Infiltration Control

Presented by (ICGA)
Infiltration Control Grouting Association

A division of NASSCO
National Association of Sewer Service Companies
Part I – Background Information
  • Clean Water Act
  • CMOM
  • Cost & Damage From I/I

Part II – Infiltration & Inflow Control Program

Part III – Stopping Infiltration with Chemical Grout

Part IV – Grouting Methods for Sewer Structures

Part V – Grouting Program Tips, Supporting Literature & Specifications
PART I – Background Information
Infiltration Control

Do you have an infiltration control program?

Every sewer district needs one!
Why?
CMOM!
Every city, town and village with a sewer collection system has to deal with infiltration of ground water into parts of their sewer collection system.
Stop the Overflows caused by excessive infiltration
What is Infiltration/Inflow?

**Infiltration**
- Groundwater which enters the sewer collection system (pipelines and manholes) through defects in the sewer system

**Inflow**
- Surface water entering the sewer via manholes, flooded sewer vents, leaky manholes, storm drains, basement drains and by means other than groundwater. Inflow is usually the result of rain and/or snowmelt events

According to the EPA estimates, infiltration and inflow represent almost half of all flow at treatment plants nationwide*

Clean Water Act

- Passed in 1972
- Amended many times
- Established a national water quality policy
  - Eliminate Pollutant discharge to navigable waters.
  - Protect and propagate sea life, wildlife and provide recreation in waterways.
Clean Water Act

- Prohibited discharge of toxic pollutants in toxic amounts.
- Federal assistance to construct publicly owned treatment plants
- Established a basis for area wide waste treatment management and control in each state.
Clean Water Act

- Funded major research and demonstration effort to eliminate pollutants discharge
- Programs for control of non-point sources of pollution
Government Regulation

- Government
- Accounting
- Standards Board
- GASB 34
  - The way state and local governments present financial information to the public.
  - Report overall state government financial health
  - Provide information about the cost of delivering services to citizens
  - Include information about the governments public infrastructure assets – bridges, roads, sewers
  - Narrative analyzing governments financial performance
GSAB 34 – What does it mean to us? CMOM

- Capacity
- Management
- Operation
- Maintenance Program
Permittee must within their system

- Properly manage, operate and maintain at all times all parts of collection system
- Provide adequate capacity for base and peak flows
- Take all feasible steps to stop and mitigate impact of sanitary sewer overflows (SSO)
- Notify parties of potential exposure to pollutants in overflow events
- Develop a written summary of their CMOM program and audit and make available to public on request
What is a Sewer System

- Collection – Get it
- Transmission – Move it
- Treatment – Change it
- Outfall – Dump it (Recharge aquifer)
Surface Water Leads to Infiltration

- Rain, Creeks, Rivers, Lakes, Basins
- Recharging the ground water
- Soil Ranges from
  - Impervious – negligible flow (Dense Soil)
  - Porous – major flow (Sandy Soil)
- Percolation through ground and utility back fill into sewer line trenches
Groundwater flows easier in soils which have been disturbed, even if the native soil has been used for backfill, leaving our collection systems susceptible to heavy flow of groundwater especially after rain events.
Ground Level

Typical Sewer Trench

Ground Water

Fill

Packed Clay

Pipe

2'-3'-5' Segments

Cement or Tar Mixture

Clay or Terracotta
PART II – Infiltration & Inflow Control Program
CMOM Applied to Sewer Collection Systems

- **Capacity**: Chemical grouting controls capacity by reducing infiltration
- **Management**: Guide, control, change and succeed at infiltration reduction
- **Operation**: ASTM and NASSCO Grouting Standard Practices
- **Maintenance**: Grouting is a manhole, joint, lateral connection & lateral line maintenance procedure

3/9/2009
Cost of Not Controlling Infiltration

- Since 1972, when Congress passed the Water Pollution Control Act, the significance of infiltration/inflow to the costliness of sewage treatment service has been recognized in the EPA’s funding process.

