

# DESIGN CASE OF LIGHTWEIGHT EMBANKMENT METHOD WITH LOWER-BUOYANCY EPS BLOCKS AS A COUNTERMEASURE AGAINST SETTLEMENT

KAZUHIKO KUROBE<sup>1</sup>, and TAKESI KUROMORI<sup>2</sup>

## ABSTRACT

Replacement of peat soil to Expanded Polystyrene (EPS) blocks has some disadvantages in preventing settlement, comparing with that of cohesive soil to EPS blocks, because peat soil has lighter unit weight. The total thickness of EPS blocks to be piled up is mostly determined by their buoyancy force related to fluctuating water levels.

With the aim of reducing the cost of work for preventing settlement, various types of EPS blocks with lower buoyancy have been recently developed to increase the number of them to be piled up and to broaden their applications in construction work. This paper reports a design case of lightweight embankment method with lower-buoyancy EPS blocks to avoid settlement. The EPS blocks used in this design have a hollow structure and slits on the side, and are designed to allow water to flow in and out of the EPS blocks freely so that their buoyancy force is reduced.

The ground at the site of embankment consists of soft ground with high compressibility, made up of topsoil of peat and subsoil of clay. Because the conventional types of EPS blocks have less stability due to problems related to buoyancy force, the newly developed lower-buoyancy EPS blocks were introduced to this design to prevent subsidence of the existing large-diameter sewer ( $\Phi 2,200$ ) laid below the city planning road which was scheduled to be constructed at this site.

It was observed that the sewer did not subside after completion of the city planning road, which demonstrating that the EPS blocks effectively contribute to lighter embankment. Therefore, it was concluded that settlement of embankment was successfully prevented by using this lightweight embankment method with lower-buoyancy EPS blocks.

**KEY WORDS:** Peat, Consolidation settlement, Large-diameter sewer, Lower buoyancy

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<sup>1</sup> Hokkaido Kaneppearl Corporation, Japan

<sup>2</sup> Kohken Engineering Inc., Japan

## 1. INTRODUCTION

In Hokkaido, where there are many areas composed of peaty soft ground, site preparation, such as preparation of housing site, was avoided because of prolonged settlement of ground and subsidence of foundations. Recently, however, population in Hokkaido has been on the rise, and then preparation of housing site and its relevant construction of roads have been increasingly carried out even at areas made up of the peaty soft ground.

The case reported here concerns lightweight embankment method with lower-buoyancy expanded polystyrene (EPS) blocks (KANEPEARL FBD®) adopted in order to prevent settlement of soft ground caused by construction of the city planning road as a part of the land readjustment project at an area of the peaty soft ground.

## 2. DISTRIBUTION AND CONSOLIDATION SETTLEMENT OF SOFT GROUND

The site for land readjustment project was located in “Ishikari Deitanchi”, or Ishiakri peaty area, as shown in Figure 1, and this site is known for an area composed of peaty soil made by accumulating sediment from back marsh. Ishikari River, and its many branches, such as Chitose River, Toyohira River, and Toubetsu River, run through this area, and the natural levee has grown along these rivers to form the fen peat.

The soil profile of the site of design is shown in Figure 2. The soft ground consists of 3-meter surface topsoil of peat and the 10-meter subsoil of cohesive soil.

Figure 3 is the standard cross section of the city planning road. The large-diameter sewer ( $\Phi 2,200$ ), constructed by using the jacking method, has been laid 4 m deep at the center of the road. It was thought, therefore, that settlement of cohesive soil (Ac4) under the existing sewer would have effects on the existing sewer.

It is estimated that when the city planning road is designed to have formation height of 0.7 m, then the consolidation settlement will be about 50 cm, and the cohesive soil (Ac4) under the existing the existing sewer will have settlement of 5 cm.

## 3. BASIC CONCEPTS FOR THIS DESIGN

Stability of the underground sewer was assessed according to the diagram, shown in Figure 4, and basic concepts for obtaining stability of the underground sewer is summarized as follows.

- (1) The existing sewer has the strength enough to endure load of the planning road.
- (2) Allowable residual subsidence of the road is 10 cm ( $S_r = 10$  cm) after it is opened for traffic.
- (3) The existing sewer is not allowed to have any subsidence in order to prevent physical damages such as breakage and cracking of the sewer, and decrease in discharge.
- (4) Some methods proposed for preventing settlement of soft ground are compared from the technical and

economical viewpoints, and the one to be chosen has to meet (2) and (3).

