DESIGN OF EPS VERTICAL WALL STRUCTURE IN ROAD CONSTRUCTION ON A STEEP HILLSIDE

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ABSTRACT

The Design of an EPS vertical wall structure does not utilize the standardized design method for a post structure. In our design, a post was structurally analyzed during the construction of an EPS vertical wall structure and at its completion. It was assumed that the post would reach a critical state when it has the head unfixed with an anchor during construction, due to the severe conditions of the construction site. In addition, allowable displacement was limited to 5 cm, because it was thought that a post should have a limited displacement to provide vertical accuracy for an EPS vertical wall structure. Moreover, hinged joints were used to connect the reinforced concrete floor slab and anchor tie-plate in order to achieve the displacement-limited structure, and this joint structure improved the durability of the reinforced concrete floor slab against compressive deformation.

KEY WORDS: EPS vertical wall structure, Design method for a post structure, Allowable displacement, Displacement-limited structure

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1. INTRODUCTION

In the design of an EPS vertical wall structure, an H steel beam is usually used as a post, though a design method for a post structure has not yet been established. In our design, the construction of the EPS vertical wall structure was scheduled to be executed in a heavy snowfall area during winter months, and, thus, it was thought that a post would reach a critical state when a certain amount of snow was loaded on the post during its construction. Based on this assumption, structural analysis was carried out of a post during its construction. In addition, it was thought that displacement of a post had to be limited to provide vertical accuracy for the wall structure. Therefore, the EPS vertical wall structure was designed with the focus placed on the displacement of a post. Moreover, the joint structure for connecting the reinforced concrete floor slab and anchor was calculated to achieve the displacement-limited structure. This paper deals with problems related to the design method for a post structure and the design methods used in our design, and also includes our considerations on our design methods.

2. OUTLINE OF EPS VERTICAL WALL STRUCTURE

The standard cross section of the EPS vertical wall structure is shown in Figure 1. An H steel beam was used as a post. The post was embedded deep into the ground to minimize the effects of excavation. The concrete basement was placed on the base rock as a measure against the slide of surface soil in front of the post because of erosion by the river. Another anchor was placed at the lower section of the wall structure to reduce earth pressure acting on the concrete basement.

3. PROBLEMS RELATED TO THE DESIGN METHOD

3.1. Problems to be solved in designing a post structure

In design method for a post structure, generally, the post structure is structurally analyzed and checked for stress at the completion of construction that is when the head of the post is restrained. When this design method is adopted in our design, the following problems arise:

(1) If construction of an EPS vertical wall structure is conducted in a heavy snowfall area during winter months, it is expected that a post would reach a critical state when snow is accumulated on a post without its head fixed with an anchor during its construction rather than at the completion of the structure.

(2) If a post without its head fixed with an anchor is embedded into the ground, its bending stress varies inversely to its displacement. Thus, determination of the size of H steel beam based only on bending stress does not guarantee the vertical accuracy necessary for the structure.

3.2 Problems related to the method for connecting the reinforced concrete floor slab and anchor tie-bar

Generally, a reinforced concrete floor slab and anchor tie-bar are connected with rigid joints to provide a displacement-limited structure for a post, when a reinforced concrete floor slab connected to the post is fixed with an anchor. In our method, EPS materials can cause compressive deformation, which may produce the risk that the reinforced concrete floor slab suffers from creep distortion. The reinforced concrete floor slab is usually a thin material of about 15 cm thickness, and breakable even if only a small bending stress is applied. Therefore, the effects of compressive deformation of EPS materials can not be ignored as one of the problems concerning the stability of the whole EPS vertical wall structure, when a reinforced concrete floor slab is designed.

4. DESIGN METHOD USED IN OUR DESIGN

4.1 Design method for a post structure

4.1.1 Basic preconditions for the design of post structure

The basic preconditions for a post structure are shown as follows, and the diagram for design procedure is in Figure 2.

The basic preconditions include:

(1) The post has no displacement around the anchor. The H steel beam bears all the lateral pressure from EPS materials.
(2) The reinforced concrete floor slab and anchor support the inertia force of back fill in an earthquake after the EPS vertical wall structure is completed.
(3) "During the construction of an EPS vertical wall structure" is defined as the time when the uppermost reinforced concrete floor slab is attached to the post, but the anchor is not placed at the upper section. Snow is loaded onto the post during its construction.
(4) Earth pressure is applied to the concrete basement, and not to the backside of the EPS materials.
(5) The frame analysis for a post structure is carried out based on the beam models shown in Figure 3.

