

PRESENT SITUATION AND NEW METHODS OF HIGH PRESSURE JET GROUTING TECHNOLOGY IN CHINA

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ABSTRACT

In the paper, the technological process and application of high pressure jet grouting are discussed. Parameters and grouting effects of single pipe dual pipes and triple pipes construction methods are given by comparison. Practical examples are also given with new developments in theory, methods and technological process and application in recent years. Some problems concerning engineering application are also raised which need to be solved in the future.

INTRODUCTION

High pressure jet grouting technology for reinforcing soft strata came from Japan in 1970s. The technology for chemical grouting and high pressure jetting occurred quickly. The boring bits reached the depths expected, with a special nozzle, which is installed in the end of the boring rod, providing cement grout jet at high pressure so the soil is cut by high pressure jets. Meanwhile the boring rod raises as well as revolves. Thus the soil and cement grout are mixed and consolidated. In the end, a columnar soil-cement solid is formed to consolidate foundations and prevent seepage.

There are three kinds of construction methods, that is single pipe, dual pipes and triple pipes. In the single pipe method for example cement grout is poured into a grouting pipe. Dual pipes method provides two kinds of grout which are simultaneously poured into two concentric pipes with different diameters, and the inner is cement grout and the outer is air. The two are jetted out of the same nozzle. Cement grout is in the centre and the outer is compress air used in jetting. Accordingly, the effective range is enlarged. Triple pipes method is made up by three concentric or parallel pipes of different diameters. The three pipes can simultaneously contain water, air and grout, all three revolve and rise at the same speed. Jet grouting piles are formed, with a different technological process, with fan-shaped swing jet piles and directional jet piles. Technical parameters and main construction device of high pressure jet grouting are shown in Table 1.

Kinds		Single pipe	Dual pipes	Triple pipes	
Technical parameters	Water	Pressure (MPa)	—	—	20~50
		Discharge (l/min)	—	—	80~120
	Air	Pressure (MPa)	—	0.7	0.7~1.0
		Discharge (m ³ /min)	—	1~2	1~2
	Grout	Pressure (MPa)	20	20	1~3
		Discharge (l/min)	80~120	80~120	100~150
	Lifting speed (cm/min)		20~25	10	10
	Rotational speed (r.p.m)		20	10	10
	Diameter of pile (m)		0.4~0.8	0.8~1.5	1~2.5
	Maximum depth (m)		45	20	53
Compressive strength of pile (MPa) In sandy soil 10~20, In cohesive soil 5~10, In loess 5~10, In sandy gravel					
Coefficient of permeability (cm/s) Sandy soil $10^{-6} \sim 10^{-7}$, Cohesive soil $10^{-5} \sim 10^{-7}$, sandy gravel $10^{-6} \sim 10^{-7}$					
Specific gravity of cement grout 1.5~1.65					
Devices	Vibrating boring machines		√	√	√
	Geological boring machines		√	√	√
	High pressure mud pumps		√	√	—
	High pressure water pumps		—	—	√
	Mud pumps		—	—	√
	Air compressor		—	√	√
	Jet grouting pipes		Single	Dual	Triple
	grout agitator		√	√	√

Table 1 : Technical parameters and construction devices

High pressure jet grouting technology is mainly used in the foundation with N SPT equal to 0 - 30, which usually consists of gyttia, cohesive soil, sandy soil, gravel and partial cobble layers. The technology can be used to prevent the settlement of foundation of railway, highway and buildings, and it also can be applied to water-tight screen and temporary support of foundation pits.

According to recent applied conditions, characteristics of the technology have been given as follows:

1. The range of static pressure grouting has been broadened as clay was not easy to stabilised grout before, and now it has been solved.
2. Because the water jet is limited drain on the grout is avoided.

3. By changing grouting materials and technique, soil-cement can meet the demand of strength and permeability.
4. Cement paste cannot cause pollution of environment and groundwater.
5. Work can be done in any level of holes.