- The U.S. Environmental Protection Agency requires applicants for water treatment facility funding to demonstrate that their collection systems are not subject to “excessive” infiltration/inflow.

1 “Excessive” is defined as infiltration/inflow that can be eliminated from the system at cost lower than the cost of treatment.
Simple Math

The cost impact of infiltration can be explained using a simple example of a sewer system with 5-foot joint spacing.

1. Assuming each joint leaks at a very low rate of 0.25 gallon/minute
2. Total ground water infiltration into the system = 138.75 million gallons per year per mile of sewer system.
3. The total annual treatment cost would be $277,500* per mile of sewer system

*Assuming a treatment cost of $2.00/ thousand gallons of water. (Nationally, treatment costs run from $1.00 - $2.00 per thousand gallons of water)
The Effects of Infiltration

- Sanitary Sewer Overflows (SSO’s)
- Back-flooding of connected properties
- Increased cost of pumping and sewage treatment
- Reduced life of pumping and treatment units
- Excessive overflows from combined sewer systems
- Erosion of sewer structure bedding and backfill
- Catastrophic sewer failures
Soil Voids Created by Infiltration of groundwater removing soil fines
The Process of Sewer (Arch) Failure

Stage 1 Initial defect, but sewer remains held in position by the surrounding soil.

Stage 2 Development of zones of loose ground or voids caused by the loss of soil fines into the sewer.

Stage 3 Failure of the sewer pipe.

METHODS TO CONTROL LEAKS IN SEWER COLLECTION SYSTEMS
Prepared by C. Vipulanandan, Ph.D., P.E. and H. Gurkan Ozgurel (GIGMAT)
Infiltration Control Program Elements

- Collection System Management Commitment
- Identify major sources of I & I
- Quantify & prioritize I/I reduction targets
- Take action to stop major sources first
How to Identify Infiltration/Inflow

Sanitary Sewer Evaluation Surveys (SSES) are utilized to detect infiltration and inflow.

The most common methods are:

- Checking manholes during rain storms for gravel and dirt
- Smoke testing
- Dye testing
- Closed circuit TV inspection
- Flow monitoring
- Identify significant surface water ponding
Source Points for Infiltration

- Cracks, fractures
- Joint displacement
- Root intrusion
- Deformation
- Collapse
- Old or poorly constructed connections
- Abandoned laterals left unsealed

3/9/2009
PART III
Stopping Infiltration
with Chemical Grout
Chemical Grouting

- Significantly reduces ground water infiltration into sewer systems.
- Stabilize sewer structure backfill and bedding material stopping erosion fines with resulting misalignment.
- Eliminate exfiltration and cross contamination from sewers into storm mains and ground water.
- Seals annulus infiltration in lined pipe systems at lateral cut-outs and manholes.
Chemical Grouting

- Chemical grouting has been successfully used in stabilizing soils and stopping water leakages in sewer pipes and tunnels and since the 1950’s.
- DOE studies have shown that Acrylamide grout has a half-life of more than 115 years.
- Chemical grout is a two-part solution that changes to a solid in a predictable period of time.
- ASTM F 2304 defines chemical grouting as “a soil sealing process, which seals the voids within the soil surrounding the exterior of the pipe at the point of leakage”.
Characteristics of Chemical Grout

- React/perform in the presence of groundwater
- Prevent the passage of water through the sewer pipe joint
- Flexible as opposed to brittle
- Must not be biodegradable
- Residual grout materials must be easily removable from the sewer line to prevent reduction or blockage of sewage flow
- Chemically stable and resistant to the mild concentrations of acids, alkalis and organics found in the soil and in normal sewage
WHAT IS CHEMICAL GROUTING?

The injection of a multi-component chemical grout into soil and voids around the pipe, liner and manhole structures to seal the leak, stabilize the ground and control infiltration.

