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Research Article

Control Points of the Compaction Technology for Subgrades and Pavements in Municipal Road Engineering

Li Pingju[1], Shi Mengzhen[2]

[1]Puyang Administrative Office of Amenities and sanitation Puyang Henan 457000, [2]Henan University of Engineering Zhengzhou Henan 451191

Abstract: With the rapid development of current social economy, China's infrastructure construction is constantly increasing. The development of transportation industry and road structure which serve as infrastructure facility for the vehicles are fundamental aspect in economy growth. It's not only convenience to people for travel, but also as a good foundation for the development of economy. Therefore, the quality of road construction is of great significance importance in the process of development. As technology advances, engineering construction is continuously expanding, especially in the road engineering sector. In this point, it's necessary to impose strict quality control over related matters and ensure the quality and safety of municipal road construction. In the construction of municipal road engineering, one of the most important components is the compaction of subgrades and pavements, which requires more supervision. The compaction should match the requirements of road design and implement relevant work.

Keywords: *municipal road engineering; compaction technology for subgrades and pavements; control points*

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Corresponding Author: Li Pingju**,** 1771533122@qq.com

0 The importance of compaction technology

During recent years, as expertise in various fields have increased in requirements for the quality of municipal road engineering, the importance of the compaction technology for subgrades and pavements has been identified by associate members. The importance of this technology is mainly expressed in the following aspects. First, the quality of the compaction technology for subgrades and pavements provides an important assurance to the safety of the vehicles and pedestrians. For example, if the construction personnel of a municipal road project neglect the quality supervision on the compaction technology for subgrades and pavements, the road will be in poor conditions, further affected by the weight of heavy vehicles or natural factors which will further the damage like cracks on the road and uneven subgrade settlement. This will not only increase the safety risk of pedestrians, but also exert a seriously adverse effect on the financial benefit of the construction company. Secondly, the effective application of the compaction technology for subgrades and pavements in municipal road engineering can prolong the duration of the road and stability of the road in service[1]. The compaction of subgrades and pavements can effectively reduce the gap in the internal structure of the roadbed and limit the soil moisture content within a certain range, so that the road can support vehicles without deterioration.

1 Key technologies in the subgrade and pavement construction

1.1 Tamping technology

In the construction process of municipal roads and bridges, tamping technology which commonly used in large-area compaction construction, is one of the most accepted compaction technologies. Large-volume rammers are used to conduct corresponding tamping

work, in the process of which clay is usually produced. The impact force of rammers on the ground enables subgrades and pavements to have a good exhaust effect, so that the quality of the compaction of subgrades and pavements is guaranteed. Due to this, the stability and smoothness of municipal road and bridge engineering are fairly strengthened to ensure the trusted quality of the engineering.

1.2 Rolling compaction technology

Rolling compaction technology mainly means to use the pressure and load produced by the roller during the rolling process to achieve the compaction work. It can also compress the soil layer to eliminate the unwanted space. As a result, the compactness of subgrades and pavements of municipal roads and bridges will be enhanced to ensure no deformation when using the road. The principle of rolling compaction technology is to overcome the friction existing in the soil and reduce the gap to ensure its degree of density. However, when practice this technology, attention should be given to the number of rolling compaction, because too many times of rolling compaction could damage constitutive property of soil, thus lowering the shear capacity of soil layer structure. It's necessary to control the number of rolling compaction to ensure a good compaction effect.

1.3 Vibratory compaction technology

The main principle of this technology is using the high-frequency vibration of the road roller's vibrator to recognize the compaction of subgrades and pavements. Vibratory compaction technology is relatively similar to rolling compaction, which can reduce the friction between subgrade and pavement, thus enhancing the compactness. However, compared with the technologies mentioned above, vibratory compaction technology often has a shorter construction time and a higher utilization rate. It is more suitable for gravel soil.

2 Influencing factors of the compaction technology for subgrades and pavements in municipal road engineering

The quality of the compaction of subgrades and pavements of municipal roads and bridges can only be improved when the technologies are wisely applied and continuous innovation to improve the quality. However, the actual application reflects the existence of many problems which requires more emphasis.

