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DRAWINGS

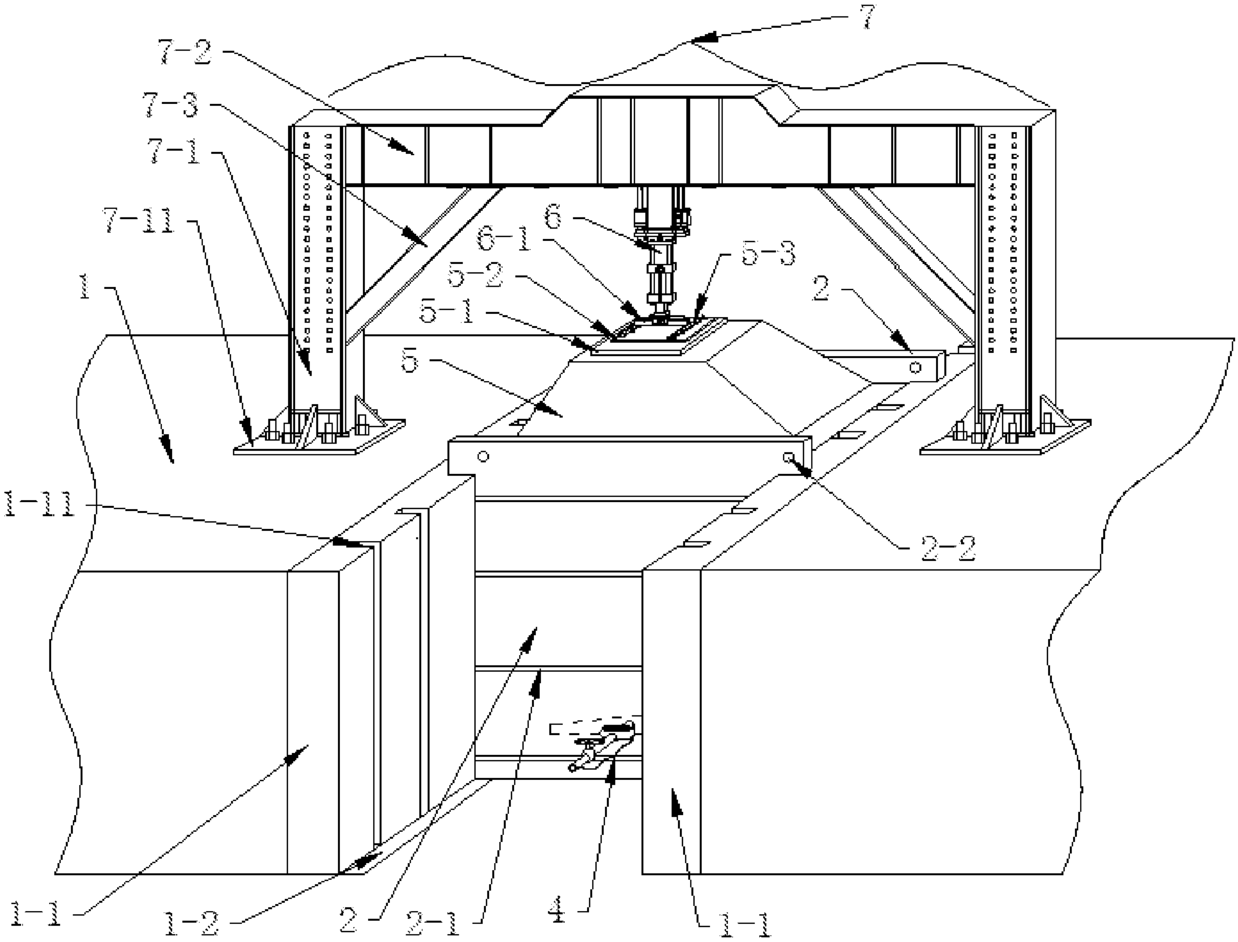

FIG. 1

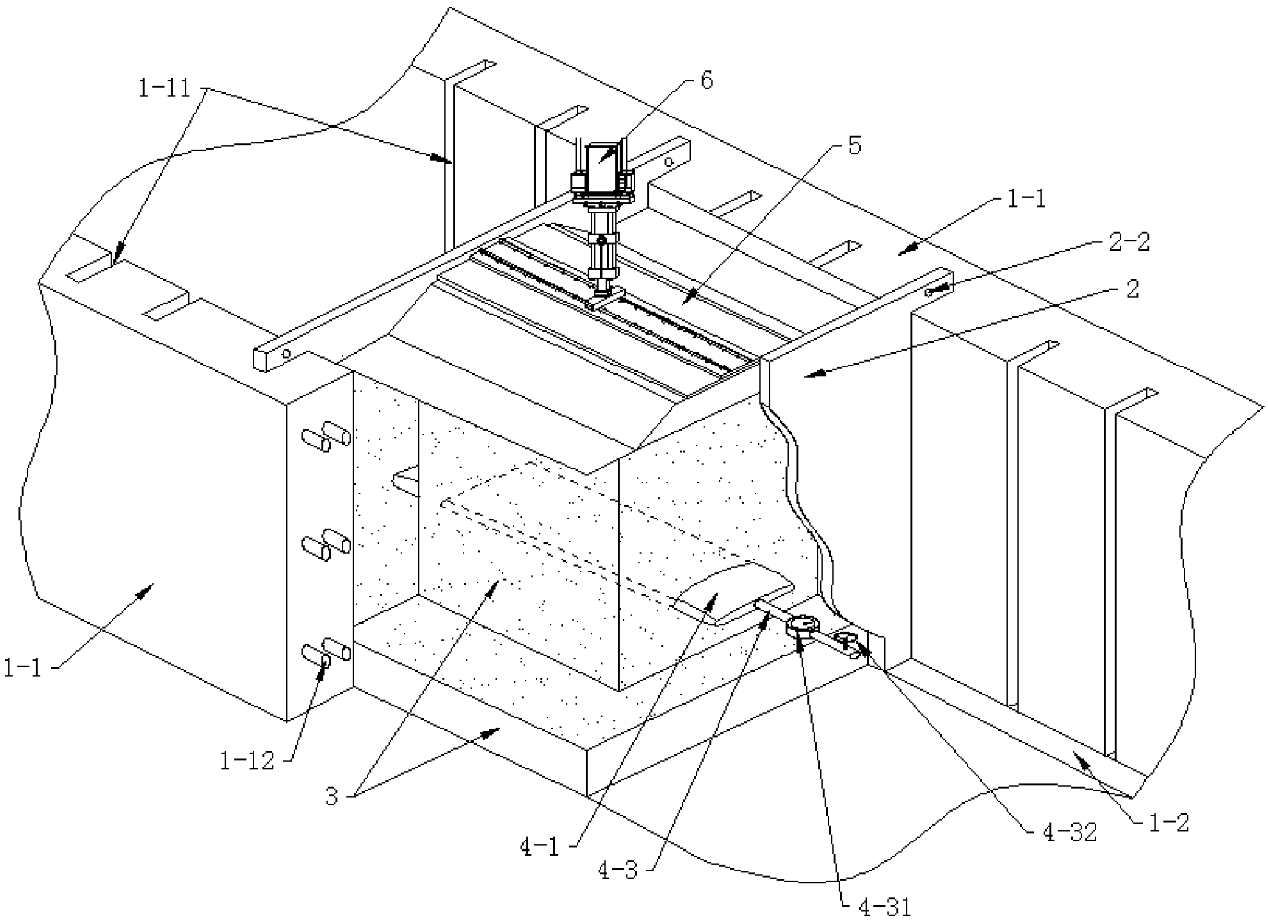

FIG. 2

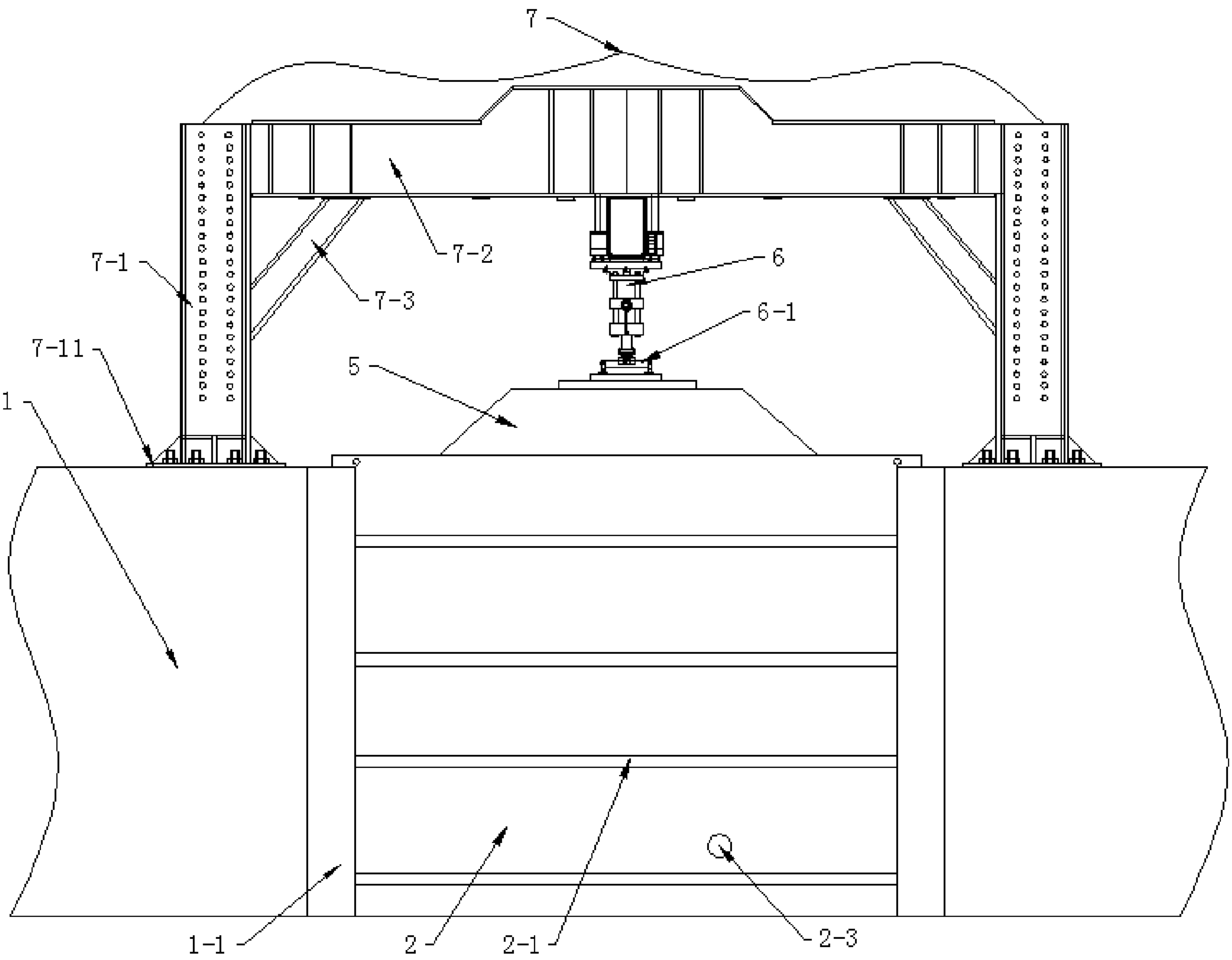

FIG. 3

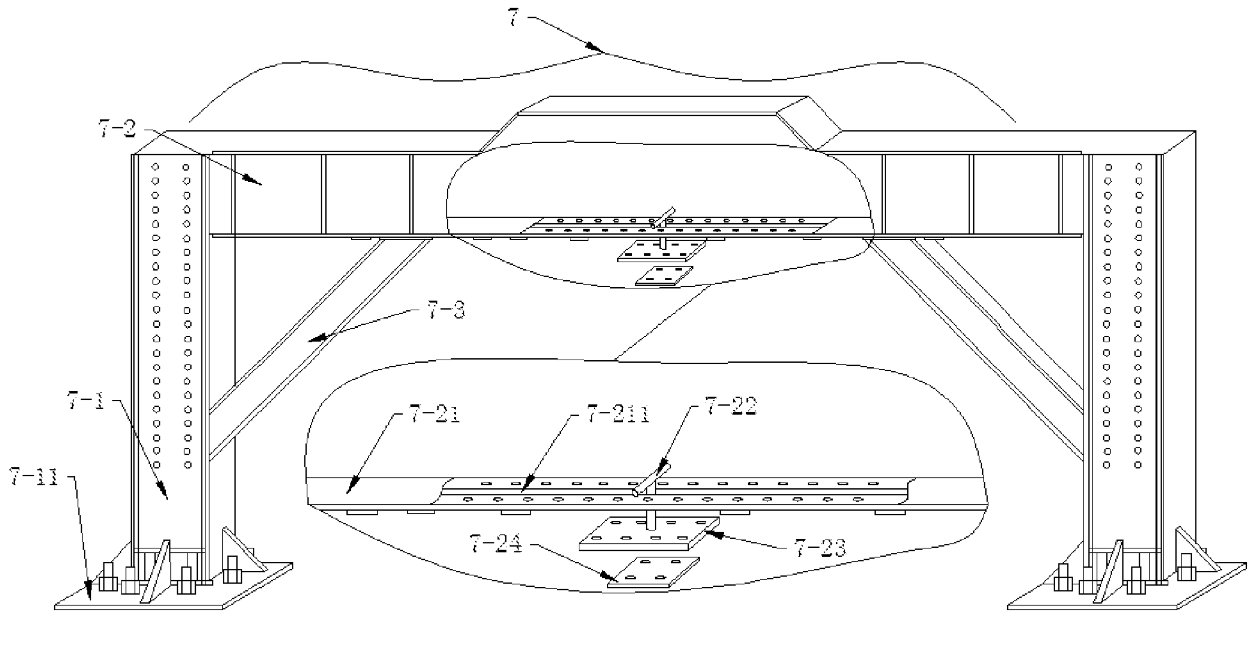

FIG. 4

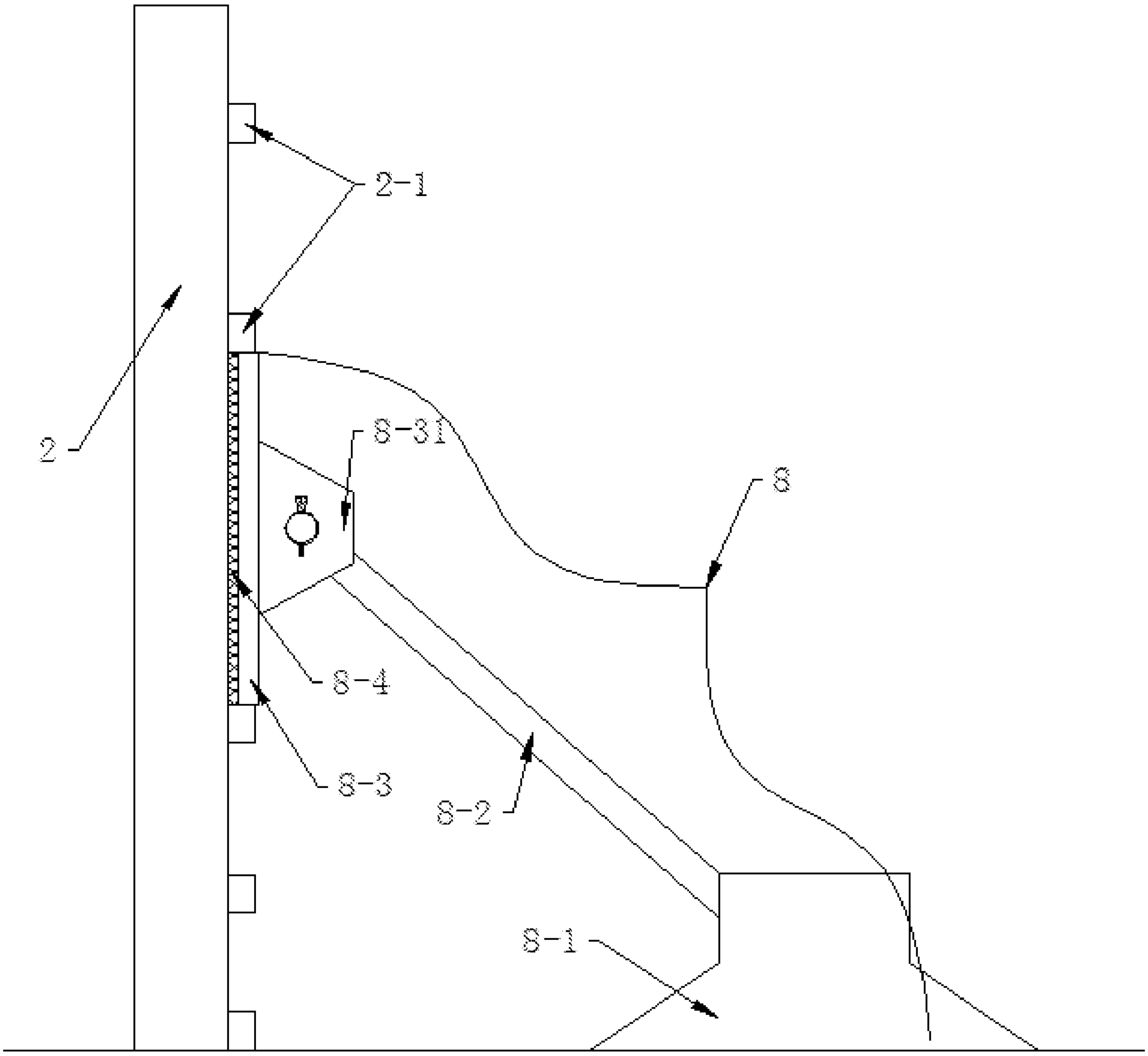

FIG. 5

FIG. 6

PSEUDO-DYNAMIC LOADING MODEL TEST APPARATUS AND METHOD FOR HIGH-SPEED RAILWAY FOUNDATION IN MINED-OUT AREA

TECHNICAL FIELD

The disclosure relates to the technical field of large-scale model tests on subgrades overlying mined-out areas, and in particular, to a pseudo-dynamic loading model test apparatus and method for a high-speed railway foundation in a mined-out area.

BACKGROUND

With the rapid development of China's high-speed railways, various technical problems have arisen on laying of high-speed railway lines, including on foundations in mined-out areas. Therefore, there is an urgent need for a great number of research achievements to support practical projects. However, in research on related issues such as construction of a high-speed railway on a foundation in a mined-out area, a large number of model tests, in addition to field tests, are also required, thereby obtaining reliable comprehensive test data to support practical projects.

