

For Information

Legislative Council Panel on Transport

**Investigation on
Prestressing Tendon Failure Incident at
Concrete Viaduct of Shenzhen Bay Bridge - Hong Kong Section**

This paper briefs Members on the investigation result of the prestressing tendon failure incident at the concrete viaduct of Shenzhen Bay Bridge - Hong Kong Section (SBB-HK).

Shenzhen Bay Bridge – Hong Kong Section

2. The Shenzhen Bay Bridge, commissioned in 2007, carries a dual three-lane carriageway of about 5.5 kilometres (km) long and spans across Deep Bay between Lau Fau Shan of Hong Kong and Shekou of Shenzhen. The Shenzhen Bay Bridge is divided into two sections according to the Guangdong-Hong Kong boundary, namely the Hong Kong Section and the Shenzhen Section with a length of 3.5km and 2km respectively. The bridge consists of multi-span concrete viaducts and two cable-stayed steel bridges respectively spanning across the navigation channels of Hong Kong and Shenzhen (see **Annex**). The concrete viaduct of the SBB-HK was constructed by precast segmental method with the precast segments assembled by a number of internal and external prestressing tendons on the bridge piers. The Highways Department (HyD) is responsible for the maintenance of the SBB-HK, and professional staff have been employed to conduct routine inspections of bridge structures.

The Tendon Failure Incident

3. During a routine site inspection to SBB-HK on 15 February 2019, a HyD staff discovered an external prestressing tendon of diameter 160 millimetres (mm) at the concrete viaduct of SBB-HK Hong Kong bound near Lau Fau Shan was ruptured. Immediately after the incident, HyD arranged departmental engineers together with professional engineering consultants to examine the structure of the

viaduct. Subsequent to the inspection, it was confirmed that the structure of the viaduct was not affected¹ and no anomalies were identified.

4. HyD immediately arranged maintenance contractors to carry out repair works to replace the ruptured tendon. Temporary traffic arrangement on the SBB Hong Kong Bound was implemented at that time to facilitate structural inspection and maintenance works. Two of the three traffic lanes of the road section concerned were temporarily closed with one traffic lane left to maintain the traffic flow. The tendon replacement works were completed on 14 March 2019 and all traffic lanes resumed normal on 15 March 2019.

Investigation Team for the Tendon Failure Incident

5. An investigation team was set up by HyD to carry out detailed investigation on the possible causes of the tendon failure incident. The investigation team is led by an Assistant Director of HyD with members including departmental engineers as well as three experts on bridges, prestressing systems and materials respectively². The investigation conducted review on four aspects including construction materials, structural design, construction process and maintenance of the bridge.

Investigation Approach

6. The ruptured external prestressing tendon is about 280 metres (m) in length spanning across several piers of a section of the viaduct. The tendon is enclosed in a high-density polyethylene (HDPE) duct filled with cementitious grout materials for protection. The investigation team inspected the ruptured tendon and the anchor heads at its two ends. The residue left at the scene of the tendon failure incident was also examined, with samples collected at various locations along the tendon for testing.

¹ The design of the SBB-HK concrete viaduct and the associated external prestressing tendons has allowed adequate safety margin for the tendon replacement situation. The bridge remains safe and operational under full traffic load even with one of the external tendons removed.

² The three experts are Professor Francis AU Tat-kwong (Head of Department of Civil Engineering at the University of Hong Kong), Professor Neil Colin MICKLEBOROUGH (Adjunct Professor of the Department of Civil and Environmental Engineering of the Hong Kong University of Science and Technology) and Dr. Eric LIM Chaw-hyon (Former Visiting Associate Professor of the Department of Mechanical Engineering of the University of Hong Kong).

7. The investigation team reviewed the design of the viaduct and verified whether the design had followed the design standards and relevant parameters. The investigation also covered information such as technical specifications, engineering drawings and site records for the relevant section of the viaduct under the construction contract, which was used to check against the design information as well as its structural arrangements on site. Furthermore, the investigation team examined the inspection and maintenance records of the concerned section of viaduct in order to review the structural inspection and maintenance works conducted.

Investigation Findings

8. The investigation team concurred that the tendon failure incident had no impact on the structural integrity of the SBB-HK. The detailed investigation on the materials, design, construction and maintenance aspects revealed that the design and materials of the external prestressing tendon system of SBB-HK complied with the design standards and material specifications, and the as-built tendon profile also followed the design requirement. In addition, the investigation team did not identify any anomalies in the maintenance work.

9. The investigation indicated that the tendon failure was due to long term corrosion attack causing deterioration of the structural capacity of the tendon. The investigation team considered that an air pocket had formed inside the tendon duct near the anchor head at the ruptured end, which provided an environment for the tendon to corrode. The reduction in effective cross-sectional area of the tendon due to long term corrosion weakened its strength, and eventually resulted in the rupture of the tendon.

