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Research on Common Road Damage Problems in Road Engineering Applications

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Abstract

As a core component of transportation infrastructure, the service status of road engineering has a direct impact on traffic safety and operational efficiency. This paper focuses on the frequent damage problems in road engineering applications. Through literature research and data analysis, it systematically sorts out three major types of common diseases: structural damage, functional damage, and auxiliary facility damage. The research indicates that overloaded traffic, construc-tion quality defects, environmental degradation, and delayed maintenance are the primary factors contributing to these issues. Among them, the incidence of dis-eases such as cracks, ruts, and uneven settlement accounts for more than 80%. For every 5% increase in the proportion of heavy-duty vehicles, the service life of the pavement can be shortened by 12%-18%. Damage problems not only cause annual economic losses of hundreds of billions of yuan but also directly or indirectly induce 17.3% of road traffic accidents. By analyzing the formation mecha-nisms and influence laws of various types of damage, this paper provides theoretical support for optimizing road engineering design, construction control, and the formulation of maintenance strategies, which is of great practical significance for extending road service life and enhancing infrastructure resilience.

Keywords

Road engineering; Road damage; Rutting; Irregular settlement

1. Introduction

With China's total highway mileage exceeding 5.2 million kilometers and the continuous expansion of road network coverage, road damage problems have become increasingly prominent. According to statistics, about 38.6% of the national highway network has varying degrees of disease, and the incidence of diseases on national and provincial highways is as high as 42.7%. Road damage not only reduces driving comfort and safety but also leads to an exponential increase in maintenance costs, forming a vicious circle of "minor diseases turning into major ones and major diseases leading to complete damage". Therefore, systematic research on the types, causes, and impacts of common road engineering damages is of great value for promoting the sustainable development of transportation infrastructure. Based on existing research results, this paper focuses on analyzing the characteristics and formation mechanisms of various damages to provide a reference for the subsequent research and development of prevention and control technologies.

2. Analysis of Common Types and Causes of Road Engineering Damages

2.1. Structural Damage

Structural damage directly threatens the load-bearing capacity of roads and is the main reason for the premature scrapping of roads. It mainly includes cracks, slab fractures, steel corrosion, and other types. As the most common disease, cracks have an incidence rate of over 80% and can be divided into transverse cracks, longitudinal cracks, and reticular cracks according to their morphology. Their formation is mainly due to material shrinkage, temperature stress, and overload. Improper concrete mix ratio or insufficient maintenance can cause early cracks, while repeated rolling of overloaded vehicles will accelerate crack expansion. When trucks with an axle load exceeding 10 tons travel frequently, crack penetration is likely to occur in areas with concentrated pavement stress.

Slab fracture disease is particularly prominent in cement concrete pavements, with corner fractures accounting for the highest proportion. On the one hand, heavy-duty vehicles frequently travel at the same corner position, leading to stress concentration exceeding the design load; on the other hand, loose and hollow base courses will make the slab corners lose effective support, resulting in fracture under the action of vehicle load and the environment. Steel corrosion is mainly caused by electrochemical corrosion when the concrete protective layer is insufficient, or the steel is exposed to a water and oxygen environment after cracking. Concrete carbonation will reduce alkalinity, destroy the steel passivation film, and further accelerate the corrosion process, leading to a decrease in structural bearing capacity.

2.2. Functional Damage

Functional damage affects road service performance and reduces driving comfort and safety, mainly manifested as ruts, potholes, bumping at bridge heads, etc. Ruts have a high incidence rate in asphalt pavements and are divided into three types: instability ruts, structural ruts, and abrasive ruts. The main causes are asphalt softening in high-temperature environments, repeated rolling of vehicles, and unreasonable mix gradation of mixtures. Severe ruts will affect vehicle driving trajectories and increase accident risks.

Potholes are mostly caused by water damage. After rainwater seeps into the pavement base course, dynamic water pressure is formed under the action of vehicle load, leading to loose and falling pavement materials, which is more serious, especially in rainy seasons or snowmelt periods. Bumping at bridge heads originates from uneven settlement of backfill behind abutments, forming a height difference between the bridge abutment and the roadbed, resulting in jolting when vehicles pass. This not only affects comfort but also exerts additional stress on the bridge structure. In addition, frost heave and frost boiling are common in cold regions. Freezing and expansion of subgrade soil lead to pavement heaving, and the bearing capacity of the soil decreases after thawing in spring, forming frost heaving.

