Research on Prefabricated Paving Technology for Temporary Roads in Construction Sites

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Abstract: In the construction process of building engineering, temporary roads serve as critical infrastructure for material transportation and machinery access. Their construction quality and efficiency directly impact the overall project timeline and cost. Traditional temporary roads primarily use gravel paving or cast-in-place concrete techniques. Although these methods are mature, they exhibit significant limitations. Addressing issues such as long construction cycles, high resource consumption, and poor reusability associated with traditional cast-in-place techniques, this paper investigates prefabricated paving technology for temporary roads, aiming to enhance its on-site applicability and economic efficiency.

1. Introduction

Temporary roadways are critical to construction site management for material transportation, heavy machinery access and personnel movement. Their construction effectiveness and functional characteristics play a significant role in how project development organization plans are implemented. At present, such temporary roads are mainly laid with gravel or concrete on site. Although these methods are quite mature in application, they expose many practical engineering challenges with respect to adaptability. In recent years, as prefabricated building technology systems have been continuously improved and developed, synergy and optimization of time limit for a project, cost and environmental benefit in the trinity has obtained relatively ideal results. This advance accelerates the paradigm shift from broad to compressed and effective practices in temporary engineering approaches.

2. Fundamentals of Prefabricated Paving Technology for Temporary Roads in Construction Sites

2.1 Core Technical Principles

The core idea of prefabricated temporary road paving technology is to change from the traditional "monolithic pouring or stacking on site" construction method to a new path of "factory-prefabricated standardized components + modular assembly on site". The technical core is about breaking down the structural function of temporary roads into unit components which could be produced, transported, and assembled separately. This form of industrialized production highlights accurate quality control, and on-site low cost rapid assembly finishes apparatus road construction, forming a closed-loop chain of "production-assembly-turnover-reuse".

In terms of structure, the system is largely composed of three main components: precast component layer, connection node layer and base support layer. The precast element layer is the main bearing body of road; hence, material selection and structural design are required based on traffic conditions before precast in factories. Now wrapped around it is the connection node layer, the linchpin to keep the road whole. Multi components can dock in seconds and with stable structure by pre-setting mortise-tenon interfaces,pile holes and other strong joints to avoid crack problems which usually happen on traditional roads due to interruption of pouring work. For the base support layer, the treatment can be more simplified according to local site foundation condition, while eliminating complex multi-layering of subgrade construction especially in traditional method.

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Place graded gravel cushion layers or roadbed boxes (when available) that provide stable support for precast components, reducing complexity in the field.

This technique is an innovation of the established characteristics of temporary roads as "one-off construction and one-off disposal." This not only establishes a technical route for resource recycling by making use of the repeated turnover of precast components. At the same time, it shifts on-site work significantly from the statics processes to factory conditions and thus avoids key drawbacks such as high weather dependency, long operating cycles and low engineering quality concerning traditional temporary road construction. This mirrors completely how strongly the practical needs of temporary engineering are aligned with concepts for industrialized construction [1].

2.2 Technical Characteristics of Prefabricated Temporary Roads

Using the construction logic which is incomparable to temporary road methods, prefabricated temporary roads have more special technical characteristics and thus their advantages in certain construction sites. The efficiency is the biggest advantage of it from a technical point of view. This allows on-site construction to skip data-heavy processes like formwork installation and curing times. Transport on site and quick assembly by means of a crane is possible with prefabricated components, way more efficient and faster than traditional concrete compaction methods. Especially useful in cases where material transport lines need to be set up very early in the projects.

Another of the World Bank core characteristics is economic efficiency. Reusing prefabricated components across different projects reduces costs associated with the cost of buying new materials over and over again as well as the expenses involved in removing construction waste. The optimized construction duration also indirectly lowers expenses concerning project management as well as machinery rentals. Most notably, this technology is also distinguished for being environmentally friendly and flexible. Concrete mixing and excavation on site leads to considerable dust, dirt and noise pollution which prefabrication offsets. The modular assembly method is a flexible approach to dynamic adjustment of the road alignment and width based on dynamic changes in the construction site layout, meeting practical needs for functional adjustments during construction.

3. Key Construction Techniques for Prefabricated Temporary Roads

3.1 Base Treatment Technology

Base treatment is the basis of bearing stability and service life for prefabricated temporary road, and its essential goal is to establish a proper base support system based on site geological conditions and road load-bearing requirements while simplifying the complex processes of traditional base construction. Prior to base treatment, geological surveys of the site are needed, mainly for four parameters: physical and mechanical properties of the foundation soil;bearing capacity; groundwater level. These parameters are used to build specific base treatment plans.

