EDO-EPS Method Applied for Rehabilitation of Expressway Hit by Earthquake

Central Nippon Expressway Company Limited.
2-18-19 Nishiki Naka-ku Nagoya
Aichi 460-0003 JAPAN

Keiichi Taneichi
Expanded Polystyrol Construction Method Development Organization, Director
3-23-1 Takadanobaba Shinjuku-ku
Tokyo 169-0075 JAPAN
E-mail: taneichi@okasanlivic.co.jp

Abstract

An earthquake of M 6.5 happened on August 11th, 2009 with its epicenter under the sea near the central part of Japan. The embankment on the expressway near the epicenter collapsed. An urgent restoration work was called for since that expressway was one of Japan's most important artery roads. Several methods for the rehabilitation work were immediately put under urgent study. As a result, the base of the embankment was consolidated by a counterfill combined with H-beam and concrete, and also by placing large sandbags treated with soil stabilizing cement on the embankment slope. EDO-EPS method (later in his report, shortened to "EPS method", "EPS Blocks") was, in the meantime, applied to the upper structure of the embankment, seeing the advantage of its work speediness as well as the lightweight nature of the used materials. Consequently, the rehabilitation work was completed only in four days to facilitate a speedy re-opening of the principal expressway.

1. EARTHQUAKE OCCURRENCE AND REHABILITATION BACKGROUND

On August 11th, 2009, at 05:07 am, an earthquake of M 6.5 hit central Japan with its epicenter near the Suruga Bay. It damaged part of an embankment on the Tomei Expressway as approx. 40 m of the outer lane failed. This is one of the most important major expressways in Japan, and the traffic was immediately stopped. Since it happened on the first day of a week's mid-summer holiday observed all over Japan, an urgent rehabilitation work was called for.

The emergency rehabilitation work was started with materials, supplies, workers, machinery and equipment which all, made available locally, were urgently transported to the site. Then, at the final phase in repairing the embankment, the EPS method was adopted considering its advantages of using lightweight materials as well as of its capability of speedy work execution. Fig.1 shows the geographical location of the site. Photo.1 shows the condition at the damaged site.

Fig.1 Site location map (marked red)

Photo1 Collapsed embankment [1,2]

2. BACKGROUND OF EPS METHOD APPLICATION

The emergency rehabilitation work started at around 14:00 on the day of the earthquake. Originally, it was planned to pile H-beams in the collapsed ground to stop further soil slides. However, vibration of piling might possibly induce further soil slides, and a big rock hidden underground was encountered during piling operations preventing further piling activities. Consequently the repair method was changed to another alternative, that is: H-beams were first to be piled in the base layer of the embankment as reinforcement, then large sandbags were stacked up from the base layer step on step upward so finally a new embankment might be completed on the top layer by applying stabilizing cement material as reinforcement.[3]

After that, concrete counterweight fills were formed on the lower layers of the embankment so as to provide further reinforcement to the base structure. Two thirds (2/3) of the collapsed embankment was restored in the first two days, but the remaining one third (1/3) was expected to take more time before completion. Application of the EPS method was determined on August 14th counting on its capability of fast work execution in addition to the benefit of the light weight of the embankment as a whole. Necessary amount of EPS blocks, then available from stock in a factory situated quite far away, was transported non-stop to the site by a fleet of large trucks specially escorted all the way by police cars. EPS blocks were thus carried in to the site by late night of the same day. A great number of workers, in the meantime, were mobilized and put to work over night till the next morning when the work was completed; 3.5m high EPS fill with a total of approx. 500m^3 of EPS blocks used. Fig.2 shows the cross-section of the rehabilitation work plan. Photo.2 shows the work completed.

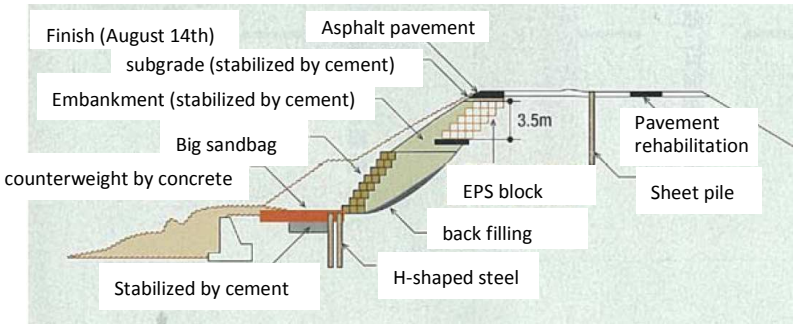

Fig.2 Emergency rehabilitation work plan design in cross-section [3]

Photo2 Emergency rehabilitation embankment in view

3. EMERGENCY REHABILITATION

Concrete slabs (10cm or 15cm thick) are, usually, placed between the EPS blocks and the road pavement so as to disperse the traffic loads. However, since fast restoration was the top priority in this case, a sub-base of cast-in-place concrete that necessitates a curing period, was not applied. Instead, sub-base of materials treated with soil stabilizing cement (55cm thick at the thinnest) was used to substitute the concrete slab. The type of EPS blocks used was D-20 (density 0.20kN/m^3, compressive strength 50kN/m^2), however, D-25 with still higher compressive strength (density 0.25kN/m^2, compressive strength 70kN/m^2) was specially applied to the top layer, while a geotextile was put in between the EPS blocks and cement treated sub-base layer. With all works concerning the placement of EPS blocks and road surface pavement now finished, the whole emergency restoration work was completed on August 16th at midnight 0:00 am. Thus, the road was re-opened to traffic at the site about five days after it was hit by the earthquake. Photo.3 shows the EPS method at work on the site. Photo.4 shows the emergency rehabilitation completed.