#### **4. CHOICE OF METHOD FOR PREVENT SETTLEMENT OF SOFT GROUND**

The four methods proposed for preventing settlement of soft ground in the site of construction are summarized as follows, and they are also shown in Figure 5.

(5) Reduction in load of embankment

Lightweight embankment method is adopted to reduce load of embankment, and to prevent settlement of cohesive soil under the existing sewer. The planning road is allowed to have settlement not more than 10 cm ( $S = 10$  cm).

(6) Protection of the existing sewer

The existing sewer is protected with a structure to control additional load of embankment. Pre-loading method is adopted to construct the city planning road.

(7) Soil improvement

The cohesive soil under the existing sewer is improved by using cement to reduce its settlement resulting from additional load of embankment. Pre-loading method is adopted to construct the city planning road.

(8) Controlling stress

Vertical sheeting is placed at the both sides of the existing sewer to prevent horizontal stress. Lightweight embankment method is adopted at the upper section of the existing sewer, and preloading method is used outside the vertical sheeting.

These four proposed methods were evaluated by comparing each other from technical and economical viewpoints, and then (1) reduction in load of embankment, or use of lightweight embankment method, was chosen for this case design. The points to emphasize in this design are described as follows:

- Ultra-light weight:

The newly developed lower-buoyancy EPS blocks are 100 times as light as the earth, and 10 to 50 times as light as the conventional EPS blocks.

- Water resistance:

Lower-buoyancy EPS blocks are made of water-resistant material. These EPS blocks do not suffer from any change in physical properties caused by absorption of rainwater or seepage water during construction.

- Easiness of execution of work

EPS material can be manually carried and installed in place due to its lightness, and execution of work can be completed in a shorter period.

#### **5. DESIGN WITH LIGHTWEIGHT EMBANKMENT METHOD**

In design of lightweight embankment with EPS blocks, it is important to check stress intensity against load from road and to consider stability against buoyancy. If they are ignored, then the subgrade (EPS blocks) may be destructed or EPS blocks will float, which may cause great damage to the road.

The design was carried out according to the diagram shown in Figure 6. The standard section of the road is shown in Figure 7.

(1) Determination of pavement

- Allowable compressive stress (half of the compressive stress at 5% strain) was larger than load combined with live load and dead load.
- EPS blocks had CBR of 8 when reinforced concrete slab ( $t = 10$  cm) was placed.
- CBR was calculated by combining CBR of EPS blocks and CBR of cohesive soil under the existing sewer.
- EPS blocks to be used and displaced materials were chosen, taking technical and economical aspects into consideration.

(2) Determination of the total thickness of EPS blocks to be piled up

- The number of EPS blocks to be piled up was determined so that they would have the residual subsidence not more than 10 cm ( $S = 10$  cm) after the road is opened for traffic, and that subsidence of the existing sewer, that is, cohesive soil under the existing sewer (Ac4) would not occur ( $S = 0$  cm).
- To prevent differential settlement at the cross section of the road, EPS blocks were placed evenly between curbstone for separating sidewalk and roadway of both sides.

(3) Stability against the buoyancy force

- Factor of safety ( $F_s$ ), which is the ratio of the total thickness of EPS blocks to be piled up, which is necessary to prevent settlement, to buoyancy force occurring when the road is submerged, was not less than 1.2.
- Lower-buoyancy EPS blocks were used to secure the stability where the stability is not obtained by using the conventional EPS blocks.
- The total thickness of EPS blocks to be piled up was calculated by 10-cm unit, but the total thickness of lower-buoyancy EPS blocks to be piled up was calculated by 50-cm unit because of their structure.

Lower-buoyancy EPS blocks used as a countermeasure against buoyancy have the same characteristics as the conventional EPS blocks have, as shown in Table 2.