Following-up Actions

10. The investigation team considered that the fundamental cause of the tendon failure was due to incomplete displacement of air during the grouting process. The air trapped inside the tendon duct subsequently formed an air pocket. Upon completion of the grouting process, the tendon duct could not be completely filled with grout to provide sufficient protection to the tendon.

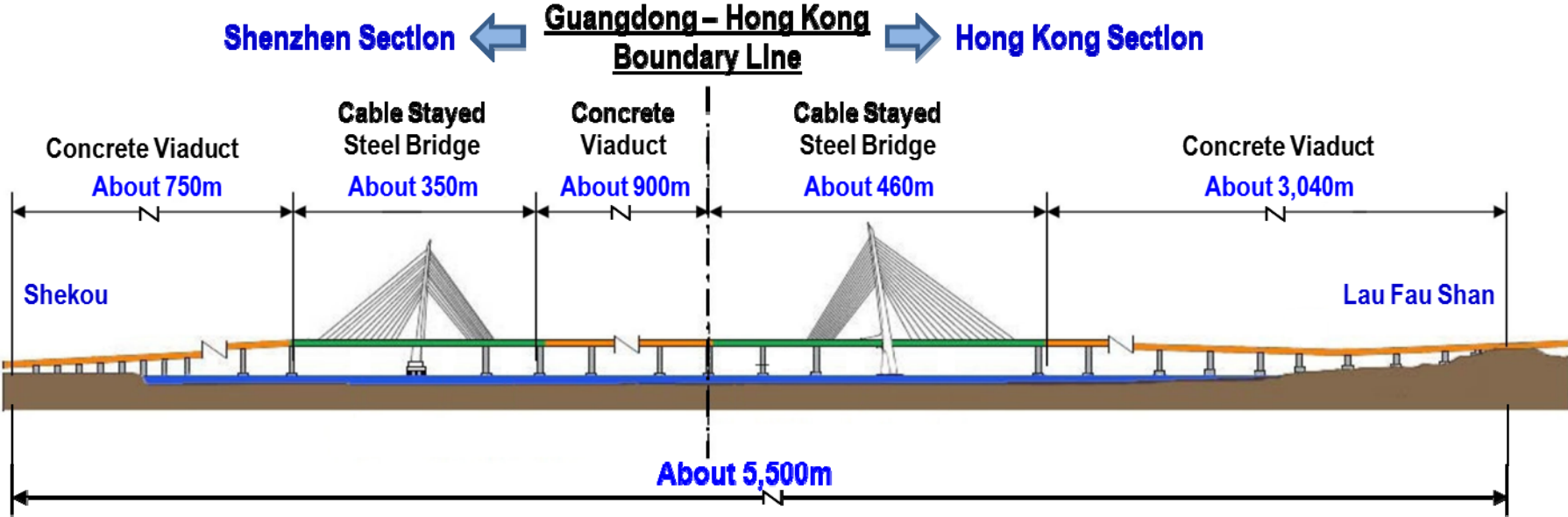
11. Since the anchor heads of tendons are enclosed in protection caps, the investigation team recommended removing the anchor protection caps of all relatively long (i.e. length exceeding 200m) external prestressing tendons of SBB-HK for detailed inspection. The investigation team also recommended the review of the current specifications for grouting, inspection and quality monitoring arrangement of external prestressing tendons, and considering enhancement measures to avoid recurrence of tendon failure.

12. HyD accepted the investigation results and the measures recommended by the investigation team. As at end of June 2019, HyD had removed the anchor protection caps of all 71 tendons of SBB-HK with a tendon length exceeding 200m (excluding the ruptured tendon). Industrial borescope inspection will then be arranged to inspect in detail the condition of prestressing tendons within the anchor heads.

13. In view of the incident, HyD also proactively conducted preliminary inspection to all external prestressing tendons of the bridges and viaducts in Hong Kong being maintained by HyD. The inspection was completed in April 2019 and did not identify any anomaly which required tendon replacement. In addition, HyD would sample some external prestressing tendons of these bridges and viaducts and arrange to remove their anchor protection caps to examine and ascertain the condition of the tendons and anchor heads, with a view to ensuring the structural safety of the bridges and viaducts. Based on the examination results and the condition of the tendons and anchor heads, HyD would review the specifications for grouting and quality monitoring arrangement, and would consider enhancement measures to avoid recurrence of tendon failure.

14. The investigation report on the tendon failure incident has been uploaded to HyD's website (https://www.hyd.gov.hk/en/district_and_maintenance/structures/doc/SBB_HK_Investigation_2019.pdf) (English only, except Executive Summary).

**Transport and Housing Bureau
Highways Department
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Annex - Elevation of Shenzhen Bay Bridge