Coastal structure toe management workshop

TALK 1: ANDY BRADBURY

- The aim of the workshop was to exchange information between contractors, engineers and scientists and share best practice knowledge with people new to the industry.
- There is often some confusion as to what the actual "toe" of a seawall structure is: it is not necessarily where the visible portion of the seawall meets the surface of the beach – the true toe may (and often does) lie below this level.
- Recently a study has been commissioned by the EA and undertaken by HR Wallingford, to document best practice of the management of toe scour at coastal structures. This study recently went to review, and one criticism was that much of the guidance was difficult to implement and carry out on-site due to the technicality of the guidance.
- The reality is that most beach managers are *maintaining* 50 year old structures rather than building new structures. There therefore needs to be more practicality in any best-practice guidance, which focuses more on asset management (monitoring) and maintenance rather than avoidance of scour from the initial design stage.
- After the wake of the 1953 storm, many coastal structures were built along the South Coast and remain today. Since many of these seawalls were built with an approximate 50 year design life, many of these structures are now coming towards the end of their serviceable life.
- If the seawalls were not built in the wake of the 1953 storm, the likelihood is that they are of Victorian origin. These structures were built primarily as a promenade and not as a coastal defence. They were often poorly designed (with respect to coastal defence) and probably had a much wider beach/inter-tidal area fronting the structure than is present today.
- Today we are therefore left with a legacy of ageing coastal defences, with little investment available for new coastal infrastructure. The emphasis is therefore heavily on maintenance of these structures rather than capital spending.

- Undermining of the toe is the most common cause of seawall failure (over 90% of all seawall failure begins with undermining of the toe).
- The familiar process of failure begins with draw down of fronting beach material during a storm, exposing the toe to direct wave loading, which promotes core material loss, thereby creating a void inside the structure, which leads to decking collapse on the promenade.
- The aim must be to *avoid undermining* in order to *avoid loss of core material*.
- Many seawalls are Gravity Walls; this is to say that there is both a landward and seaward load acting on the structure, and the mass of the

structure is held in place primarily by it's weight. The toe, therefore, plays an important role in preventing the structure from overturning.

- When the beach level lowers, the stability provided by the fronting beach disappears and the seawall then has an uneven load acting on it (being pushed seaward). If the beach level continues to drop, a scour hole may form and undermine the toe of the structure. This makes the structure considerably more unstable and likely to overturn.
- Surprisingly, a lot of seawalls are *not* founded on a hard bed rock – many will extend down only to a clay level or even within the overlying gravel beach.
- For the majority of the time, seawalls are not under load. However, for short periods of time they are under massive loads. Failure can occur within hours.
- Before the South-east Regional Coastal Monitoring Programme (SERCMP) the problems were dealt with post-storm by the coastal engineers, but there was very little knowledge of the processes and events directly leading up to the event. Pre and post-storm topographic and hydrographic monitoring improves the accuracy of trigger levels (e.g. critical, alarm and known failure beach volumes and levels).
- By using monitoring data, the performance of the beach/structure under certain storm conditions can be understood. These trends can then be extrapolated to larger events and can be a powerful indicator of defence performance under storm conditions.
- However, post-storm surveys do not always capture the magnitude of beach lowering that occurs in front of a structure. Investigations using scour monitors show that beach lowering coincides with high water during storm events, and some subsequent build up of material (beach recovery) occurs by the time low water is reached. Since post-storm surveys usually take place around low water, they therefore do not capture the full magnitude of beach lowering around the structure toe. However, there is very little data to verify whether this tidal difference in toe scour is commonplace or significant.
- Where the monitoring data is not available, there are other indicators of beach change. One indicator, for example, is where access steps that are built into the seawall structure are left high and dry.

- There is a disparity between the industry-standard guidance and the practicality of carrying out this guidance. For example, to define accurate trigger levels, the guidance may suggest to carry out a structural analysis on the seawall structure to determine the likelihood of overturning under certain wave loadings. However, in practice, engineers managing structures that are 50 years old or older rarely have original design drawings, and even more rarely have as-built structure drawings available to carry out these type of analyses.
- Therefore, a proper structural analysis cannot be carried out because assumptions need to be made about the seawall structure. For example

when the Milford seawall failed in 2008, it was found that sheet piling at the toe of the structure only extended down some 0.6m whereas it was previously assumed they would extend down much further than this (at other locations, piling can extend down some 6 or 7m).