2.1 Disproportionate material ratio

The effectiveness of the compaction work in subgrades and pavements of roads and bridges requires more focus on materials to ensure right measure of material ratio. However, although current compaction technologies for subgrades and pavements automatically control materials, there are still many problems exist in determining ratio, especially when there are differences between corresponding environments, basic conditions, and soil bulk densities, which requires standard design and plans. However, in practice construction companies lack of understanding and poor achievement in research and development. In addition, the problems of relatively single material ratio and low degree of compactness are obvious. Although other construction companies aware about the material ratio and formulated relevant systems, but they lack skilled man power to act. Some construction workers fail to control the ratio, because they want to reduce the quantity of work and costs.

2.2 Insufficient control over water content

In the actual process of compaction construction, the water content of subgrade soil or that of the material of pavement structure layer has a great influence on the quality of compaction. In general, the internal friction resistance and the bond force in the soil layer tend to change according to the density. If the water content in the soil layer is relatively low, the internal friction resistance between soil masses will increase accordingly. Once pressed, the compaction effort can't rival the resistance of the soil layer, thus making the dry bulk density quite small. If the water content in the soil layer continuously increases, the internal friction resistance will decrease, which guarantees a better dry bulk density if the compaction effort applied is the same. It should also be noted that as the air volume in the soil layer shrinks, the volumes of solids and water increase. Therefore, if the water content of the soil layer is greater than the corresponding value, the dry bulk density will also decrease when applied the same compaction effort. This is because, although the internal friction resistance in the soil layer is reduced and the air volume is already very small hence the volume of water is increasing. Therefore, the dry bulk density can be increased only by ensuring proper water content, which is also the optimal water content.

2.3 Inadequate innovation in technology application

The level of the compaction technology for subgrades and pavements of roads and bridges has much influence on compaction quality. Relevant construction situations in the current setting show innovation in technologies is inadequate. For example, in the actual construction, the standard of heavy compaction is inconsistent. The deformation rate of pavements is quite high, lacking corresponding flatness hence the pavements are unstable. In addition, there are many factors influence the compaction of subgrades and pavements in the road construction, among which water content and rolling technology are the most common. However, some construction team ignore the in-depth understanding and investigation showing lack of creative thinking in the application of technologies and fail to control the time limit, speed and thickness of rolling compaction. If relevant companies fail to explore and adapt in technology innovation, the compaction of subgrades and pavements will not successful. Serious problems are possible to arise, which will diminish the economic benefits of companies and reputation as well.

3 Control points of the compaction technology for subgrades and pavements in municipal road engineering

3.1 Compaction technology for subgrades in municipal road engineering

The subgrade is the foundation for road engineering and the core for compaction operations. The compaction work of the subgrades in municipal road engineering comprises many elements. If any of the component is failed, the construction work will be affected. Therefore, construction company need to combine the construction features of the subgrades of municipal roads and engineering requirements so that well control of the compaction quality can be achieved. In order to reach the balance development of compaction work, construction companies need to focus on the following relevant procedure[2]:

3.1.1 Choosing the appropriate compaction machinery

Generally, if the particles of the coarse materials on the road surface are relatively large, vibratory rollers are usually used in the rolling process. Heavy-duty pneumatic tyre rollers are usually used in the compaction of dense asphalt mixture pavements. Since the temperature in certain time can affect the compaction quality, no matter which kind of machinery we choose, in the actual compaction construction we should maintain control over the rolling temperature. In order to prevent the compaction problems, it is necessary to ensure that the rolling temperature meet relevant requirements. The optimal rolling temperature can effectively prevent road rollers from moving horizontally in practice thus providing enough support for the mixtures.

3.1.2 Defining the compaction standard of subgrades

The compaction of subgrades and pavements of municipal roads needs to be done in accordance with standard operating procedure, which is crucial for solid compaction effect. As the main index for evaluating the compaction effect of subgrades, compaction degree refers to the ratio of the dry density after compaction to the standard maximum dry density of the soil, compaction degree $k=\rho d/\rho o\times 100\%$. Therefore, in the compaction construction of subgrades, construction companies need to control the compaction degree accurately. In certain condition, the compaction standard varies with the change of the top surface and the depth of the roadbed, as shown in Table 1.

