Report on Emergency Felling of Stonewall Trees on Slope No. 11SW-A/R577 at Bonham Road / St Stephen's Lane on 7 August 2015

1. Background

1.1 At slope no. 11SW-A/R577 between Bonham Road and St. Stephen's Lane, there were six stonewall trees (trees T1 to T6) growing on it (Figure 1.1). All the trees and the stonewall were maintained by Highways Department (HyD).

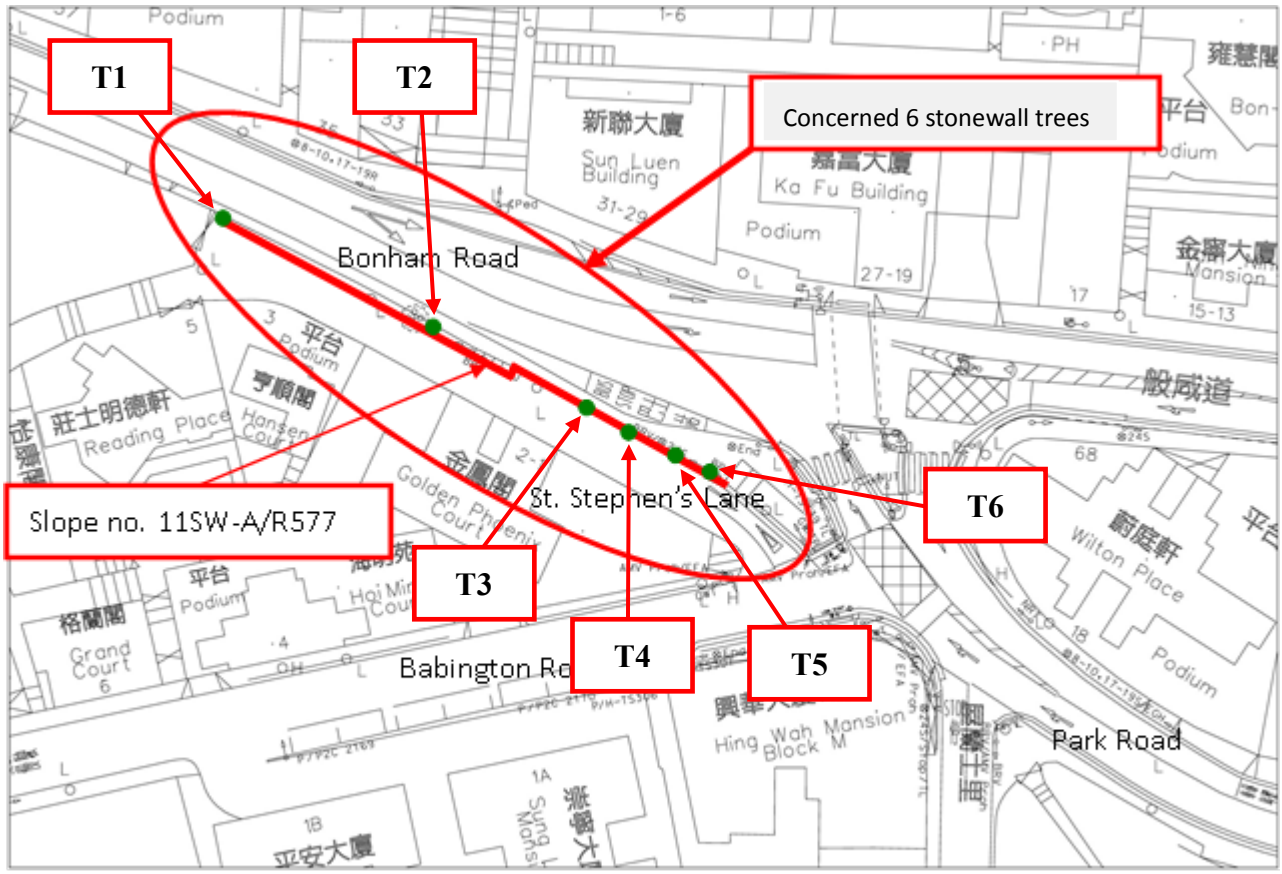


Figure 1.1: Location of the concerned stonewall trees

1.2 The stonewall trees were located at an environment in close proximity to private buildings, busy pedestrian and vehicular traffic on Bonham Road. The consequence of any tree failure, which could be caused by the trees themselves or any other external factors such as adverse weather condition and emergency road excavation at St Stephen's Lane for repairing of underground utilities, would be serious and undesirable.

1.3 In 2013, some signs of risks of root detachment and trunk cavity at trees T4 and T5 respectively were observed. HyD had invited an external tree expert to carry out a study to identify the factors affecting the health and stability of the stonewall trees, formulate suitable maintenance measures for their sustainable growth and advise on mitigation measures to minimize the risk of tree failure (the 2013 Study). The overall view of the trees is shown on Photo 1.1.