Soil Sealing Process

Void filler

Stabilizes the area around the structure

Not a structural repair

3/9/2009
Key factors to consider when choosing a chemical grout

- Location – manholes vs. pipes
- Viscosity – penetration
- Controllable set time - adjustable
- Environmental Conditions – moisture content, temperature, etc.
- Additives available for specific conditions
PART IV
Grouting Methods for Sewer Structures
Manhole Infiltration Control
Chemical Grouts commonly used in Manhole Sealing

- Acrylamide
- Acrylic resins
- Acrylates
- Urethane gels
- Urethane foams
- Activated oakum
Possible Chemical Grout Additives

- Latex emulsion/reinforcing agent - increases the compressive and tensile strength
- Accelerators – speeds up the gel time (urethanes)
- Dichlobenil – inhibits growth of roots into system
- Tracer Dye – illustrates proper mixing and travel
- Ethylene glycol – protects against freezing or drying out
- KFe Potassium Ferricyanide - extends gel time (acrylamide & acrylate)
- Diaotamaceous earth

Always verify with grout manufacturer/supplier for recommendations and ratios.
Manhole Grouting

**PRIMARY USE:**
- Infiltration Control
- Void Stabilization
  - Void filler
  - Soil stabilization
- Seal leaks before coating

**TRAINING & EQUIPMENT:**
- Drill and Bits
- Dual or Single Component Pump
- Injection Gun
- Injection Grout
- Safety Equipment
Manhole Grouting

- **Tips for success**
  - Plug high volume water flows
  - Begin injections at base
  - Stage injections to set grout
  - Prepare for secondary leaks
Manhole Sealing
Curtain Grouting

Holes are drilled through the structure, starting at the bottom of the structure, in a spiral pattern towards the top.
Chemical grouts are then injected through special packers and gel outside the structure. Grout travel can easily be observed either through other defects or drilled holes. Injection holes are then cleaned and patched with a waterproof quick setting mortar.
Manhole Sealing

Leaking joints are identified, cleaned and patched with a waterproof quicket mortar.
Manhole Sealing

Injection holes are drilled through the wall of the structure surrounding the defects.
Manhole Sealing

Grout is injected through the special packers into and through the defective joints.
Manhole Grouting
Activated Oakum Technique or EGP (Expanded Gasket Procedure)

Oil free oakum or jute rope is soaked in a urethane grout and forced into the open joint (normally 0.5 inches or larger opening) until it sets and forms a new gasket.
Point Grouting

Point Grouting is a procedure used to stop point leaks in below grade pipes. This procedure is a cost effective repair that requires no excavation and little disruption to the client.
Water blasting injection probes into the ground
Injection probe is equipped with a grout hose and a water hose.
Equipment Needed

1. Camera Truck
2. Vac Truck
3. Injection Probes
4. Injection Pump
5. Chemical Grout
Setting Grout Probes
Manhole / Pipe Joint Injection Grouting
Point Grouting Storm Drain Pipes
Insert Probes to Proper Depth

Cured Chemical Grout

3/9/2009
Mainline Grouting

Testing each joint and sealing defective joints along the mainline of the pipe, moving from manhole to manhole.
PREPARATORY PROCEDURES (Sealing Mainline Sewer Joints)

- Cleaning of the mainline must be adequate for seating a packer over the sewer main joints.
- Videotaped CCTV inspections of the mainline.
- Services protruding more than 1" into the mainline must be cut back to avoid interference with the test & seal equipment.
- Roots that prevent the passage or seating of the packers must be removed.
Since mainline joints are not as accessible as manholes, different equipment is required to perform the test & seal operations.
Grout Truck

Self contained CCTV, joint test and grout delivery system
Remote Manhole
Chemical Tanks
Grout Pump System - Acrylamide

A
Blue

Motor

B
Red

1
Pump

1
Grout Pump System - Urethane

A
Blue

B
Red

Motor

Pump

8:1 Ratio
Delivery Hose and Packer


Red  Test  Plug  Ends  Blue
The two component grout is pumped through the hoses and only mixes once they exit the packer delivery ports.
Mainline Packer