Invention patent No. CN101787716A provides a model test apparatus for studying dynamic response and long-term subsidence rules of a high-speed railway. The apparatus can only test vibration displacements, velocities and accelerations of a subgrade and a shallow foundation under cyclic dynamic loads of high-speed trains without consideration of cumulative deformation of a deeper foundation in a mined-out area under cyclic dynamic loads. Utility model patent No. CN204405654U provides an apparatus for simulating mining in a mined-out area, which achieves the purpose of simulating mining in a mined-out area by discharging sand with a hollow pipe inserted into a rubber pipe full of sand. In this apparatus, the rubber pipe is full of sand and laid horizontally, and the sand is unlikely to move under dead load of the overlying soil. Besides, the operation is difficult and steps are unclear with poor test effect. The apparatus can only simulate a shallow mined-out area and cannot simulate the effects of cyclic dynamic loads of high-speed trains on a foundation in a mined-out area.

SUMMARY

To solve the above technical problems, the disclosure provides a pseudo-dynamic loading model test apparatus and method for a high-speed railway foundation in a mined-out area.

The technical solution of the disclosure is as follows: A pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area, including a test platform, where the test platform has a model tank; two sides of the model tank are formed by wall slabs; one side of the wall slab abuts against the test platform, and a plurality of clamping grooves distributed uniformly and horizontally are formed vertically on the other side of the wall slab; a tetragonal test rock and soil mass is placed in the model tank; a mined-out area simulation assembly is disposed within the test rock and soil mass; the mined-out area simulation assembly includes a water storage bag located within the test rock and soil mass; a water inlet pipe penetrating through a baffle on one side is disposed at one end of the water storage bag, and a water outlet pipe penetrating through a baffle on the other side is disposed at the other end of the bag; a flowmeter and a valve are mounted on the water outlet pipe; the baffles inserted into the clamping grooves are arranged on two sides of the test rock and soil mass; a loading base of a truncated-pyramid-shaped structure is disposed over the test rock and soil mass; a loading plate is horizontally laid over the loading base; a track baseplate is arranged over the loading plate; two parallel loading tracks are secured over the track baseplate; a reaction frame spanning over the model tank is disposed above the test platform; a downward loading device is disposed on the reaction frame; and a rigid beam spanning over the loading tracks is connected to the bottom of the loading device.

Preferably, a wave-absorbing material is disposed on an inner side of the wall slab and an inner side of the baffle.

Preferably, the loading device is an actuator.

Preferably, the reaction frame includes columns secured to the test platform on two sides and a cross beam spanning over the model tank; each of the columns and the cross beam is of a hollow structure; a mounting plate is disposed at the bottom of the cross beam; a sliding groove is formed in the middle of the mounting plate; a T-shaped hanger rod is disposed in the sliding groove; a transverse rod of the hanger rod is located above the mounting plate, and a vertical rod of the hanger rod penetrates through the sliding groove, with a lower end of the vertical rod being fixedly connected to a connecting plate; the connecting plate is connected to the mounting plate by means of a bolt; a plurality of uniformly distributed preformed through holes are formed in parts, on two sides of the sliding groove, of the mounting plate; and the actuator is fixedly connected to the connecting plate.

Preferably, a diagonal brace is connected between the column and the cross beam; a bottom plate at the bottom of the column is secured to the test platform by means of a bolt; a plurality of uniformly distributed ribbed plates are connected between the bottom plate and the column.

Preferably, uniformly distributed cross braces are disposed on an outer side surface of the baffle; and preformed pipe holes for the water inlet pipe and the water outlet pipe to pass therethrough are formed in the baffle.

Preferably, a support frame is disposed on an outer side of the baffle; the support frame includes a supporting seat, a brace rod and a support plate; the supporting seat is secured to the bottom of the model tank; one side of the support plate abuts against the outer side face of the baffle, and a connecting seat is arranged on the other side of the support plate; the brace rod has one end fixedly connected to the supporting seat and the other end protruding slantwise and upwards and hinged to the connecting seat.

Preferably, the support plate is located between two cross braces; and a rubber pad is arranged on a surface, in contact with the baffle, of the support plate.

A test method for above test apparatus includes the following steps:

step 1, measuring actual conditions, zooming out a high-speed railway subgrade and underlying mined-out area based on the similarity principle to obtain a corresponding size of the test rock and soil mass, and setting the positions of the clamping grooves based on the size of the test rock and soil mass;

step 2, fabricating the test rock and soil mass inside which the mined-out area simulation assembly is embedded in a corresponding position;

step 3, placing the test rock and soil mass into the model tank and adjusting the positions of the baffles;

step 4, discharging water in the water storage bag according to a determined similarity ratio;

step 5, simulating natural precipitation by spraying water over the test rock and soil mass;

step 6, laying the loading base, the loading tracks and measuring instruments above the test rock and soil mass after the mined-out area is stable;

step 7, mounting the reaction frame and the loading device;

step 8, simulating load applied by a running high-speed train by the loading device; and

step 9, transmitting measurement results of the measuring instruments to computer software for processing and analysis to obtain test results.