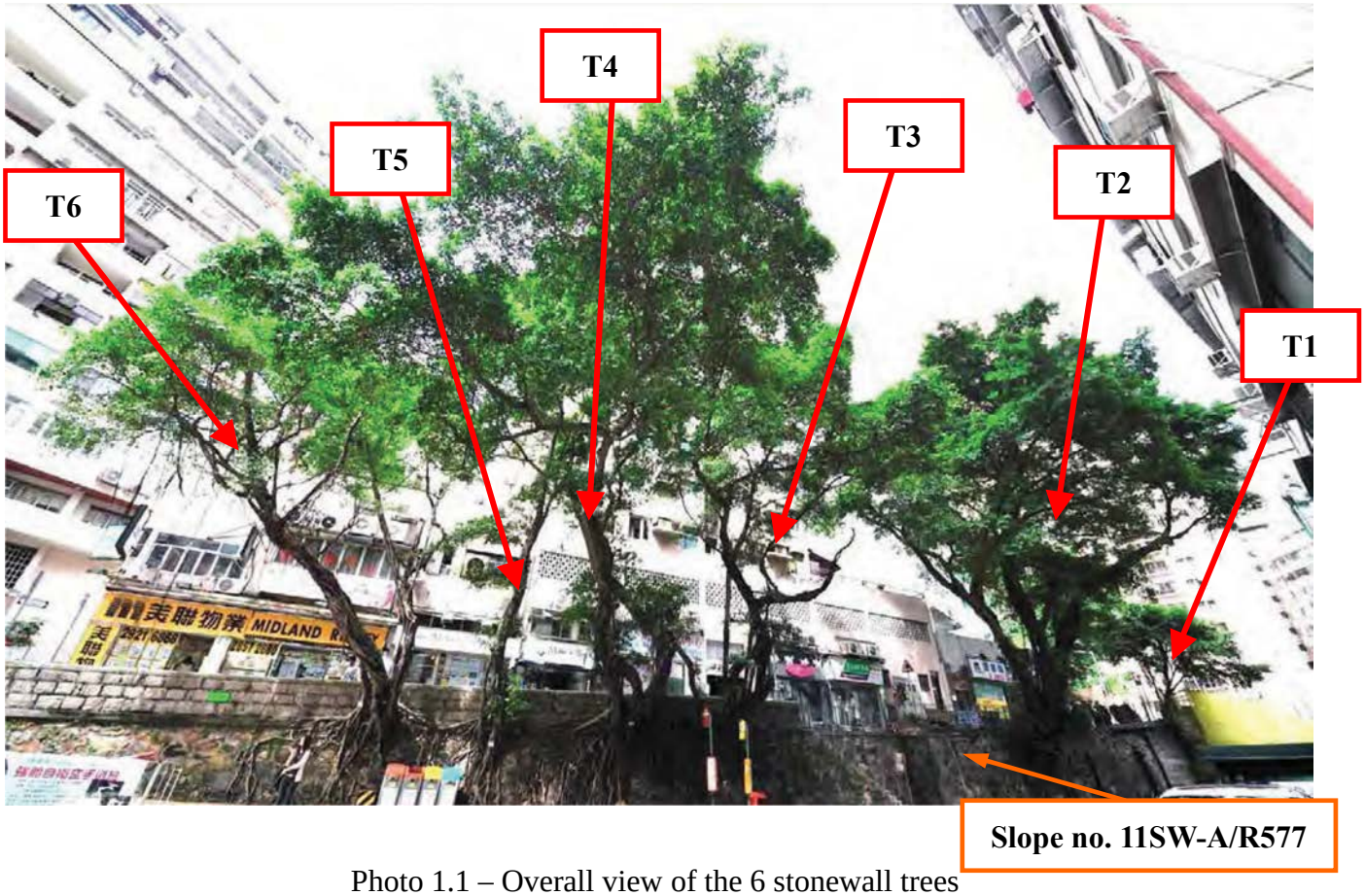


Photo 1.1 – Overall view of the 6 stonewall trees

1.4 The tree conditions as assessed in the 2013 Study are summarized as follows:

(i) T1 – This was a small tree with little structural problem or decay problem. Tree hazard assessment had a score of 5[1] and was rated as **low risk level**.

(ii) T2 – This was an Old and Valuable Tree (OVT) with the Registered Number HYD CW/7. The tree was generally in good health and had a well-formed scaffold. Tree hazard assessment had a score of 5 and was rated as **low risk level**.

[1] Risk score ranges from 3 – 12, from very low risk (score = 3) to high risk (score = 10 – 12).

(iii) T3 – This was a semi-mature size tree with much confined scaffold development. Tree hazard assessment had a score of 5 and was rated as **low risk level**.

(iv) T4 – This was a twin stemmed mature size tree which was the most tilted of the 6 stonewall trees at the site. The tree had low live crown ratio and incipient anchorage failure. Tree hazard assessment had a score of 9 and was rated as **medium risk level.** However, as the tree had one additional risk factor [root detachment from stonewall], it was therefore described as **alarming risk**.

(v) T5 – This was a mature size tree with low live crown ratio, narrow & confined crown and large cavity with decay at the trunk base. Tree hazard assessment had a score of 8 and is rated as **medium risk level.** However, as the tree had one additional risk factor [large trunk base cavity], it was therefore described as **alarming risk**.

(vi) T6 – This was a twin stemmed mature size tree with heavy lean, asymmetrical crown. Tree hazard assessment had a score of 5 and was rated as **low risk level**.

1.5 As the stonewall trees T4 and T5 were identified in the 2013 Study as having alarming risks, HyD had examined in 2013 nine methods to support the trees as follows-

(1) Cables anchor on structural member of a nearby building at St. Stephen's Lane
(2) Cables tie-in on steel frame to be anchored at St. Stephen's Lane
(3) Installation of supporting frame beneath the trees with supports at stonewall and Bonham Road pavement
(4) Cables anchor at the crest of stonewall
(The above four methods were proposed in the external tree expert's study report)
(5) Cables anchored on vertical structural members in front of shops at the St. Stephen's Lane
(6) Cables anchored on vertical structural members away from the concerned locations
(The above two methods were proposed by Expert Panel on Tree Management)
(7) Steel post support at Bonham Road southern footpath
(8) To cover the bus stop and the section of footpath underneath the two concerned trees T4 and T5

(9) Support by structural steel frame from opposite footpath at Bonham Road
(The above three methods were included by HyD for further study.)