- After undermining of the toe, there can be abrasion of the concrete toe. These rates can be up to 15mm/yr at some locations (e.g. At Selsey – David Lowsley). These abrasion rates can be used when estimating the residual life of a structure.

- Kinking can also occur in walls when fronting beach levels drop; direct wave loading at the toe causes differential pressures to build up behind the structure (standing water – lack of drainage), which pushes the structure seaward, allowing core material to be sucked out promoting structural instability and eventual failure.

- There have been a variety of different design responses to toe scour problems visible along the South Coast:
  1. Addition of a scour apron
  2. Rock infill of the scour trough
  3. Toe modifications
  4. Underpinning / encasement of the seawall toe
  5. Thrust block and piled seawall toe
  6. Timber bulkhead with rock toe protection
  7. Scour mattresses with gabions
  8. Concrete slope revetment (built in front of seawall)
- All of these responses, however, are chasing the problem seaward. This problem is self-inflicted because we build wave-reflective structures which often promote beach lowering, which leads to scour and structure failure.

TALK 2: DAVID LOWSLEY

- In 2007, there was a seawall failure at Selsey
- There were no obvious indicators prior to the seawall failure; piles were vertical, and beach levels, although low, had been at similar levels for approx 3 years
- In February 2007 a single enormous swallow hole appeared behind the seawall
- The toe apron had collapsed (the toe fixing to the apron had failed), core material was sucked out, the seawall cracked and a large void appeared
- The structure failed after an event that was not especially large
- The cause of the failure was probably the sustained low beach levels which caused undermining, the high rainfall and runoff that had occurred that year and the weak surrounding geology (which includes fine white sand, that almost dissolves when exposed to wave action).

- In addition, it was found that a Tertiary relict river channel ran underneath the structure which may have contributed to collapse. During seawall reconstruction, sheet piles were driven down approximately 7m because of the unconsolidated sediments in this relict channel. However, every third pile was left shorter so that any fines washed out along this channel area wouldn't distort the piling and toe protection.
- Because immediate access for personnel was unsafe emergency repairs involved pumping concrete over the inside edge, and dropping rip rap into the void to provide interim coastal protection and to prevent further cliff recession and loss of cliff-top properties.
- More substantial works followed. A tipping barge dropped rock in front of the seawall structure, and a seal was placed on the front of the repaired seawall. To maximize the opportunity of the use of the barge, works were also carried out to sites adjacent the area of failure where beach levels were also very low.
- Around £55,000 was spent on the initial emergency works, around £60,000 was spent on the additional works and around £800,000 was spent on the reconstruction of the seawall. However, it was concluded that the cost of doing nothing was greater, as there are 18 properties in danger on the cliff-top. Therefore the cost: benefit ratio was strongly in favour of repair works.

- There is no duty for the council to carry out maintenance works (according to the Coastal Protection Act).
- If this collapse had occurred in 2011, Chichester Council probably would need to seek contributory funding from residents to meet the cost of the repairs.
- ***Suggestion from Nigel Eglon (Civils):*** it is important to find the problem before failure. There is a need to monitor the back of the structure as much as the fronting beach. Leaking of fines from the core often begins some time before final structure failure. It would be a good idea to have inspection chambers (retrofitted) along many seawall structures along the South Coast, so if fines had been leaching out of the core then grouting could be pumped in to stabilize the leak, before more expensive and dangerous structure failure occurs.

TALK 3: PETER FERGUSON

- In August 2007 there was a healthy, wide beach at Milford-on-sea
- By August 2008, there was almost no fronting beach (levels were close to the underlying clay line).
- Reduced beach levels led to the failure of one of the timber groynes due to increased wave loading, further exacerbating the problem.