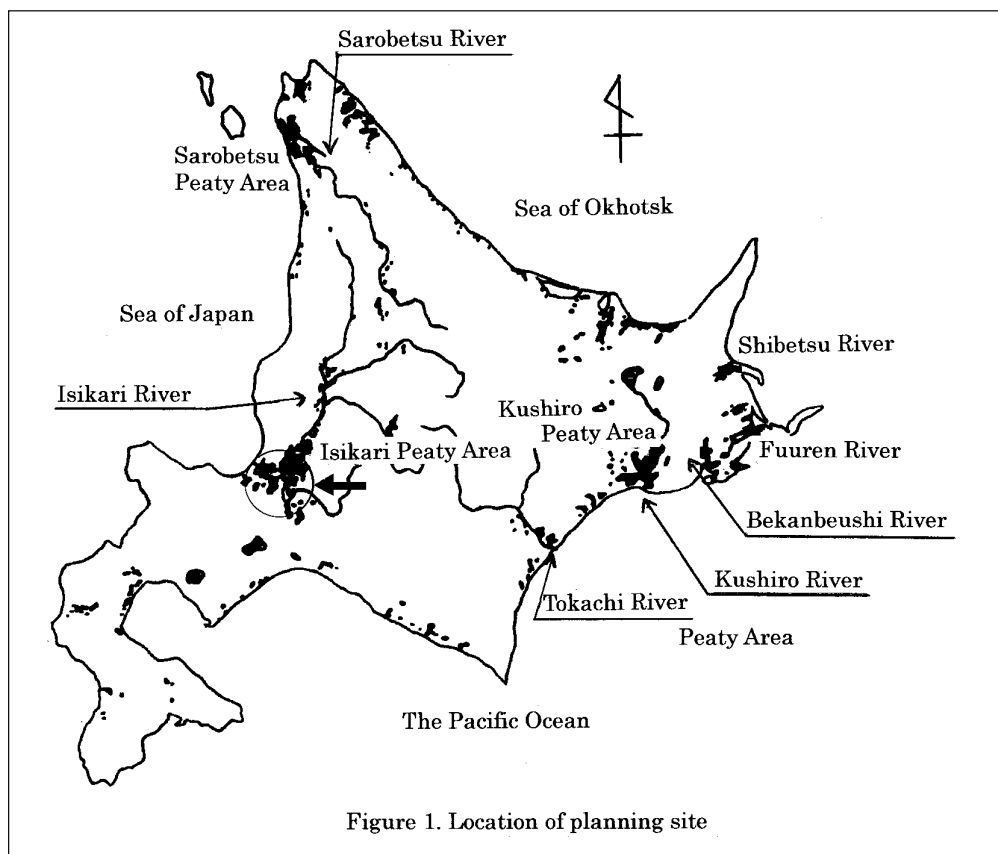
Many types of lower-buoyancy EPS blocks which are available, though the lower-buoyancy EPS block used in this design case, which is shown in Figure 8 and Photograph 1, is characterized by a hollow structure and slits on the side. These characteristics allow water to flow in and out of the EPS blocks freely, which offering about 60% reduction in buoyancy.

Although some years have passed since the road was completed, the road has kept allowable residual subsidence not more than 10 cm, and it was found that the measure taken to prevent settlement of embankment provides favorable result. In addition, observations showed that the existing sewer had no subsidence, which demonstrates that lighter embankment with lower-buoyancy EPS blocks has no effect on subsidence of the road.

## 6. POSTSCRIPT.

In Japan, EPS method was firstly adopted in Sapporo city in 1985. Since then, EPS method has been used at areas consisting of peaty ground in Hokkaido for about 15 years and has provided good results.

EPS method is usually adopted to achieve lighter embankment. The conventional EPS blocks tend to float with increase in water level when it rains. They have faced limitation of number of them to be piled up because of their buoyancy force. This problem can be solved by using lower-buoyancy EPS blocks. It is expected, therefore, lower-buoyancy EPS blocks will broaden their applications, and this design case will help design work for preventing settlement of soft ground and execution of its work.