After detailed examination, all the above methods were considered not feasible mainly due to the various actual site constraints (e.g. congested and narrow carriageway and footpath, heavy traffic, existence of major underground utilities, etc).

Finally, having consulted Central and Western District Council, HyD carried out major pruning works on trees T4 and T5 in 2013 to mitigate the risk of collapse.

1.6 HyD continued to maintain close monitoring on the six stonewall trees.

2. Tree T2 Collapse Accident of 22 July 2015

2.1 On 22 July 2015 at around 12:00 noon, tree T2 collapsed suddenly. Bonham Road was blocked totally by the collapsed tree in a toppling manner. Moreover, a male newspaper vendor and a female pedestrian were injured. A truck passing by was hit and damaged. The buildings facing the collapsed tree at the opposite side of Bonham Road and the escalator cover at Centre Street were damaged.

Photo 2.1 – Tree T2 collapsed on 22 July 2015

2.2 During the incident, the stonewall was also damaged. GEO confirmed that it was not a landslide incident. The caved-in portion was localized around the root of the tree. The other portion of the stonewall appeared to be intact and did not exhibit any sign of distress.

Photo 2.2 – Stonewall Damaged together with Tree T2

2.3 HyD, TMO and GEO conducted joint site inspection immediately after the incident. At the parapet wall behind tree T3, which was supported and connected to the top of the stonewall, five cracks were found. No such cracks were observed at the parapet wall behind trees T4, T5 and T6 (there was no parapet wall but just railing at the location of tree T1) at that time. HyD and TMO assessed that the cracks were an alarming sign of the tree anchorage instability and there were risks of imminent collapse of tree T3.

2.4 Based on the above findings, it was decided to remove tree T3 as soon as possible for the sake of public safety. The tree felling works was done on the same day. For the remaining four stonewall trees, pruning was carried out on the same day to mitigate risk of collapse.

3. Review of Tree Collapse Accident on 22 July 2015

3.1 After the tree T2 collapse accident, HyD reviewed the possible cause of tree collapse.

3.2 Generally speaking, there were four possible failure modes for stonewall trees (see **Diagram 1**) as follows –

A. Tree trunk failure : This mode of failure would be due to structural failure of the tree trunk itself such as decay of the trunk. This mode of failure would not have significant damage to the stonewall;

B. Root detachment failure : This mode of failure would be due to the tree root not able to securely attach to the stonewall. This mode of failure also would not have significant damage to the stonewall;

C. Tree anchorage shallow failure : This mode of failure would be due to failure of the tree anchorage. The root of the stonewall trees normally would not only grow on the surface of the stonewall, but would also intrude into the stonewall core or beyond into the ground behind the stonewall. The root on the surface of the stonewall together with the root intruded into the stonewall core or beyond would form a tree anchorage supporting the tree, with the anchorage depth and extent varies depending on the engineering condition of the stonewall, the ground condition behind and the growth condition of the trees. The occurrence of shallow failure of tree anchorage would cause localized damage to the stonewall around the root of the tree; and

D. Overall failure : This mode of failure would be due to the significant weight of the stonewall tree itself and the significant external loading like strong wind, etc captured by the tree crown causing the overall collapse of the tree and the stonewall as a whole. This mode of failure would have substantial damage to the stonewall. Such an overall failure is rare and there is no record of its occurrence in the past.

3.3 For the collapsed tree T2, it was grew on and supported mostly by the upper part of the stonewall body. The tree trunk did not show any symptom of decay. Moreover, part of the stonewall collapsed together with the stonewall tree. The damage to the stonewall was nevertheless localized around the root of the tree, while the other portion of the stonewall appeared to be intact and did not exhibit any sign

of distress. From the caved-in left behind by the collapsed tree, root intrusion to the stonewall core was observed. It was considered that the tree collapse was due to the failure of the tree anchorage at the upper part of the stonewall body (i.e. failure mode C as described in paragraph 3.2) as a result of the dead weight of the tree and the external loadings at the time of collapse, like wind and rain water intercepted/absorbed by the tree. There was no sign that the collapse was caused by any instability of the stonewall itself.

4. Monitoring of the Remaining Four Stonewall Trees

4.1 After the accident of 22 July 2015, HyD closely monitored the conditions of the four remaining stonewall trees.

4.2 The growth situation of the four stonewall trees was similar to the collapsed tree T2 and the felled tree T3. The tree T1 was located on the west of tree T2 and was similarly grew on and supported mostly by the upper part of the stonewall body. For the trees T4, T5 and T6 locating on the east of tree T3, there was a parapet wall supported and connected to the top of the stonewall. The trees similarly grew on and were supported mostly by the upper part of the stonewall body, while some of the roots also grew on the parapet wall. Please refer to **Diagram 1** for a typical section of the stonewall trees.

4.3 On 3 August 2015, HyD, TMO together with members of Expert Panel on Tree Management attended a joint site inspection to the stonewall trees. During the site inspection, members provided some suggestion to strengthen the stonewall trees as follows:

a. Opening up the carriageway at St. Stephen's Lane behind tree T1 as a trench of about 2 m width to facilitate root growth;
b. Setting up cable anchors to buildings at St. Stephen's Lane to support trees T4, T5 and T6; and
c. Setting up cage system at Bonham Road to encase trees T4, T5 and T6.

4.4 Regarding suggestion (a), GEO was consulted on its potential implication to the stability of the stonewall. Given the concern on the rain water infiltration into the soil behind the stonewall which would have detrimental effect to its stability and the site constraint preventing the addition of any further protection works, suggestion (a) was considered to be not feasible. Regarding suggestions (b) and (c), they were similar to those alternative options studied in 2013 which feasibility could also not be established.

