Key Technical Points for Subgrade Surface Construction in Settlement Sections of Municipal Road and Bridge Engineering

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Abstract: Municipal road and bridge projects are the dominant subjects of urban infrastructure and its good construction quality directly affects the safety of urban transportation facility service life,. The settlement section of the subgrade becomes one of several important places to provoke problems when building municipal roads and bridges. The settlement region of the subgrade usually has troubles like excessive agreement, cracks at joints and negative bearing ability due to geological situations, build technique and seasonal environment. These problems not only compromise the smoothness of pavements and cause vehicles to bump up more, but in extreme cases can also lead to destressing structural deformations in bridges and roads which increase safety risks. Accordingly, the article summarizes the useful technical methods applicable in different aspects such as pre-construction preparation, core technical points of work processes and technology selection and adaptation strategies during ongoing construction monitoring and key parameter adjustment. The purpose is to be able to provide guidance for engineering practice, and then it can help solve the settlement section problems that must occur when constructing the subgrade of municipal road and bridge projects.along with the long-term stable operation.

1. Introduction

Municipal road and bridge projects form the backbone infrastructure of urban transport networks, allowing residents to get around their city, connect functional urban areas and enable economic development. As China speeds its urbanization process, municipal authorities have raised standards on the scale and quality of road and bridge construction. Such structures not only have to provide appropriate traffic-carrying capacity, but must also be safe and stable in the long term. Subgrade surface, which is a load-bearing base for the superstructures of roads and bridges directly determines both the main service life of operation and associated performance.

2. Pre-construction Preparations for Subgrade Surface in Settlement Sections of Municipal Road and Bridge Projects

2.1 Technical Preparations

And first of all, technical personnel must conduct an examination to visualize the construction drawings and compare them with the general design plans for municipal road and bridge project. Concentrate on verification of the dimensions and elevations along with connection details between the subgrade surface in settlement sections and connected structures, which can be bridge abutments or subway tunnels etc. All deviations or ambiguities identified must be announced in a timely manner to the design unit for clarification in order to ensure the accuracy of the drawings.

Then, a technical disclosure meeting should be convened to ensure that area leaders are covered on the subgrade surface construction process requirements in each settlement section and have explained it comprehensively to project on-site construction teams, quality inspectors and monitoring personnel. This involves specifying settlement control criteria, key operational processes and quality acceptance criteria that enables all participants to have an unambiguous understanding of technical specifications [1]. It is then up to Technical Personnel to properly analyze

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detailed geological survey reports, including taking special note of soil types in the region (soft soil, silty clay or sand), soil bearing capacity and groundwater depth. We must assess these geological conditions to identify potential risk for settlement, as well as provide a foundation to developing specific plans for construction. Finally, a detailed construction design with monitoring for settlement, process parameters during subgrade filling and reinforcement (e.g., amount of soil required to be added), and contingency plan must be prepared. For it to be implemented, this plan needs formal review and approval before implementation.

2.2 Material Preparations

Material Management Personnel It is to Choose Proper Fill Materials for the Subgrade Select high strength, water-permeable, and low-compressibility fill materials based on design requirements and geological survey reports. Graded crushed stone and soil improvement are widely used, while it is necessary to avoid materials with poor stability. Regarding geogrids, crushed stone for pile foundations and cement slurry for cement-mixed piles and others; an assessment of suppliers must be carried out to ensure their compliance with the set design specifications. For instance, geogrids tensile strength and elongation are required to comply with standards, and crushed stone particle sizes need to be controlled between 20–50 mm. After the material arrives, management personnel need to arrange inspection in sample. A sample of fill and reinforcement materials for each batch should be taken and submitted to accredited testing institutions following standard requirements [2]. The types of tests that will be carried out are: moisture content and compaction degree of soil fill materials, physical mechanics properties of reinforcement materials. Materials which do not pass these tests are not to be used. At the same time, specific storage locations need to be allocated by separating and isolating each fill type to avoid mixing. Moisture sensitive materials such as cement and geogrids must be protected using weatherproof shelters or tarpaulins. Drainage slopes should be included in the storage zones for moisture-sensitive fill materials to avoid abnormal amounts of moisture due to rainwater infiltration and to keep material that was previously qualified, in a qualified state before use.

