Research on Prefabricated Road base Technology under the concept of Sponge City

Lin Yan*

Chengyi University College, Jimei University

Abstract. The problems of construction period, quality and coordination between road construction and maintenance and road traffic often exist in the process of traditional urban road construction. The development of urbanization has brought about the rapid expansion of urban roads, and the changes in the permeability of urban underlying surface have also brought about urban waterlogging and urban water security problems. Making full use of the environmental protection, high efficiency and economic characteristics of the prefabricated process, through data investigation, theoretical calculation and mechanical analysis as the main means, the prefabricated prefabricated road base is studied and designed, drawing on the stress characteristics of the raft foundation of the building structure and the concept of beam and slab force transmission, forming the prefabricated beam and slab base in the form of raft structure, taking into account the actual drainage capacity of the urban pipe network and the outdoor drainage regulations, and setting drainage holes and gravel layers, Make the prefabricated road base have the function of organized drainage and water storage at the peak of runoff, so as to alleviate urban waterlogging to a certain extent and solve urban water safety problems.

1. Introduction

The past decade has witnessed the rapid development of the construction industry and the rapid urbanization of China. With the rapid development of urbanization, urban road construction has also made great achievements. According to the announcement on China's urban construction status in 2021 issued by the Ministry of housing and urban rural development on September 30, 2022, by the end of 2021, the length of urban roads nationwide was 532000 kilometers, and the area of urban roads had reached 10.54 billion square meters[1]. The rapid development of urban roads has greatly met the travel needs of urban residents, but also brought a series of problems. The substantial increase in the proportion of road hardening has reduced the surface permeability, rainstorm has hit, the surface runoff has increased, the urban pipe network drainage is not timely, and the urban roads are seriously waterlogged. The resulting urban waterlogging and rainwater runoff pollution threaten people's travel safety and life and health safety.

At the same time, the construction process of urban roads also has problems such as the coordination between road construction and maintenance and road traffic[2]. Road construction often needs to occupy limited traffic space. The reduction of traffic space reduces the traffic capacity of urban roads, which leads to various traffic problems. Under the pressure of huge urban traffic flow, in order to ensure the normal traffic of the city, the road construction period has been compressed again and again, and the schedule can not meet the basic needs of the construction process. Especially, the road base is an underground concealed project, which has become a victim of the construction period compression.

2. Current situation of urban road construction

The road base is the structural layer under the pavement, which is the bearing and force transfer layer connecting the preceding and the following in the road structure. Its mechanism is to evenly distribute the uneven vehicle load and impact load transmitted from the road surface layer to the subgrade, so that the lower layer will not be in the overstress state, and at the same time, provide a suitable lower bearing layer for the upper road surface layer, so that the surface layer will not be in the overstress state. Therefore, the quality of road base plays a decisive role in the service quality and service life of pavement. Insufficient base strength and poor water stability often lead to cracks, settlements, pits and other diseases on the pavement, which greatly shorten the service life of urban roads.

The traditional road base structure is a semi-rigid structure that produces strength through mixing, rolling and curing with inorganic binder, lime, fly ash, graded crushed stone and a certain amount of water[3]. According to the current composition of road base materials in Fujian Province, cement stabilized gravel is the mainstream form, as shown in Figure 1. During the construction of cement stabilized macadam base, the quality of raw materials, mixture ratio and construction quality all affect the quality and strength of road base. Nowadays, the raw materials in the market are difficult

*312564704@qq.com

to guarantee, and the technical level of construction units is uneven, which makes it difficult to guarantee the quality of road construction. In addition, the initial strength of the structure formed by cement stabilized macadam is low, and its strength needs a slow growth process. The cement stabilized macadam shall be cured in time after completion, which shall not be less than 7 days. Curing is an important factor affecting the strength of cement stabilized macadam base. Appropriate conditions (moisture, temperature and time) are very important for the strength growth of cement stabilized macadam base. Even with better mixture and mix design, without appropriate curing conditions, it will not produce satisfactory use effect. The heavy traffic pressure often leads to the duration and conditions of the curing period can not be guaranteed, which greatly affects the quality and life of urban roads.