4.5 On 5 August 2015, 11 new cracks were found at the parapet wall behind T4, T5 and T6 (Refer to **Diagram 2**). The cracks were not noticed during the inspection of 3 August 2015. HyD immediately stepped up monitoring the situation.

4.6 On 6 August 2015, HyD noticed that the situation of the cracks had worsened and carried out measurement on the width of the cracks. (Refer to **Annex 1**) Together with the five cracks found at the parapet wall behind tree T3 before, a total of 16 cracks were found with the greatest width of about 2cm. They were located at different parts of the parapet wall close to the tree anchorages. Please refer to **Annex 2** for photo records of the cracks.

4.7 On 7 August 2015, HyD, TMO and GEO carried out a joint site inspection to further assess the situation. The crack condition was rechecked and crack width reconfirmed. Moreover, at the U-channel nearby the crest of the stonewall at St Stephen's Lane, a longitudinal gap of about 1.5cm wide along the side of the U-channel close to the stonewall was found (Refer to **Diagram 2**). Another longitudinal gap behind the coping of the stonewall where tree T1 was located, as well as a transverse crack cutting through the same coping, were also found. These cracks and gaps were additional to the five cracks noticed previously. Please refer to **Annex 3** for photo records of the gaps.

5. Tree Stability Assessment

5.1 From the above new findings since 5 August 2015, HyD immediately reviewed the situation together with TMO and GEO on 7 August 2015. The cracks and the gaps found in a short period of time were signs indicating that the tree anchorage had displaced outward. The findings were considered as an alarming sign of the tree anchorage instability.

5.2 It was considered that the cracks found at different parts of the parapet wall were caused by lateral forces exerted on the wall and displacements of the parapet walls had occurred. These cracks also indicated that the integrity of the part of the tree anchorage connected to the parapet wall had already been hampered and its contribution to the resistance to the toppling of trees T4, T5 and T6 had also been weakened.

5.3 Further, the longitudinal gaps throughout the length of the U-channel at the crest of the stonewall was also considered to be another alarming sign of displacement which had occurred at the tree anchorages located at the upper portion of the stonewall.

The gap indicated that displacement had occurred at the base of the parapet wall and the crest of the stonewall. Such sign of instability, together with the parapet wall cracks, occurring at the top part (tension part) of the tree anchorage, could have detrimental effect on the resistance to tree toppling. Besides, such gap of persistent length might penetrate to a depth along a significant stretch of the stonewall crest. It could induce a tree anchorage shallow failure (similar to that of the collapsed tree T2) to any of trees T4, T5 and T6. The combination of the cracks at the parapet wall and the gap at the U-channel increased the likelihood that the root anchorage of the trees was being compromised, which in turn increased the likelihood of their destabilization. They might fall together with parts of the stonewall crest (as evidence in the collapsed tree T2) and a significant stretch of the parapet wall.

5.4 Trees T4, T5 and T6 (unlike the collapsed tree T2) were located close together and their roots might have interwoven together both on the surface and behind the stonewall. Upon failure of any one of the trees, the collapsed tree would induce a pulling force through the interwoven root swamp causing instability to adjacent trees as well. All the three large stonewall trees might hence collapse as a whole in seconds. The scale of collapse could cover an extensive area leaving little chance for the pedestrians and vehicular traffic passing by to escape from being hurt. The passengers waiting at the bus stop underneath the trees would be hard hit. In view of the tallness of the trees, the lower levels of the residential buildings and the ground level shops on the opposite side of Bonham Road would also be extensively damaged. The consequence of failure if occurred at busy hours could be disastrous.

5.5 Tree T1 was located on the western most part of the stonewall in isolation. Unlike the other large trees T4, T5 and T6, its root system mainly developed at the gap between the stonewall and the adjoining wall of the nearby private development. Under such an adverse condition, the extensiveness of the root system and hence its stability to anchor the tree was in doubt already. The longitudinal gap at the back and the transverse crack across the coping of the stonewall also indicated that displacement had occurred at the tree anchorage zone with resistance against toppling of the rapidly growing tree T1 reduced. The weakened tree anchorage could fail at shallow depth locally at the crest of the stonewall.

5.6 Unlike tree T4, T5 and T6 which might fail as an integrated system, tree T1's collapse if occurred could happen on its own and with a less extensive affected area. Even though it was the smallest stonewall tree at the location, its falling height would be the greatest one. As such, the risk of causing loss of human life (e.g. the collapse of a private tree at Robinson Road in 2014) and significant damage to vehicular traffic and property could not be underestimated, particularly on a busy

road like Bonham Road.

5.7 HyD assessed that there were risks of imminent tree collapse similar to the accident of 22 July 2015. As the tree concerned had already been substantially pruned on 22 July 2015, the development of new cracks and gaps cast doubts on the effectiveness of the pruning works. The risk of collapse could not be entirely alleviated by another round of extensive pruning. Various options of supporting system installation have been studied in detail in 2013 and their feasibility was also considered not feasible.

6. Conclusion and Action

6.1 The risk of sudden tree collapse, be it a large scale collapse with tree T4, T5 and T6 as a whole or an individual collapse of tree T1, was determined to be apparent and imminent by a multidisciplinary expert team of geotechnical engineering, civil engineering, arboriculture and landscape architecture professionals. Given the alarming sign of tree anchorage instability, failure could occur any time. The consequence could be disastrous.

6.2 Pruning could not entirely alleviate the risk of collapse. The feasibility of providing alternative means to effectively stabilize the trees which had been examined in details in 2013 was not forthcoming. In the absence of any other feasible mitigation measures and with an impounding thunderstorm outlook on 7 August, HyD considered that the removal of the trees as soon as possible was urgently required to ensure public safety, which was endorsed by TMO. Central and Western District Council had been informed before the removal of the trees.