2.3 Equipment Preparations

The first should be to organize the specific equipment table of the work order for each project. The mentions for construction machinery types used in planning and arrangement of Facilities include compaction equipment (different tonnages rollers, small impact hammers), measurement and monitoring equipment (total stations, leveling instruments, settlement observation devices) and specific processes related reinforcement equipment (e.g. vibroflotation machines to build gravel piles or cement mixing pile drivers) [3]. It is the job of equipment operators to examine and calibrate every piece of machinery afterwards. This includes testing brake systems, inspecting roller conditions checking for oil leaks and unusual sounds as well as install tonnage displays/rolling speedometers on compactors etc. Instruments used for measurement or monitoring must be calibrated to high precision, using established standards that have been verified by certified institutions: (collimation axis error specifications applying for leveling instrument). For reinforcement equipment, the operators need to check pile frame verticality and drill bit wear conditions, as well as fine-tune cement slurry pump pressure and flow rates to keep a steady construction state. Because failing equipment can lead to construction delays, equipment managers will also need to schedule maintenance and keep a supply of certain wear parts on hand.

3. Application Strategies for Subgrade Surface Construction Technologies in Settlement Sections of Municipal Road and Bridge Projects

3.1 Selection of Appropriate Construction Technologies

Technical personnel should choose detailed construction techniques for numerous kinds of strata, which the construction division shall perform in a matching requirement as stated with the subgrade stabilization. Specific approaches include:

3.1.1 Settlement Sections with Soft Soil Subgrade

For the soft soil foundation, technical personnel must first ensure the use of the combined "gravel pile + cement-mixed pile reinforcement" technology as well as dynamic compaction for leveling and load-bearing capacity improvement; Construction teams have to go through a sequence:

Installation of gravel pile: The length of the pile shall be designed so that the depth of penetration in hard stratum reach at least 1.5 times the thickness of soft layer

Cement-Mixed pile construction: The pile diameter is to maintain 50 cm apart the distance between piles shall not be lesser than 1.8 m (to avoid uneven reinforce). It is necessary to guarantee complete integration of the cement slurry and the soil at installation time [4]. Dynamic compaction – A level of compaction energy between 2000–2500 kJ shall be exercised with drop points arranged in a quincunx pattern Blows per point for additional soft soil consolidation (6–8) In case of soft ground of thickness more than 5 m additional Geogrid layers would be required (two layers for technical staff). Hence, construction teams should have an 18 cm longitudinal and a 22 cm transverse overlap (17.5-22cm) fastened by means of specialized fasteners that minimize the topographic dislocation of grids while improving average subgrade deformation resistance.

3.1.2 Settlement Sections in Fill Subgrade

In fill subgrade settlement sections, despite the dynamic settlement in the filling process because of assorted factors, technical personnel usually make use of lime-stabilized soil filling technology. This technique enhances the engineering properties of the fill material and minimizes compaction effort by using lime as a part of fill. The construction team will follow the following procedures:

Material Preparation: The original soil needs to be dried and moulded in accordance to the necessary fill requirements of the project before a proper blending with lime (applied at 8%-10% relationship compose) occurs. The specimen shall be examined and water content modified in ±2% of optimal compaction wetness contents hence that post-compaction deformation [5]. Layered Fill: The material to be stabilized shall be placed in layers of 25 - 30 cm, per layer. Compacted for 5–6 Times using 20Ton Heavy Duty Roller on each Layer. Following all passes of the compactor, surface evenness shall be checked to prevent under-compaction. Geogrid: Geogrid shall be placed, secured and anchored at every three filled layers; If a layer of these is not placed inside embankment and limited you cannot fill more than those three layers. This reinforcement adds another layer of structural integrity to the fill as well as interlayer settlement restriction and provides additional support to the section via stabilisation.