3.1.3 Controlling rolling quality

Rolling construction are influenced by three factors: thickness, method and speed of rolling. In practice if rolling thickness is too large, the compaction degree of the rolling layer will be directly affected and fail to meet the standard requirements. Hence, the overall

Table 1. Compaction standard of subgrades

Depth under the top surface of the roadbed (cm)	Road type	Compaction degree (%)
	Express way, arterial road	≥95
0~30	Sub-arterial road	≥93
	Branch and other paths	≥90
	Express way, arterial road	≥95
0~80	Sub-arterial road	≥93
	Branch and other paths	≥90
	Express way, arterial road	≥93
80~150	Sub-arterial road	≥90
	Branch and other paths	≥90

compaction degree of the construction will be impacted. Every roller's compaction work can affect the quality of the construction. In order to guarantee the quality, it is necessary to choose the rolling thickness accordingly. At the same time, rolling methods are also equally important. The marginal area of the subgrade should be compacted first, followed by the middle part. The speed of rolling also need to monitor according to standard operating procedure. First, the rolling level should be slow and light then steady change to fast and heavy pace. Rolling speed is the control point. If the speed is too fast, the road surface will be uneven, and if it's too slow, the load capacity of the road surface will be directly affected. Therefore, it is necessary to select a reasonable method on site to effectively ensure the quality of the project.

3.1.4 The compaction technology for the substrates of subgrades

The perfect compaction of the substrate for subgrade has a great influence on the practical application and the overall quality of the road. Currently, during construction there are many compaction problems related to different soil textures arise, such as wet soil subgrade and loess subgrade. These issues have a significant impact on the overall quality of the road. Number of severe problems may even cause corresponding casualties and property losses, which will pose a great threat to the safety of roads and bridges. Therefore, before the construction authority need to focus on weather factors and effectively analyse the soil conditions at the construction site so that scientific and reasonable compaction methods can be used in accordance with actual conditions. The safety and quality of the road engineering can also be secured[3].

1) The compaction of wet soil subgrades

In order to ensure a good compaction effect, the compaction of wet soil subgrades needs to follow according to the design requirements, among which the main concerns are related to compaction degree data and related standards. Usually, compared to the general soil, in the course of construction, the compaction degree of wet soil needs to be reduced from 3% to 4% and the consistency of the soil layer needs to be 1.1. The liquid limit should be greater than 40. In this case, light-duty compaction standards are used to make the soil suitable for the roadbed padding. Continuous improvement of the properties of fillings can effectively increase the amount of quicklime used in the soil. In addition, new types of water absorbent materials can be used for further strengthening.

2) The compaction of loess subgrades

The compaction construction of loess subgrades requires a reasonable consolidation of the water in the soil so that the compactness of the soil can be increased to reach the effective reinforcement of loess soil for good compaction effect. In this case, the number of stamping should be controlled to 35 times as much as possible so that the water content can meet the requirements. The compaction at edge of the embankment requires slow construction, which can reduce the probability of the slippage that may occur to construction machinery in the actual construction. If machinery causes folds on the road surface during construction, second cycle of compaction should be implemented.

3) Substrate processing technology for different cross slopes

In the construction of substrates for different cross slops, if the ratio of the cross slope is less than 1:5: the embankment can be directly filled. In the meantime, dry wall or mortar rubble can be used to protect the subgrade. Second, when the ratio of the cross slope is between 1:5 and 2:2.5, it is necessary to excavate steps greater than two meters on the ground. If the coverage of the subgrade is relatively thin, the overburden layer should be investigated before excavation. Third, if the ratio of the cross slope is greater than 1:2.5, it is necessary to test the sliding stability of the subgrade and the lower layer of the embankment to ensure the coefficient of sliding resistance meets relevant requirements and regulations. Protection measures need to be taken in accordance with the actual requirements if the need fail to meet.