6.3 The tree removal works was commenced at about 8:00pm of 7 August 2015 and was completed at around 4:00am of 8 August 2015.

Highways Department
August 2015

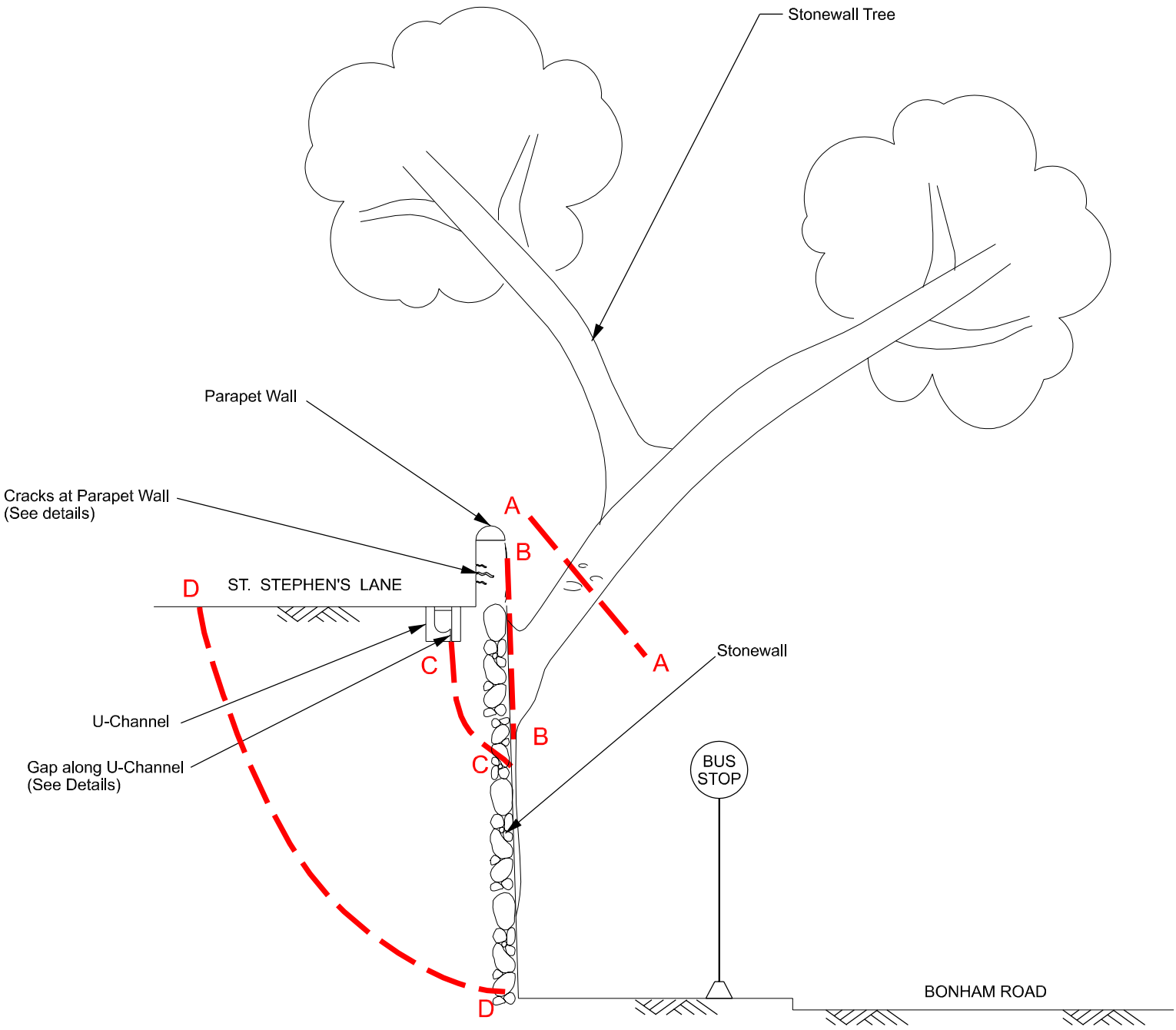
Possible Failure Modes :

