SUCTION EFFECTS ON RIPRAP PROTECTION AROUND BRIDGE PIERS

YEE-MENG CHIEW and YAN LU

This study investigates the performance of riprap protection around a bridge pier under the influence of bed suction. Published studies have identified five main failure mechanisms associated with riprap failure around bridge piers without suction. They are shear failure, winnowing failure, edge failure, bedform-induced failure and bed-degradation induced failure. The aim of the experimental study is to examine how suction affects riprap layer as a pier-scour countermeasure.

The range of flow velocity in the study ranges from u/u_c = 1.1 to 1.8 where u = undisturbed mean velocity; and u_c = critical mean velocity for sediment entrainment. This range of velocity allows tests to be conducted not only on a flat bed but also on a dune-bed. Since a comparatively large riprap stones with a median diameter = 30 mm were used, there is no shear failure in all the tests. Only winnowing failure and bedform-induced failure were observed depending on the experimental flow conditions. Suction was produced at three locations, including one just beneath the riprap layer in order to determine a practical arrangement for the efficient use of bed suction to enhance riprap protection.

Observations showed that degradation of the riprap layer is predominantly due to winnowing failure for the case of u/u_c = 1.1 and 1.4 when only 1 suction pipe was used. Under these flow conditions, the approaching bed is essentially flat with negligible dune height. Published studies have shown that suction has a tendency to reduce the turbulence intensity in a flow. The present experimental data reveal that the depth of riprap layer degradation decreases with suction. This observation is a reflection of the reducing turbulence intensities due to suction because the extent of winnowing failure is decreased under this condition. The data confirm that suction can reduce the threat of winnowing failure by decreasing the level of turbulence around the pier. A reduction in excess of 50% was measured when the suction ratio, Q_s/Q = 0.82% with one suction pipe is used.

In the case of u/u_c = 1.8, dunes were observed on the approaching bed. Under this condition, winnowing failure is not necessarily the dominant failure mechanism; observations showed that bedform-induced failure is the most critical in affecting riprap stability, consistent with published results. Experimental data show that on a dune bed, suction can affect the stability of pier-riprap in two ways:

It increases the height of dunes resulting in an increase of the threat of bedform-induced failure; and

It decreases the turbulence intensity around the pier.

The overall stability of the riprap layer depends on the relative magnitude of these two opposing effects. In the series of experiments (u/u_c = 1.8) conducted with a small suction rate (e.g., Q_s/Q = 0.11%), the depth of riprap degradation reduces more than that without suction, which may be interpreted as that the positive effect induced by a decrease in turbulence intensities is more than the negative effect induced by the increase in the dune height. With higher suction rates (e.g., $Q_s/Q = 0.41\%$) on the other hand, the negative effect becomes more significant resulting in a smaller %RDP. It must be pointed out that the above results are still very preliminary presently and further tests are needed to examine how the location of the seepage pipes will affect riprap stability. Moreover, injection, which has a tendency of reducing dune height and increasing turbulence intensity, still has not been tested.