Sonic Drilling Offers Quality Control and Non-destructive Advantages to Geotechnical and Construction Drilling on Sensitive Infrastructure Sites

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Sonic Drilling for Geotechnical, Civil & Infrastructure Works

Topics:

- Brief History
- Industry Applications
- Features & Advantages
- Basic Principles
- Applications on Sensitive Sites
- Construction Drilling Performance
- Platform Configurations
- Relevant Projects
- Conclusions
- Questions

Pennsylvania Department of Transportation SR-33 Bridge Foundation Project, PA, USA

Sonic History in Brief – North America

Late 1940's	**Development** of sonic technology begins.
1946 to 1958	Funding for sonic **research**.
1957	Sonic drilling **production** found to be 3-20 times greater than conventional rates are reported.
1960's	Sonic **prototype** is developed.
1976 to 1983	Sonic prototype research continues, modern rotasonic head is built, **patents** received.
1985	**North Star Drilling** of Minnesota, USA begins using rotasonic for environmental drilling. First operator in the USA.
1990's	Rotasonic drilling becomes widely accepted in USA. North Star Drilling becomes a division of **Boart Longyear Company**.
2000's	Sonic applied to many **new markets** (geotechnical, construction, mining, etc.) and exported to Canada, Australia, Africa, South America and Europe.

Industry Market Applications

- Environmental Site Investigations and Remediation
- Geotechnical Design Investigations, Exploration and Testing
- Rehabilitation for Critical Structures
- General Construction for Micropiles and Earth Retention
- Infrastructure, such as Dams, Tunnels and Bridges
- Aggregate Resource Location
- Oil & Gas Exploration
- Mining Exploration

Exploration and Grouting Project, MA, USA

Geotechnical and Construction Applications

Sonic Niche Applications:

- Exploration & testing
- Micropiles
- Earth retention
- Dewatering
- Grout injection
- Instrumentation
- Pre-drilling obstructions
- Pre-collaring casing installation
- Confirmation cores for ground improvement
- Void location filling & grouting

NYC DEP, Gilboa Dam, Catskills, NY, USA

Sonic Strengths

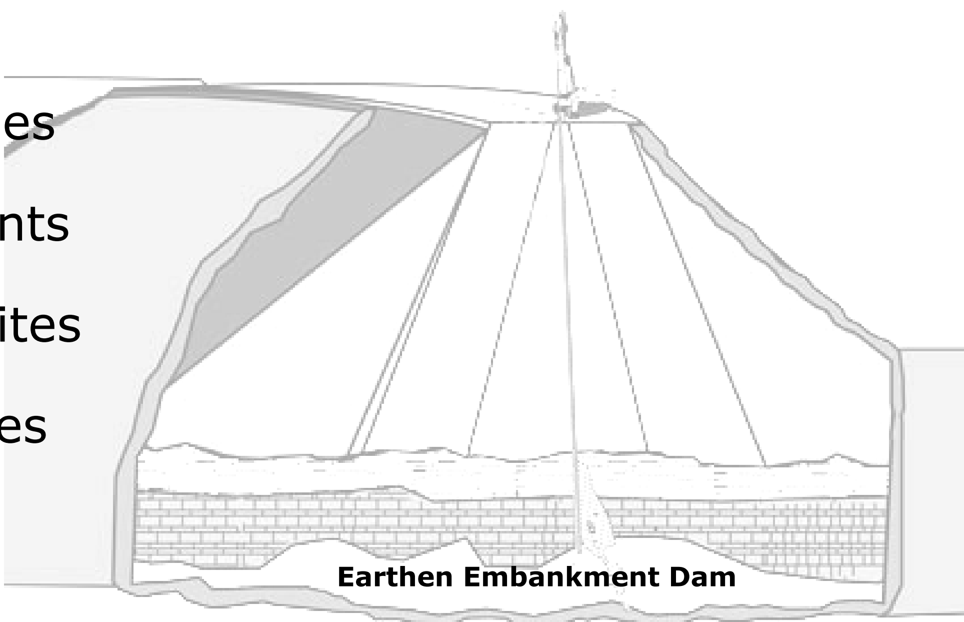
- Vulnerable sites and structures
- Sensitive subsurface conditions
- Drill waste elimination
- Quality Control (QC) sonic cores
- Measurement While Drilling (MWD)
- Ecologically critical areas
- Environmentally contaminated sites
- Penetration
- Productivity
- Versatility
- Safety