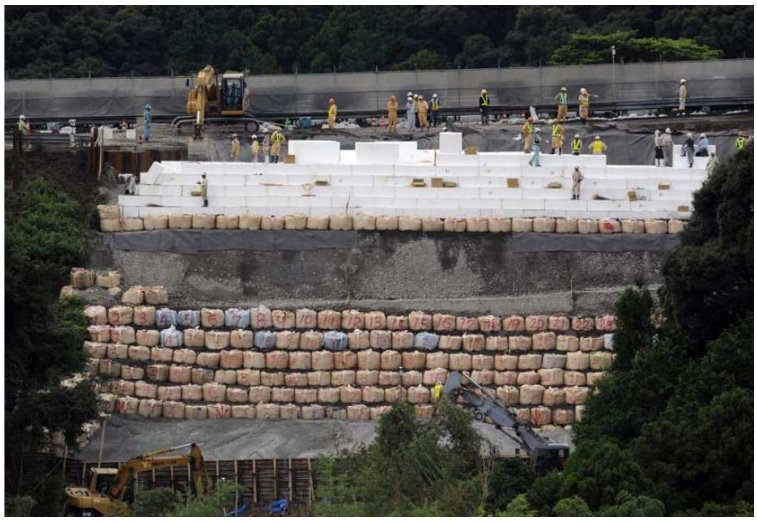

Photo 3 EDO-EPS blocks being laid.

Photo 4: Emergency work just finished[1]

4. FULL-SCALE PERMANENT REHABILITATION WORK

Soon after completion of the emergency work a committee meeting of experts and specialists was held, where analysis and studies were made on the cause of the collapse of the expressway as well as on the repair measures for full-scale rehabilitation of the embankment. The base of the collapsed road embankment was found forming an A-shape (reversed V, or chevron) across the road, and pan-bottom shape along the length of the road. Accordingly this was a topographical condition liable to water influx and accumulation on its inside. And as a mechanism that worked at the time of the earthquake it was estimated that mudstones present in the lower layer of the embankment had significantly lost its strength due to the effect of constant influx of the ground water over many years. This had in turn lowered the permeability and as a result raising the underground water level inside the embankment, which induced by the earthquake action, consequently aided in causing the collapse of the road embankment.[2,3]

As a measure for the permanent full-scale rehabilitation of this site, it was determined that the most important factor was to establish proper drainage conditions inside the embankment and also to improve the stability of the embankment base. The full-scale restoration work should start toward the end of October 2009 with a time target to finish it before the start of the rainy season (mid-June) of the next year.

In the meantime, the EPS method Development Organization (EDO) carried out research on whether or not a concrete slabs should be placed on top of the EPS blocks. As a result, it was determined as better not to re-excavate the site for placing the concrete slab taking into consideration such facts as: the thickness of the sub-base was relatively large; acting stress on the EPS blocks was lower than the allowable stress limit; and since the work method was liable to affect the daily traffic on the main lanes of the expressway, it should be avoided as far as possible.

According to "EDO-EPS Method Designing/Application Code", the sub-base above the EPS should be three times thicker than the concrete slab if the concrete slab is omitted in order to obtain the necessary stress distribution of traffic loads.[4]

Now, the sub-base placed on top of the EPS blocks and treated with soil stabilizing cement in this emergency rehabilitation work measured 55 cm in thickness at its thinnest part, which is equivalent to a thickness much larger than 3 times that of the normally applied concrete slab layer (10cm). It was therefore considered that proper dispersion of traffic loads would be obtained (45° dispersion within the pavement/sub-base; 20° dispersion within EPS blocks).

Fig.3 shows the cross-section of the full-scale rehabilitation work.

Rehabilitation work for the embankment's main body was completed on June 8, 2010 and the incidental works other than the main lanes of the expressway were completed as well toward the end of July 2010 to finalize the whole scope of the work.

Fig.5 shows the full-scale permanent rehabilitation work just completed.

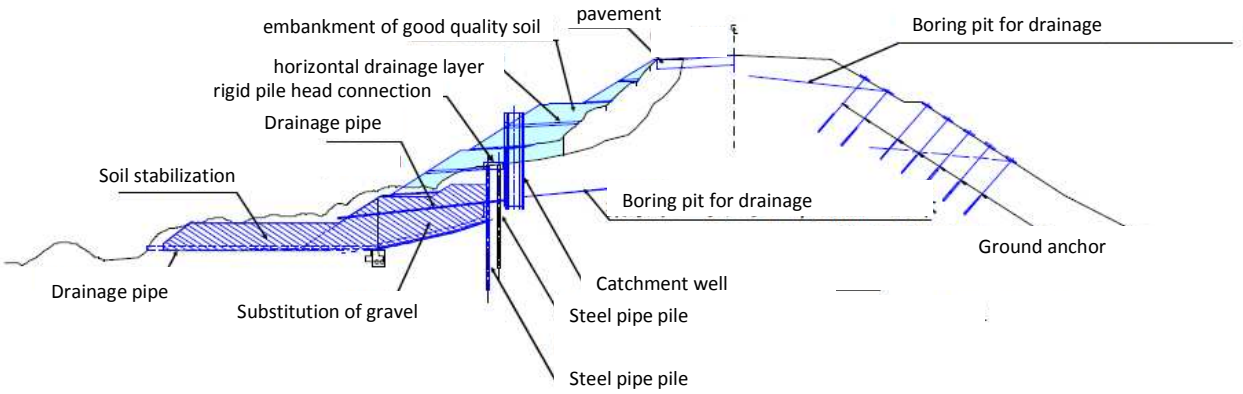

Fig. 3 Cross-section of full-scale permanent work [5]

Photo 5: Full-scale permanent work completed.[5]

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