Further, in step 2, when fabricating the test rock and soil mass, soil is prepared layer by layer; a corresponding measuring device is buried in each layer, and overlying soil is prepared only after related physical indexes of each layer of soil specimen are detected as acceptable.

The disclosure has the following beneficial effects:

According to the disclosure, with the clamping grooves formed in the wall slabs of the model tank, the baffles can be inserted into the clamping grooves, so that the positions of the baffles are fixed and horizontal reaction can be provided. Moreover, the positions of the baffles can be adjusted according to the positions of the clamping grooves, so that the model tank can accommodate test rock and soil masses different in size.

The loading base, the loading plate, the track baseplate and the loading tracks over the test rock and soil mass simulate a high-speed railway subgrade, a concrete base, a track slab and a high-speed railway track, respectively, so that actual conditions of a high-speed railway can be effectively simulated.

According to the disclosure, the wave-absorbing material is arranged on the inner side of the wall slab and the inner side of the baffle, which can prevent stress wave rebounding.

According to the disclosure, the mined-out area simulation assembly disposed within the test rock and soil mass has the water storage bag to simulate a mined-out area. A water drainage speed of the water storage bag can be controlled by the flowmeter and the valve, so that the evolution process of the mined-out area can be simulated. The mined-out area simulation assembly features high time controllability and good liquidity and can effectively simulate the evolution rule of a sagging zone of a mined-out area with relatively low disturbance to soil. Moreover, the water storage bag can be designed into any shape with good plasticity and can simulate mined-out areas in different situations.

In the disclosure, the hanger rod is disposed on the mounting plate below the cross beam, which facilitates position adjustment of the actuator for ease of adjustment of an appropriate loading position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a three-dimensional schematic diagram illustrating a structure according to an example of the disclosure.

FIG. 2 is a schematic diagram illustrating a partial section structure according to an example of the disclosure.

FIG. 3 is a front view illustrating a structure according to an example of the disclosure.

FIG. 4 is a three-dimensional schematic structure diagram of a reaction frame according to an example of the disclosure.

FIG. 5 is a schematic structure diagram of a support frame on the outer side of a baffle according to an example of the disclosure.

FIG. 6 is a schematic structure diagram of a mined-out area simulation assembly according to an example of the disclosure.

In the drawings, what reference numerals denote are as follows: 1, test platform; 1-1, wall slab; 1-11, clamping groove; 1-12, reinforcement; 1-2, drainage channel; 2, baffle; 2-1, cross brace; 2-2, lifting hole; 2-3, preformed pipe hole; 3, test rock and soil mass; 4, mined-out area simulation assembly; 4-1, water storage bag; 4-2, water inlet pipe; 4-3, water outlet pipe; 4-31, flowmeter; 4-32, valve; 5, loading base; 5-1, loading plate; 5-2, track baseplate; 5-3, loading track; 6, actuator; 6-1, rigid beam; 7, reaction frame; 7-1, column; 7-11, bottom plate; 7-2, cross beam; 7-21, mounting plate; 7-211, sliding groove; 7-22, hanger rod; 7-23, connecting plate; 7-24, actuator baseplate; 7-3, diagonal brace; 8, support frame; 8-1, supporting seat; 8-2, brace rod; 8-3, support plate; 8-31, connecting seat; and 8-4, rubber pad.

DETAILED DESCRIPTION

Specific examples of the disclosure are as shown in FIG. 1 to FIG. 6.

The technical solution of the disclosure is as follows:

A pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area, as shown in FIG. 1 to FIG. 6, includes a test platform 1. The test platform 1 has a model tank perforated at two ends. Two sides of the model tank are formed by wall slabs 1-1 which are concrete slabs with reinforcements 1-12 therein. One side of the wall slab 1-1 abuts against the test platform 1, and a plurality of clamping grooves 1-11 distributed uniformly and horizontally are formed vertically on the other side of the wall slab 1-1. A tetragonal test rock and soil mass 3 is placed in the model tank. A mined-out area simulation assembly 4 is disposed within the test rock and soil mass 3. The mined-out area simulation assembly 4 includes a water storage bag 4-1 located within the test rock and soil mass 3. A water inlet pipe 4-2 penetrating through a baffle 2 on one side is disposed at one end of the water storage bag 4-1, and a water outlet pipe 4-3 penetrating through a baffle 2 on the other side is disposed at the other end of the bag. A flowmeter 4-31 and a valve 4-32 are mounted on the water outlet pipe 4-3. Drainage channels 1-2 are disposed on two sides of the bottom of the model tank next to the wall slabs 1-1, and the toe of the drainage channel 1-2 is not less than 3%. The baffles 2 inserted into the clamping grooves 1-11 are arranged on two sides of the test rock and soil mass 3, and two lifting holes 2-2 are formed above the baffles 2 on two sides. The baffle 2 is made of tempered glass. Uniformly distributed cross braces 2-1 are disposed on the outer side surface of the baffle 2. Preformed pipe holes 2-3 for the water inlet pipe 4-2 and the water outlet pipe 4-3 to pass therethrough are formed in the baffle 2. The surfaces of four sides of the test rock and soil mass 3 abut against the baffles 2 and the wall slabs 1-1, respectively. A wave-absorbing material is arranged on the inner side of the wall slab 1-1 and the inner side of the baffle 2. The wave-absorbing material on the inner side of the wall slab 1-1 and that on the inner side of the baffle 2 can prevent stress wave rebounding. A loading base 5 of a truncated-pyramid-shaped structure is disposed over the test rock and soil mass 3. A loading plate 5-1 is horizontally laid over the loading base 5, a track baseplate 5-2 is arranged over the loading plate 5-1. Two parallel loading tracks 5-3 are secured over the track baseplate 5-2. A reaction frame 7 spanning over the model tank is disposed above the test platform 1. A downward loading device is disposed on the reaction frame 7. A rigid beam 6-1 spanning over the loading tracks 5-3 is connected to the bottom of the loading device. The loading device is an actuator 6. The actuator 6 may be an electro-hydraulic servo dynamic actuator 6. The actuator 6 is connected to a constant pressure variable servo oil source and controlled by a computer. The loading device can simulate not only high-speed trains different in speed and axle load, but also high-frequency operation with different waveforms.

According to the disclosure, the clamping grooves 1-11 are formed in the wall slabs 1-1 of the model tank, and the baffles 2 can be inserted into the clamping grooves 1-11, so that the positions of the baffles 2 are fixed and horizontal reaction can be provided. Moreover, the positions of the baffles 2 can be adjusted according to the positions of the clamping grooves 1-11, so that the model tank can accommodate test rock and soil masses 3 different in size. The loading base 5, the loading 5-1, the track baseplate 5-2 and the loading tracks 5-3 over the test rock and soil mass 3 simulate a high-speed railway subgrade, a concrete base, a track slab and a high-speed railway track, respectively, so that actual conditions of a high-speed railway can be effectively simulated.

Further, the mined-out area simulation assembly 4 is disposed within the test rock and soil mass 3. The mined-out area simulation assembly 4 has the water storage bag 4-1 to simulate a mined-out area. A water drainage speed of the water storage bag 4-1 can be controlled by the flowmeter 4-31 and the valve 4-32, so that the evolution process of the mined-out area can be simulated. The mined-out area simulation assembly 4 features high time controllability and good liquidity and can effectively simulate the evolution rule of a sagging zone of a mined-out area with relatively low disturbance to soil. Moreover, the water storage bag 4-1 can be designed into any shape with good plasticity and can simulate mined-out areas in different situations.

The reaction frame 7 in the disclosure includes columns 7-1 secured to the test platform 1 on two sides and a cross beam 7-2 spanning over the model tank. Each of the columns 7-1 and the cross beam 7-2 is of a hollow structure. A diagonal brace 7-3 is connected between the column 7-1 and the cross beam 7-2. A bottom plate 7-11 at the bottom of the column 7-1 is secured to the test platform 1 by means of a bolt. A plurality of uniformly distributed ribbed plates are connected between the bottom plate 7-11 and the column 7-1. A mounting plate 7-21 is disposed at the bottom of the cross beam 7-2. A sliding groove 7-211 is formed in the middle of the mounting plate 7-21. A T-shaped hanger rod 7-22 is disposed in the sliding groove 7-211. A transverse rod of the hanger rod 7-22 is located above the mounting plate 7-21, and a vertical rod of the hanger rod 7-22 penetrates through the sliding groove 7-211, with the lower end of the vertical rod being fixedly connected to a connecting plate 7-23. The connecting plate 7-23 is connected to the mounting plate 7-21 by means of a bolt. A plurality of uniformly distributed preformed through holes are formed in parts, on two sides of the sliding groove 7-211, of the mounting plate 7-21. The actuator 6 is fixedly connected to the connecting plate 7-23. The hanger rod 7-22 facilitates position adjustment of the actuator 6 for ease of adjustment of an appropriate loading position. Uniformly distributed mounting holes are formed on two sides of the columns 7-1, so that the cross beam 7-2 can be adjusted in connection position. An actuator base plate 7-24 is connected between the actuator 6 and the connecting plate 7-23.

In the disclosure, a support frame 8 is disposed on the outer side of the baffle 2. The support frame 8 includes a supporting seat 8-1, a brace rod 8-2 and a support plate 8-3. The supporting seat 8-1 is secured to the bottom of the model tank. One side of the support plate 8-3 abuts against the outer side face of the baffle 2, and a connecting seat 8-31 is arranged on the other side of the support plate. The brace rod 8-2 has one end fixedly connected to the supporting seat 8-1 and the other end protruding slantwise and upwards and hinged to the connecting seat 8-31. The support plate 8-3 is located between two cross braces 2-1. A rubber pad 8-4 is arranged on the surface, in contact with the baffle 2, of the support plate 8-3. The support frame 8 can prevent deformation of the baffle 2 under a large loading force.