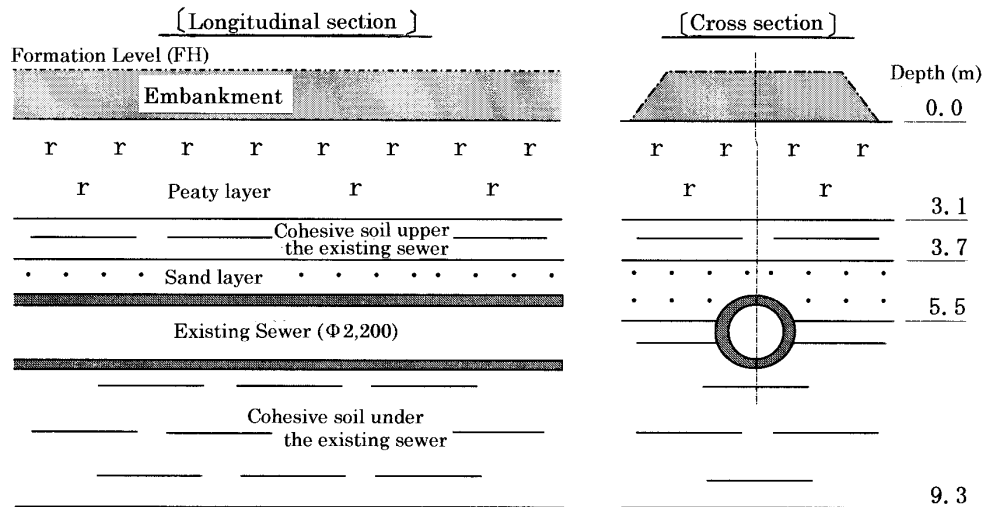


Figure 2 Soil profile of the design area