- On the 18th of August 2008 wave overtopping of the seawall occurred due to the lack of a beach. This was by no means a severe event (with an Hs of 1.2m (at high tide)), albeit unseasonal conditions for August.
- At this time, the underlying sheet piling toe at the base of the wall had become exposed; however, it was assumed that the piles were structural and several metres in length.
- After a couple of days of being exposed at the toe of the structure, the piles started to (unexpectedly) become loose and move about under wave action.
- NFDC immediately arranged for rock to be brought in to protect the base of the wall. Fortunately, NFDC had already sourced rock for another job and rearrangements were made for this rock to be diverted to the site instead.
- Daily surveys were being carried out to check for any movement occurring to the seawall, decking, retaining wall and promenade.
- Unknown to NFDC at the time the sheet piling was non-structural and averaged 1.4m in length. The piles barely penetrated the underlying clay.
- Inspections showed that many piles quickly failed and became separated from the base of the wall leading to the seawall becoming undermined and allowing waves to penetrate below the toe and wash out / suck out the core fill material from behind the seawall and below the decking slabs.
- The removal of material led to a cavity of approximately 500m^3 forming under the decking slabs. The unsupported decking subsequently led to collapse occurring on 24th August 2008.
- The failure had occurred during conditions that were not unusual – the wave height was not especially large and the failure occurred during the summer period.
- There was the worry that if the promenade retaining wall (above & behind the seawall) were to collapse, it would endanger the structural integrity of the White House (a seafront building housing 14 flats).
- The first stage of the response was to call a search & rescue team from the fire service to check that no one was trapped beneath rubble in the cavity area; this was a concern especially since the collapse occurred on an August bank holiday weekend when beach hut & beach users may have been present in the area. Fortunately no-one was found and the site was closed and made safe.
- The communication stage involved many different organisations (the EA to secure emergency funding, the MMU to deal with licensing issues involved with importing sediment onto the beach, local Councilors, beach hut owners & the local and regional media).
- New Forest District Council (NFDC) have a 5 year coastal maintenance contract with Civils (UK) – a small engineering firm specialising in coastal works, who were able to mobilise quickly and managed to deliver large plant and materials to the beach soon after the event.
- Shingle was delivered from a local quarry by truck and tipped onto the beach at a point of access, approximately 100m from the area of seawall

collapse. A temporary access track could then be constructed along the upper part of the beach to provide access for the plant up to the damaged seawall section.

- For the temporary works / permanent repairs, consultants (Halcrow) provided expert information on risk assessments and concrete details.
- The first stage of the temporary works involved placing rock in front of the damaged section of vulnerable seawall in order to prevent further wave damage (and possible failure of the structure.
- Once the rock was in place, it formed a temporary 1000T breakwater and this avoided damage occurring during a week of very unsettled weather which immediately followed (Hs of 2m for several days) which prevented works from proceeding.
- With calmer conditions, permanent repairs could commence. The beach was excavated down to the clay level and short sections (approximately 6m) were shuttered below the wall and filled with concrete in order to underpin the wall. The decking slabs that had fallen into the cavity were used as make-shift shuttering to reduce disturbance to the void area behind the wall as the remaining material was still offering support to the promenade wall located (above & behind the seawall), and adjacent to the void.
- After the retaining wall was underpinned, permanent rock toe protection with a geotextile underlayer was put in place to protect the toe of the repaired seawall. This was then overlain with the recharged beach material.
- ***Question from Matt Hosey:*** If the recharge material is lost so quickly at this site, is beach recharge a sustainable protection method here?
- ***Answer from Pete Ferguson:*** A large amount of the sediment lost in this area accretes at the eastern end of this frontage. Therefore much of the sediment is "recycled" and sourced from the eastern end and placed again around the White House area.
- ***Question from Scott Mills:*** The White House seems to be a heavily defended section – is this likely to contribute to the chronic erosion problem seen at Milford?
- ***Answer from Andy Bradbury:*** Yes, the White House structure and the fronting revetment produce an unsustainable shoreline planshape which causes chronic loss of beach material to the lee of the structure (where the wall failed).
- ***Question from Tom Mortlock:*** It seems there was a wide, healthy fronting beach in 2007 and then considerable sediment loss in just one year. Why was there so much sediment loss during this period?
- ***Answer from Pete Ferguson:*** There were quite a few significant storms during this period (over the winter of 2007/2008). Losses of the material led to the beach level lowering to a critical point when the boards of a number of groynes were undermined below board level resulting in a significant reduction in groyne efficiency. Sediment is not retained by the structures and the beach loss becomes more rapid.

CONCLUSION: ANDY BRADBURY

- In two case studies, we have seen how seawalls have failed after storm events where wave loadings are not particularly large (Milford, Selsey). This re-enforces the point made by Nigel (Civils UK) that seawalls are often undermined a long time before eventual seawall failure occurs. Core sediment is progressively sucked out via the toe as waves hit the structure, after gradual / sustained beach lowering. Monitoring hatches, retrofitted into seawall structures, could provide a way to prevent seawall failure before it occurs by checking the core of the structure and re-filling it if necessary.