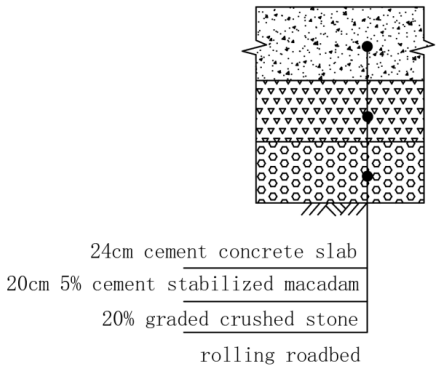

Fig 1. Structural diagram of traditional road (taking cement concrete surface course as an example)

3. The design of prefabricated road base

Based on the importance of the road base and the possible problems in the construction process, this thesis proposes a prefabricated road base structure. The prefabricated road base is a rigid base with reinforced concrete as the main material. Compared with traditional semi-rigid base materials, rigid base has higher strength and better water stability. At the same time, as the load-carrying layer of the pavement, in order to reduce the problems of pavement cracking, subsidence, pits and other problems caused by uneven settlement of the foundation caused by the concentrated load of vehicles, the prefabricated road base structure used the foundation design concept adopted in the building structure to reduce the uneven settlement of the frame structure in the design process, adopted the raft like foundation in the structural form, and increased the stress area of the base, Reduce the pressure per unit area of foundation soil and the impact of concentrated load on the foundation, so as to improve the surface quality and service life.

In the process of overall function design and mechanical analysis of prefabricated road, in order to realize the "purification, storage and drainage" function in the urban water cycle, compared with the traditional road, which directly paved the road surface above the cement stabilized material base, the prefabricated road added a certain thickness of gravel layer between the road base and the surface layer to achieve a certain degree of "purification, storage" function, and in order to optimize the stress mode of the road surface layer, In terms of road structure design, two rectangular beams parallel to the driving direction of the road are set on the base slab by referring to the force transfer mode of the house beam slab structure. On the one hand, under the normal use condition of the road, the rectangular beam is the support of the pavement, as shown in Figure 2. The mechanical model of the pavement can be regarded as a simply supported outrigger beam. The pavement is considered as the standard axle load of 100kN for the single axle load of double wheel group, and the load is simplified as 100kN concentrated load. The stress diagram is shown in Figure 3. On the other hand, under the hoisting condition of prefabricated components, the rectangular beam is also the support of the base plate. The mechanical model of prefabricated members under this working condition can be regarded as a simply supported outrigger beam with rectangular beam as the support and subjected to uniform load (dead weight of base plate), as shown in Figure 4.

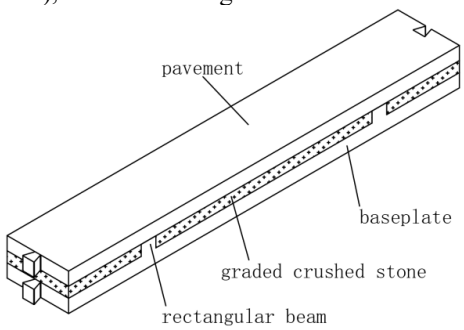

Fig 2. Stereoscopic view of prefabricated road base structure

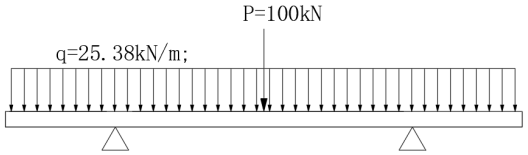

Fig. 3 Stress diagram under normal operating conditions

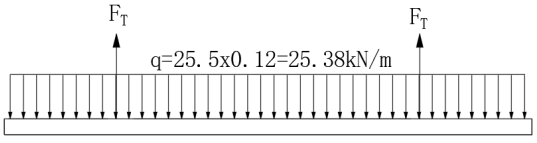

Fig. 4 Stress diagram under hoisting condition

According to the stress calculation formula:

$$\sigma = \frac{F}{A} \leq [\sigma] \quad (1)$$

where σ =stress(kPa); F= force(N); and A = area (m^2)[4].

When the section width of the rectangular beam is 200mm, that is, A=0.2m^2, the compressive stress of the rectangular beam under normal working conditions is 503.8kPa, and the tensile stress of the rectangular beam under hoisting conditions is 253.8kPa. The compressive strength of C30 concrete used for prefabricated base course can reach 34.5MPa or more, and the tensile strength is 1.43MPa, so the strength requirements of the rectangular beam under both working conditions are met.

In the selection of the position of rectangular beam, in order to ensure the strength and performance of the components of the prefabricated base under the hoisting condition, the position of rectangular beam refers to the principle of the best stress layout of the bending beam

under uniform load as shown in figures 5. For a simply supported outrigger beam under uniform load, when the cantilever length a=0.207L, the beam is in the most reasonable stress position. Considering the feasibility of hoisting prefabricated components and the matching degree with the size of conventional lanes, the size of the prefabricated base plate is set as 4000mm× 500mm, then L=4000mm, a=828m. Therefore, the dimension from the center of the rectangular beam to the plate end is 850mm, that is, the distance from the beam edge to the plate end is 750mm, as shown in figures 6.