3.1.3 Settlement Sections at Bridge Abutment/Culvert Transitions

To facilitate the compacting of large machinery, technical personnel will use a "small-scale rammer + thin-layer filling" building methodology to fill small space sections when transitioning from bridge abutment/culvert settlement. The construction team must follow these implementation principles: Thin-Layer FillingEach fill layer is limited to 15–20 cm in thickness (thinner than standard fill layers) Dynamic Compaction: 30 kN impact rammer, 8–10 blows/layer for full-thickness compaction of transition zones [6]. Application of a bonding agent: A bonding agent (like a glue) shall be applied to the surfaces on either side of the abutment prior to filling. Filling

4. Strengthening Dynamic Monitoring During Construction

At this time, monitors, technical staff and the construction team all need to work together on real-time monitoring, data analysis and dynamic parameter adjustments in order to maintain subgrade settlement within design-permitted limits. Specific measures include:

4.1 Implementation of Dynamic Monitoring

Agency staff monitoring will create a plan for automated tracking and manual checking of compliance. Automated inspection and observation instruments were required to be previously installed at those key points both sides of the subgrade settlement section and around bridges abutting point connections. So they should be firmly tied to sturdy observation points to prevent errors from vibration. The instruments will automatically gather data every 2h, including millimeter-level vertical settlement of the subgrade surface, daily settlement rates and lateral displacement distances. At the same time, personnel monitoring using instruments level and total stations check manually daily data in order to measure again points of observation. The automatic data will be cross-verified with manual measurements to validate the automations and mitigate risk of any equipment malfunction [7]. Immediate recording and upload of all monitoring data: Following each collection or verification, staff will immediately arrange the information in a time table standardized table indicating the timing of collection, observation point ID, settlement magnitude and settlement rate respectively to upload it in real-time through the construction control platform. Any delays would have resulted in missing out on early warning signs for possible hazards. In addition, staff responsible for monitoring will conduct the maintenance of instruments regularly, including weekly cleaning dust and rainwater on instrument surfaces and conducting monthly calibration to ensure stable operation in a long time.

4.2 Analysis and Interpretation of Monitoring Data

Technical personnel are required to do an analysis of the received monitoring data in less than 1 hour:Threshold Comparison: The alert design values are compared with the present data, to check which reading is out of limits. Analysis of Settlement Curve: A settlement curve is prepared with time (x-axis) and the magnitude of settlements (y-axis) to review trend patterns. Stable subgrade settlement is shown by a constant decline in the curve portion of the model, whilst sudden steepening of curve or continuous state, where settlement rate greater than 1 mm/day persists for two consecutive days are considered as "abnormal" compensation for which immediate corrective actions should be initiated. In addition, technical staff need to bring data analysis into context with the progress of construction work. Take the fifth-layer filling of the subgrade as an example: if the settlement rate exceeds alert thresholds, it is needed to discriminate whether excessive layer thickness or insufficient compaction passes are responsible. If behavior of the first four layers (30 cm thick, compacted 5 times with satisfactory results) is normal but fifth layer displays abnormality under identical conditions then few reasons may be minimum moisture content in fill material [8]. When previously untested fill materials are used, their performance must be validated to prevent focusing system adjustments toward the wrong direction based purely on surface level data candidly interpreted without last contributing factors understood.

5. Conclusion

In general, the construction technology of subgrade in municipal road and bridge engineering should go through a systematic process that is "pre-construction preparation—adaptive technology selection—in-process control—dynamic optimization". Pre-construction preparation lays the groundwork for technical implementation, and adaptive technology selection according to the geological conditions in conjunction with parameter adjustment driven by real-time monitoring data during construction forms a closed-loop technical control system. This methodology effectively resolves common problems like high subgrade surface settlement and low connection quality, increasing the stability and load-bearing capacity of surfaces. It as well prolongs the service life of town infrastructure and avoids excessive maintenance prices afterward. With the increasing demand for construction precision, subgrade settlement control technology will have a deeper integration with intelligent monitoring technology and advanced reinforcement materials, to achieve technological innovation and upgrading. It is suggested that the engineering practitioners should take a flexible approach to apply technical methods in this paper based on project conditions, continue to summarize experience and promote the development of subgrade settlement control technologies toward higher efficiency and accuracy. The task will particularly contribute to an upgrade of urban infrastructure development overall.

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