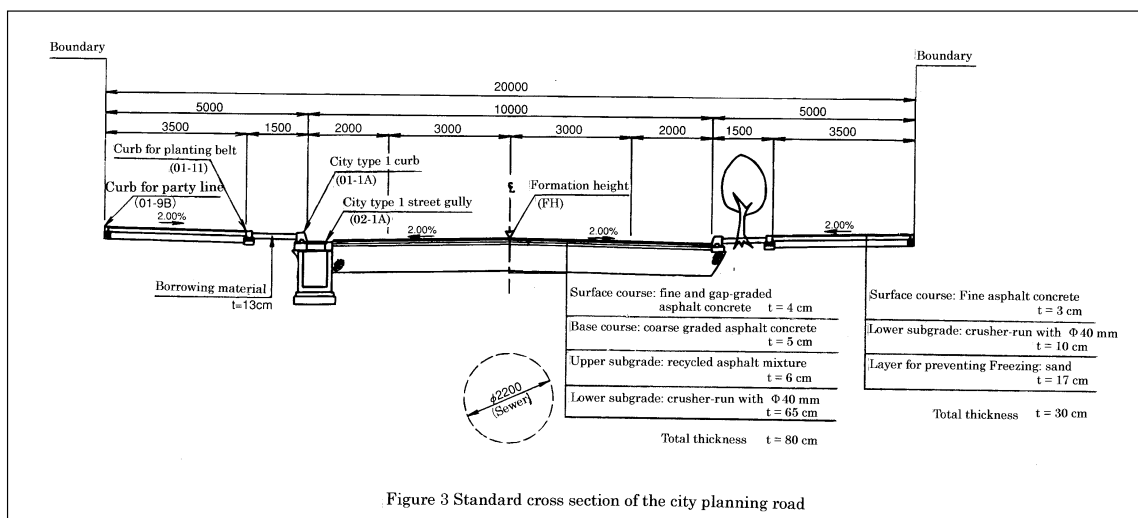
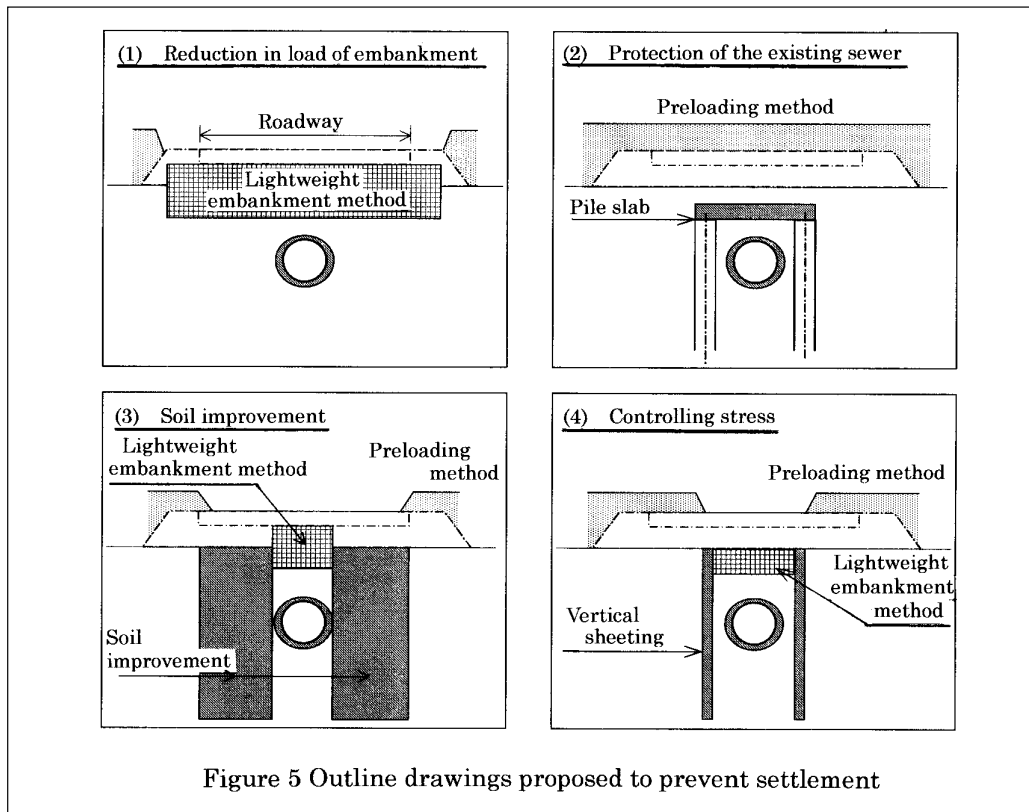