Sonic Multipurpose Construction Crawler Rig

Advantages - Vulnerable Infrastructure

Examples - Appropriate Niches for Sonic Drilling:

- Dams, levees, locks and spillways
- Tunnels, shafts, mines
- Viaducts, bridges, towers
- Railroad and light rail foundations
- Underground structures and utilities
- Urban buildings, factories and plants
- Congested & logistically difficult sites
- Environmentally contaminated sites
- Ecologically sensitive sites



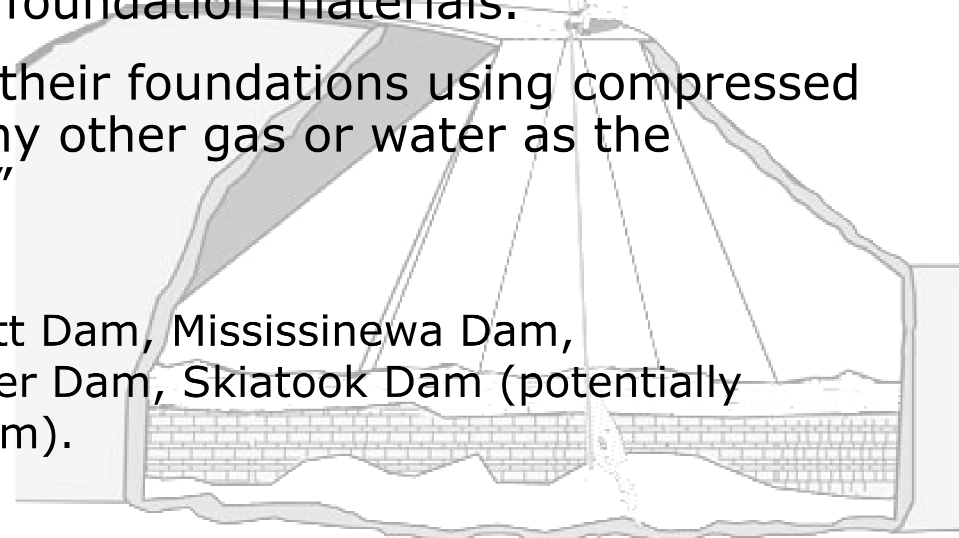
Earthen Embankment Dam

Advantages - Sensitive Soil Conditions

US Army Corps of Engineers, Regulation 1110-1-1807 Drilling in Embankments:

- “5. …there have been many incidents of damage to embankments and foundations. While using air (including air with foam), there have been reports of loss of circulation with pneumatic fracturing of the embankment as evidenced by connection to other borings and blow outs on embankment slopes. While using water as a circulating medium, there have been similar reports of erosion and/or hydraulic fracturing of the embankment or foundation materials.”
- “6.c. Drilling in embankments or their foundations using compressed air (including air with foam) or any other gas or water as the circulating medium is prohibited.”

North American Examples: Bennett Dam, Mississinewa Dam, Mohawk Dam, Gilboa Dam, Clearwater Dam, Skiatook Dam (potentially Tuttle Creek Dam and Wolf Creek Dam).



Features of Sonic Drilling

- Continuous large sample cores, inherent to drilling process
- Drill without the use of air, water or mud "circulation"
- 70 - 80% less waste production
- Eliminate problems associated with hydraulic fracturing and borehole erosion
- Low amplitude and high frequency sonic energy limits impact to existing vulnerable structures
- Drills through all geological conditions, both natural or man made
- Simplicity in variable conditions with a single drilling system
- Safety by fewer moving parts
- Faster penetration rates in overburden
- Rig conversion to HQ/PQ coring, air rotary, fluid rotary, dual rotary

Till

6" Granite

Features of Sonic Drilling (cont.)

- Accuracy by elimination of annulus assists to achieve tolerances
- Depths to 300 m (750 to 1,000 ft)
- Casing Diameters 114 mm to 318 mm (4.5, 5.5, 7.5, 8.5, 10.5, 12.5 inches)
- Core size range 114 mm to 267 mm (4 inch to 10 inch)

Acrylic Sample Liners

Challenging Subsurface Conditions

Penetrates Obstructions:

- Embankments
- Existing foundations
- Wood piles and timbers
- Metals
- Boulders
- Bedrock