A test method for the pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area includes the following steps:

Step 1, measure actual conditions, zoom out a high-speed railway subgrade and underlying mined-out area based on the similarity principle to obtain a corresponding size of the test rock and soil mass 3, and set the positions of the clamping grooves 1-11 based on the size of the test rock and soil mass 3.

Step 2, fabricate the test rock and soil mass 3 inside which the mined-out area simulation assembly 4 is embedded in a corresponding position. When fabricating the test rock and soil mass 3, soil is prepared layer by layer; a corresponding measuring device is buried in each layer, and overlying soil is prepared only after related physical indexes of each layer of soil specimen are detected as acceptable.

Step 3, place the test rock and soil mass 3 into the model tank and adjust the positions of the baffles 2.

Step 4, discharge water in the water storage bag 4-1 according to a determined similarity ratio.

Step 5, simulate natural precipitation by spraying water over the test rock and soil mass 3.

Step 6, lay the loading base 5, the loading tracks 5-3 and measuring instruments above the test rock and soil mass 3 after the mined-out area is stable.

Step 7, mount the reaction frame 7 and the loading device.

Step 8, simulate load applied by a running high-speed train by the loading device.

Step 9, transmit measurement results of the measuring instruments to computer software for processing and analysis to obtain test results.

CLAIMS

1. A pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area, comprising a test platform, wherein the test platform has a model tank; two sides of the model tank are formed by wall slabs; one side of the wall slab abuts against the test platform, and a plurality of clamping grooves distributed uniformly and horizontally are formed vertically on the other side of the wall slab; a tetragonal test rock and soil mass is placed in the model tank; a mined-out area simulation assembly is disposed within the test rock and soil mass; the mined-out area simulation assembly comprises a water storage bag located within the test rock and soil mass; a water inlet pipe penetrating through a baffle on one side is disposed at one end of the water storage bag, and a water outlet pipe penetrating through a baffle on the other side is disposed at the other end of the bag; a flowmeter and a valve are mounted on the water outlet pipe; the baffles inserted into the clamping grooves are arranged on two sides of the test rock and soil mass; a loading base of a truncated-pyramid-shaped structure is disposed over the test rock and soil mass; a loading plate is horizontally laid over the loading base; a track baseplate is arranged over the loading plate; two parallel loading tracks are secured over the track baseplate; a reaction frame spanning over the model tank is disposed above the test platform; a downward loading device is disposed on the reaction frame; and a rigid beam spanning over the loading tracks is connected to the bottom of the loading device.

2. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 1, wherein a wave-absorbing material is disposed on an inner side of the wall slab and an inner side of the baffle.

3. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 2, wherein the loading device is an actuator.

4. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 3, wherein the reaction frame comprises columns secured to the test platform on two sides and a cross beam spanning over the model tank; each of the columns and the cross beam is of a hollow structure; a mounting plate is disposed at the bottom of the cross beam; a sliding groove is formed in the middle of the mounting plate; a T-shaped hanger rod is disposed in the sliding groove; a transverse rod of the hanger rod is located above the mounting plate, and a vertical rod of the hanger rod penetrates through the sliding groove, with a lower end of the vertical rod being fixedly connected to a connecting plate; the connecting plate is connected to the mounting plate by

means of a bolt; a plurality of uniformly distributed preformed through holes are formed in parts, on two sides of the sliding groove, of the mounting plate; and the actuator is fixedly connected to the connecting plate.

5. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 4, wherein a diagonal brace is connected between the column and the cross beam; a bottom plate at the bottom of the column is secured to the test platform by means of a bolt; a plurality of uniformly distributed ribbed plates are connected between the bottom plate and the column.

6. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 5, wherein uniformly distributed cross braces are disposed on an outer side surface of the baffle; and preformed pipe holes for the water inlet pipe and the water outlet pipe to pass therethrough are formed in the baffle.

7. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 6, wherein a support frame is disposed on an outer side of the baffle; the support frame comprises a supporting seat, a brace rod and a support plate; the supporting seat is secured to the bottom of the model tank; one side of the support plate abuts against the outer side face of the baffle, and a connecting seat is arranged on the other side of the support plate; the brace rod has one end fixedly connected to the supporting seat and the other end protruding slantwise and upwards and hinged to the connecting seat.

8. The pseudo-dynamic loading model test apparatus for a high-speed railway foundation in a mined-out area according to claim 7, wherein the support plate is located between two cross braces; and a rubber pad is arranged on a surface, in contact with the baffle, of the support plate.