# Application of Settlement Control Technology in Municipal Water Supply and Drainage Pipeline Construction

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**Abstract:** Municipal water supply and drainage pipeline construction quality influence urban operation efficiency and residents' living standard directly, is an essential part of urban infrastructure. However, among the most common problems during construction is a settlement that causes rupture to the pipe and damage to the surrounding environment. Construction enterprises should employ settlement control technology in municipal water supply and drainage pipeline construction to minimize landfill subsidence. This article analyzes the influencing factors of settlement in construction of municipal water supply and drainage pipeline, describes the given working for applying settlement control technology beforehand and only discusses the specific application of settlement control technology in this kind of project. It intends to serve as a theoretical reference and practical guidance for enhancing the construction quality of municipal water supply and drainage pipeline engineering.

## 1. Introduction

The fast development of cities asks for better stability and durability of the infrastructure. Municipal water supply and drainage pipelines play a crucial role in maintaining urban infrastructure, providing essential services for drinking water delivery and wastewater disposal. The safe operation of these means is a basic guarantee for the normal operation of a city. Inevitably, with the rapid development of urbanization in recent years, a large number of municipal water supply and drainage pipeline projects have emerged. Nevertheless, the complex geology of construction site areas and the high density of adjacent buildings and underground utilities often lead to settlement problems during construction. Settlement is vertical displacement resulting from the effective stress equilibrium between successive strata and soil deformation following construction. At present, the industry has monopolized an integrated settlement control system encompassing geological investigation, design planning, construction management and monitoring feedback. However, further optimization of targeting technology selection and coordination among different stages are needed. Thus, as per the real demands of municipal water supply and drainage pipeline construction combined with typical engineering experience, it is essential to analyze in details the application scenarios and implementation key points of settlement control technology in order to provide practical methods on how to improve pipeline engineering quality and minimize settlement risks.

## 2. Influencing Factors of Settlement in Municipal Water Supply and Drainage Pipeline Construction

In this study, settlement in municipal water supply and drainage pipeline construction was caused by the multi-factors synergistic effect. Describing the mechanism of every factor is common precondition to develop targeted control technologies. According to engineering practice, a geological condition, construction technology and surrounding environment can supply three different types of these.



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## 2.1 Geological Conditions

Settlement is mainly caused by geological conditions, while soil properties are decisive. Soft soil strata, with high water content and strong compressibility, are prone to consolidation settlement under construction loads. Therefore, the strata of sandy soil are with weak particle consolidation ability; if the parameters of dewatering operation are not controlled properly, it will easily trigger piping or quicksand phenomena, causing stratum instability and settlement when encountered during construction. Local stratum bearing capacity imbalances can be caused by special structures, such as geological faults and karst caves, which directly lead to uneven settlement of the pipeline [1]. It simultaneously can worsen risks of settlement with changes in groundwater level. With excessive dewatering rates or depth, the effective stress of the stratum will increase, which may lead to soil compression deformation and expands settlement range.

## 2.2 Construction Technology

The effectiveness of settlement control is directly determined by construction technology factors. In the trench excavation stage, due to inadequate use of layered excavation technology, uncontrolled digging speed, or unreasonable support structure selection; it may break the original stress balance of stratum, resulting in damage to the trench slope and settlement of surrounding stratum. For example, the construction of a pipeline foundation or ground improvement work is not completed; or the strength of concrete pile foundation is low; or if there is insufficient curing and moisture in it—all these cases will cause the underground bearing capacity to decrease and hidden danger of settlement when running pipeline later on. The external environment can also apply external stresses to the pipe during removing and placing processes, etc. that may lead to larger leakage risks caused by joint vacuums. At the trench backfilling stage, the usage of both mixed soil or high-water-content soil, or when the designed compaction density is not reached for backfill can lead to sedimentation due to later consolidation of the backfill and friction which senses pipeline resulting in settlement.

## 2.3 Surrounding Environment

The congenial and regional lodgment of surrounding environmental characteristics on settlement. Old buildings and dense roads in the surroundings of construction area can impose loads on the construction strata, thus increasing the chance of occurrence of settlement. However, in regions with intensive underground pipelines, improper protection of existing pipelines may not only damage the pipeline but also lead to settlement through disturbance conduction near stratum. When construction dewatering is not accompanied by recharge measures, the groundwater level of the surrounding stratum will drop, causing regional settlement and endangering the safety of surrounding buildings and pipelines [2].

# 3. Preliminary Preparations for Settlement Control in Municipal Water Supply and Drainage Pipeline Construction

In the construction of municipal water supply and drainage pipeline, settlement control adopts prevention first, combining prevention with mitigation. Solution: Pre-construction preparations beforehand are crucial in mitigation of risk to the settlement and mainly include three aspects: Detailed geological investigation, reasonable engineering design as well as scientific monitoring plan formulation.