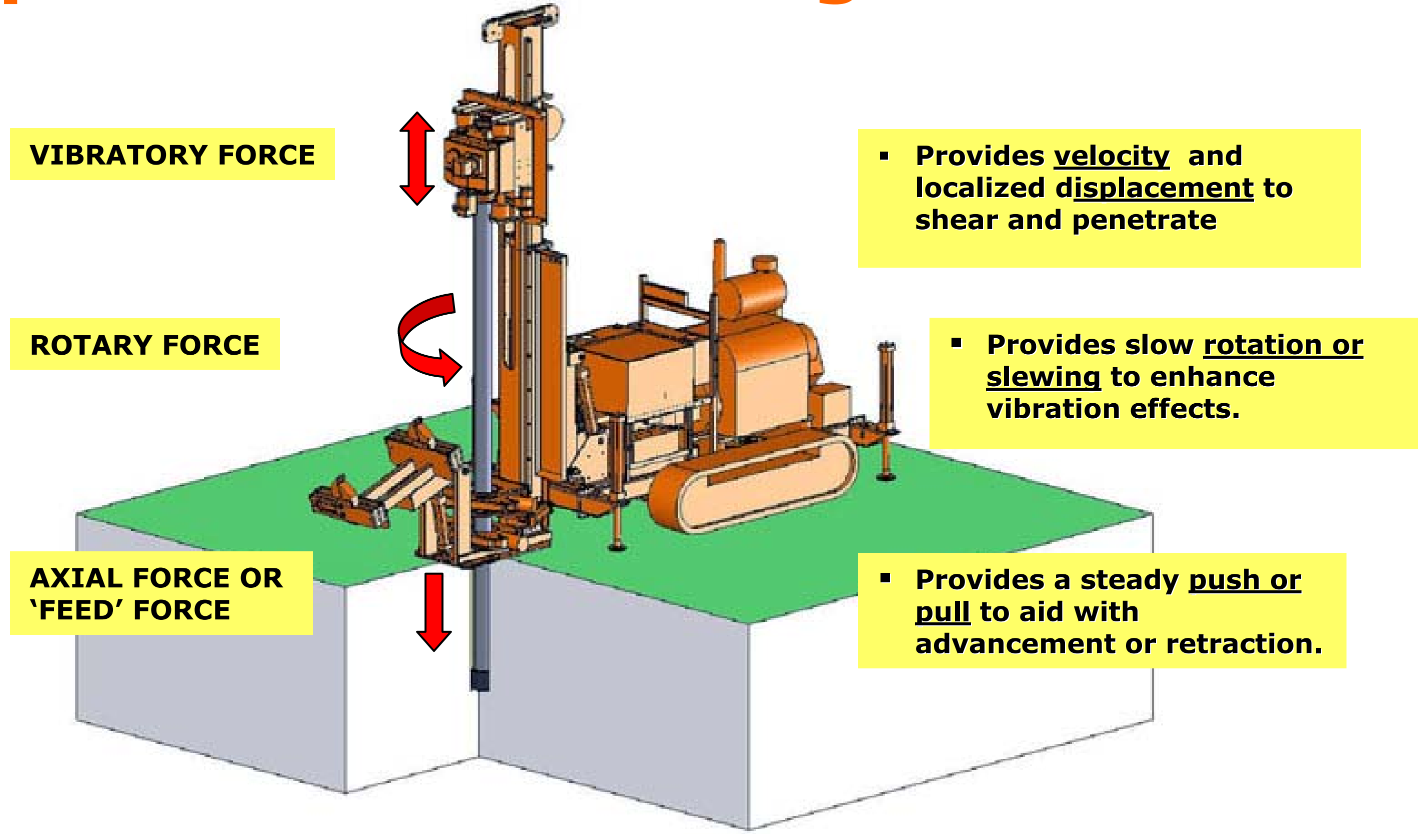
Railroad Rails Cores

Also:

- Combinations of all of the above
- Loss of circulation zones
- Karstic solution features - Voids
- Formations at risk of erosion

Sonic Bit Range

Principles of Sonic Drilling



- Sonic uses high frequency (50-150 Hertz) mechanical vibration combined with rotation and down-pressure, generated by eccentric counter-rotating rollers in sonic drill head.
- Vibrations coincide with natural resonant frequency of drill pipe.