A Tree trunk failure

B Tree root detachment from stonewall

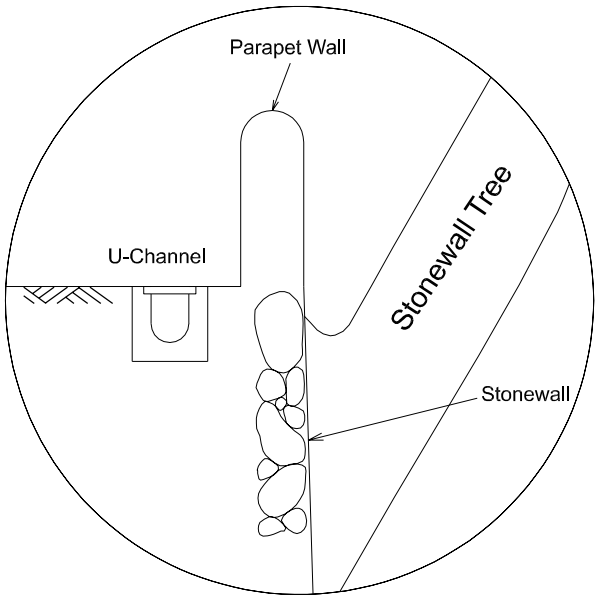
C Tree anchorage shallow failure

D Overall failure

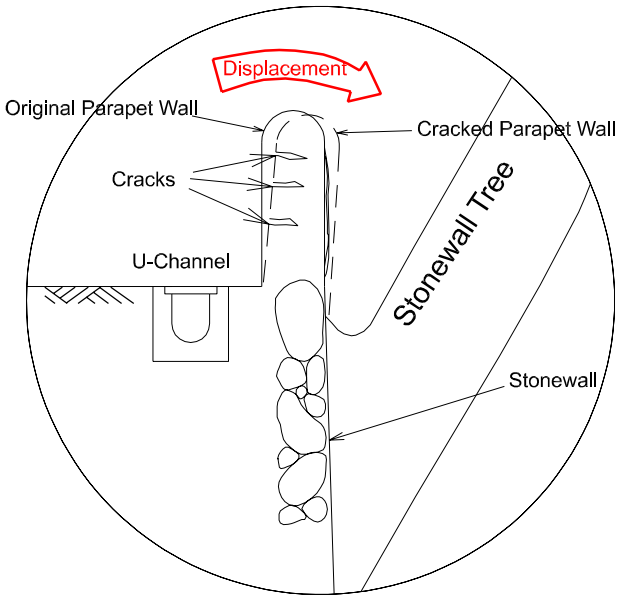


Original Stonewall Trees at Bonham Road

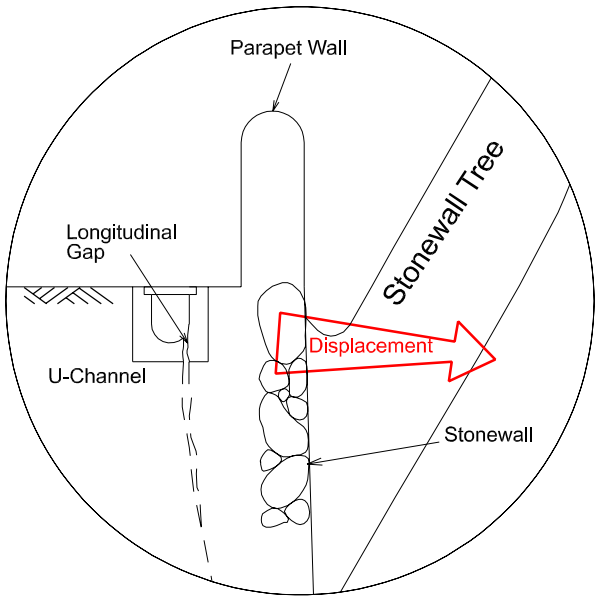
Diagram1



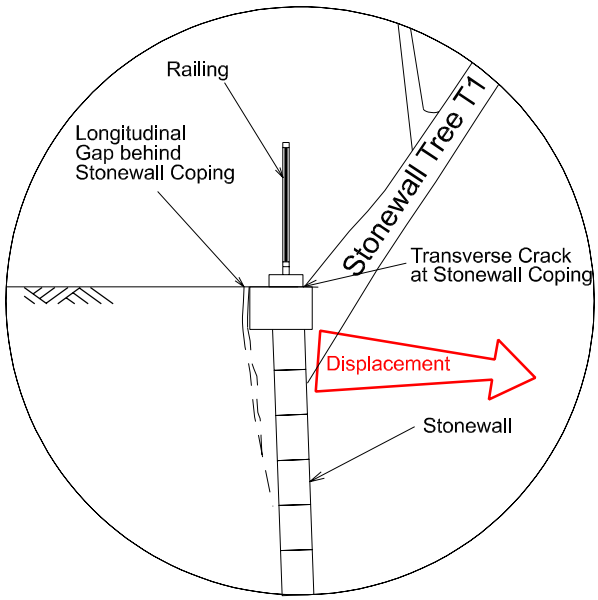
Original Stonewall Tree Section



Cracks at Parapet Wall



Longitudinal Gap at U-Channel



Longitudinal Gap behind Stonewall

Diagram 2

Location: BONHAM ROAD Slope No.:11SW-A/R577
Monitoring of cracks

Crack P.11 (2015-08-05)

Crack P.11 (2015-08-06)

Location: BONHAM ROAD Slope No.:11SW-A/R577
Monitoring of cracks

Crack P.5 (2015-08-05)

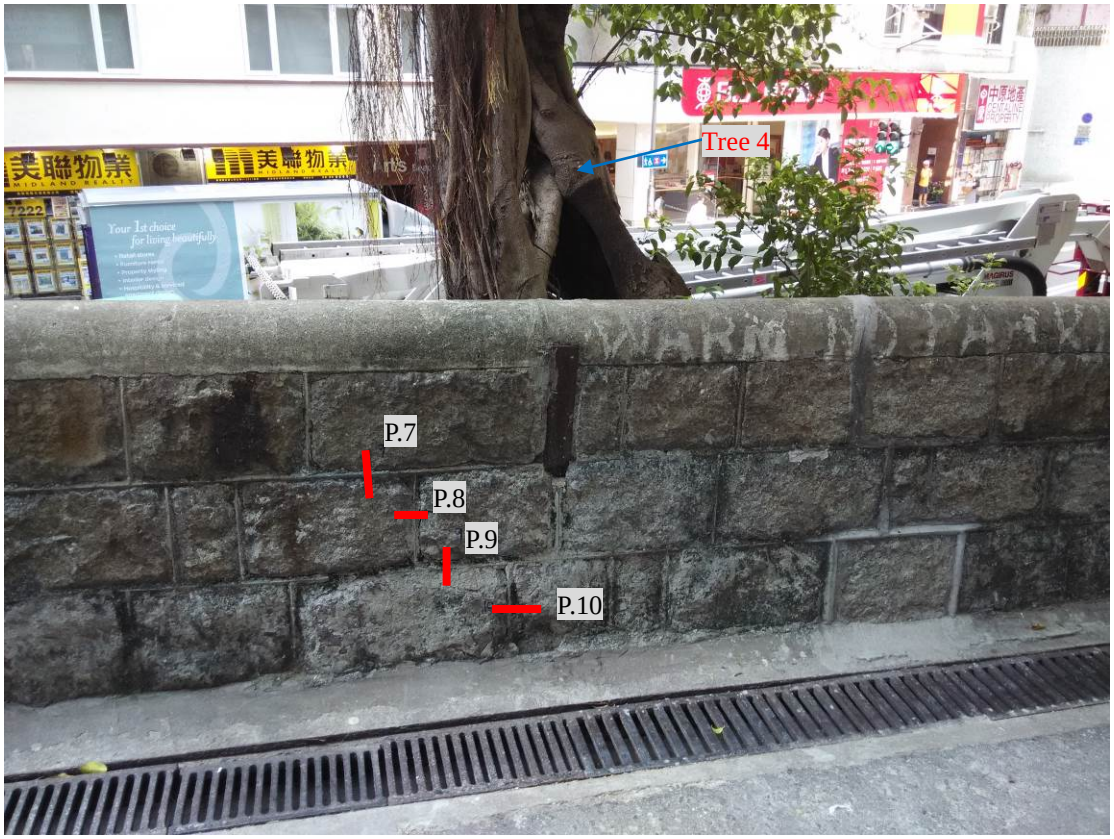
Crack P.5 (2015-08-06)