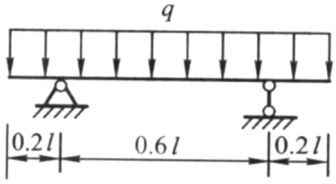

Fig. 5 Optimal stress arrangement of beam

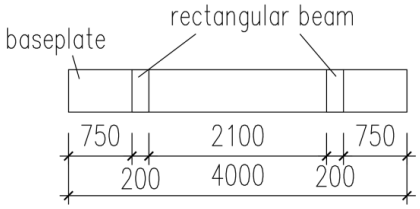

Fig. 6 Top view of prefabricated base module

The determination of the section height of the rectangular beam takes into account the needs of road drainage and flood peak delay. The determination of the height of the rectangular beam section takes into account the needs of road drainage and flood peak retarding. The rainstorm intensity formula is designed according to the "Technical report on revision of rainstorm intensity formula and design rainfall pattern research in Xiamen". (Xiamen Meteorological Bureau 2016)

$$q = \frac{928.15\times(1+0.716lgP)}{(t+4.4)^{0.535}} \quad (2)$$

where q =rainstorm intensity; P= return period; and t = rainfall duration (min).

According to the "Standard for design of outdoor wastewater engineering" (GB20014-2021) and relevant research, the actual drainage capacity of Xiamen urban drainage network is selected as once-in-a-year. According to the rainfall duration of 120mm(t=120mm), the average rainfall intensity of the 120min rainfall (q) in Xiamen is 0.425mm/min. That is, the actual drainage capacity of Xiamen urban drainage network is 0.425mm/min. It is assumed that the part of rainfall data less than 0.425mm/min infiltrates into the base course through the pavement and is discharged to the drainage network through the organized drainage of the prefabricated base course.

According to the "Standard for design of outdoor wastewater engineering" (GB20014-2021), the discharge formula of the drainage pipe channel is

$$q = av \quad (3)$$

where q= design discharge (m^3/s); a= effective cross-sectional area of the flow (m^2); and v=velocity (m/s).

In addition, the velocity formula of drainage pipe network under the condition of constant flow is

$$v = \frac{1}{n}R^{\frac{2}{3}}I^{\frac{1}{2}} \quad (4)$$

where R=hydraulic radius; I=hydraulic gradient, taken as 3%; n=roughness coefficient of drainage irrigation channel, and concrete n=0.013 is selected for calculation.

By combining the above two formulas (3) and (4), it can be obtained that in order to meet the drainage demand, the total aperture of the base drainage pipeline should not be less than A=0.0140m3. Therefore, in order to meet the drainage demand, three equally spaced semicircular drainage holes perpendicular to the beam direction are set at the bottom of the two rectangular beams on the prefabricated base, and the radius of the semicircular drainage holes is 40mm(r=40mm). According to the relevant structural provisions of openings on beams in "Code for design of concrete structures" (GB50010-2010), the height of openings shall not be greater than 40% of the beam height, then the beam height shall be greater than 100mm.

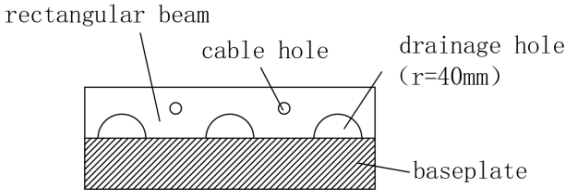

Fig. 7 Sectional view of prefabricated road base structure

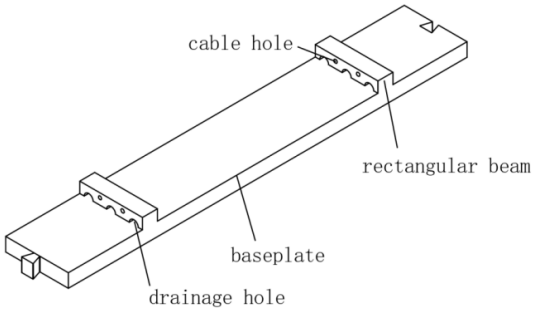

Fig. 8 Three dimensional schematic diagram of prefabricated road base structure

According to the above calculation results, the overall design of prefabricated sponge type road base module is shown in Figure 8: the base plate refers to the requirements of raft foundation structure, the thickness of the base plate is 120mm, the section size of two rectangular beams parallel to the road driving direction is 200mmx240mm, and the strength grade of precast base concrete is C30. According to the requirements of minimum reinforcement ratio of beams and slabs in "Code for design of concrete structures" (GB50010-2010), the reinforcement of base plate is double-layer and two-way ⌸8@150. The full-length reinforcement of rectangular beam is 4⌸20, and the stirrup is 6⌸8. The connection between prefabricated bases is also the introduction of traditional wood structure mortise and tenon technology, which can prevent loosening, improve the stability of modules and facilitate the repair and replacement of materials, as shown in Figure 9.