Sonic Construction Drilling Process

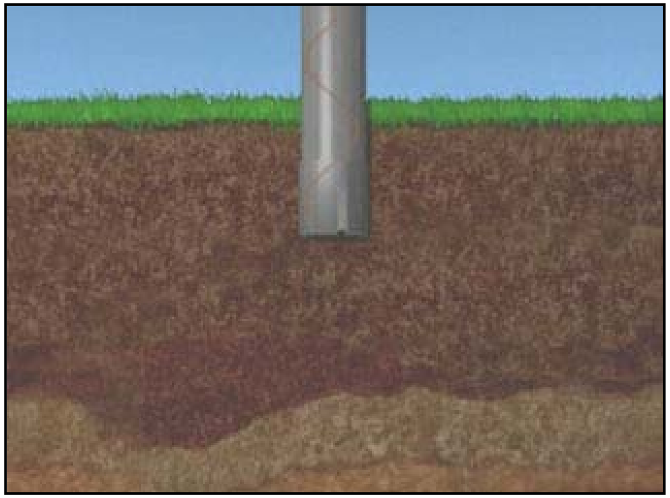
1. A core barrel of variable length is advanced using sonic energy transmitted through drill rods,
2. The outer drill casing (or micropile) is advanced to depth to stabilize the borehole,
3. The core barrel is then removed from within the outer casing,
4. The sonic core is extracted at surface to verify soil conditions,
5. The process is repeated.

- This continuous coring process provides sampling using the inherent cores of the strata during production to confirm subsurface conditions or foundation bearing zones.
- Cores enable quality control (QC) while advancing casing for grouting, earth retention or micropiles.




Sonic Drilling for Geotechnical, Civil & Infrastructure Works

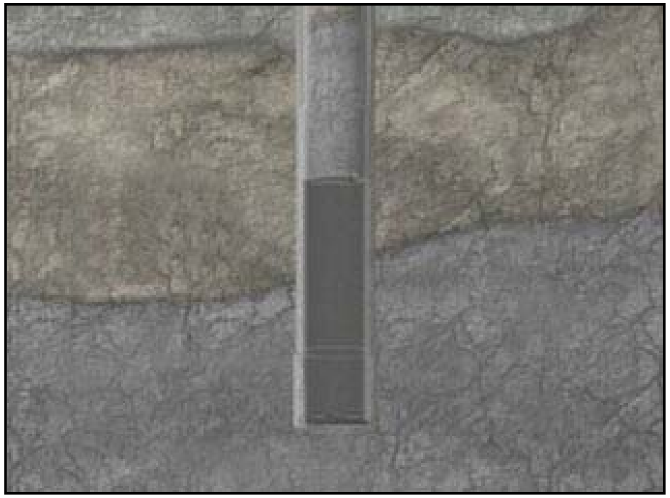
1. Advance core barrel on rods with sonic head



2. Core interval (variable length intervals)

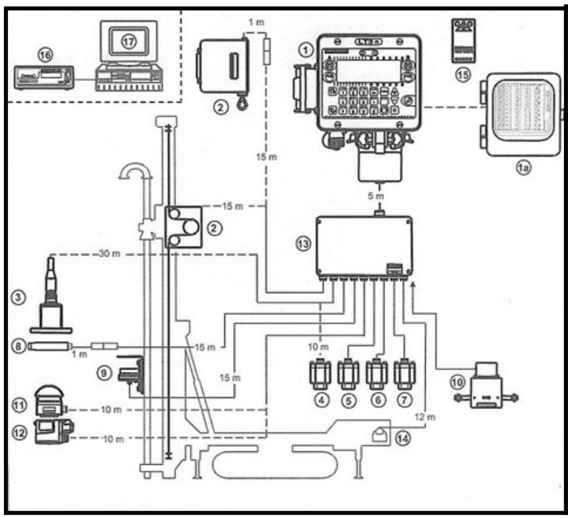
3. Leave core barrel in hole and advance outer casing with sonic head to depth

4. Re-connect to core barrel, pull core and extrude at surface



Measurement While Drilling (MWD)

- Computerized MWD instrumentation records drilling parameters as subsurface conditions change – to correlate with sonic cores.
- Data can be used to convert to Specific Energy by engineers.
- The goal is to give a more complete profile of the subsurface for exploration, micropiles, anchors and grout applications.