2.3. Joint and Edge Damage

As weak links of the pavement structure, joints and edges have a high incidence of damage, mainly including joint damage, edge spalling, etc. Joint damage is manifested as joint filler loss, aging, and joint faulting. The service life of asphalt-based joint fillers is only 3-5 years, and their sealing performance decreases by 60% after aging, which cannot effectively prevent rainwater infiltration and aggravates base course erosion. Frequent braking and starting of vehicles will increase the impact force at the joints by 40%, leading to loosening and displacement of joint fillers and accelerating the damage process.

Edge spalling is mainly caused by construction quality and environmental factors. Insufficient vibration during construction will make the porosity of the edge concrete exceed 5%, and an unreasonable steel arrangement will weaken the structural strength. Under the combined action of external loads, rainwater scouring, and chemical erosion, concrete blocks are prone to falling off. Non-standard installation of curbstones will also aggravate edge damage, resulting in displacement, inclination, and other problems, affecting the overall stability of the road.

3.3. Results and Discussion

3.3.1. Analysis of Core Impacts of Damage Problems

The research results show that road damage problems present significant characteristics of multi-factor superposition. The four factors of traffic load, construction quality, environmental conditions, and maintenance management interact, leading to the diversification and complexity of damage types. Overloaded traffic is the most critical inducing factor. The actual traffic load far exceeds the design standard, making the pavement structure enter the fatigue period in advance. Especially in sections with concentrated trucks, the incidence of damage is more than 30% higher than that in ordinary sections. Construction quality defects provide "innate conditions" for damage. Problems such as insufficient base compaction, unreasonable material mix ratios, and lax process control make the road structure have hidden dangers in the early stage of use.

The aggravating effect of environmental factors on damage cannot be ignored. Extreme weather such as heavy rains, high temperatures, and freeze-thaw cycles accelerates material aging and structural deterioration. The carbonation rate of concrete increases significantly in humid environments, and freeze-thaw cycles will lead to loose and spalling pavement structures. Delayed maintenance management allows early minor damage continue to develop. It is estimated that the cost of timely repairing early cracks is only 1/10 of that of later reconstruction. However, due to the untimely maintenance of most sections, the degree of damage continues to deepen.

3.3.2. Discussion on Prevention and Control Strategies

In view of the formation mechanism and influence laws of road damage, it is necessary to construct a full-life-cycle prevention and control system of "prevention-monitoring-repair". In the design stage, the adaptability of load standards should be improved, the material mix ratio should be optimized, and the damage resistance of the structure should be enhanced; in the construction stage, it is necessary to strictly control the compaction degree, vibration quality, and joint treatment process to reduce quality defects. In terms of maintenance management, a regular monitoring mechanism should be established, and technologies such as closed-loop crack treatment and deep subgrade reinforcement should be adopted to realize timely repair of early damage.

At the same time, it is necessary to comply with the development trends of low carbonization and intelligence, promote new durable materials and advanced construction technologies, such as high-performance joint fillers and intelligent compaction monitoring equipment, to improve project quality. At the policy level, it is necessary to strengthen the management of overloading, improve the quality supervision system, and implement the full-life-cycle responsibility system to reduce damage-inducing factors from the source. Future research can focus on the construction of damage prediction models, realize accurate prediction of damage risks through big data analysis, and promote the transformation of maintenance strategies from passive response to active prevention.

4. Conclusion

This paper systematically studies the common damage problems in road engineering applications, clarifies four major types of damage: structural damage, functional damage, joint and edge damage, and auxiliary facility damage, and reveals the core causes of overloaded traffic, construction defects, environmental erosion, and delayed maintenance. The research confirms that road damage not only seriously affects traffic safety and operational efficiency but also causes huge economic losses. Constructing a full-life-cycle prevention and control system is the key to solving this problem. Through the multi-dimensional coordination of design optimization, construction control, regular maintenance, and policy guarantee, the incidence of damage can be effectively reduced, and the service life of roads can be prolonged. In the future, it is necessary to further strengthen the research and development of damage prediction technologies and new repair materials, improve the durability and resilience of road engineering, and provide support for the high-quality development of transportation infrastructure.

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