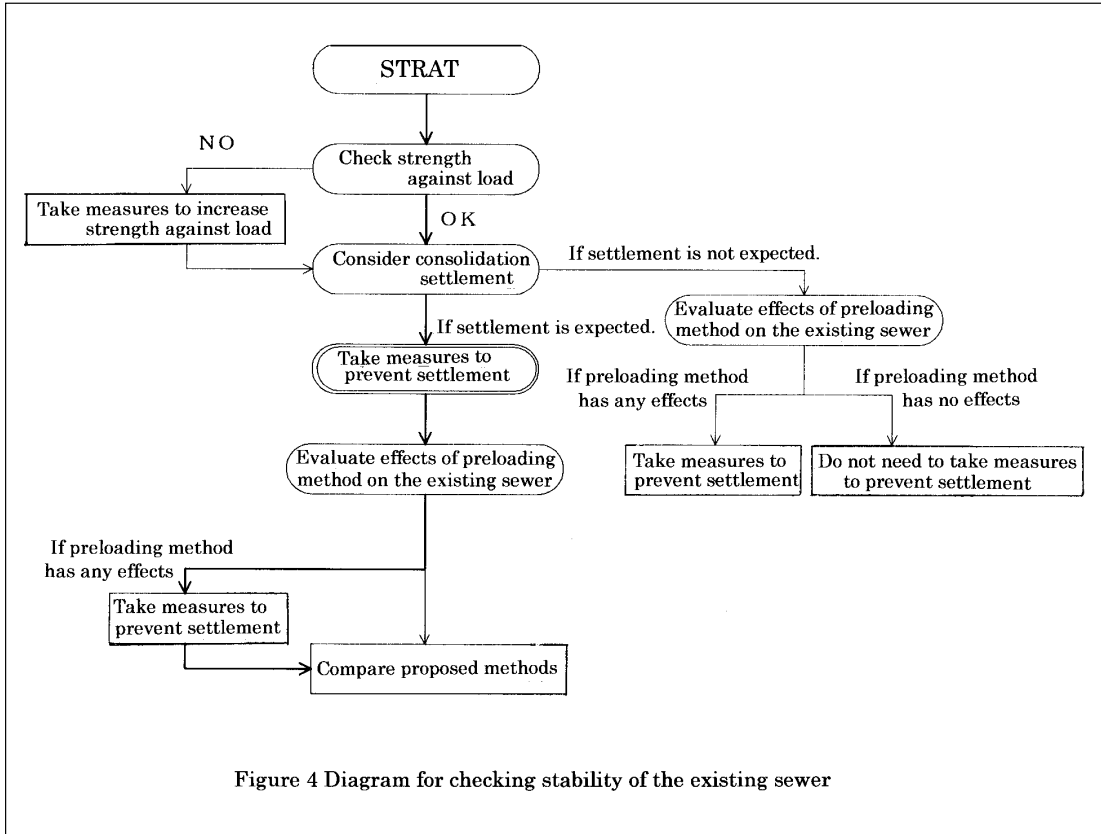
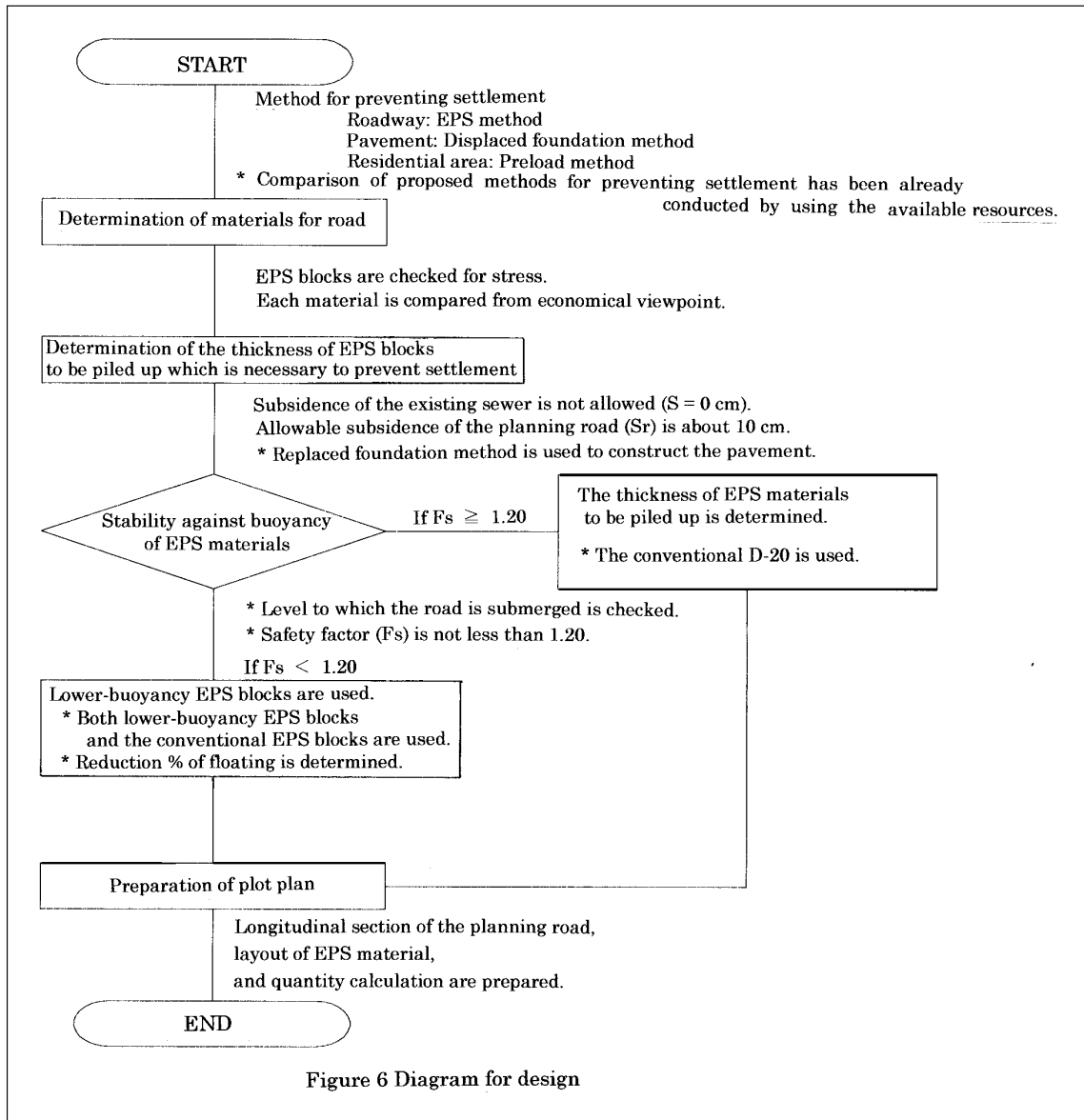