Drilling parameter

	Measure		Measure
1	LT3 / EPF	10	Grout flow
1a	Printer (option)	11	Driller's button
2	Depth	12	or Pressostat
3	Vibration	13	Junction box
4	or Holding pressure	14	Power supply
5	Grouting pressure	15	Digital memory card
6	Weight on bit	16	Memory card reader
7	Torque	17	Processing software
8	Rotation speed		
9	Inclinometer XY		

+

Example: Jean Lutz MWD System Data Acquisition

Sonic Core

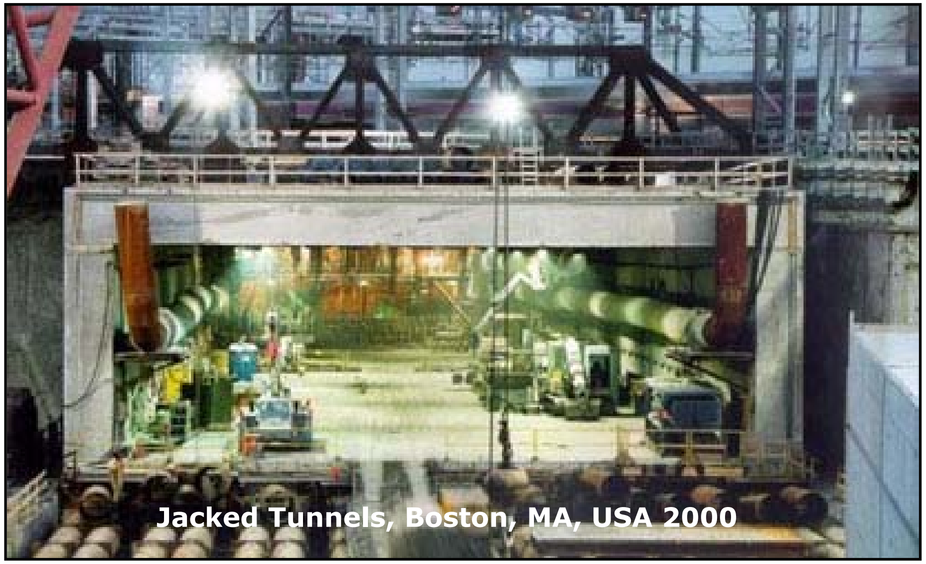
Sonic Rig Configurations

- Crawler (for construction)
- Truck
- Skid
- Heliportable
- All Terrain
- Enclosed Trailer
- Barge
- Railroad-carriers
- Turn-table
- Custom Configurations for Special Projects

Infrastructure Drilling with Sonic

Recent Examples:

1. Bridge Failure Exploration for Construction
2. Tunnel Ground Stabilization Construction Drilling
3. Earthen Dam Pre-drilling for Grout Curtain
4. Compaction Grouting
5. Embankment Seepage Exploration
6. Embankment Depression Exploration
7. Micropile Pilot Test

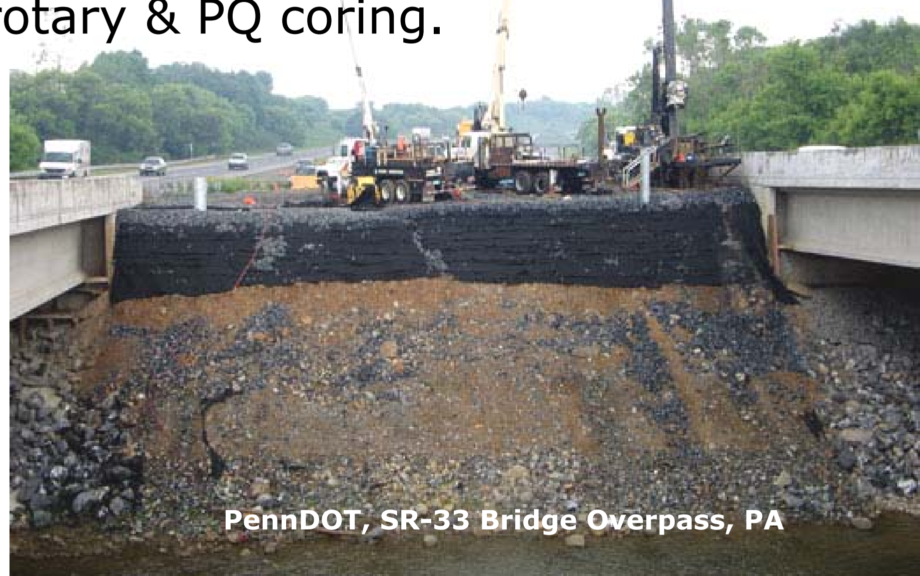

Jacked Tunnels, Boston, MA, USA 2000


"Big Dig," Boston, MA

Bridge Exploration for Karstic Voids

PennDOT, SR-33 Bridge Overpass, Stockertown, PA

- **Problem:** New bridge overpass replacement over creek is failing due to settlement supported by new 178 mm (7 in) x 107 m (350 ft) micropiles. The previous construction of micropiles using "air rotary" had caused huge and dangerous sink holes at the site.
- **Drilling:** Vertical and battered sonic drilling was used to parallel micropiles to depths of over 168 m (550 ft) through alternating Karstic limestone and voids containing silt, sand & clay. Rigs were able to alternate between sonic, air rotary & PQ coring.
- **Advantage:** By eliminating use of air & water circulation (except in competent rock), large diameter sonic cores clearly demonstrated location of Karstic features below bridges. Further sink holes were avoided by using sonic rather than air rotary.