During the geological survey stage, it is important to get accurate and full data. It needs to cover the pipeline route and an area 5-10m on either side, in terms of the scope of investigation. The pipeline depth bottom should be greater than 3-5m in the higher end to ensure that deep soil properties, groundwater level distribution, etc. Particular techniques integrate drilling, geophysical prospecting (such as ground-penetrating radar) and in-situ testing (for example, Standard Penetration Test, Cone Penetration Test) to perform a complete evaluation of important parameters such as soil bearing capacity and compressibility. Once investigation has been done, the data needs to be integrated and analyzed; as well as geological profile maps must be drawn such that risk high settlement's hotspots are figured out including soft soil concentration and higher groundwater level areas need identification with targeted suggestions for risk response [3].

In the engineering design stage, the program should be based on the core of "anti-settlement" to carry out optimization. In practical applications, route planning should avoid high-risk areas, when unavoidable special treatment measures need to be taken. Pipeline materials should choose good toughness and high crack resistance, such as PE pipes and ductile iron pipes to replace the traditional brittle concrete pipeline. Geological conditions dictate the foundation design: concrete strip foundations making for an increased bearing capacity in soft soil strata, while gravel foundations can be built to enhance stability of sandy strata. The trench excavation and backfilling parameters should be specified, such as the excavation slope of soft soil (controlled at 1:1.5 ~ 1:2.0), and the filling material is preferably well-graded gravel (the degree of compaction can reach more than ≥95%).

Monitoring should be in place on the pipeline route and trench slopes, surrounding buildings, existing utilities, etc., to effectively reflect settlement dynamics with real-time data during project implementation; therefore, they need to be taken into consideration during monitoring plan design stage. For Pipeline monitoring, Set One point after every 20-30m on the pipeline route & A separate one on important surrounding Building corners. Examples of monitoring indicators are settlement amount, rate or horizontal displacement. As instruments need balance between accuracy and convenience: level with an accuracy of ±1mm can be used for settlement, total station with ±2mm in horizontal settling direction displacement; automated settlement gauges can be installed for real-time transmission as well. 1-2 times daily during excavation & backfilling stages, once per 3 days after complete pipeline laying until stability of settlement [4].

## 4. Specific Application of Settlement Control Technology in Municipal Water Supply and Drainage Pipeline Construction

### 4.1 Settlement Control Technology in the Trench Excavation Stage

It is the part of construction phase least disturbed by stratum, and settle risk can be minimized good with layered excavation + support protection + dewatering stabilization combined technical system to control stratum deformation. In particular, during the layered excavation stage, settlement control technology is implemented throughout the construction process where using the layers of not more than 1.5m for each layer of excavation and daily control to about 2-3 layers to avoid excessive excavation speed leading to sudden change stress field in stratum. As part of the excavation process, a 0.3–0.5m thick protective layer of undisturbed soil should remain and be removed manually (i.e., not by machine) immediately prior to laying the pipeline foundation above this base layer of undisturbed soil with minimal disturbance to this top-dressed coated one. It involves accurately identifying the support structure based on the geological situation and trench depth. In the case of soft soil strata or trench depths exceeding 3m, ensure sheet pile support is first. The length of the sheet piles should be 2-3m longer than the depth of the trench, and at least 1.5m deep embedded for support stability. In sandy soil layers, the support of row piles is applicable. To reduce pile spacing to 1.2–1.5 m, it is required that a cap beam be established at the top of the pile in series to improve overall stiffness [5]. In this case, when dewatering stabilization technology is applied, the depth of groundwater table should be selected as an evaluation index. Under the conditions that the depth of groundwater table is 6m or less, use well points while maintaining a spacing of 1.0-1.5m, and deep wells need to be used when depth is more than 6m with its well should appear above the groundwater level for at least 3-5m; The groundwater level during dewatering process needs real-time monitoring with control between 0.5-1.0mbottom position from trench bottom in order to avoiding water level fluctuations lead to stratum settlement.

### 4.2 Settlement Control Technology in the Pipeline Foundation Construction Stage

As a principal construction unit, the pipeline itself bears loads of the pipeline; to mitigate and minimize later problems with settlement in the ground head paper and foundation quality control measures for ground improvement; For certain construction, when ground improvement technology should carry out the specific geological conditions in the construction of enterprise testing application. In weak soil strata, the replacement method can be adapted: the weak soil layer is excavated and replaced with well-graded gravel or lime soil, which in layers must be compacted to obtain density. For such cases, when sandy soil interlayer exists, the sand drain should be used and thin pile construction should be adopted to the selection of compaction pile method for sandy soil strata, which is to compact foundation soil structure under piles in order to improve its bearing performances. In complex geological conditions like dense existing utilities, grouting reinforcement can be applied. Through the injection of cement slurry or cement-sodium silicate double-fluid slurry, the foundation stability is improved after diffusion and solidification of slurry, achieving a significantly enhanced bearing capacity after reinforcement [6].

