

# PRESSURE GROUTING OF TUNNELS

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## STATE OF THE ART

Pressure grouting is used in many ways and for various purposes in tunnel construction. As a construction tool, pressure grouting is used frequently for one or more of the following purposes:

1. To shut off high inflow of water;
2. To reduce high hydrostatic pressures on the tunnel;
3. To solidify running sand;
4. To consolidate loosened material at or above the working face;
5. To strengthen a poor rock face, especially after the face has failed; and
6. To fill chimneys.

As a design method, pressure grouting is used frequently for one or more of the following purposes:

1. In soft ground tunnels driven with shields or tunnel machines to fill the annular space outside of the lining left by the tailpiece of the shield;
2. As contact grouting to backfill grouting behind lined tunnels to ensure that all voids between the lining and the soil or rock are filled;
3. As high pressure grouting in water tunnels to seal all possible leaks through the tunnel rock;
4. To shut off water infiltration into a finished tunnel; and
5. To strengthen weak sections of old tunnels.

To accomplish these purposes, a wide range of materials is used. Most commonly used is portland cement mixed with water only; sand; soil; fly ash; bentonite or local clay; sawdust, bran, or other filter builders; water-reducing agents; retarders; accelerators; expansion agents; and reagents to closely control set time (seconds or minutes). Other particulate grout (particles in suspension) materials used are bentonite, silicate-bentonite, local clay, fly ash, lime-clay, lime-fly ash, and emulsified asphalt.

Chemical grout (pure solutions, no particles in suspension) can penetrate fine sands, silts, and fine rock fissures that particulate grout is unable to penetrate. To varying degrees, the following material systems are commonly used: Joosten process (silicate-chloride), silicate-formamide, silicate-acid salt, acrylic resin, urea-formaldehyde, phenolics, and polyurethane.

The state of the art in the United States is less advanced than that in Europe, although an awareness of use of the available technology has recently increased in the United States. The equipment, materials, and skills are available in this country, but they are mostly used on small private projects or by tunnel contractors who turn to grouting as a last resort.

Modern grouting is a highly specialized field that requires continual analysis and field modification for optimum cost effectiveness. The few knowledgeable grouting engineers in this country are mostly employed by specialty contractors. As long as pressure grouting is considered "contract" work,

rather than a professional engineering service, U.S. design work will follow standard specifications and be limited to portland cement, with a few standard modifications, and to one or two chemical grout systems.

## Underground grouting operation.



## FUTURE RESEARCH

### Stress-Strain Design Criteria

Stress-strain design criteria for different chemical grouts under different soil conditions are necessary for adequate and economic solidification of soft ground to facilitate tunnel driving and to make rational analytical predictions of surface movements.

### Grouting Tailpiece Annular Space

Techniques for grout filling tailpiece annular space and materials to allow filling of that space as the cavity is formed are especially important for urban area soft-ground tunneling where surface settlement is critical.

### Grouting by Tunnel Machine

Grout injection systems should be incorporated into tunnel machines to provide continuous grouting as the tunnel advances. Most work today requires stopping the tunnel driving for grout injection or else grouting ahead from the surface. Under most conditions, grouting from the surface is economically more wasteful than grouting from the face.