Plants can protect the soil from erosion, this is an advantage in designing protective engineering of subgrade slope. The plant protection design can be divided into skeleton plant protection, anchor concrete frame grass protection and hollow block plant protection. In general, skeleton plant protection is mainly applied in rocky slopes where the soil is relatively soft and inclement weather. It can prevent the slope from turning into grooves after the heavy rain. This kind of protection design can stabilize the weathered slope. Anchor concrete frame grass

protection is mainly applied in poor structural surfaces and unaffected rocky slopes. This design can avoid the wedge-shaped damage caused by the excavation and well implement the work related to skeleton plant protection. Hollow block plant protection is mainly applied in slopes of strong weather rocky subgrades. Generally, hexagonal concrete precast void slabs are used to divide the slope into small blocks for support work. This design can effectively avoid the erosion caused by rain and ensure the good stability of the slope.

4 Compaction technology for the pavements in municipal road engineering

In the actual construction of municipal roads, high-quality compaction of pavements will ensure the safety of vehicles and reduce the problems related to pavements. Research shows that most of municipal roads have asphalt concrete pavements. Therefore, the following discussion focuses mainly on the analysis of the compaction of asphalt concrete pavements[4].

4.1 Fully preparing the compaction

After the paving of municipal roads is completed, in order to ensure the smooth application of compaction technologies, inspection of paving quality should be conducted. Irregularities as well as joints that lack of enough materials need to be repaired. According to the pavements design requirements, the compaction machinery applied is determined through experiments. In order to be able to construct in a relatively narrow area, small vibratory road rollers or compaction tool need to be prepared. Beyond that, construction companies need to identifty compaction targets and construction plans along with strictly implement the compaction construction of pavements in accordance with corresponding requirements.

4.1.2 Ensuring the compaction quality of each link

The compaction construction of asphalt concrete pavements can be divided into three links: initial pressure, re-pressing, and final pressure. In the construction process, the following points should be emphasized: firstly, initial pressure means to use steel rollers to conduct static pressure twice. The driving speed of the roller should be maintained at 1.5-2km/h. The sequence is mainly inward to shape the pavement. In addition, in the course of construction it is necessary to strengthen the inspection of compaction quality especially the quality of road cambers and flatness. Existing problems need to solve promptly. During the process of initial pressure, the temperature should be not less than 120°C. Secondly, re-pressing work mainly use heavy-duty rollers with rubber wheels to conduct the compaction work for four to five times. The rolling speed needs to be controlled at 4-5km/h. Adjacent compaction areas should overlap 10-20cm. During the process of re-pressing, the temperature should not be less than 90°C. Thirdly, final pressure means to use vibratory steel rollers to conduct static pressure for two to six times to control the flatness of the pavement, thus eliminating the unevenness produced during the work.

4.1.3 Focusing on details

The compaction construction of municipal roads involves many links. In order to avoid significant impacts on pavements, construction companies need to pay more attention to relevant details in the course of compaction, especially the following details. First of all, during the process of final pressure, if transverse cracks are found, the compaction should be paused. After cooling, the temperature of the asphalt should be no less than 70°C when compaction finishes. Secondly, if the roller needs to change its direction during actual driving, it needs to reduce the speed and avoid turning or braking in places where the compaction is still underway. When the roller is repeating the compaction work, the distance between the two positions where the roller stops should be kept within ten meters to prevent the gasoline or grease from being released on the pavement. The compaction work should not cover certain areas around the dead center of the paving point. After the completion of re-paving work, these areas need to be uniformly compacted to ensure a smooth connection. Finally, the rolling wheels of the roller need to be kept clean to avoid the negative impact of the asphalt concrete that may stick to the wheels on the flatness of the pavement. Areas where the compaction work is out of place need to be re-compacted in time to ensure flatness. In addition, it is also necessary to properly inspect the quality of paving and protect working achievements. First, the inspection of walling cribs and manhole covers on asphalt concrete pavements, which needs to be well conducted before paving, should be given greater emphasis. In the installation of walling cribs and manhole covers, four control lines should be used as much as possible,

namely, two horizontal lines and two vertical lines to strengthen the control over the well plane and ensure that walling cribs and manhole covers have the same height as the top surface of the road does. Second, after the completion of the final pressure of the concrete pavement before cooling, construction machinery is not allowed to the construction site[5].