Due to the different foundation conditions, base treatment methods according to a differentiated adjustment. Soft sites with low bearing capacity must be strengthened by a layer of gravel cushion of varying particle sizes at the bottom of each trench, thus increasing the support for the foundations. The materials of the graded gravel cushion shall be controlled strictly according to particle gradation requirements. When laying, layered rolling construction should be adopted, and the compaction thickness and density of each layer must be strictly controlled to ensure that the overall strength of the cushion meets the design requirements. And in the case of soft soil or muck, just putting down a gravel pad probably won't provide the desired bearing effect. Use base support structures made from specialized roadbed boxes. Preliminary site work is required prior to laying the roadbed boxes to prevent uneven stress on them caused by site undulations which could lead to future road surface deformation or damage of precast components.

3.2 Component Assembly and Fixation Technology

Finally, the assembly and fixation technology for components has a direct impact on the structural mechanical performance as well as traffic safety of prefabricated temporary roads. Essentially, the goal is to make connections among precast elements stable using standardized assembly procedures while minimizing the cycle time for on-site assembly processes. Prior to assembly, precast elements must also be visually examined for quality defects (e.g. not cracked or damaged edges with nominal width of the components) surface and checks on dimension deviations must conform to requirements for assembly . This prevents effects of component defects on assembly quality.

Container Assembly Assembly operation should follow the construction flow path of "positioning, docking, and fixation". Control Lines for element placement to maintain positions in the assembly will be drawn on the prepared base, this is done based on the distance planned and width of the design alignment of temporary road. In the case of parts being assembled via a mortise-tenon assembly, this means that the convex and concave interfaces are faced towards one another seamlessly. If necessary, mechanical assist equipment can be used to get components into position where fastening is desired; this would ensure tight interface contact with minimized gaps. When it comes to sealing materials for assembly gaps, the solution is simple: only specialized filling 4 should be used, as rainwater infiltration can lead to foundation softening. For components that fix with bolts, very accurate alignment must be done based on predetermined locations of the holes in the component for bolt fastening. Tightening torque must be controlled to ensure firm connections in micromechanics, especially during bolt installation. Also, the unpainted part of bolt native anti-rust handling, in order to cause rusting at high humidity environment caused by disassembly and connection strength affects the quality.

3.3 On-Site Construction Organization and Management

To ensure the effectiveness and quality of prefabricated temporary construction road construction, it is necessary to be organized and managed on-site. It can go on and on and no reason to throw the baby out with the bathwater. A specialized construction plan should be prepared prior to the commencement of construction, clarifying the construction flow path, personnel division of labor, equipment configuration and key points for quality and safety control. Organize the technical briefings for construction personnel to be fully masters of the operational standard requirements and basic conditions when implementing key processes: Component hoisting, Component assembly [2].

Transportation and storage of components calls for dedicated attention. Use special fixing devices when the components are carried on-site to prevent shaking and collision of components, avoid damage to edges and corners. On-flat storage must be organized as per progressive development of construction and nature at which components can be made use of. A storage area should always be even and hard and cushioning layer have while stacking the component with layers to avoid deformation under pressure. More over it is also necessary that rain and moisture be prevented so as to not cause quality issues owing to the environmental factors.

A real-time quality control must also be set during construction, with staff monitoring important parameters such as the precision of Assembly, strength of fixation and leveling of the base. Issues should be rectified promptly. Performance of safety protection must also pay attention to: when hoisting operations in construction warn area shall be set up, to ensure that unauthorized personnel and vehicles can not enter the hoisting operation site;Hoisting equipped with operating tools must be implemented according to the regular use specifications for testing and inspection, so as not to cause accidents such as equipment tipping or components dropping. It is recommended that after the construction is completed, phased acceptance be carried out to determine whether the quality of road paving meets the design requirements before being opened for use in order to ensure that material transport and mechanical access with access directed towards carrying out future project construction work [3].

