Key Technology Research into Foam Concrete Lightweight Embankment with Cast-in-Situ Baffle instead of Conical Slope at Bridge-head

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**Keywords:** Without conical slope at bridge-head, Cast-in-situ baffle, Lightweight embankment.

**Abstract.** According to the features of foam concrete of low density, small load on foundation after filling to greatly reduce ground treatment intensity and no need for dynamic compaction or rolling after pouring so that pavement structure layer can be directly laid, in this paper, a construction method was, with inside step-slope on embankment, cast-in-situ concrete baffle structure on the outside of embankment and foam concrete to fill bridgehead subgrade, explored to solve the problem of earth pressure and conical slope setting at abutment as well as optimize abutment to be the structure without conical slope, so as to reduce the span which may be enlarged due to conical slope and greatly cut project cost. At the same time, using this method, settlement and uneven settlement decreased and post-construction settlement of abutment filling was eliminated so as to avoid bumping at bridge-head and reduce maintenance cost.

**Preface**

In present construction, in order to prevent and control bumping at bridge-head [1], plastic drainage plate, surcharge preloading and low strength concrete pile are usually adopted [2]. From high-grade roads being completed and delivered for use, especially highways, operation conditions are not ideal with many problems in roadbed-bridge transition section, among which, pavement subsidence or fracture at abutment with backfill are more common [3] to cause bumping while vehicles pass through abutment. Fast vehicles will jog, vibrate and make noise due to bumping at bridge-head which also results in partial loss of traction of wheels or even uncontrollable and slipped body driving on snow-covered and icy bridge to not only affect speed and comfort of vehicles, but damage bridge abutment back, bridge expansion joint and joint pavement, or seriously cause traffic accidents.

Lightweight embankment could, for its small weight, reduce post-construction settlement. It could also be used as filler to reduce space demand and save the costs [4]. So lightweight embankment filling technology [5] is widely used in subgrade construction. And foam concrete with low density as well as higher compressive strength, tensile strength and shear strength than compact soil [6-8] has vast application prospect on the embankment on soft soil foundation [9-12]. In order to protect the stability of bridgehead embankment, designers often arrange conical slope at bridge-head [13]. Bridgehead conical slope occupies large area, is not conducive to sustainable development and encroaches on the space under bridge.

In view of this, it is a problem for urgent solution to adopt some technical measures to not only maintain higher strength and stability of embankment structure without conical slope at bridge-head [14, 15], but conform to the requirements of green construction.

**Process Principle and Features**

According to the features of foam concrete of low density, small load on foundation after filling to greatly reduce ground treatment intensity and no need for dynamic compaction or rolling after pouring so that pavement structure layer can be directly laid, in this research, foam concrete was
used to fill bridgehead subgrade to solve the problem of earth pressure and conical slope setting at abutment as well as optimize abutment to be the structure without conical slope, so as to reduce the span which may be enlarged due to conical slope and greatly cut project cost. At the same time, it was realized to decrease settlement and uneven settlement, eliminate post-construction settlement of abutment filling, avoid bumping at bridge-head and reduce maintenance cost. Two layers of lime-stabilized soil for water-resisting and high plastic surrounding soil at the back of abutment effectively prevented rain infiltration and maintained roadbed stability to inhibit bumping at bridge-head due to rain erosion. Field mechanized pumping and pouring as well as rapid construction method were adopted to cast foam concrete by layer. According to casting process, layered supporting for internal formwork was placed along construction joint. After foam concrete reached initial strength, a formwork with the height of next layer pouring was set and then next layer of foam concrete was poured. During initial setting time after bridgehead was poured on one side, it was immediately poured on the other side to shorten construction period. After all pouring followed by timely sprinkling maintenance, the construction was completed.

