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Title: ***Successful Technology for Utility Installations in Mixed Ground <96" (2.5m)***

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ABSTRACT

This paper discusses recently employed methods for installing steel casing and reinforced concrete cylinder or jacking pipe in mixed ground conditions ranging from 36" to 96" at depths less than 35 feet. These methods use common auger boring and pipe jacking equipment in conjunction with hybrid or customized cutting heads to match a variety of mixed ground conditions. The equipment can range from small 36" diameter auger boring cutting heads to small diameter man-entry single shield tunnel boring machines up to 96". These machines excavate hard, relatively dry glacial till or alluvium containing hard rock cobbles and boulders greater than 1/3 the bore diameter and with unconfined compression strengths greater than 10,000 psi .

A brief overview of the development of these small mixed ground tools is presented. The paper examines the advantages and disadvantages of the technology and how they can be used with common mechanical excavation methods. Details of recent projects including operation and site requirements are presented.

INTRODUCTION

Growth in the use of underground infrastructure installations has created a demand for equipment to bore through all types of ground conditions. Trenchless methods such as auger boring, horizontal directional drilling (HDD), pilot tube boring, pipe jacking, microtunneling, pipe ramming, and small diameter tunneling have been developed and continue to evolve to fill the needs of designers and specialist contractors. Each of these methods has their place depending on the type of product to be installed, the purpose of the installation, the local geology, and water table. They are typically based on the knowledge of the designer, site restrictions, and competitive market forces. However, the advantages and disadvantages of each method have an important effect on the success of the project.

In soft ground for example, if the pipe installation is generally less than 24" and ~ 300 Lf in length with site restrictions requiring a small starter shaft, the pilot tube method is the

most promising choice, particularly for pipes requiring strict line and grade control. If the ground is rock, a small pneumatic hammer can be used to continue penetration. In soft ground, such as unconsolidated sand or silt below the water table, slurry microtunneling is a common method of choice. For long oil and natural gas pipelines or power cable installations under a river, HDD is the typical method of choice. On railroad crossing projects through hard rock, auger boring attachments using small disc cutters, such as the Small Boring Unit (SBU), are the proven means of excavation. In addition, pipe ramming has proven successful for short distance, large diameter steel cased installations above the water table in dirt or consolidated soils with cobbles.
All of the above methods are typically chosen after a good geological study has highlighted the hazards and a competitive bidding process has been completed. For ground conditions that are mixed and where the final carrier pipe may range from 16" ductile iron pipe to 48" reinforced concrete pipe, the choice of the correct cutting tool or installation method becomes more difficult. Possible solutions on these projects include the auger boring and pipe jacking methods.

MIXED GROUND CONDITIONS

The definition of mixed ground can conjure up many perspectives. For this study, we will consider it to be defined as:

Dry alluvium with a consolidated matrix of cobbles and boulders (see Figures 1 & 2) to dense glacial till or hard pan clay (N = ~250 blows/foot) with cobbles and boulders greater than 1/3 the bore diameter with low water inflow rates (see Figures 3 &4).

Figure 1 - View of Dry Alluvium with Cobbles

Figure 2 - View of Dry Alluvium with Boulders

The consolidating matrix of dry alluvium is soft and generally easy to break. However, the hardness of the cobbles and boulders could vary from soft sedimentary rock to hard igneous rock > 30,000 psi Unconfined Compressive Strength, or UCS.

In dense glacial till or hardpan clay, the porosity is low so water inflow rates are usually negligible even when working below the water table. If sections of the excavation are wet and sticky, typical shallow de-watering methods can be used to temporarily lower inflow rates and 'dry' the excavation alignment. Although this type of geological condition can be hand mined, if the crossings are over 100 feet long and located in developed countries where labor rates are higher, the speed of mechanical excavation is typically more cost effective.

Figure 3 - View of Dense Glacial Till

Figure 4 - Additional View of Dense Glacial Till (Note Excavator Arm)

The equipment for these excavations varies with the size of the pipe. For bore diameters greater than 44”, excavator shields (see Figures 5 & 6), which use pick or bucket excavator style arms to mine, have proven successful. These open face machines allow the contractor to physically access oversized boulders and break them up with hand mining tools. However, an excavator shield lacks the production rates of rotating style cutterheads where spoil removal is continuous. From an owner’s perspective, it is

economically more advantageous to select a method where the equipment is more pervasive and where the population of proficient contractors is larger.

