Case Histories

Cap and Compaction Grouting for Sinkhole Remediation

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Cap Grouting

• Capping the top of the rock surface with grout to provide a barrier that prevents soil loss into Karst features within the bedrock.
• Typically performed by pumping a cement based grout with a slump of between 3 and 6 inches.
• Grout strength may range from 500 psi to 2,000 psi, must be strong enough to bridge across voids in the top of rock.
• Cap should be thick enough to withstand soil and hydrostatic pressures....typically a volume of grout that would create a cap approximately 1’ to 2’ thick is pumped at each injection location.
• Injection spacing may range from 10’ between holes to 20’ between holes depending on the application and risk levels chosen.
Compaction Grouting

- Compaction of the soil can be accomplished by pumping a thick grout at relatively slow speeds, monitoring for pressure increase as compaction occurs.
- Often combined with cap grouting to remediate sinkholes and repair overburden soil damaged by sinkhole activity.
- Can be used for lifting and leveling of structures suffering settlement due to sinkhole activity.
- May be used beneath shallow foundations that have been affected by sinkhole development.
Case Histories in Karst

- Iowa Mine Sinkhole, Linville, IA
- Wyeth Pharmaceuticals, Vonore, TN
- Water Treatment Storage Pond – Alcoa, TN
- Natural Resources Recovery, Knoxville, TN
Linville, IOWA Sinkhole

- Rinker Materials Limestone MINE
- Dropped out in county road
- Several repair attempts
- GAS line nearby prevented excavation style of repair.
- Grouting was the final solution
- Recently completed – Nov. 2010
- Near Davenport Iowa – Eastern End of the state
Initial filling operation

Conveyed around 1,100 tons of material into the primary hole.
Initial plug placed

Concrete pipes and barriers were thrown into primary hole. A concrete plug was placed in the throat of the primary hole.
Secondary plug placed

Steel I-beams were thrown into the hole. These rested on top of the initial plug. These covered by appx. 2 or 3 feet of concrete.
Secondary hole filled and ready for road fill.
Filled with shot rock (top size > 24”).
New hole, same spot.

This is the throat of the hole on the north side.
New hole

Looking to the north.
New hole

Southern edge.
X-Section of the Problem
Linville, IOWA Sinkhole

Mobilization/Demobilization = $ 20,000
Casing Advancement = 1596 LF @ $45/LF = $ 71,820
Cap Grout 305.28 CY @ $ 375/CY = $ 114,480
Total $ 206,300

Project Duration = 8 days on site (4 days travel)

NOTE: Drilling price and project duration are higher than normal for a compaction grouting project of this size due to increased drilling difficulty caused by the “backfill” place during prior repairs.
Wyeth Pharmaceuticals, Vonore, TN

- Formally Wyeth, now Pfizer
- 600,000 SF Distribution Center
- Slab on Grade
- Shallow Foundations
- 18 Sinkholes on Site
- 6 Sinkholes within the Bldg. pad area
Timeline

- Site Grading – Fall 1998
- Floor settlement first observed – early 2001
- Floor continues to settle through 2001
- Structural Engineers evaluate Stresses in the building frame – “OVERSTRESSED” - Late 2001
- Geotechnical Exploration confirms Sinkhole
- Repair Efforts Begin - 2002
Site Geology

- Knox Group - Limestone and Dolomite
- Near Tellico Lake
- ACTIVE Karst Area surrounding the facility
- Upper soil zone was geogrid-reinforced undercut – approx. 20’ depth
- Depth of rock varies from 50’ to 70’
- Weight of Hammer soil for lower 20’
- Voided bedrock down to extreme depths (100’ to 140’ in some cases)
Highlights

- 600,000 SF total floor area
- Approx. 300,000 SF affected by settlement
- Approx. 200,000 SF suffers ACTIVE settlement

- NO FURTHER SETTLEMENT ALLOWED!!!
- RESTORE BUILDING TO ACCEPTABLE STRESS LEVELS FOR INSURABILITY!!!!
- NOW!!!!!
• NO further settlement......
• Restore acceptable floor slab elevations......

• Micropile all columns in the affected areas !!!
• Grout to cap the bedrock and raise the settled areas to acceptable levels.
• FAST-track schedule
• Owner is willing to spend big $$$ to minimize risk of future settlement and restore insurability
Repair Process

- Cap and Compaction Grouting to stabilize soil at bedrock surface and prevent further soil loss.
- Compaction grouting from the bedrock up to the base of the engineered fill (at 20’ depth).
- Lifting and leveling of the structure using the grouting process.
- Micropiles installed following lifting and leveling to provide permanent fixity for building columns – REDUNDANT SUPPORT
Floor Level Survey – One Area Only

- Settlement Maps
- Black is 0” to 0.2”
- Red is over 2”
- Points taken on floor slab DAILY
- Could compare elevations and see sinkhole activity and REPAIR Progress
- Some areas down as much as 7” Total
Not too many photos inside.....
Compaction Grout Equipment
Wyeth Details....

- Approx. 10,000 CY grout placed
- Approx. 60 micropiles installed
- 24-hour operations, 3 phases, timed around the operation of the distribution center
- Total project duration approx. 14 months
- Design and decision making about 2 months
- Grouting continuously for about 7 months
- Pile Installation about 2 months
- Stand-down about 3 months
$\$\$\$ and sense....... 

- Total cost.....
  
  Approx. $8 Million

- Estimated cost of repair if completed during site development – Approx. $1.5M
Both Projects involved sinkhole dropouts in active process water ponds, allowing loss of process water in a very short time period. Both projects repaired using Cap Grouting. Successful repairs, even beneath active process water ponds. History of repair is now approaching 8 years at Alcoa WTP, without recurrence.
NRRC – Knoxville, TN

• Sinkhole formation in West process water pond. Spring of 2004.
• Subsurface exploration to evaluate depth to rock and using CPT to delineate limits of soft soil near the active sinkhole.
• Cap Grouting of the bedrock surface.
• Approx. 40 injections used to cover a 100’ by 100’ area.
• Success..........not so fast.......
Following the initial grouting of the west pond, approx. 2 months later, a new dropout occurred about 200’ to the northeast of the treated area.

Another round of exploration and cap grouting was performed.

No damage occurred in the area that was previously grouted.
Wait a minute......

• Round 3 – Following the 2\textsuperscript{nd} round of grouting....about 2 months later, another dropout occurred about 150’ further to the northeast.

• This time, another process water pond lost 3M gallons of water in a period of approx. 2 hours.

• No damage to prior grouted areas.

• Round 3 for grouting begins.......
ALCOA WTP – Intake Reservoir

• Approx. 8M gallon reservoir
• Lined pond in known Karst Geology
• Sinkhole activity allowed liner breach
• Loss of all 8 Million gallons........overnight.
• Geotechnical exploration revealed depth to rock ranged from 40 to 70 feet.
• Grouting program was completed prior to patching the liner.
Total cost and duration.....

• NRRC, Knoxville, TN
  • Approx. 90 compaction grouting injections were completed in 3 phases with a total cost of approximately $800k
  • Total project duration, approx. 20 days of grouting

• Alcoa WTP
  • Approx. 16 grout injections were completed at a total cost of approximately $125k
  • Work was completed in approximately 7 days.
  • Repairs at both sites are currently performing well.
Foundation Support • Soil Stabilization • Specialty Grouting

Rembco
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