4.1.2 Determination of allowable displacement

Public engineering works which place the utmost importance on the vertical accuracy of a wall structure include self-standing earth-retaining structures and sheet pile type quaywalls. These structures are usually designed so that the allowable displacement is within 5.0 cm. The EPS vertical wall structure during construction is also considered as one of these self-standing wall structures. In addition, because the post is fixed at the head while its head is kept deformed due to snow load, displacement during construction is equal to that at the completion of construction. Therefore, allowable deformation was set within 5.0 cm in our design. It was expected that this would provide vertical accuracy for the wall structure.

4.1.3 Results of the structural analysis of a post structure

In our design, 8 points were chosen for structural analysis of a post because the wall height and the coefficient of subgrade reaction varied from point to point. Analytical results of a post structure placed at 8 points are shown in Table 1. The size of H steel beam for each point was determined according to the displacement of the post during construction, and all bending stresses were within the allowable stress (140 N/m??2??), providing very satisfactory results.

4.2 Joint structure for connecting the reinforced concrete floor slab and anchor

When a reinforced concrete floor slab and anchor tie-bar are connected with rigid joints, EPS material can cause compressive deformation. It is well known that this compressive deformation may produce bending moment at the joints. It is difficult, however, to elucidate the distribution pattern and amount of bending moment. Especially, it is thought that the estimation of creep deformation is extremely difficult because the works involving pavement subbases course adopt multi-stage execution. These problems led us to decide that it is necessary to use hinged joints to connect the reinforced concrete floor slabs and anchor the tie-bars in our design.

In our design, therefore, the reinforced concrete floor slabs and anchor tie-bars were connected with hinged joints, as shown in Figure 4. The use of hinged joints provided lower bending moment for the reinforced concrete floor slabs, compared with the use of rigid joints, and improved the durability of the reinforced concrete floor slabs.

5. CONSIDERATIONS

If our design method is adopted when a post structure is designed, the size of the H steel beam can in many cases be determined depending on the displacement of a post during construction. It is necessary, therefore, that a load not be set at a certain value to determine the suitable H steel beam, but rather be calculated according to the particular conditions of every site. Though our design method used 5 cm of allowable displacement, it is thought that allowable displacement of a post structure has to be clearly defined and be well coordinated with that of other road structures.

In the structural analysis for a post structure, the method for supporting lateral pressure from EPS materials acting on a post is another issue to be considered in the future. Measures to avoid possible effects of lateral pressure from EPS materials would include cushion material placed between H steel beam and EPS materials for absorbing lateral pressure. The method for placing a post structure by making full use of the self-standing characteristics of EPS materials needs further consideration.

We can not say that hinged joints used to connect the reinforced concrete floor slabs and anchor tie-bars in our design provide fully-secured stability for the reinforced concrete floor slabs. It would be worthwhile to examine safer and more reliable designs of joint structures such as one in which a post and anchor are directly connected with a tie rod and the limitation of displacement does not depend on a reinforced concrete floor slab.

6. POSTSCRIPT.

In road construction works in Japan, it is expected that EPS vertical wall structures will be increasingly used under complicated geological and topographic conditions and for the sake of environmental preservation, limited utilization of sites, and reduction of construction periods. It is necessary to establish a basic design method for EPS vertical wall structures and to standardize their basic structural design in order to meet the above-mentioned needs. Design methods for EPS vertical wall structures should not include difficult and complicated techniques, because the designs will face frequent changes under the severe conditions of the sites, and it is important to immediately respond to these changes in the design method. In addition, it is thought that improvement in construction methods and methods for construction management is another issue to be considered in the future.

Table 1. Results of Structural Analysis of a Post

CASE	Size of the H steel beam	Height of the H steel beam from the ground to the top	Coefficient of the deformation of the ground	Maximum deformation (mm)		Maximum bending moment (KNm)		Bending stress
		m	KN/m²	During road construction	At completion of road construction	During road construction	At completion of road construction	N/mm²
CASE1	H-250	7.100	8400	46.521	6.784	53.032	38.616	61.67
CASE2	H-300	7.450	8400	37.870	4.726	70.028	43.137	51.87
CASE3	H-300	7.450	8400	33.844	5.730	73.410	42.494	54.38
CASE4	H-250	6.850	140000	33.448	5.306	52.998	45.697	61.63
CASE5	H-250	7.100	140000	39.006	6.253	60.301	53.748	70.12
CASE6	H-300	8.350	140000	39.502	6.233	81.614	70.298	60.45
CASE7	H-300	8.600	28000	48.191	7.335	85.398	70.328	63.26
CASE8	H-250	6.850	8400	41.209	5.937	49.917	36.073	58.04