Figure 5 – Pick Type Excavator Shield Front View

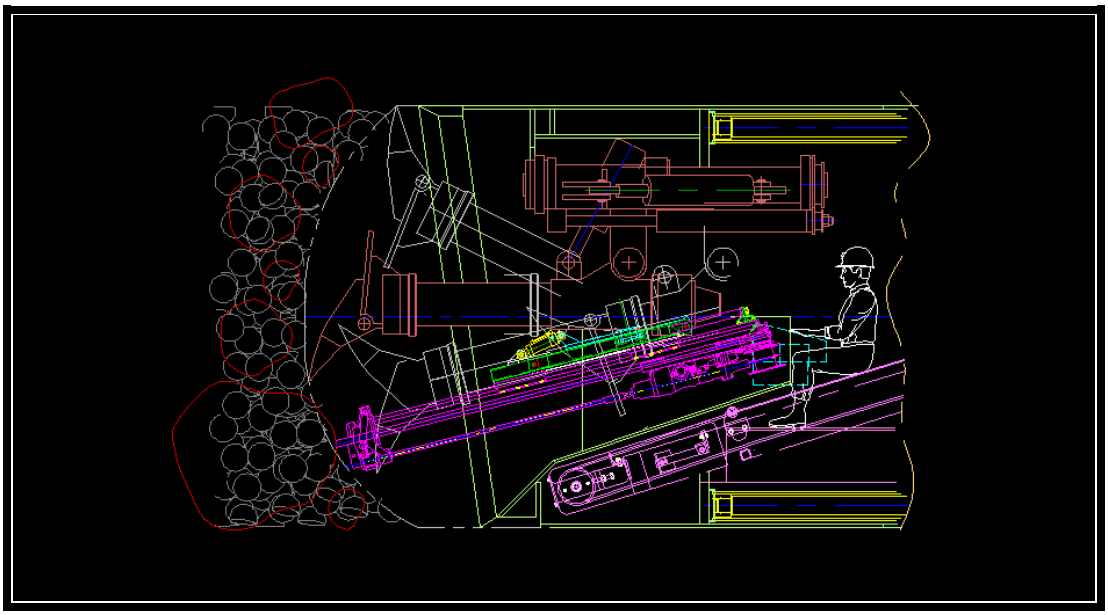

Figure 6 - Excavator Shield rendering with Rock Breaker

EXCAVATION PROCESS

Relatively small rotating cutterheads < 96” for use with auger boring machines can be characterized as having both hard rock and soft ground tooling. The hard rock tooling consists of disc cutters with a spacing that allows them to break or chip the large in-situ cobbles and boulders. As the boulders break, heavy grill bars keep the larger pieces forward and in the path of the disc cutters where they are sized and eventually fall thru the relatively large openings on the cutterhead. If clay is present, it will encapsulate the stray broken rock chips and assist in the excavation process. Bore scrapers also aid in spoil removal by pushing the spoil from the invert, directing it into the forward shield body for removal by auger or belt conveyor. In soft ground, the discs will penetrate approximately ½” before the alluvium or clay spoils are scraped by spade-like carbide cutter bits (see Figure 7). The relatively low cost carbide cutter bits have a tungsten carbide insert along the leading edge to increase wear life.