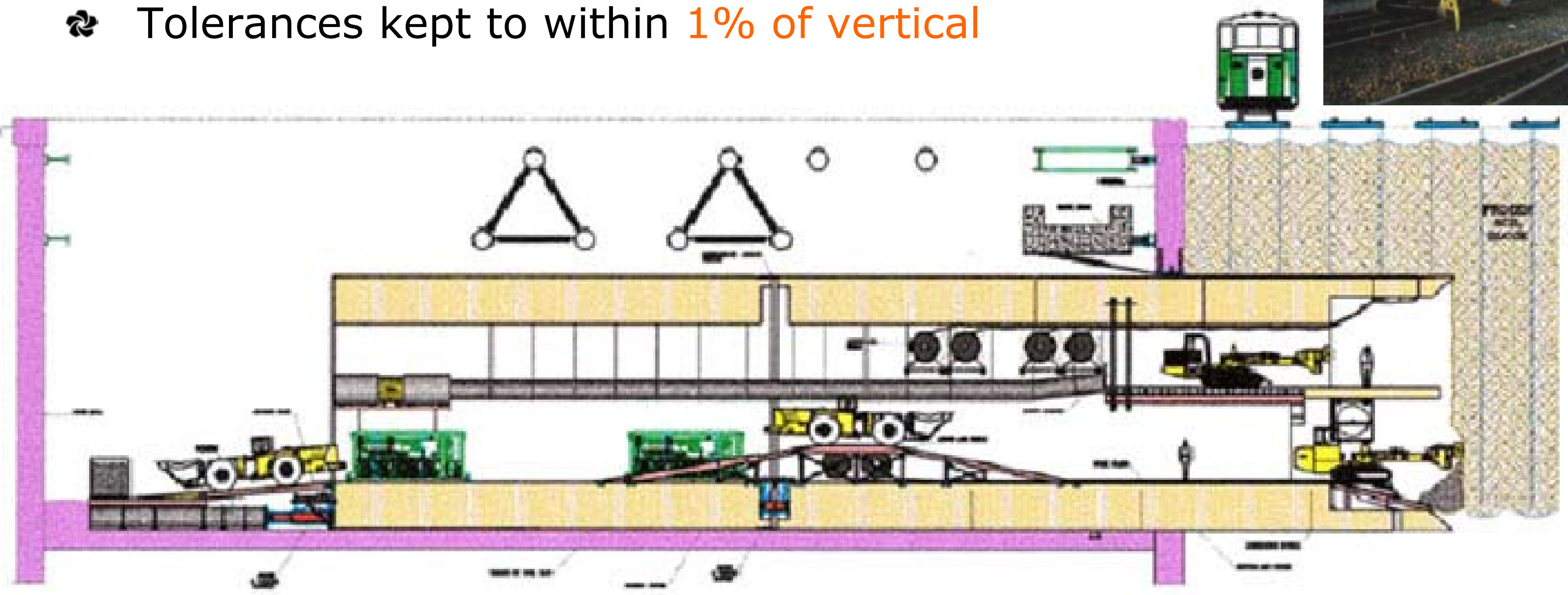
PennDOT, SR-33 Bridge Overpass, PA

Casing Installation on Tunnel Project

Central Artery/Tunnel Project, I90/I93 Interchange, Boston, MA, USA

Ground Stabilization for Tunnel Jacking, Boston, MA

- "Big Dig" World's Three (3) Largest Jacked Tunnels
- 2,200 drill locations through fill and obstructions
- 33,500 m (110,000 ft) sonic drilling casing installation
- Vertical & battered casings 11 m (35 ft) - 43 m (140 ft)
- Obstruction fill was first cored with sonic
- Sonic drove casings directly from fill to invert
- Tolerances kept to within 1% of vertical



FROZEN GROUND

Casing Installation on Tunnel Project (cont.)