4. Optimization Paths for Prefabricated Paving Technology of Temporary Roads in Construction Sites

4.1 Material Performance Innovation and Lightweight Optimization of Precast Components

Precast components are the key load-bearing units of prefabricated temporary roads, so good material performance directly determines the load bearing capacity, service life and construction convenience of the road. Boil down to three core goals of "high strength, lightweight, and durability", material innovation should advance. The need to overcome the restrictions of traditional materials is urgent, and it is essential to study the use of new composite building materials. For instance, the use of high-performance fibers can improve crack and impact resistance while using less cement to lower component weight. In relatively light traffic situations, it is possible to create lighter polymer composite resources that reduce excess weight relative to standard polymer composites, decreasing devices stress while in transport and hoisting although still passing standards as well.

Material optimization should also take into full consideration the need for ecological adaptation. The new type of precast components is designed for extreme climatic areas, such as rainy or cold regions, with materials having properties such as anti-seepage and anti-freeze properties. This can involve alteration of material mix ratios or, in some cases, a coating applied to component surfaces such that the longevity under harsh climates is improved through minimizing performance nosedive and damage effects caused by climate factors. Construction requirements should also be matched with the material required to be used. Target material formulas can be targeted, customized according to certain needs (traffic load levels and service life of roads) to avoid unnecessary "over-design" at the same time ensuring that the performance of materials is accurately matched with these on-site construction environmental conditions in achieving the goal of "material selection by demandoptimal performance".

4.2 Integration of Intelligent Technology in the Entire Construction Process and Efficiency Improvement

Integration of intelligent technology is an important way to break the bottleneck in prefabricated temporary road construction and improve the control accuracy during the whole process. It will need to traverse the full design, production, construction, and maintenance cycle. At the design level, you can introduce BIM technology in creating a 3D model to digitally design dimensions of each component and forms of interfaces. The Early detection of conflicts and optimization of components layout and assembly schemes will lead to fewer need for further adjustment on-site through simulation before actual pre-assembly. During the production period when a project hits mass production, automated production lines can be used, where CNC equipment and technology is used to standardization of pour, mold, and cure processes. Real-time data collection of production can form a quality traceability system, so that the component quality is stable and controllable.

Intelligent Optimization During the Construction Phase: Involves Operational Efficiency Improvement and Quality Control Smart monitoring devices can be used in conjunction with IoT technology to capture key indicators like the base levelness and assembly gaps in real time. Dynamic quality alerts Data can be dynamically transmitted in a synchronous manner to a management platform. Through the integration of unmanned hoisting equipment and on-site positioning technology, components can be accurately hoisted for assembly to minimize manual error and improve construction efficiency. Online, a digital construction management platform can be created to aggregate resource information regarding personnel, equipment, and components so that you can see visually how the project is coming together with what resources available. This optimizes process link-up, thus foreclosing time limit for project delays caused by disconnect between production processes.

4.3 Improvement of Technical Standard System and Expansion of Adaptability

At this stage, prefabricated temporary road technology still has problems such as uneven technical standards and poor scenario adaptability in application. This requires the establishment of a sound technical standard system and scenario adaptability, promoting the upgrading of this technology as a whole. First, technical standards on the whole links of the "component design, construction process, quality acceptance, and recycling" should be formulated. It is also important to define key technical indicators such as dimensional tolerances of production components, assembly accuracy testing and bearing capacity to support precast elements, so as to avoid different construction standards chaos leads to uneven quality."

Simultaneously, differentiated technical application guidelines should be developed for scenarios with different foundation conditions and traffic needs. Specialized technical requirements such as component selection, base treatment schemes, and assembly methods should be specified to enhance the technology's adaptability to complex construction scenarios [4].

The standard system should also add environmental and resource recycling requirements. Similarly, technical specifications relevant to the recycling, repair and reuse of components should also be formulated, including standards for quality evaluation of component turnover use and establishing a component recycling process. It encourages the change of temporary road for "one-time use" to "circular turnover." Also, the ties to standards (as well as standard methodologies) and how they connect with engineering in practice needs improving. Industry collaboration mechanisms enable collection of application feedback on projects and regular updates to standard content, ensuring the standards not only guide technological development but also comprehensively address the pain points of on-site construction so that technical standards and engineering practice adapt dynamically.

5. Conclusion

In short, the three optimization paths of material performance innovation, integration of intelligent construction technology and improvement of standard system put forward in this paper are not separate but assemble into a organic whole, which can support and collaborate synergy. They can overcome limits of prefabricated temporary roads on load-bearing, construction efficiency, and scenario fitness. In the future, with more breakthroughs in new building material technologies, more widespread use of intelligent construction equipment, and continuous improvement of industrial standards, prefabricated temporary road technology can help create value for more construction projects to provide new impetus for high-quality development of the construction industry.

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