CHAPTER ONE HUNDRED EIGHTY FIVE

A Review of Breakwater Development in Australia

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1. Introduction

Prior to 1970 rubble mound breakwaters in Australia were armoured with rock or concrete rectangular prisms. Model testing was rarely undertaken. During storms some damage to the breakwaters was tolerated with repairs being undertaken as and when necessary. This procedure is still successfully used today. However since 1970 there has been a move towards designing breakwaters to minimise or eliminate maintenance and to optimise costs. This paper reviews some of the less conventional developments that have taken place over this period, with references to reports and papers for those who wish to obtain more detailed information on any of the projects.

2. Sea-Wall Mascot Airport N.S.W.

The extension of Mascot airport into Botany Bay required that the perimeter be protected from wave attack. The design wave conditions were 4.6 m significant height with a depth limited upper wave height of 5.8 m in a water depth of 7.6 m. The designers were the Department of Housing and Construction. Model tests were undertaken at the Water Research Laboratory (Ref 9).

Interesting features related to the project are:

i. Dry construction was specified. An initial bund of sand was pumped along the alignment of the seawall to above the reach of normal tides and waves. A trench was then cut through the sand bund and the seawall placed in the dry. The offshore sand was then pumped onto the reclamation area and the seawall completed to its design height. This technique worked extremely well with substantial cost savings.

ii. Uniform placed Tribars were used as armour. The mass of the unit was 5 tonnes designed according to conventional practice. As it was known that the seawall would be constructed in the dry the benefits that might be achieved by pattern placement of the units was studied. The first pattern tested was the most dense possible (lowest porosity) with the legs of a Tribar abutting the webs of the adjacent units. Rather surprisingly (at that time), this section failed at wave heights very much less than the design wave as the legs of the Tribar could easily rotate about the webs and interlocking was lost. Model testing (Ref 9) showed that the most

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structurally stable pattern was one such that all the legs were in contact. This had the added advantage that it was the least dense (highest porosity) with a consequent cost saving in concrete and number of units to be placed. With this configuration Hudson damage coefficients in excess of 100 could be achieved. However, as failure tended to be catastrophic the pattern placement was used only as an added factor of safety and to reduce concrete and placement costs.

The seawall was constructed in 1970 and no maintenance has been required. However as a result of configuration dredging for port development (Ref 24), wave conditions at the site have been significantly reduced and the structure has not and will never be subjected to the design wave conditions. Some minor breakage of the legs of the Tribars have occurred as a result of settlement.

3. Seawall Banksmeadow N.S.W.

The development by the Maritime Services Board of Botany Bay as a major port for N.S.W. is described in Ref 23. An interesting feature was the use of configuration dredging to reduce wave action in the shipping lanes (Ref 24).

The development required the construction of a revetment/breakwater to provide protection to the harbour area. The design offshore wave conditions were a significant wave height of 7.8 m. Water depths at the toe of the structure varied between zero and 13.5 m and limited the height of the maximum wave. Model testing of the structure was undertaken by the Water Research Laboratory of the University of N.S.W. (Refs 6, 8, 16 and 17) and the Hydraulic Research Station Wallingford (Ref 19).

Features of interest are:

i. The initial design was a copy of the Mascot seawall using pattern placed uniform Tribars of 2, 8 and 20 tonnes depending upon the water depth.

ii. Construction methods were not specified and the contractor elected to undertake the work in the wet.

iii. The pattern placement was extremely difficult to achieve as divers were required for the placement of each unit. As a consequence primary armour placement lagged behind the placement of the core and secondary armour.

iv. Storms in May/June 1974 (Ref 10) caused major damage to the unprotected core and secondary armour. As a result the contractor was in considerable difficulty to meet his obligations and requested consideration be given to a re-design of the remainder of the breakwater using Dolosse.

v. Model testing indicated Dolosse would be a suitable alternative armour. However, as a stockpile of Tribar units had already been produced, a composite armour of Dolosse below water and pattern placed Tribars above water was tested and finally adopted.

vi. Model testing indicated that in the composite design the junction between the Tribar and Dolosse units was a weak point and vulnerable to damage. It was initially thought that the best junction would be to anchor a leg of the Dolosse below the Tribar. However, this proved to be negative as movement of the Dolosse acted as a catapult to dislodge the Tribar. The best joint developed was simply a butt joint.

The prototype performance has been satisfactory. The structure has been subjected to near design wave conditions on two occasions. Some breakages of Dolosse units have occurred. A lot of this damage is towards the bed and is the result of settlement. There has been negligible damage of the Tribar armouring.

The composite armour used arose from the construction difficulties of pattern placing Tribars below water. Despite its adequate performance use of a composite section is not recommended as the junction between the units is a definite weak spot.

