Key Technology Research into Foam Concrete Lightweight Embankment with Prefabricated Baffle Instead of Conical Slope at Bridge-Head

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Abstract. In order to solve the problems of bridgehead diseases and reduced space under bridge due to conical slope at bridge-head, in this paper, a construction method was explored to utilize inside step-slope on embankment, prefabricated baffle structure on the outside of embankment and foam concrete, with self-supporting after solidification, low elastic resistance, adjustable strength and durability, to prevent vehicle bumping and, without conical slope, to enlarge the space under bridge. It has excellent technical and economic benefits.

Preface

There is differential settlement between embankment and structure of highway bridge and culvert structure built on soft soil foundation so as to easily cause road diseases, such as vehicle bumping, structure damage and subgrade instability [1-2]. For design and construction of bridge structure in coastal marine sediment plains, bridges could often not be normally installed due to abutment slipping and forward-tilting caused by the pressure of filling at back abutment [3-5]. While embedded abutment, pile abutment and column abutment or abutment layout could not absolutely retain soil, in order to protect the stability of bridge embankment and prevent erosion, designers usually arrange conical slope at bridge-head [6]. For high-filled soil sections, to guarantee the stability of roadbed, conical slope at bridge-head is generally arranged by stage to not only occupy more highway construction land [7], but also, to avoid excessive use for available space under bridge, make bridge longer significantly to cause increase in engineering investment and waste of land resources.

Theoretically, there are two methods to realize "rigid-flexibility transition" [8] for abutment backfill: variable stiffness material used in the range of abutment backfill, with the stiffness to gradually change from subgrade soil stiffness to abutment wall stiffness [9], which in fact is unlikely; or certain material with the stiffness between subgrade soil and abutment wall material and with the thickness which changes along length direction, that is to say, abutment refilling with small thickness in far distance and large thickness in near distance, so as to achieve "rigid-flexibility transition" for abutment backfill [10].

Therefore, in order to solve the problems of bridgehead diseases and reduced space under bridge due to conical slope at bridge-head [11], in this paper, foam concrete, for self-supporting after solidification, low elastic resistance, adjustable strength and durability, was studied to prevent vehicle bumping and, without conical slope, to enlarge the space under bridge. It has excellent technical and economic benefits.

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.

Baffles were arranged at both ends of embankment during construction. Perforated prefabricated baffle with penetrating connection holes being uniformly distributed at its lower was used as baffle and was concave-convex spliced by several convex prefabricated plates. There was groove at the top of baffle to place integrated connection plate. Groove was prepared while baffle foundation was poured, with a fixed end of anchor cable recessed at its bottom. Baffle and baffle foundation were penetrated and connected through penetrating connection rod. Reinforced subgrade body was constructed in the soil and reinforcement layer was constructed at the bottom of filling conical slope. Capping beam was arranged at subgrade end. In the outside of baffle, a column was built, with embedded nuts for equal interval to be attached to column strut which was connected to perforated prefabricated baffle through guide bar; Perforated prefabricated baffle was equipped with baffle foundation at its end and penetrating connection holes uniformly distributed at its lower. On the side near to foam concrete, embedded plate transverse holes and embedded connection rings were arranged alternately. Before foam concrete was poured, two layers of reinforced fabric were placed at upper and lower of pouring position and were connected through vertical erection bar to guarantee the integrity of subgrade filling area.
Construction Process and Key Points for Quality Control

Construction Process

1. Embankment filling: for the construction of reinforced cushion and according to design elevation, native soil was used to fill embankment and compacted.

2. Excavation of ladder groove: according to design drawings, treatment section, transition section and joint section were respectively grooved for foam concrete.

3. Baffle foundation pouring: filling soil was excavated to be soil mould. An embedded terminal was arranged for connection rod and then baffle foundation was poured according to design requirements. Baffle connection groove was set while pouring, with a fixed end of anchor cable recessed at its bottom.

4. Lifting of perforated prefabricated baffle: to lift perforated prefabricated baffle, an anchor cable was, with one end to be mounted to fixed end recessed at baffle foundation and another end to pass through penetrating hole of anchor on perforated prefabricated baffle, tightened to place the bottom of perforated prefabricated baffle in baffle connection groove and fix it at baffle foundation through penetrating connection rod and straight thread sleeve. Void was filled with post-pouring self-compacting concrete.

5. Connection of prefabricated baffle and capping beam: column strut was, at its one end, connected to embedded nut 3 and to guide bar on perforated prefabricated baffle at another end.

6. Inside fixation for prefabricated baffle: lateral tie bar was placed into embedded plate transverse hole. Tie bar in the outside of embedded plate transverse hole was, at the end, welded to end plate of lateral tie bar. Fixed nuts were arranged in the inside near embedded plate transverse hole. Its other end was welded to vertical connection reinforcement; V-shaped connecting piece was set at embedded connection ring. V-shaped angle was equipped with angle bar in the inside and welded to vertical connection reinforcement in the outside.

7. Assembly for perforated prefabricated baffle: prefabricated baffles were spliced through
concave-convex connection by integrated connection plate in groove at the top of baffle to be whole.

8. Steel fabric laying: lower reinforced fabric was installed, to which, vertical erection bar was bound, and then lateral erection bar was laid with upper steel fabric at its top. Specific construction process is shown as follows:

- measurement paying
- Fabrication of perforated prefabricated baffle
  - reinforcing cage assembling
  - embankment filling
  - arrangement for embedded nuts
  - embankment compaction
  - formwork erecting
  - excavation of ladder groove of foam concrete
  - concrete pouring
  - baffle foundation construction
  - lifting of perforated prefabricated baffle
  - connection of perforated prefabricated baffle and baffle foundation
  - connection of perforated prefabricated baffle and column
  - connection of perforated prefabricated baffle and vertical connection reinforcement
  - lower reinforced fabric laying
    - arrangement for vertical tie bar
    - arrangement for lateral tie bar
    - upper steel fabric laying
      - foam concrete pouring
      - pavement structure construction

Figure 2. Construction process of foam concrete lightweight embankment with prefabricated baffle instead of conical slope at bridge-head.

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.

| Number | Material          | Measurement precision |
|--------|-------------------|-----------------------|
| 1      | Aggregate and admixture | ±2%                  |
| 2      | Cement and additive | ±2%                  |
| 3      | Water             | ±2%                  |
| 4      | Blowing agent     | ±5%                  |

Table 1. Measurement precision of material.

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:

| Number | Item                              | Position                      | Within 80cm under depressed trough | Other areas |
|--------|-----------------------------------|-------------------------------|------------------------------------|-------------|
| 1      | wet unit weight of foam concrete slurry | ≤7.5kN/m³                    |                                    | ≥6.5kN/m³   |
| 2      | unconfined compressive strength of 28 days | ≥0.8MPa                      |                                    | ≥0.6MPa     |
| 3      | porosity                         | 60%                           |                                    | 65%         |

Table 2. Technical requirements for foam concrete filling body.

Conclusions
In this paper, key technology for foam concrete lightweight embankment with prefabricated baffle instead of conical slope at bridge-head was studied. Main conclusions are as follows:
1. Construction method for foam concrete lightweight embankment with prefabricated baffle instead of conical slope at bridge-head may lower filling load greatly 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.
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