Because of the practical use of high pressure jet grouting, many improvements have been made since 1970's in China, the number of applications for the technology to projects and experiments has amounted to over 100. Some typical cases are introduced as follows:

1. Leak proofing of dam bases.

Wuluo Reservoir in Gong Country Town Hennan Province was built several years ago. It was only available in low water level because of permeability of sandy gravel layer of the dam base. It is not until 1993 that high pressure jet grouting and water-tight screens have been adopted for the purpose of leak proofing SGP30-5 model of grouter (Triple pipes) is used in the grouted cut-off wall of the dam. The depth of grouting amounts to 53.4m, which sets a record in depth in China.

2. Stabilising foundation after building construction

After the office building of Oil Chemical Industrial Construction Company in Henan Province had additional layers, cracks appeared in the building, it became uneven and subsided

3. Prevention of bridge abutment subsidence

After Jinsha Temple of Baocheng Railway was made the pier became uneven and subsided. In 1980, settlement had amounted to 99mm at no. 3 abutment. By using high pressure jet grouting, it is now safe.

4. Cast-in place piles and jet grouting piles for lining deep pits.

In Wuhan Steel Company, an underground road way ore bin needed excavation of the foundation pit. Since ore bin walls are vertical and the ground water level is high, the lining of deep foundation pit calls for water seal as well as keeping off the soil. In 1990, the method of water seal and keeping off the soil with cheap cast-in-place piles and jet grouting piles achieve complete success for the first time.

NEW DEVELOPMENTS

1. New Development in Theory

In the construction of the Wuluo Reservoir dam base the use of the triple pipe technique with high pressures has been used in deep holes in folded strata containing porous rock. For grout pressure in bore holes $p_1 = \gamma_1 x h$ (where γ_1 is gravity density, h is the depth of the holes). If air pressure and grout pressure are greater than p_1 then the emplacement of grout and soil can be made. Therefore, it is reasonable that air pressure should be used according to the depth of a hole. Air compressors should keep air pressure in 0.6 ~ 1.0MPa. In deep holes with fine grained strata high air pressures are needed, for holes 40-50 metres deep air pressure needs to be greater than 0.7 - 0.8 Mpa or 0.8 - 1.0 Mpa. It has been found that 1.0MPa is the best choice for holes 40 - 50 metres deep.

Wang Baoyu et al. have used sand for consolidation and seepage-proofing. Except for five functions, that is: punching and agitation, replacement, filling and extruding, percolation and consolidation and wrapping. The siphon action of negative pressure by coaxial jet of water and air have been developed to make grout flow and agitate along the jetting direction.

2. Developments in construction equipment

Liaoning Province Water Company and Hydropower Institute has developed SGP30-5 model of high pressure grouter (Triple pipes), which has been used in Wuluo reservoir in Henan Province and in foundation pit construction of high-rise building in Benxi city. For extra-deep (>50m) and coarse grained formations its functions are ideal, with good durability and high quality grout. The highest grouting depth is 55m; power 13kw; lifting force 19.6 kN; lifting height 15m; Variable rotational speed; sway angle 0~30°; running speed 1.5 m/min; shortest distance between grouting holes to building 0.35m.

3. Suitable applications for high pressure grouting

1. Used in extra-deep formation for leak proofing
2. Used in formation with coarse grained soil for leak proofing
3. Used in cohesive soil formation
4. Used in rock joints and uneven ground
5. Used in silty sand subsoil
6. Used in leak proofing foundations and slope stability
7. Used in new building project
8. Used to rectify deviation of buildings
9. Used in projects on the water and restricted areas
10. Used to link up the two underground engineering works or to repair the underground engineering
11. Used in subways, tunnels, mining pit shafts and civil air defence engineering
12. Used in filling stabilisation piles

CONCLUSION

High pressure jet grouting is a new technique for consolidation and leak proofing. It needs to make further developments to be perfected. There are still many problems: carrying out research into the quality of jet grouting piles, improvement concerning the structure of jet nozzles and the pipeline, working out the standard of design and construction, field technique management, problems on reducing costs and sending up grout. In the future further research should improve the technique of jet grouting.

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