Design Studies for an Artificial Surfing Reef: Cable Station, Western Australia.

Charitha Pattiaratchi
Centre for Water Research, Department of Environmental Engineering,
The University of Western Australia, Nedlands, WA6009

Summary: Design studies undertaken to investigate the feasibility of constructing an artificial surfing reef, by enhancing an existing surf break, at Cable Station, Western Australia are described. These include physical model tests in a random wave flume and a 1:40 scale model in a 40m x 40m wave basin. The optimum bottom slope, where a plunging wave was present for a range of wave heights and wave periods was found to be 1:20. This is also the natural bottom slope of the study area and is also the slope recorded in many surfing breaks worldwide. Several reef shapes were investigated in the wave basin and a shape that minimises the amount of fill required and that which merges with the existing reef was selected as the final design.

1. INTRODUCTION

In south-western Australia, the coastline is sheltered from the direct effect of swell and storm wave activity by an extensive chain of offshore reefs. As a result, wave energy at the shoreline tends to be low except at a few locations where surfing activity is concentrated (Pattiaratchi et al. (1)). In Western Australia, it is estimated that approximately 185,000 people (11% of population) participates in surfing. Due to lack of suitable surfing locations, competition between surfers, swimmers and fishermen for the use of the beach has increased and resulted in a number of injuries to both surfers and swimmers. The main source of injuries to surfers was due to fish hooks and during three summer periods (1985/86 to 1987/88) over 40 surfers were injured in this manner. Injuries to swimmers result from being hit from surfboards and over the same 3 summer periods, this type of injury accounted for more than 110 injuries including one death. In addition, there is overcrowding of surfers at good surfing locations and up to 250 surfers may be present at godd location such as Trigg. All of these factors resulted in a demand by the surfing community to construct an artificial surfing reef that can produce a 'surfable' wave whenever there are incident swell waves. This was assumed to alleviate the problem of overcrowding at the existing beaches and also minimise competition for beach use between surfers, swimmers and recreational fisherman. The Government of Western Australia formed a committee in 1988 to investigate the feasibility of constructing such a reef along the Perth metropolitan coastline. As a result, a series of studies were undertaken to:

(1) determine the location of an artificial surfing reef within the Perth Metropolitan region;
(2) investigate the feasibility of building a reef to provide ‘surfable’ waves;
(3) undertake an engineering design of the reef; and,
(4) examine the environmental impacts of the reef.

At the completion of these studies, expressions of interest were requested from interested parties to propose construction techniques and costings. Based on the results of these studies, the Government of Western Australia approved and allocated funding for the construction of the reef. Construction of the reef began in February 1999 and is expected to be completed by April 1999.

Cable Station, located to the south of Cottesloe (32^o 00’ 115^o 45’), was selected as the ideal location for the construction of the artificial surfing reef (Figure 1). This was based on the results of wave refraction studies, bottom topography, current beach use, access to public transport and possible environmental impacts.

In the design of the Cable Station surfing reef, the following were considered:

- the reef should produce left and right breaks
- incident swell wave heights ranging from 0.5 to 3.5 m
- peel angle be 45^o, on the basis that 30^o is appropriate for beginners and 60^o is desirable for professional riders
- wave steepness should be such that a plunging wave is common

2. DEFINITION OF A ‘SURFABLE’ WAVE

When the design studies began in 1990, very little information, in terms of engineering or scientific criteria, was available to define the surfability of a wave. Surfability depends upon a number of criteria. The height of the breaking wave is obvious, and generally the larger the breakers, the better the surfing. It was accepted that the shape of the breaking wave depends on the bottom slope and the incident wave height and period. If these parameters were known, then, it is possible to define whether a spilling ("mushy" in surfing terminology), plunging ("tube" or "hollow") or a collapsing ("cruncher") wave will occur at the break point (Dally, (2)). Breaker type can be predicted using the surf similarity parameter or Irribarren Number:

$$\xi_b = \tan\beta \Big/ \sqrt{H_b / L_o} \qquad (1)$$

where L_o is the deep water wave length given by:

$$L_o = gT^2 / 2\pi \qquad (2)$$

Spilling breakers occur for ξ_b < 0.4, plunging breakers occur when ξ_b = 0.4–2, and surging/collapsing breakers occur for ξ_b > 2 (Battjes, (3)).