4. Rock Breakwater Little Grassy Bay Tasmania

This rather unconventional breakwater arose from the availability of large quantities of waste rock overburden from a nearby sheelite mine. Five per cent of the rock was in the range 2 to 10 tonnes, with 95% being run of quarry less than 2 tonne.

Design wave conditions were estimated to be 10.5 m significant with a depth limited upper wave associated with a 18 m water depth.

The proposal was to push a core of run of the quarry material out to an adjacent offshore island which would act as a roundhead. The core would be allowed to pull down under wave action to form a beach on which would be placed selected 6 to 10 tonne armour rock as required. The purpose of this armour was to increase the stability of the breakwater and to reduce losses from littoral drift along the breakwater.

The initial crest width of the core was 60 m to allow for an adjustment of the face slope to 1 in 10.

The breakwater was designed by Maunsell and Partners, Consulting Engineers. Testing by the Water Research Laboratory (Ref 7) indicated that the proposal was feasible. Construction commenced in 1972 and was completed in 1974.

Construction and behaviour of the prototype is discussed in Ref 5. During construction the seaward face rapidly pulled down to a slope of 1 in 3.5. During storm action it can be expected that this will pull down to a flatter slope. Model tests indicated that the equilibrium slope of the core material (without armouring) would be between 1 in 7 and 1 in 10. However prototype experience indicates that the actual slopes may be somewhat steeper than that predicted by the model. Over the 10 year period since its completion the breakwater has satisfactorily performed its design function.

5. Rosslyn Bay Breakwater Queensland

Rosslyn Bay is a small fishing and recreational port in mid Queensland. Normal wave conditions are moderate; however, during cyclones (hurricanes, typhoons) the site is subject to design waves of significant height of 4.6 m superimposed on storm tide levels of 3 to 8.5 m on low water datum as compared to H.A.T. of 4.8 m. The high storm surge presents problems in the design of breakwaters in the lower latitudes which covers much of Australia's coastline as economics normally require a crest level subject to overtopping under extreme conditions.

The original breakwater was constructed in 1966 and suffered severe damage during Cyclone David in 1976 as a result of overtopping of the crest. A detailed account of this failure is given in Ref 14. Some notable features of the failure were:

i. The failure was catastrophic taking place over a few hours.

ii. After failure the structure continued to give substantial protection, significantly reducing damage to the harbour infrastructure and enabling the harbour to be used for its design function under the more common weather conditions that followed.

iii. Model testing (Ref 11) was able to closely simulate the failure and the breakwater profile after failure.

Repairs to the breakwater were designed by Blain Bremner and Williams, Consulting Engineers. The repair made as much use of the failed breakwater as possible. The seaward face was flattened to 1 on 4 and the landward face to 1 on 2. Armour mass was increased to 5 tonne nominal and was carried over the crest and down the leeward face to allow for overtopping. The tests indicated that damage to the crest is a function of wave period and water levels as well as wave height and there was a critical combination of these variables which resulted in the highest damage. Further studies related to this aspect are given in Ref 13.

After the quarry was opened up the yield of 5 tonne rock was less than anticipated. For this reason the crest was actually armoured with 3.2 tonne modified cubes and the seaward and leeward face with a composite armour of 6 tonne rock and 3.2 tonne modified cubes which provided a dense interlocking combination which has proved very satisfactory.

Construction of the breakwater was completed in 1978 and has been subjected to several severe cyclonic storms with no significant damage.

6. Breakwater and Seawall Townsville Queensland

To provide additional infrastructure to the port facilities at Townsville an area of land was to be reclaimed. The seaward face of the reclamation was to be protected against a significant wave height of

4.15 m superimposed on a storm tide level of 4.45 m corresponding to the 1 in 100 year event. The high value bulk and containerised cargoes required that the system be designed for zero overtopping.

Three alternatives were considered:

i. A seawall along the face of the reclamation using conventional design practice.

ii. A shore parallel offshore breakwater to provide protection to the reclamation area using conventional breakwater techniques.

iii. A shore parallel submerged breakwater to provide protection to the reclamation area.

Economic analysis indicated that the third proposal offered cost savings of about 40 per cent over the other two. However, as all breakwater construction in Australia is undertaken using land based plant, there was difficulty in constructing such a breakwater in its final form. The failure of the Rosslyn Bay breakwater had indicated that damage to a breakwater of this type occurs in a controlled manner and that model testing could be used to simulate this damage. The concept was therefore to construct a mound of nominal 4T rock which would be allowed to reform as a submerged breakwater under the action of storm waves. The design was undertaken by Blaim Bremner and Williams, Consulting Engineers, and was model tested by the Water Research Laboratory. Details of the investigations are given in Refs 1 and 15 which demonstrated the feasibility of the proposal. Construction was undertaken in 1980. To date no significant cyclones have occurred at the site and the prototype performance can not as yet be evaluated.