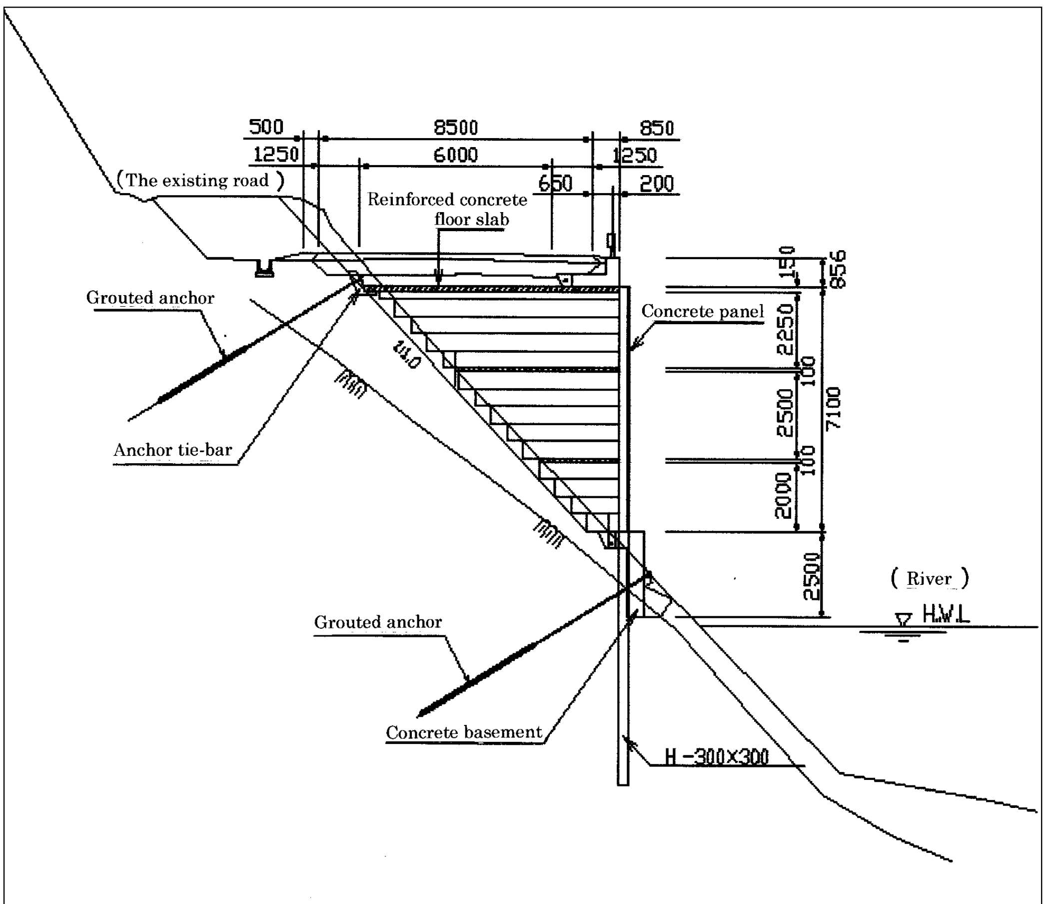

Figure 1. Standard Cross Section of EPS Vertical Wall Structures

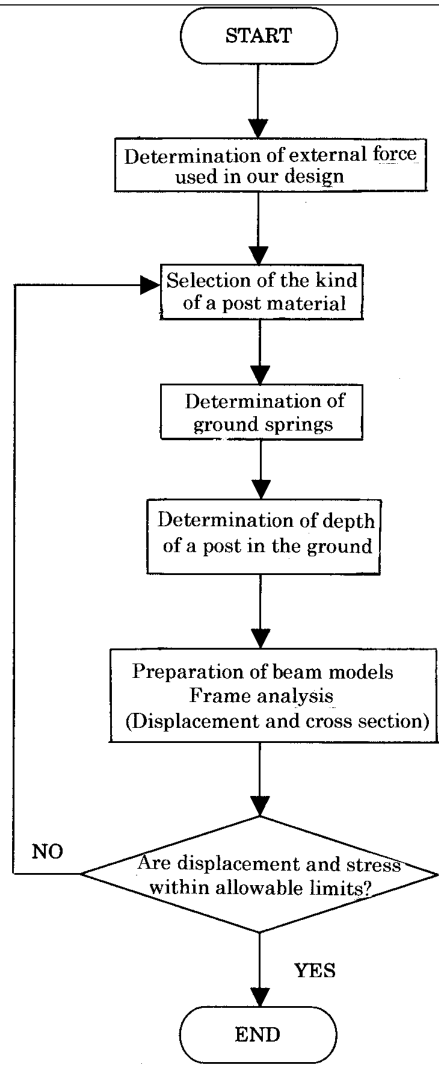

Figure 2. Design procedure for a post structure