Wind speed and direction can also influence the breaking characteristics of the wave. However, it is not only the breaker type that determines the surfability of a wave. The wave should also break at a rate at which a surfer can maintain a mean speed that is equal or greater than the rate at which the point of incipient breaking translates along the wave crest. This is defined as the peel rate, V_p and is defined by Walker (4) as:

$$V_p = c_b / \sin\alpha \qquad (3)$$

where c_b is the celerity of the waves at the break point and α is the angle between the incident wave crest and the bottom contours, ie. the peel angle. If the peel angle is very small, the peel rate is very large; the breaking wave will “close-out” and is not rideable. A minimum peel angle of 30^o is generally required for surfing (Walker, (4)). Large peel angles are generally associated with non-uniform bottom contours, eg. wave breaking on the edge of a bar/reef. If the breaking segment of the wave overtakes the surfer, the wave 'closes out' and becomes unsurfable. Walker (4) suggested that maximum board speeds were of the order of 12 m/s and produced a diagram to classify different types of surfer (Figure 2).

2. SITE SELECTION

Examination of shoreline changes in the Perth metropolitan region over the past 10 years indicated that the Cable Station location (Figure 1) to be one of the most stable, due in part to the presence of rocky cliffs. The inshore region of the Perth Metropolitan coast has a complex topography of limestone ridges and depressions. This complex topography is formed from lithified Pleistocene marine and aeoliantic calcarenites of the Tamala formation and is very resistant to erosion (Hegge, (5)). Hence, no coastal stability problems would be encountered at this site.

At present the beach is not suitable for other activities, such as fishing or swimming due to the difficult access and rocky foreshore during the winter months.

It presently exists as a surfing site where board riders are able to surf about 5-7 times per year. The bathymetry and existing reef formation indicated two existing peaks in the reef, separated by relatively deep water. It was assumed that the existing reef could be enhanced by an appropriate structure (Figure 3) to create a left and right hand break that is operational for greater part of the year. The site is open to ocean swell conditions and is located 250 m offshore.

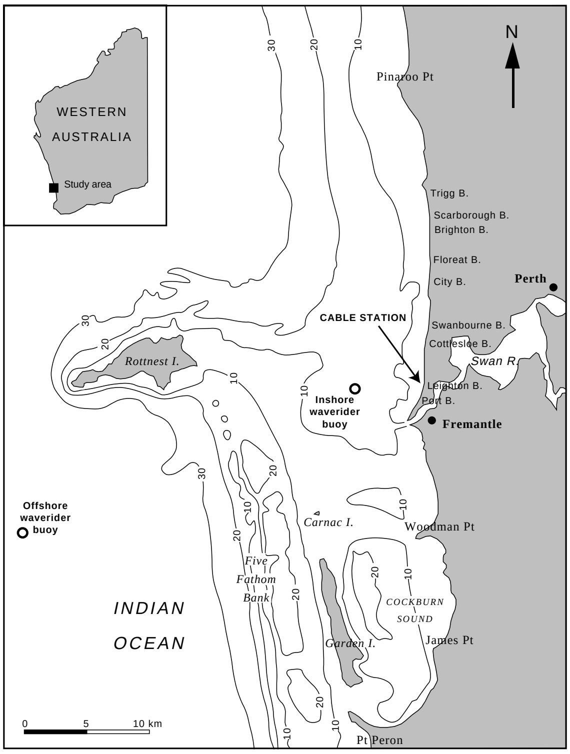

Figure 1 - Location map showing bathymetry and study sites.

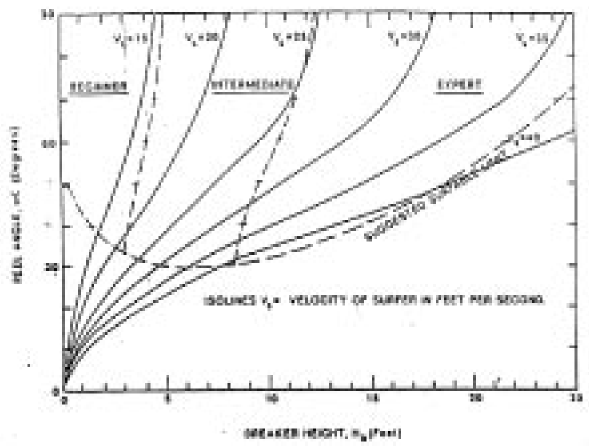

Figure 2 - Classification of surfing waves (after Walker, (1974).