During construction, cement mixed piles were used to reinforce foundation and cast-in-situ columns were arranged at the outside of cast-in-situ baffle and fixed to guide plate of the formwork of cast-in-situ baffle through screw sleeves reserved while columns were poured. Strip baffle foundation was then constructed with opening in its middle, at the same time, baffle connection reinforcement and connector were embedded. Baffle foundation and mold fixed plate were welded and fixed to the connector. While the formwork of cast-in-situ baffle was erected, it was, at its bottom, connected to mold fixed plate through screw as well as mold guide fixed plate was connected to embedded screw sleeves through template strut. Split bolt penetrated two side formworks and was fixed with fastening nut. Concrete was poured after formwork installation. Side formworks, template strut and split bolt were removed after cast-in-situ concrete baffle reached anticipated strength. Before foam concrete was poured, two layers of reinforced fabric were arranged at upper and lower of pouring position and were connected through vertical erection bar to guarantee the integrity of subgrade filling area.

![Figure 1. Structure of foam concrete lightweight embankment with cast-in-situ baffle instead of conical slope at bridge-head.](image-url)
Construction Process and Key Points for Quality Control

Construction Process

(1) Foundation reinforcement: cement mixed piles were used to reinforce foundation. Cement mixed piles were distributed at treatment section, transition section and 1/4 length of joint section;

(2) Installation of embedded parts: embedded screw sleeves were buried before column concrete was poured and mold guide fixed plate was welded on side formwork;

(3) Reinforcement layer construction: pavement base was first paved, and then composite geotextiles and grids;

(4) Baffle foundation construction: prefabricated strip foundation was used as baffle foundation, with opening in its middle. In the process of fabrication, baffle connection reinforcement and connector were first embedded. The connector was then, at its upper, welded with mold fixed plate;

(5) Baffle construction: the formwork of cast-in-situ concrete baffle was first erected. Side formwork was, at its bottom, placed in the slot formed by two mold fixed plates and mounted with mold fixed screw. Mold guide fixed plate was connected to embedded screw sleeves through template strut. Split bolt penetrated two side formworks and was fixed with fastening nut. After formwork was installed, concrete was poured. Side formworks, template strut and split bolt were removed after cast-in-situ concrete baffle reached anticipated strength;

(6) Steel fabric laying: at treatment section, vertical connection reinforcement was first installed, and then lower reinforced fabric, lateral connection reinforcement and upper steel fabric. Lower reinforced fabric, vertical erection bar, lateral connection reinforcement and upper steel fabric were installed in turn at transition section and joint section;

(7) Foam concrete filling: foam concrete was cast according to the order of treatment section, transition section and joint section;

(8) Permeable layer construction: rubble material was laid as permeable layer;

(9) Pavement construction: concrete was used for pavement base and upper material complied with design requirements.

Specific construction technology is shown in the figure below:
Key points for Quality Control

**Quality Control of Raw Materials.** Raw materials will directly affect the quality of bubble mixed light fill, so the quality of cement, blowing agent, water and additive in foam concrete were strictly controlled.

1. **Water**
   Water for general engineering can be used and should comply with relevant national standards of water for ordinary cement concrete. Water with refuse or oil was forbidden to avoid undesirable impact on strength and endurance of bubble mixed light soil.

2. **Blowing agent**
   Blowing agent technology is key for foam concrete to ensure light weight and liquidity of bubble mixed light soil. During construction, blowing agent was uniformly distributed in bubble mixed light soil. Pollution-free blowing agent was used with necessary certificate of inspection, performance report and product instructions.

3. **Cement**
   Cement with necessary quality certificates and test data was stacked at the site according to different manufacturers, batches and varieties. Cement beyond expiry date or lumped because of humidity was strictly prohibited for use. Approach acceptance of cement was carried out for variety, grade, packaging or warehouse number of cement in bulk and production date. The strength and other essential performance indicators were re-inspected to ensure the quality to comply with current national standards.