Pressure Sensor Diaphragm

Chemical 1 In
Chemical 2 In
Air Test

Pressure Transducer

Inflation Air In

Cable From Pressure Transducer
Mainline Packer
Mainline Packer

- Ethylene Glycol Filled Closed Pressure System
- Pressure Sensor Diaphragm
- Air In
- Pressure Transducer
- Pressurized Void Area
- Electrical Signal to Pressure Readout And On-Screen
Mainline Packer

- Mixed Chemicals Injected Into Soil
- Chemical 1 In
- Chemical 2 In
- Mixed Chemicals 1 & 2
VOID PRESSURE READOUTS
(OPERATOR’S & INSPECTOR’S EYES)

As no one can accurately predict the amount of grout necessary to effectively seal a leak, VOID pressure readouts will be an important source of information for the operator and inspector.
A pressure gauge or transducer connected to the sensor diaphragm outlet port (at the packer) will accurately transmit the void pressure and provide the operator and inspector with precious information on what is happening beyond their sight (testing and grouting pressures of the void).

Void pressure stable at 6.5 psi

Timer

Gallons of grout pumped

(Lateral sealing 30 feet)
void pressure gauge

valve to simulate leak
test cylinder (PVC pipe)

digital readout on panel

ASTM required test
Packer & camera are winched in tandem to the furthest joint downstream
Packer is positioned and inflated over the joint
Chemical grout is pumped until refusal or back pressure is sustained.
After the sealing and post test, the packer is moved to the next upstream joint where the procedure is repeated.
The seal is not achieved by the internal grout ring but by…
...the grout that has been placed on the outside of the joint.

To be most effective, the grout mixture must be pumped beyond the defective joint or crack into the surrounding soil where it consolidates the soil and backfill stopping water flow thru the soil into the pipe joint.

3/9/2009
Mainline Sealing Capabilities

Packers for elliptical pipes

8” x 7 foot span for longitudinal cracks

10 foot box culvert
Infiltration at lateral connections in lined sewer mains can be sealed with chemical grout.
LATERAL CONNECTION TEST & SEAL SETUP

CCTV Grout Van with Lateral packer option (rotation, pneumatic and vacuum controls)

Pan & Tilt camera
Test & Seal Lateral Packer
Remote winch

Exclusive Property of Avanti International, used with permission
Collection of Information

If you can’t see what you want to fix, how are you going to fix it?

Before starting the battle you need to know the battlefield to have an advantage. CCTV inspections of the laterals can sometimes be a challenge but are a necessary evil to determine a plan of action.
Collection of Information

View of important root mass with satellite camera (from the main) beyond the view of pan & tilt camera (30 feet from the lateral connection) requiring corrections before lateral sealing beyond this point.

3/9/2009
There are effective tools to clean the laterals from the mainline sewer when above ground accesses are inexistant.
PREPARATORY PROCEDURES
(Lateral Sewer Sealing from the main)

- Cleaning of the mainline and lateral must be adequate for seating a packer in the mainline and lateral bladder.
- Services protruding more than 5/8 of an inch in 8 inch pipe must be cut back to avoid interference with the test & seal equipment.
- Roots and debris preventing the passage or seating of the packer or lateral bladder must be removed.
LATERAL PACKERS FROM THE MAINLINE SEWER

Available for 6" through 24" mainline pipe. Larger diameters available upon request.

Motor and anchoring device for clockwise & counter-clockwise rotation of the packer.

Flexible Housing extension for the inversion of the lateral grouting plug within the mainline packer assembly (storage area).

Lateral Grouting Plug for 4", 5" or 6" laterals as short as two feet or as long as 40 feet if necessary.

Two ports for the chemicals, one port dedicated for the test medium and void pressure monitoring system.

Fully expandable mainline sleeve.
Gel Times of the grout must take into consideration;

Volume of the void (between the packer & the pipe)
Pumping rate of the pumps (air vs electric pumps)
Travel distance before exiting the pipe
Travel distance outside the pipe
Lateral Packer for 8” pipe with 3 & 6 foot long lateral bladder
How far can you go!

Special lateral packers available

3/9/2009
PROCEDURE

- With the use of a winch and CCTV camera, the packer is positioned at the first lateral from the downstream manhole.