5 Measures to improve the compaction technology for subgrades and pavements in road engineering

5.1 The application of compaction technology in the soil with high or low water content

First of all, if the soil of the subgrade has relatively high-water content, the construction personnel can reduce it by air drying. Meanwhile, the fineness and dryness of the soil should be optimum to ensure that they meet the flatness requirements of the pavement. Second, if the water content in the soil is relatively small, the construction personnel can use plows to dig up the soil and use road rollers to compact the soil until its compaction degree meets the requirements. The construction personnel must reasonably control the rolling speed and ensure the water content in the soil did not lose massively. Third, if there is a rainfall during construction, the construction personnel need to handle compaction work on the completed soil layers and pay more attention to the drainage work than before. After raining the water content in the subgrade is usually very high. In this case, the construction personnel need to add materials like gravelly soil and coal ash to guarantee that its compactness and safety are in line with the relevant requirements in the Technical Specification for Construction of Road Subgrades[6].

5.2 The application of excavation and soil change technology

Before the compaction construction of pavements, if the thickness of the soft soil layer is less than two meters, the soil can be changed. First, the soil masses inside the substrate are dug out and replaced by some high-strength soil masses that are not easy to be affected by the outside world, such as gravel or lime soil. It should be noted that soil change technology is not suitable for all soil layers, for example, it can be used in some bearing stratums[7].

5.3 The application of road rollers

In the compaction construction of subgrades and pavements, construction workers need to ensure that the rolling length of the roller is coordinated with the working speed in the paving. It is also necessary to keep them stable. If the conditions of the construction site do not support the use of road rollers, compaction work can be implemented through vibrating compaction. In addition, the construction personnel need to determine the temperature and wind speed during the construction according to the length of rolling and other relevant conditions instead of following the traditional construction method. In meantime, it should be noted that in order to ensure the cleanliness of the road engineering, compaction machinery or other oil materials need to avoid when the bituminous mixtures of the road are still cooling down[8].

5.4 Methods of inspecting the compaction quality

5.4.1 The application of nuclear density instrument

It's common to use nuclear density instrument to inspect the compaction degree of pavements. The inspections using this instrument mainly focus on the quality and thickness of bituminous mixture pavements, in which the compaction degree of the asphalt surface is inspected mainly by light scattering, and the compaction quality of the materials of substrates is inspected by direct transmission. The operating steps of this method are as follows: first, we need to confirm the test position and preheat the instrument. The test position is defined by random sampling. The nuclear density instrument is ensured to be well preheated and stable in the test position at the same time to prepare for the inspection. Second, in the process of measurement and the acquisition of data, device should be open and conduct the measurement according to the guideline. After the completion of measurement, the result can be obtained directly. The measuring instrument should be closed at the same time. Third, after the measurement is completed, the nuclear density instrument should be placed in a special instrument container that meets the requirements of radiation to guarantee the safety of the instrument and personnel[9] [10].

5.4.2 Sand cone method

In the inspection of the compaction quality of subgrades and pavements, sand cone method is mainly used in certain complicated construction environments, such

as the construction of rock-filling embankment. The principle of this method is mainly to free the uniform sand from corresponding height to the test hole, and then perform tests in combination with the data such as water content of the aggregate on condition that the unit quantity is unchanged.

6. Conclusion

In short, in the construction of road engineering, the compaction of subgrades and pavements is of great importance, which has a great influence not only on the quality of roads, but also on the service life and functions. Therefore, it is necessary to promote the reasonable application of the compaction technology for subgrades and pavements. The practical application of the compaction technology for subgrades and pavements at this stage shows that the technologies are controlled within corresponding standards. However, despite the continuous development of science and technology, as well as the constant emergence of new technologies, many minor problems still exist to prevent the compaction of subgrades and pavements from gaining a good effect. In order to solve these problems, during the compaction construction, the emphasis should be placed on improving the rationality of material ratio, water content control, and promoting the innovation in the application technology, so as to make sure the optimization and perfection of the compaction technology for subgrades and pavements, and the good quality of the road construction.

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