Location: BONHAM ROAD Slope No.:11SW-A/R577
Monitoring of cracks

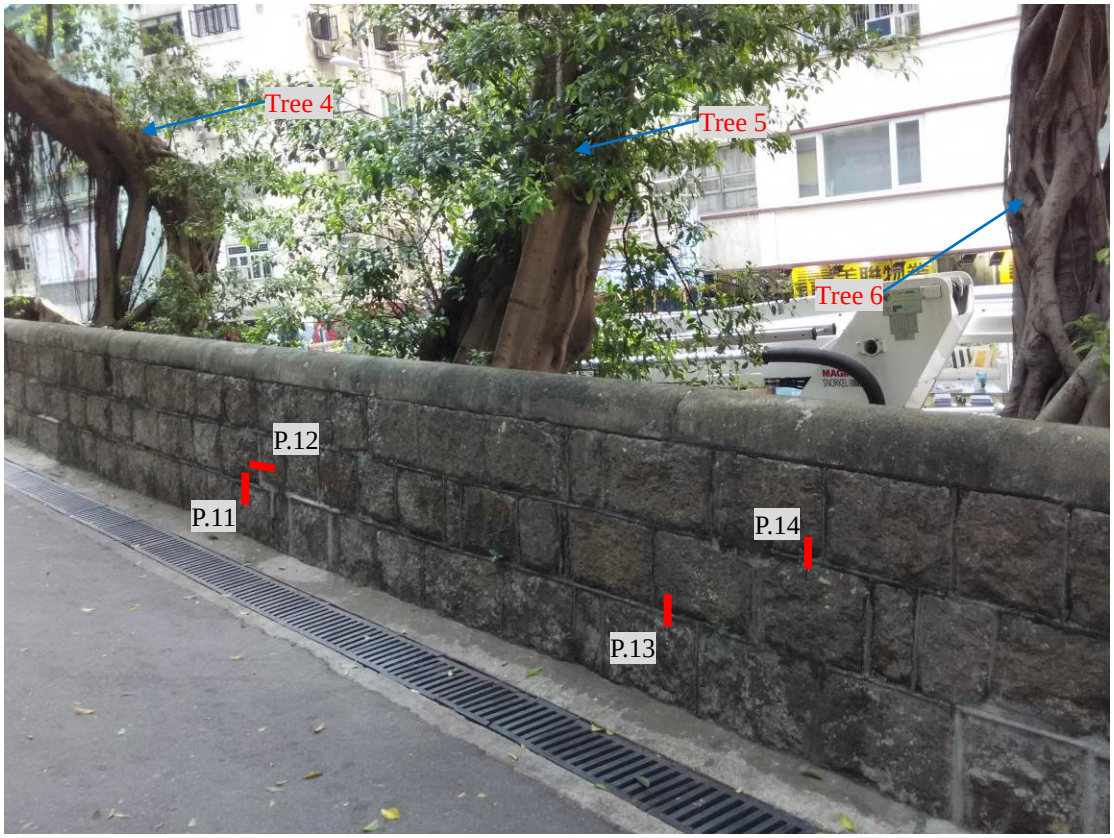
Crack P.2 (2015-08-05)

Crack P.2 (2015-08-06)