- The packer is rotated to align the lateral grouting plug with the service connection.
PROCEDURE

- Once aligned, the packer is rotated and air pressure is used to invert the lateral grouting plug from the mainline packer into the service lateral and the mainline bladders are inflated isolating the « Tee » or « Wye » section.
PROCEDURE

The forward end of the lateral grouting plug expands against the host lateral pipe and the remaining portion expands to a predetermined diameter creating an annulus between the inflated lateral bladder and the inside pipe wall. If no visible leaks are apparent, this area is then air tested (See ASTM F2454-05)
PROCEDURE

- If the air test fails, the packer remains in position and chemical grout is pressure injected into the void and out through defects until a satisfactory grouting pressure is obtained (approximately 7-8 psi) and the leak is sealed. Gel times of the grout must be long enough to ensure that the grout will travel out of the void prior to «gelation».
PROCEDURE

Once the test & seal operation has been completed, the lateral grouting plug is vacuumed back within the packer and a flush is obtained from the occupant to confirm lateral flow verification. The packer can then be winched to the next upstream connection where the test & seal procedure is repeated.
Fluid migration into lined pipelines

Tunnelling and Underground Space Technology
Volume 20, Issue 5, September 2005, Pages 452-462
Infiltration at lateral connections in lined sewer mains can be sealed with chemical grout.
View of grouted lateral connection and view with pan & tilt camera looking up the lateral.
Grout migration demonstration
Grout migration demonstration
- Grout followed path of least resistance
- Grout filled voids
- Consolidation of the sand particles for a homogeneous mass
- Stop the infiltration of groundwater
- Stabilize the bedding around the structure
Grouted Sandbox 15 months later left at room temperature
Building layers of grout may be necessary when outside voids are present.

First attempt

Second attempt breaking the initial seal and forming a second layer

Third injection breaking through the initial layers until a seal is achieved
Example of grout/soil matrix formed on the outside of the pipe
Special lateral Configurations

One of these two laterals needs to be blocked off while the other one is sealed.
Special lateral Configurations

Mrs Smith

Common lateral

Mrs Jones

Mainline pipe
Special lateral Configurations

The lateral bladder chosen must be smaller in length as not to inflate in the lateral opening or beyond.
FLEXIBLE PUSH TYPE PACKERS
Sealing Laterals from an Above Ground Access
Flexible Push Type Packer

5 foot long grouting chamber
Flexible enough to get through bends
FLEXIBLE PUSH TYPE PACKERS

Entry from cleanout
Pushed/Pulled to the furthest joint
Test & Seal individual joints or predetermined length
Test & Seal elbows or bends

FPTP with 3 foot long grouting chamber for 6" laterals.
Leaking 90 deg bend sealed with chemical grout!
Man Entry Push Packers

3/9/2009
Man Entry Push Packers
PART V
Grouting Program Tips, Specifications, & Supporting Literature
Conditions for a successful grouting project

- Preparation work (cleaning, cctv, documentation)
- Most appropriate grout for the job
- Start at the downstream end & build the “dam” from the bottom/ up.
- Adapt to existing field conditions (gel times, grout additives, pumping rate, stage grouting etc.)
- Knowledgeable contractor, operator and inspector
- Pump the quantity of grout that is **needed**.
- Pump until “refusal”
- Good specifications ([ASTM F2454-05 for laterals] & [F2304-03 for mainlines])
Sealing at refusal (blow-by or 8 p.s.i.), as long as the proper technique is used, is a test in itself.