Figure 3 Standard cross section of the city planning road







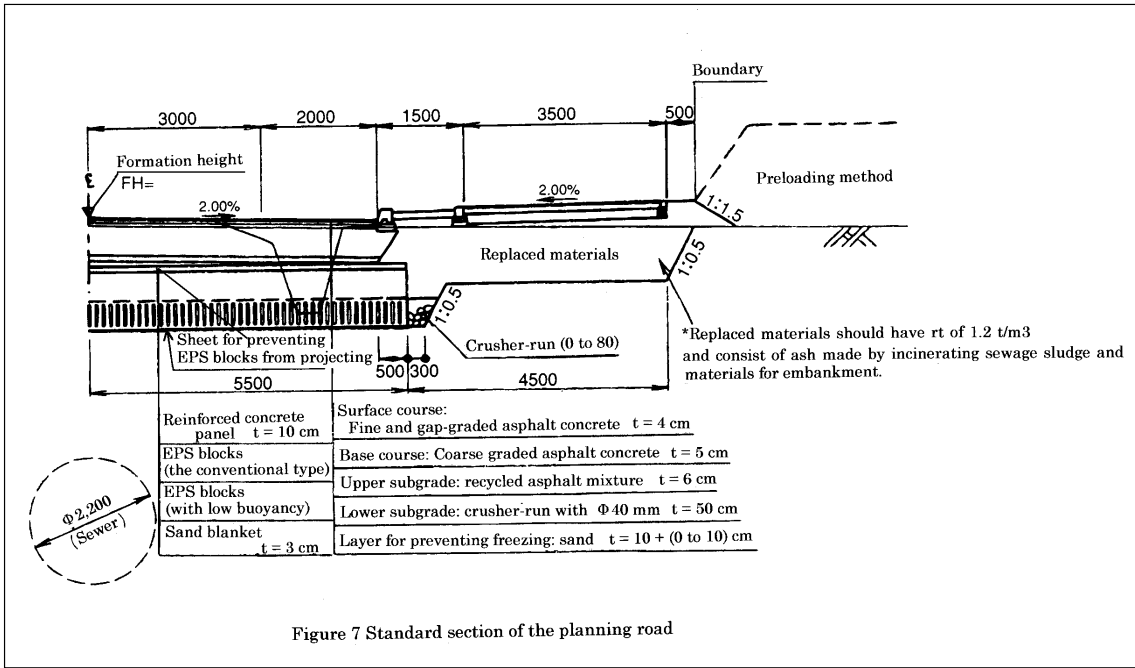


Figure 7 Standard section of the planning road

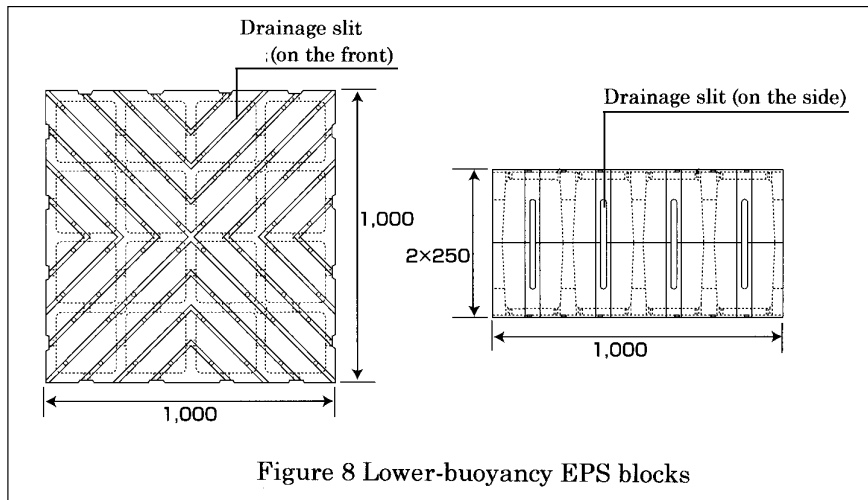


Figure 8 Lower-buoyancy EPS blocks

Photograph 1

Right: EPS block with drainage slits  
and hollow structure

Light: EPS block  
(1,000 x 1,000 x 5,00 mm)