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015



Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015



Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.1 – 24mm

Crack P.2 – 10mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.3 – 5mm

Crack P.4 – 5mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.5 – 6mm

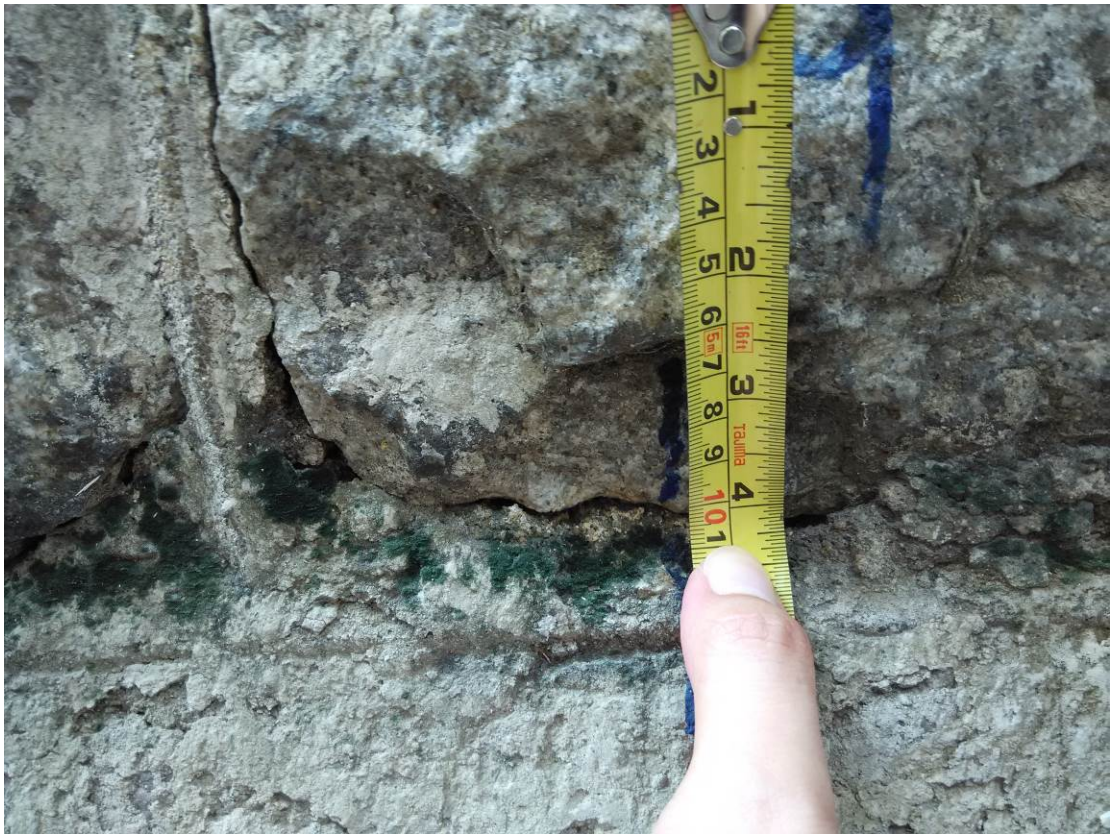
Crack P.6 – 3mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.7 – 3mm

Crack P.8 – 5mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015



Crack P.9 – 2mm

Crack P.10 – 5mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.11 – 10mm

Crack P.12 – 2mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.13 – 8mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.14 – 12mm

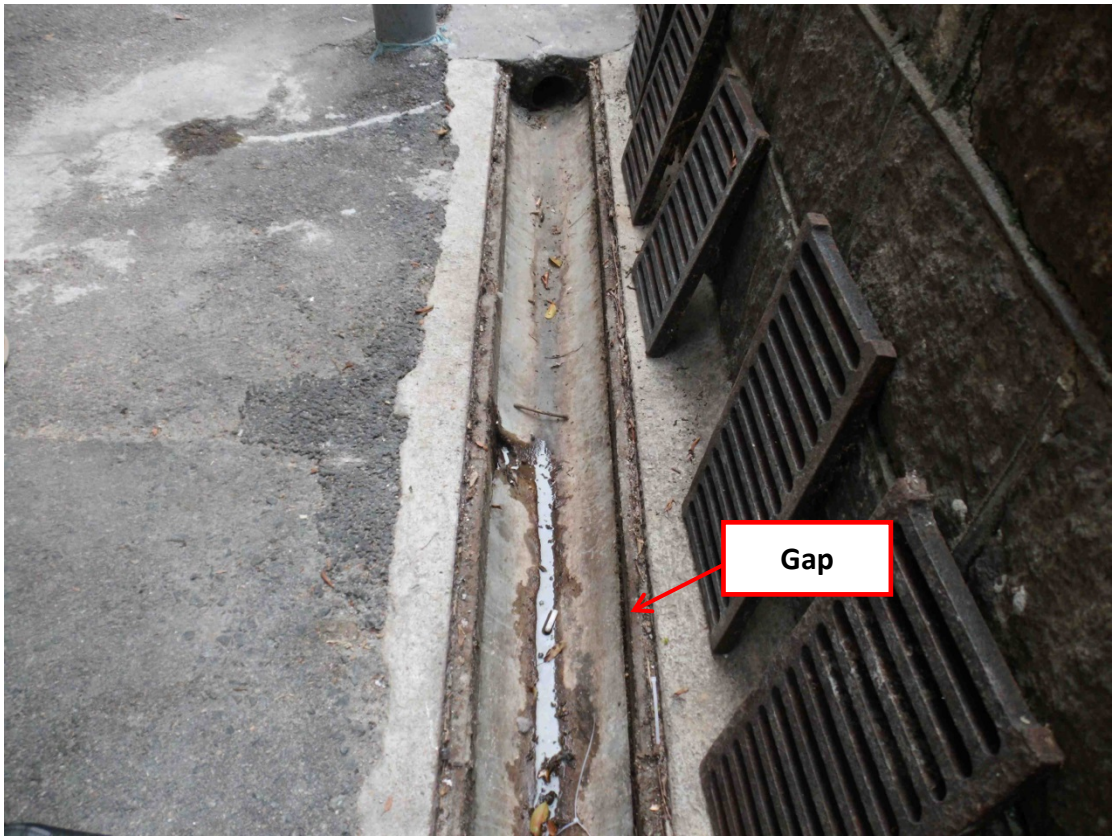
Crack P.15 – 10mm

Location: BONHAM ROAD Slope No.:11SW-A/R577
Site Inspection Date: 06-08-2015

Crack P.16 – 14mm

Record of 15mm wide longitudinal gap found along the side of a U-channel at the coping of stonewall

Record of 15mm wide longitudinal gap found along the side of a U-channel at the coping of stonewall



Annex 3

Record of longitudinal gap found along the back of copping of stonewall near tree T1 and transverse crack through the same coping