Throughout the foundation pouring process, there must be effective and strict quality control in place. Concrete foundation, it is preferable to use commercial concrete, its strength class and mix ratio can be determined by tests; the slump meets the requirements of construction. The operation method of pouring is layered, and each layer shall be vibrated and paved until compacted to avoid affecting foundation strength caused by construction defects. Therefore, moisture-retaining curing period for concrete pouring is timely, and loading shall not be allowed during the curing period, otherwise it is easy to produce premature stress deformation of foundation. In addition, in case of erection on soft soil, it is possible to use flexible foundation technology. The use of geogrids at the foundation bottom takes advantage of the tensile property of the grid to transport loads, which allows them to better adapt to slight settlements and avoid cracks in foundations.

### 4.3 Settlement Control Technology in the Pipeline Laying and Joint Handling Stage

The quality of pipeline laying and joint construction is directly related to the anti-settlement ability of pipeline. Thus, the smooth laying operation and flexible joint technology should be adopted to reduce pipeline damage and leakage risk due to settlement. On the one hand, when laying pipelines, prioritizing stability and on-point control is needed: during hoisting, specialized lifting tools can be used to prevent rigid tools from directly contacting with the pipeline; During future hoisting maintenance work, it is necessary to control the speed of hoisting so that the pipeline remains stable; meanwhile avoid collisions between tranches slope or base during lowering to prevent pipeline deformation caused by uneven stress [7]. The emphasis is laid on following the exact design elevation and gradient during laying so that checks of elevation and centerline position are regularly held to prevent localised stress zones in the pipeline caused by deviations accepted at this stage. However, flexible joint technology can be prioritized for the purpose of joint handling (for more delicate relieves when housing helps the spool and outer compart hasn't settled by quite enough). Select corresponding flexible joint types according to the system pipe type: rubber ring joint for ductile iron pipe, should select specific material rubber ring and use lubricant while making sure of sealing effect; butt fusion joint for PE pipes, viscous control butt fusion parameters in strict accordance with the characteristics of pipes to ensure joint stability; after completion of joints or joints or need to make a variety of leakage test check its sealing performance, confirm no hidden danger leakage. At special locations: such as at the pipe bend and size change place, should be set concrete thrust blocks; rubber gaskets follow on the contact surface between the thrust block and pipeline so that due to earthquakes and other resistance of rigid collision results in settlement differences are used to improve its anti-settlement capacity.

### 4.4 Settlement Control Technology in the Trench Backfilling Stage

The last construction procedure, and the quality of trench backfilling will have a direct impact on the settlement status in the future. In order to control the backfill consolidation settlement, guarantee the safety of piping and ensure construction personnel select materials scientifically, compaction methods standardized and dynamic monitoring throughout the is required. When selecting backfill materials, construction personnel should pay attention not only to anti-settlement performance but also to environmental requirements and make differential selections for different parts of the pipeline. Grades of gravel or lime soil well are important in the sides and above the pipe areas. To avoid settlement due to material properties in the future, such soil full of stones, impurities, and abnormal water content must be avoided. For this area up to the ground surface above the pipe, plain soil could be used for backfilling, but large particles or impurities must be taken out first to give a uniformity of backfill soil [8]. When backfilling and compacting, the thickness of each backfill layer should be controlled according to the particularity of the backfill position and material characterisitcs to suit with correct compaction machine. For one side, it is required to track the water content of the backfill soil in real time during compaction and coordinate air drying or sprinkling permits water content remains in an appropriate range, thus obtaining better compaction effect. Moreover, settlement monitoring should be sustained over the backfilling stage to acquire an up-to-date understanding of strata alterations. Upon detecting abnormal settlement ratios, backfilling operations should be immediately halted and the underlying cause investigated and remedies applied. Construction can only restart after the stabilization of the settlement and to avoid worsening settlement issues.

## 5. Conclusion

Municipal water supply and drainage pipeline construction settlement control is a systematic project that must run through the whole process of construction. Therefore, when applying settlement control technology to an actual project, to reduce the settlement risk and to ensure the safe operation of the pipeline, it is necessary to accurately determine its influencing factors and scientifically select control technology; however in terms of implementation process, quality management measures should be strictly implemented. By analyzing the influencing factors of settlement control in municipal water supply and drainage pipeline construction, construction enterprises need to clarify specific application points for settlement control technology from trench excavation stage, pipe foundation construction stage, pipe laying joint handling stage to trench backfill stage. Its purpose is to reduce the settling problems in key construction stages, minimize disturbances in environment around, and provide powerful technical support for high-quality construction of municipal water supply and drainage pipeline engineering.

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