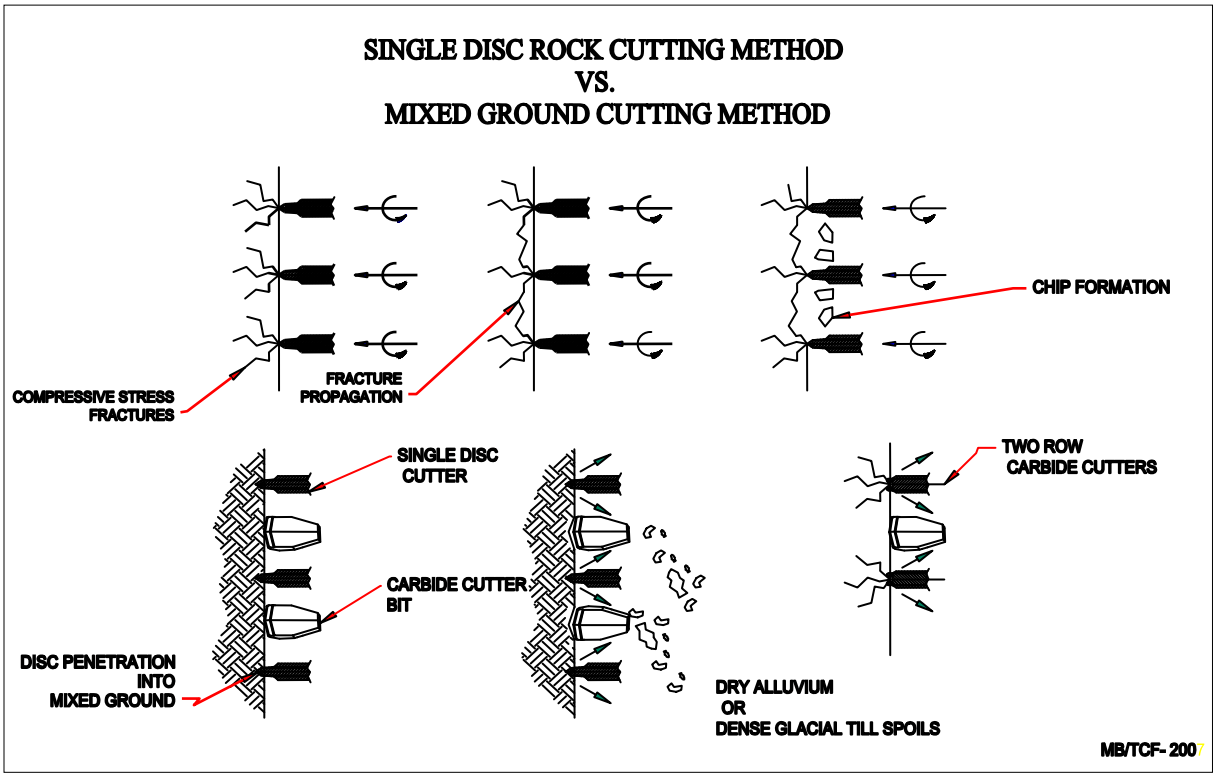

Figure 7 - Rock vs. Mixed Ground Cutting Process

Two types of disc cutters can be mounted on the cutterheads depending on the type of geology present. In dry alluvium, as shown in Figure 1,single disc cutters are the recommended cutterhead configuration (see Figure 8). If the ground is dense glacial till with high blow counts (~ 250 blows/foot as noted in Figure 3), two row carbide cutters would be the disc type of choice (see Figure 9). Cutter sizes range from 6 ½” to 11 ½” diameter discs.

MIXED GROUND CUTTERHEADS

Due to the large population of auger boring machines (ABMs) and the use of steel casing as the primary liner, mixed ground cutterheads have been developed for auger boring applications (see Figures 8 and 9).

Figure 8 - Mixed Ground Cutterhead with Single Disc Cutters for Auger Boring

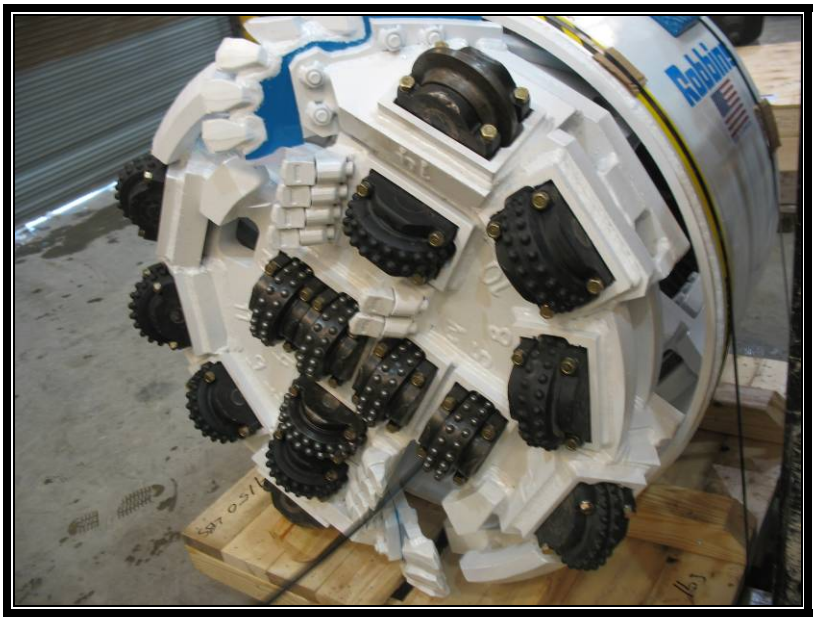

Figure 9 - Mixed Ground Cutterhead with Two-Row Carbide Disc Cutters for Auger Boring

For tunneling or pipe jacking operations, the cutterhead must rotate in both directions so the machine can roll correct. In this case, the carbide cutter bits are inversely oriented along each spoil opening to allow excavation and spoil removal in both directions (see Figure 10 and Figure 11 for comparison).

Figure 10 - View of 96” Mixed Ground Cutterhead for Tunnel Boring

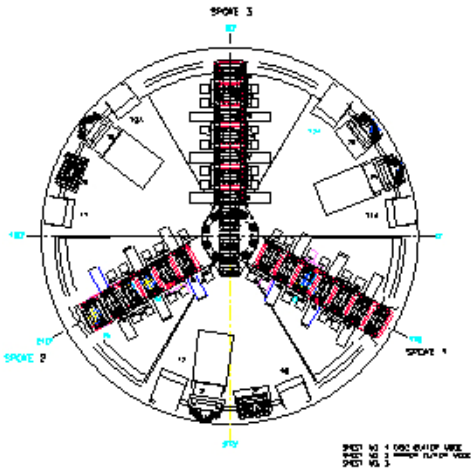

Figure 11 - Example of Larger TBM (> 96”) Mixed Ground Cutterhead

CONCLUSIONS

Small diameter auger boring based applications are beingtested in a variety of locations from Pennsylvania to Georgia to validate the design. Early returns are positive. All specialist contractors have completed their bores with casing diameters ranging from 42” in Manassas, VA (up to 240 Lf) to 66” in Harrisonburg, VA (up to 78 Lf). However, the total footage bored is below 3,000 Lf total for all sizes. The single disc cutters on the 66” cutterhead did show extreme impact loading and wear (See Figure 12) but the auger boring cutterhead did complete the bore.

Figure 12 – Example of Impact Loading on 11.5" Single Disc Cutters in Mixed Ground with Granite Boulders