Central Artery/Tunnel Project CO9A4, Boston, MA, USA

Permanent casings advanced through entire vertical extent of wood piles, brick, steel, concrete foundations, slabs & granite seawalls

- Clay – Silt – Sand
- Concrete Structures – Reinforced Foundation Slabs
- Steel Rails, Beams and Sheeting
- Wooden Piles – Wooden Timbers
- Brick Walls – Granite Sea Walls
- Cobbles – Boulders – Bedrock

Buried Rails Cored with Sonic

Embankment Dam Grouting Project

Clearwater Dam – Missouri, USA

- **Problem:** Sink hole drilling for grouting required pre-drilling through embankment.
- **Drilling:** Drilling at 15-degree angles along the embankment composed of gravel, clay, cobbles, boulders.
- **Advantage:** Previous conventional air and fluid rotary drilling methods had taken five (5) days to complete a borehole and risked damage to structure using fluid circulation techniques. Sonic drilling was non-destructive, minimized water use, eliminated fluid circulation, provided continuous and large cores, and achieved accurate tolerances at 15-degrees to average one (1) day to complete, each.

Clearwater Dam, Missouri, USA

Compaction Grouting Project

Construction Site, Bayonne, NJ, USA

- **Problem:** Previous pile driving operations penetrated landfill liner under future building site, requiring grouting to seal off possible contamination and gas migration to surface.
- **Drilling:** 200 boreholes to depths of 8 m (25 ft), using 102 mm (4 in) sonic casing, were drilled, and high solids grout was injected precisely at the liner location.
- **Advantage:** No permanent tube-a-machete or casing was needed. Sonic casings was vibrated directly into subsurface. Penetration of landfill debris had limited previous conventional drilling to 3 holes per day. Conventional driller was then removed from site, and sonic was used to drill & grout 15 holes/day.

Embankment Seepage Exploration

Mohawk Dam, Columbus, Ohio, USA

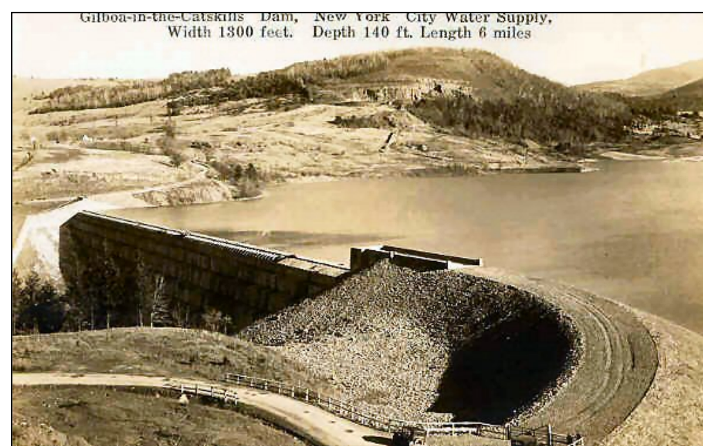
- **Problem:** High seepage below embankment is becoming a concern to the USACE.
- **Drilling:** Drilled 43 m (140 ft) boreholes with sonic methods at the toe of the downstream side of the embankment to verify geology within embankment foundation and cored rock at interface.
- **Advantage:** Previous conventional drilling and sampling was unable to verify the geology due to the frequent presence of cobbles which would block or stop split spoon sampling or block Becker hammer samplers. Soil and rock coring was possible with the sonic rig. No risk of hydraulic fracturing.