CCTV inspection after cleaning (post test & seal)

CCTV inspection approximately 11 months after completion of work preferably during high ground water tables or test 10% of the work approximately 11 months after completion of work (failures will be resealed at no expense to the owner). If failure rate is higher than 5% another basin of similar size will be chosen.
STANDARDS & SPECIFICATIONS

**ASTM F2414-04**
Standard Practice for Sealing Sewer Manholes Using Chemical Grouting

**ASTM 2304-03**
Standard Practice for the Rehabilitation of Sewers Using Chemical Grouting

**ASTM 2454-05**
Standard Practice for Sealing Lateral Connections and lines from the mainline Sewer systems by the Lateral Packer Method, Using Chemical Grouting

*Nassco Specification Guidelines*
Grouting Contract

- Different than road or construction contract
  - Predictable Equipment Cost
  - Unpredictable Chemical Cost
  - Chemical cost contingencies 100%+
  - Hidden Soil and Pipe Conditions
  - No Visual Confirmation or Inspection
  - One Year Performance Retest
Chemical Grouting

➢ The most effective repair technique to eliminate infiltration is to use Chemical Grout and an inflatable packer guided by a CCTV.

➢ Chemical grouting has been used successfully for more than 50 years.

➢ Using Chemical Grouting to control leaks reduces the permeability of the soil outside the leaking joints, but does not reduce the capacity of the system.

➢ Chemical Grouting provides a long-term solution to the leaking problem, while stabilizing the soil outside the joint.
Key to Successful Grouting

- ASTM F 2304 indicates that no joint shall be considered sealed unless, while under continual pressure, an attempt is made to pump grout to “refusal”.

- The term “refusal” means the mixed chemical grout has flowed throughout the void, through any joint failure and into the surrounding soil.

- It has gelled and formed a cohesive seal stopping further grout flow, thus the rise in void pressure shows a “refusal” to pumping more grout into the void area.
Tips for Success!

- **Initial mixing of the grout:** 8%, 10% 12 % by weight. Has to take into consideration that under active infiltration dilution will occur.

- **Additives are available for specific conditions**

- **Gel time vs pumping rate:** The gel time must be long enough for the grout to migrate through the defects and saturate the soil before it gels, otherwise it may plug up defects of the pipe prematurely prevention the grout from going on the outside of the structure.

- **Stage grouting:** May be necessary where outside voids are large and continuous pumping does not provide a seal.

- **Gallons pumped:** An attempt should be made to pump ¼ of a gallon of mixed grout per inch pipe diameter. That extra gallon of grout pumped could make the difference between a temporary and permanent repair. Grout pumped should be priced as a separate item.

- **Grouting pressure as measured at the void:** The pumped grout must fight the groundwater pressure to get out of the pipe and into the soil. If there is no groundwater present, the rule of thumb is to pump at pressures that would represent the potential groundwater table(approximately 1/2 psi per vertical feet of depth above the pipe).

- **Good Specs:** Standards & specifications are available through ASTM & Nassco.
Case Study: Downingtown, PA

- In the early 1990’s, a 5000 foot of 10” pipe had been lined at a cost of over $250,000.
- Mainline joints and lateral were then grouted
- Infiltration was reduced from 62k gpd to 2k gpd.
- By 1995 Downingtown was able to sell 300k of their sewer treatment allotment to a neighboring community for $2.4 million.
Case Study: Erie County, Ohio

- Sanitary sewers have been and are being repaired by installing liner systems.
- Lateral connections are being grouted
- Sewers rehabilitated in 2000 have reduced wet weather over-flows to Ruggles-Mittiwanga Wastewater Plant by more than 50 percent.
Conclusions

It is expected that city sewer systems in the United States will continue to be prone to infiltration problems due to deteriorated joints even though the pipes may remain structurally sound.

- Chemical grouting has proven to be the **least expensive remediation** alternative for stopping leaks and infiltration.
- Chemical Grout has a **50 year history** of sealing leaks.
- To date, the **only proven method of stopping infiltration** is the application of chemical grout.
Many papers and articles from industry leaders & publications have been published over the years.
How long does it last?

The pictures below show a 15 inch rcp pipe that was originally grouted in 1986. These pictures were taken in the summer of 2007 where the water table lies above the crown of the pipe showing no infiltration. Residual acrylamide grout can be seen in the joint 21 years later.
For more information on ICGA & its members
(Infiltration Control Grouting Association)

Visit

www.sewergrouting.com or

Nassco
(National Association of Sewer Service Companies)

www.nassco.org