, which Stevens (1994) approximates below:

> Administrative savings of 1/10th of 20% yield a 2% project savings. Projects will be completed up to 20% faster according to the Virginia Transportation Study, which allows for faster progress payments and reduces the project's financing costs.
>
> Engineering savings of 1/20th of 10% yield a 1/2% project savings. By employing digital transfer of survey data into CADD files, and by having conflicts with underground structures resolved by SUE techniques, results occur in design savings.
>
> Construction cost savings of 1/20th of 45% yield a 2.25% project savings. Bids for construction are reduced due to fewer conflicts with underground structures and the increased confidence in having correct information on the project's plans. A critical point is that the liability for identification of utilities is borne by the SUE company, not by the constructor.
>
> Cost Overrun savings are 1/3 of 15%, or 5%. This is a significant savings resulting from reducing contractor delay claims, engineering rework, and utility cut damages.
>
> Utility Relocation Costs realize savings of 1/2 of 10%, or 5%, which again, reflects a significant cost savings resulting from designers accepting the accurate, complete, utility

information as part of the design process throughout the design phase. Large scale utility relocations before construction can start are eliminated by minor design changes.

Conclusion

There is increasing congestion of utilities and other underground structures in today's urban areas, military bases, and industrial locations. This congestion increases the need for complete and accurate utility and underground structure location information in the best interest of the general public and private facility owners.

The need for rebuilding and upgrading existing facilities and infrastructure continues to grow throughout the nation. Cost effective SUE techniques and technology need to be employed in the development and design of these projects to obtain the most for the construction dollar. With SUE's techniques and technology for locating subsurface utilities, SUE can be used to locate features under built floors and behind walls in building refurbishing projects. Several owner studies indicate that cost savings, typically around $10 for each $1 spent for SUE services, can be achieved for most projects. SUE is proven technology in this area.

An increasing number of projects are now being designed with better subsurface information on the existing underground structures located within the project's site. The contractor benefits from better subsurface information records on the condition of utilities. The contractor can then, before construction begins, make proper, safe excavation protection and utility line protection systems choices. The result is a safer more economical excavation project.

Recommendations

Develop a national consensus or regulatory standard for the depiction of utility information on construction documents, including methods to obtain the information.

1. Issue permits through public agencies for public occupancy work or work in the public right-of-way for work to be completed with an underground damage prevention plan sealed by the proper professional showing the quality level of the underground features shown on the plans.

2. Require the use of the Subsurface Utility Engineering process on all projects that are publicly funded where underground features may be encountered.

3. Institute a program to update existing plan underground information on public facilities to a quality level of at least "B."

4. Develop procedures to change the standard disclaimer statement on drawings to one that clearly addresses the responsibility for the location of underground features.

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