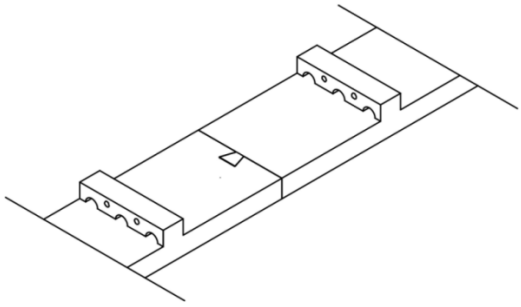

Fig. 9 Connection diagram of prefabricated road base structure

In order to facilitate the drainage of the road base course, the drainage gradient of the base course surface is selected as 3%. Secondly, the accommodation space formed between the beam and the base course plate is made of graded crushed stone with particle size of 20-40mm. The large-size gravel has the functions of filtering and storage, delaying the peak runoff. At the same time, each beam is equipped with three equally spaced semicircular drainage holes perpendicular to the beam direction, so as to realize the organized drainage of the road base course and the function of peak runoff storage, Reduce surface runoff and reduce the possibility of ponding on urban roads.

4. Social effects of prefabraicated road base

In order to ensure the strength of base course and reduce pavement cracks, settlements and pits caused by insufficient base course strength, the curing period of traditional cement stabilized gravel after rolling shall be up to 28 days, and the traffic shall be closed during the curing period. The precast concrete base only needs 3 days of joint filling mortar curing period, so the precast base can be opened to traffic 25 days earlier than the traditional cement stabilized gravel base, thus easing the contradiction between road construction and urban traffic.

Secondly, during the traditional road construction, the construction machinery with large vibration such as vibratory roller is required, which is easy to produce large noise pollution. Especially in the noise sensitive area of the urban area, in order to prevent and control noise pollution, additional measures should be taken to reduce noise during on-site construction. The prefabricated road base are produced in the factory. From the preparation of concrete to the maintenance of components, they are all realized through the factory assembly line, and they need to be assembled when transported to the site. While ensuring that the quality of the base meets the requirements, the noise pollution and dust pollution on the site are reduced to the greatest extent. With the improvement of urbanization and the aging of population, the lack of labor force and the rising labor cost at the construction site have also become a major problem encountered at the construction site. Mechanized assembly line construction can well solve the problems of insufficient manpower and increased cost. At the same time, it can avoid the problems of unqualified road construction quality caused by uneven road construction level to a certain extent, and plays a good role in reducing cost and increasing efficiency.

5. Conculusionocial

Urban roads are the skeleton of a city. In urban construction, road construction is an important construction content. How to improve the construction quality of roads is an important means to meet the needs of urban construction. With the deepening of urbanization, the problems of construction period, quality and coordination between road construction and maintenance and road traffic in the process of traditional urban road construction need to be solved. By making full use of the environmental, efficient and economic characteristics of the assembly process, the prefabricated road base module proposed in this thesis has the advantages of factory production, product quality standardization, controllable construction quality, convenient construction, rapid replacement and repair, etc. in terms of construction technology, which can better solve the problems of uneven road construction level, difficult management and maintenance in the later period, and greatly simplify the on-site construction operation, The construction difficulty is reduced, the construction progress is greatly improved, and the impact on surrounding traffic is reduced. The construction pollution is small, and the noise is small, which meets the requirements of green city construction. In terms of road structure design, the prefabricated module innovatively borrowed from the design characteristics of house building structure, and adopted raft like foundation and beam slab structure mode in the structure, which can better share the load pressure and reduce the impact of uneven settlement of the foundation on the surface layer.

Secondly, in view of the urban waterlogging problem and urban water security problem caused by the rapid expansion of the city, the prefabricated sponge type road base module proposed in this thesis can achieve the purpose of delaying the peak runoff through the filtration, regulation and storage of large particle size gravel. At the same time, multiple drainage holes also realize the function of organized drainage and drainage of roads, so that urban surface runoff can flow to urban municipal drainage pipelines and other relevant urban green drainage and water storage facilities in an organized way after infiltration through the road surface. While improving the road drainage and water storage capacity, it can reduce the impact of surface runoff on the road and the safety around the road, activate the internal regulation and storage capacity of the city, and achieve urban water safety.

Acknowledgement

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