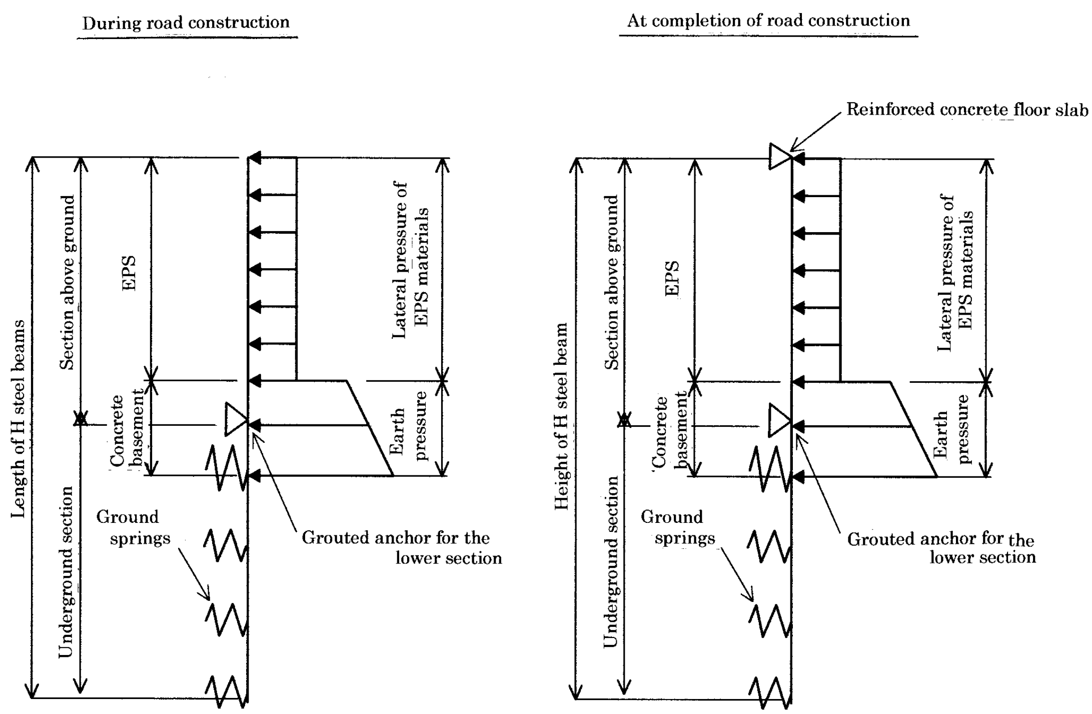

Figure 3. Models for structural analysis of a post structure

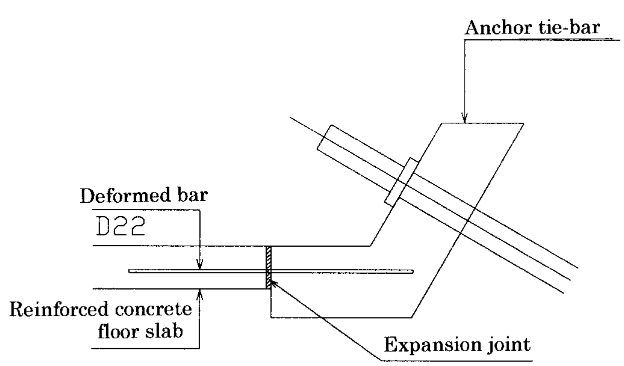

Figure 4. Joint structure for a reinforced concrete floor slab and anchor tie-bar