7. The Hanbar Unit

Many of the older breakwaters in N.S.W. have been armoured with rock or concrete rectangular prism dumped at their natural angle of repose. A commonly adopted size of the concrete units is 40 tonnes on the trunk and 60 tonnes on the head.

Along this section of coast extreme deep water significant wave heights are 8 to 10 m (May 1974, 9.5 m Ref 10; March 1978, 7.7 m with a maximum recorded wave of 16.4 m Ref 20). Under these conditions some damage to the breakwaters resulted requiring maintenance to be undertaken. Following damage to a number of breakwaters in the storms of May 1974, the N.S.W. Department of Public Works undertook an investigation into other forms of armour which might have a better performance. The restricted access, uneven slope and size of existing armour and the immediate need for patch repairs using readily available equipment, often in remote locations, suggested the need for a tippable unit. The unit finally adopted was a modification of British Transport Dock Board Tripod to simplify form work and to reduce construction costs. In Australia the unit is known as the "Hanbar". Prototype tests on both reinforced and un-reinforced units showed that when tipped on the Port Kembla breakwater they fell a distance of 7 m down the slope without breaking, and with only minor damage to the extremities. Consequently all future units have been un-reinforced. Between 1975 and 1980, some 1,500 units have been used for repair of existing breakwaters.

Model tests by the Department of Public Works (Ref 21) indicate values of Hudson damage coefficient under depth limited breaking waves of approximately 7 for 0 to 5 per cent damage.

Since development of the Hanbar it has proved to be competitive with other units such as the Dolosse because of its relatively low construction cost, and has been used recently in seawalls at Port Kembla and Hay Point.

8. Abbott Point Mole Queensland

Armouring of the mole at Abbott Point, Queensland, against a depth limited 4.3 m wave height was undertaken using the recently developed Seabee unit (Refs 2-4) at a cost significantly lower than other armour units. This unit is hexagonal in cross-section and is placed in an array. The length, mass and porosity of the unit can be varied to suit design and construction requirements. The unit was developed by Chris Brown, Consulting Engineer, and has been extensively tested by the Water Research Laboratory.

The mole was designed by MacDonald Wagner and Priddle, Consulting Engineers. The characteristics of the units adopted were Trunk (diameter 1800, length 900, porosity 36.5%, mass 2.9 tonne) and Head (diameter 1800, length 1200, porosity 36.5%, mass 3.9 tonne).

Model testing of the structure was undertaken by the Water Research Laboratory and considerable effort was made to determine the minimum acceptable standard of construction (i.e. surface condition of underlay, gaps between units, etc.). As a result of this work it was established that acceptable minimum standards of placement were 90% on the trunk and 80% on the roundhead of the theoretical maximum cover provided gaps greater than half a meter were filled with in situ concrete.

Construction was completed in 1982. The breakwater has been subjected to near design wave conditions and has performed to design expectations.

9. Hay Point Tug Harbour Queensland

This breakwater is proposed to provide protection to a harbour for tugs used to berth bulk coal carriers at the Hay Point offshore coal loading terminal. At present these tugs have to operate out of MacKay some 20 km away. The design wave and storm tide conditions for the 1 in 100 year return period are 5 m significant height with a 7 second peak period superimposed on a storm tide level of 4.50 m. Offshore depth limits the maximum wave height at the structure to approximately 7 to 8 m.

The breakwater has been under consideration since 1977. The initial proposal was for a conventional breakwater armoured with a 6 to 8 tonne Dolosse (Ref 18). This proved to be too expensive and a modified design was undertaken of an overtopped structure using 12 tonne Dolosse on a slope of 1.5:1 with a cap designed to be overtopped with cast in situ concrete blocks each of 400 tonnes in weight (Ref 22). However, the cost of the breakwater was still substantial and raised doubts of its economic viability. Further investigation of quarries in the region indicated the possibility of obtaining large quantities of rock ranging in size between 3 to 7 tonnes and a modified design was considered using a similar principal to that adopted at Little Grassy, Tasmania. The concept was to place a mound of sufficient size to allow storm waves to pull it down to a stable profile.

The breakwater was designed by Blain Bremner and Williams, Consulting Engineers, and was model tested at the Water Research Laboratory (Ref 12). Some of the interesting aspects of the tests were:

i. Damage was much less than anticipated.

ii. Whilst severe overtopping was expected this did not occur.

iii. Provided the initial estimates of rock quantities from the quarry are proven, the cost will be approximately 30 per cent less than that of a conventional breakwater.

10. Conclusions

Breakwater construction in Australia over the past 25 years has seen some developments which might be described as non-conventional. These have achieved improved performance and most importantly, cost savings. The paper summarises some of these developments. For further details the reader is referred to the references, most of which can be obtained on request from the Water Research Laboratory of The University of New South Wales.