Sonic Drilling for Geotechnical, Civil & Infrastructure Works

Dam Instrumentation and Grouting

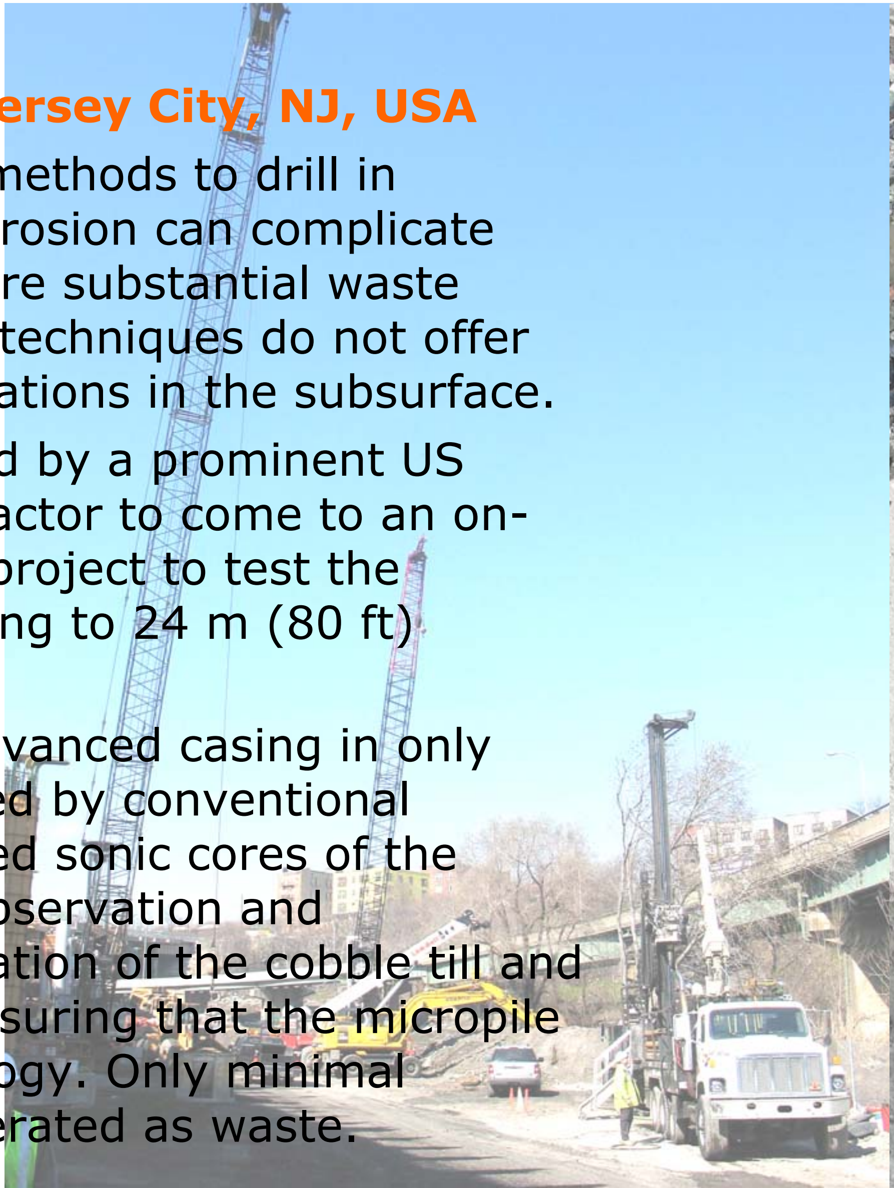
NYC Department of Environmental Protection, NY, USA

- **Problem:** Provides 16% of NYC water. Depressions formed during high precipitation in northeast during the hurricane season of 2005.
- **Drilling:** Drilled 46 m (150 ft) boreholes at 10-degrees from vertical with 178 mm (7 in) and 14 cm (5 in) **Minisonic**^{SM} crawler rig along crest and embankment of the dam with absolutely NO water use. Performed installation of instruments.
- **Advantage:** As one of the chief water sources to NYC, the vulnerable condition of the dam presented a great concern to the DEP, requiring the safest form of exploration available - sonic.



Micropile Pilot Test

Bridge Rehabilitation Project, Jersey City, NJ, USA



- **Problem:** Using conventional methods to drill in overburden prone to borehole erosion can complicate micropile installations and require substantial waste handling. Conventional drilling techniques do not offer accurate information about variations in the subsurface.
- **Drilling:** A sonic rig was invited by a prominent US geotechnical construction contractor to come to an on-going micropile bridge support project to test the efficiency of 178 mm (7 in) casing to 24 m (80 ft) installation to rock.
- **Advantage:** Sonic methods advanced casing in only 60% to 75% of the time required by conventional methods. Each borehole provided sonic cores of the geology and bearing zone for observation and confirmation. The interface location of the cobble till and Schist Diabase was possible, ensuring that the micropile was installed in the proper geology. Only minimal amounts of sonic core was generated as waste.

Conclusions

Sonic Offers Advantages:

- Non-destructive to existing structures
- Sensitive soil conditions protected
- Quality control through soil cores
- Monitors drilling with instruments
- Fluid and air circulation eliminated
- Accuracy and tolerances enhanced
- Penetrating ability increased
- Productivity improved
- Depths and diameters
- Less soil handling for cleaner site
- Rig configurations versatile
- Simplicity with single system
- Safety

Pennsylvania DOT, SR-33 Bridge

Pennsylvania DOT, SR-33 Bridge

Gilboa Dam, NYC, USA

Central Artery/Tunnel (Boston Big Dig)

Questions ?

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