4. **Admixtures**
All admixtures conformed to the requirements in national standard of "Concrete Admixtures". Water content ratio and fine particle composition of sandy soil will influence the quality of foam concrete. Specific proportion was determined in construction based on tests and according to relevant provisions to adjust rate or change material.

Table 1. Measurement precision of material.

<table>
<thead>
<tr>
<th>Number</th>
<th>Material</th>
<th>Measurement precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aggregate and admixture</td>
<td>±2%</td>
</tr>
<tr>
<td>2</td>
<td>Cement and additive</td>
<td>±2%</td>
</tr>
<tr>
<td>3</td>
<td>Water</td>
<td>±2%</td>
</tr>
<tr>
<td>4</td>
<td>Blowing agent</td>
<td>±5%</td>
</tr>
</tbody>
</table>

Technical Requirements for Foam Concrete Filling Body.

(1) Steel wire mesh was arranged 80cm below top surface, with lap length of 10cm.
(2) A transverse construction joint was set every 10m for longitudinal foam concrete. Three longitudinal construction joints were arranged at center position between center line of roadbed and half cross section. Other filling requirements are showed in following table:

Table 2. Technical requirements for foam concrete filling body.

<table>
<thead>
<tr>
<th>Number</th>
<th>Item</th>
<th>Position within 80cm under depressed trough</th>
<th>Other areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>wet unit weight of foam concrete slurry</td>
<td>≤7.5kN/m³</td>
<td>≤6.5kN/m³</td>
</tr>
<tr>
<td>2</td>
<td>unconfined compressive strength of 28 days</td>
<td>≥0.8MPa</td>
<td>≥0.6MPa</td>
</tr>
<tr>
<td>3</td>
<td>porosity</td>
<td>60%</td>
<td>65%</td>
</tr>
</tbody>
</table>

Maintenance for Foam Concrete

After the top of foam concrete was poured to design elevation, impervious geo-membrane was laid in time. Or plastic film could be used for coverage for moisture retention of foam concrete bridgehead subgrade. The following points for maintenance should be paid attention to:

(1) After pouring and initial setting, foam concrete should be covered and maintained by spraying water in time to prevent too fast moisture loss and shrinkage crack.
(2) Foam concrete could not be disturbed before final setting. The next layer of pouring could be carried out only after the last layer of concrete is finally set.
(3) After foam concrete is poured to design elevation, its surface should be covered with plastic film or geo-membrane for maintenance for not less than three days.
(4) Mechanical equipment could not directly touch the surface of foam concrete unless there is protective layer.

Analysis for Technical and Economic Benefits

Foam concrete is lightweight material, with small load on foundation after filling to greatly reduce ground treatment intensity and shorten ground treatment period. Foam concrete has, for simple construction, fast filling, short time limit, low density, high strength, compact filling, little post-construction settlement and less maintenance after construction, vast application advantage in process method to connect main bridge to approach. Foam concrete is produced and pumped with special equipment. Its work surface is small and its construction will neither occupy other construction equipment nor affect the construction in other sections. Less influence by the weather, satisfactory self-compacting ability and fast construction speed guarantee the period; For little load...
of filling body on foundation and no settlement after filling, the construction of pavement structure layer could be carried on 24 hours after filling; This technology, with little late settlement, could both prevent and control bumping at bridge-head to effectively reduce maintenance fees, lower comprehensive cost and finally obtain better quality effect and economic benefit. Great importance should be attached to the quality during construction. Foam concrete could, because of self-supporting after solidification, low elastic resistance, adjustable strength and durability, be used to solve the problem of vehicle bumping and, without conical slope, to enlarge the space under bridge. It has excellent technical and economic benefits.