REFERENCES

[1] Bremner, W., Foster, D.N., Miller, C.A. and Wallace, B.C. "The design concept of dual breakwaters and its application to Townsville, Australia". Proc. 17th Internat. Conf. on Coastal Engineering, Sydney, 1980.

[2] Brown, C.T. "Armour units - random mass or disciplined array". A.S.C.E. Coastal Structures, Alexandria, March, 1979.

[3] Brown, C.T. "Blanket theory and low cost revetments". A.S.C.E. 16th Internat. Conf. on Coastal Engineering, Hamburg, August 1978.

[4] Brown, C.T. "Seabees, a third generation armour unit". 7th Internat. Harbour Congress, Antwerp, Royal Society for Flemish Engineers, May 1978.

[5] Burren, K.R. "Investigation, design and construction of a harbour on King Island Tasmania". Institution of Engineers, Aust., Civil Eng. Trans. Vol. CE17 No. 1, 1975.

[6] Foster, D.N. "Banksmeadow breakwater - stability of a combined face of uniform random and pattern placed tribar armouring". Uni. of N.S.W., Water Research Lab., Tech. Report 73/1, 1973.

[7] Foster, D.N. "Investigation of quarry run breakwater - Little Grassy, King Island". Uni. of N.S.W., Water Research Lab. Tech. Report 69/20, 1969.

[8] Foster, D.N. and Adams, J. "Banksmeadow revetment Botany Bay - tests on the stability of toe cubes". Uni. of N.S.W., Water Research Lab., Tech. Report 75/12, 1975.

[9] Foster, D.N. and Dudgeon, C.R. "Model studies of seawall for Mascot runway extensions". Uni. of N.S.W., Water Research Lab., Tech. Report 70/6, 1970.

[10] Foster, D.N., Gordon, A.D. and Lawson, N.V. "The storms of May-June 1974 Sydney N.S.W." Proc. Second Conf. Coastal & Ocean Eng., Inst. of Engs. August 1975.

[11] Foster, D.N. and Haradasa, D.K. "Rosslyn Bay boat harbour breakwater model studies". Uni. of N.S.W., Water Research Lab., Tech. Report 77/6, 1977.

[12] Foster, D.N., Haradasa, D.K.C. and Foster, S.J. "Half tide tug harbour, hydraulic model studies". Uni. of N.S.W., Water Research Lab., Tech. Report 83/15, 1983.

[13] Foster, D.N. and Khan, S. "Stability of overtopped rock breakwaters". Uni. of N.S.W., Water Research Lab., Research Report 161, 1984.

[14] Foster, D.N., McCrath, B.L., and Bremner, W. "Rosslyn Bay breakwater, Queensland, Australia." Proc. 16th Internat. Conf. on Coastal Engineering, Hamburg, 1978.

[15] Foster, D.N., Miller, C.A. and Wallace, B.C. "Townsville harbour eastern breakwater extension hydraulic model studies". Uni. of N.S.W., Water Research Lab., Tech. Report 80/1, 1980.

[16] Foster, D.N. and Nagle, B. "Banksmeadow revetment Botany Bay - stability of Dolosse and composite Tribar and Dolosse armour". Uni. of N.S.W., Water Research Lab., Tech. Report 74/10, 1974.

[17] Gordon, A.D. "Breakwater stability stage 1 revetment, Botany Bay" Uni. of N.S.W., Water Research Lab. Tech. Report 72/11, 1972.

[18] Higgs, K. and Foster, D.N. "Model testing of the eastern breakwater Hay Point tug harbour". Uni. of N.S.W., Water Research Lab. Tech. Report 77/12, 1977.

[19] Hydraulic Research Station, Wallingford. "Banksmeadow breakwater - model tests on stability of Tribar armouring". Report No. EX538, March 1971.

[20] Lawson, N.V. "Wave climate around Australia". Water Research Foundation Symposium, Energy and Economics of Water Utilization, Wollongong, Feb. 1983.

[21] N.S.W. Public Works Department Hydraulic Laboratory. "Port Kembla sea wall model". Manly Vale Laboratory Report No. 272, Sept. 1979.

[22] Queensland Covernment Hydraulic Laboratory. "Hay Point tug harbour structural model of an overtopped breakwater". Deakon Lab., Dept. of Harbours & Marine Report M11/1, June 1981.

[23] Silva, E.J. "Hydraulic investigations associated with the development of port facilities in Botany Bay, Sydney". Australia and New Zealand Association for the Advancement of Science 44th Congress Sydney, Aug. 1972.

[24] Wallace, J.M. "Control of wave action by configuration dredging at the entrance to Botany Bay, Sydney, Australia". 1977 P.I.A.N.C. Congress Leningrad.