Compared with common construction plan with conical slope pair and foam concrete exchange filling only behind abutment, increase or decrease in quantities and costs for bridgehead roadbed with vertical baffle foam concrete instead of conical slope is listed as follows:

In both construction plans, the foundation is treated and preloaded for several months, and then foam concrete is backfilled after back excavation. The difference only lies in the existence of conical slope at bridge-head (including abutment). In the plan of vertical baffle without conical slope, preloading embankment within about 10 meters behind abutment is excavated, surrounded by baffle and filled with foam concrete lightweight material. Conventional back fill excavation is adopted for other areas which adjoin the region, with conical slope at connecting site. There is no conical slope at abutment and conical slope behind abutment is also moved backwards to posterior end of vertical foam concrete wall. In common construction plan, conical slope is arranged at abutment to require a longer span. Without conical slope, the length of span could be shortened or a span could be spared, with increased plastic drainage plate processing for normal segments, to save a lot of construction fund. By the calculation, this plan to shorten bridge length has remarkable economic benefit, with RMB 1 million saved for each bridge.
Table 3. Economic comparison between different plans (main quantities).

<table>
<thead>
<tr>
<th>Item for comparison</th>
<th>(1)</th>
<th>(2)</th>
<th>(2)-(1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam concrete vertical wall without conical slope</td>
<td>253.9</td>
<td>380.0</td>
<td>9.6</td>
</tr>
<tr>
<td>increased C25 concrete (m³)</td>
<td>73.9</td>
<td>575.0</td>
<td>4.3</td>
</tr>
<tr>
<td>HRB400 increased HRB400 (Kg)</td>
<td>3149.0</td>
<td>5.7</td>
<td>1.8</td>
</tr>
<tr>
<td>HRB300 increased HRB300 (Kg)</td>
<td>447.8</td>
<td>5.8</td>
<td>0.3</td>
</tr>
<tr>
<td>increased angle bar (Kg)</td>
<td>1331.9</td>
<td>7.7</td>
<td>1.0</td>
</tr>
<tr>
<td>increased bridge area (m²)</td>
<td></td>
<td>236.3</td>
<td>106</td>
</tr>
<tr>
<td>Reduced soft foundation treatment for normal segment</td>
<td></td>
<td>4500</td>
<td>539</td>
</tr>
<tr>
<td>plastic plate (m)</td>
<td></td>
<td>-12690.0</td>
<td>-4</td>
</tr>
<tr>
<td>gravel cushion layer (m³)</td>
<td></td>
<td>-246.0</td>
<td>-2</td>
</tr>
<tr>
<td>geotechnical material (m²)</td>
<td></td>
<td>-984.0</td>
<td>-2</td>
</tr>
<tr>
<td>road earthwork (m³)</td>
<td></td>
<td>-1178</td>
<td>-9</td>
</tr>
<tr>
<td>foam concrete exchange filling (m³)</td>
<td></td>
<td>-424</td>
<td>-16</td>
</tr>
<tr>
<td>surcharge preloading (m³)</td>
<td></td>
<td>-543</td>
<td>-4</td>
</tr>
<tr>
<td>Total</td>
<td>17.0</td>
<td>68.2</td>
<td>51</td>
</tr>
</tbody>
</table>
Conclusions

In this paper, key technology for foam concrete lightweight embankment with cast-in-situ baffle instead of conical slope at bridge-head was studied. Main conclusions are as follows:

(1) Construction method for foam concrete lightweight embankment with cast-in-situ baffle instead of conical slope at bridge-head could greatly reduce filling load and additional stress of soft foundation, inhibit settlement and lateral displacement of soft soil foundation as well as improve the stability of embankment.

(2) Using this construction method, sudden change of material stiffness at combining site of abutment and embankment could be reduced.

(3) Compression settlement of filler is eliminated. Its construction is convenient and needs less space and small work surface.

(4) Foam concrete used for embankment section filling could, with small load on foundation after filling greatly reduce ground treatment intensity. For self-supporting of foam concrete and its little effect of pushing and pulling on abutment structure, conical slope at abutment is not required so as to enlarge the space under bridge and reduce the length of bridge.

Acknowledgement

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References