3. LABORATORY STUDIES

3.1 Wave flume studies

A series of laboratory tests were undertaken in a 50 m wave flume, capable of generating random waves, to identify the optimum bottom slope or multiple slopes which could provide a 'plunging' breaker for a range of wave height and periods (Button, (6)). Also the effect of a ‘step’ in the reef slope was investigated as such a step would be required in the prototype (Figure 3).

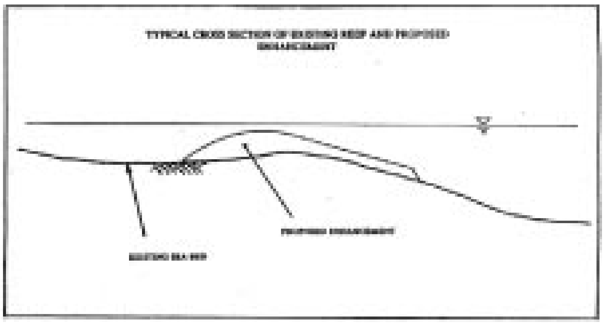

Figure 3 - Conceptual design of the proposed enhancement at Cable Station reef.

Results of these experiments indicated that a complex bottom slope (i.e. consisting of one or more abrupt changes or 'steps') effected both the shoaling and breaking characteristics with the latter depending on wave height rather than on wave steepness. This effect was minimal when $H < 0.3\ h$ (H is wave height and h is the depth of water at the crest of the step). For $H > 0.3\ h$, the wave height dominates the breaking process. Tests also indicated that to optimise breaking wave height and shape characteristics, the bottom slope should remain constant. For the range of wave periods and heights experienced at Cable Station, it was found that a simple 1:20 slope (which is also the natural slope under consideration) would produce plunging waves under most conditions. If a step in the bottom profile is required then, the height of the step should be less than the design wave height and should be located in a water depth equivalent to 1.5 times the design wave height.

3.2 Wave basin studies

Following the wave flume tests (section 3.1) a series of experiments undertaken on a 40x40m wave basin to determine the three dimensional plan shape of the reef which defined the length of the ride, peel angle and the orientation of the reef to the incident wave climate (Lyons, (7)). An undistorted model of the existing reef was constructed at a scale of 1:40. It covered a prototype area from the shoreline to the 7 m depth contour (approximately 350 m) and about 600 m in the longshore direction centered on the existing reef. This corresponded to a model of approximately 10x15m. The model was tested for its similarity to the prototype situation and then four reef designs were constructed and tested. The sea level was set at a mean tide level of 0.78 m above datum.

Monochromatic waves were generated from a 12 m wave paddle and simulated the present wave climate at the Cable Station. The swell conditions were: 0.5, 1.0, 1.5 and 2 m and periods of 8, 10, 12 and 14 s. Thus a matrix of 16 wave conditions were recorded for each reef. Wave climate studies (eg Hurst, (8)) have shown that, at Cable Station, regardless of the offshore wave direction the incoming swell waves are incident within a narrow directional spread ($< 10^o$). Swell direction was taken to be predominantly from the west. Additional tests were undertaken by changing the wave direction 10^o to the north and south of west.

Initially it became clear that it would be easier to design a surfing reef on uniform (flat) topography. With the existing reef, the location of the artificial reef in relation to the existing bathymetry was a critical factor that determined whether a surfable wave could be maintained over a prescribed distance.

The existing reef plus five different reef designs were tested in the wave basin. The final design reef was such that the existing 3 m depth contour was extended offshore and a 1:20 slope was constructed up to the 1 m contour of the existing reef (Figure 4). The slope of the reef was set at 1:20. This reef shape ensured that a left and right hand breaks existed on the reef under a range of incident swell conditions. The length of ride for the left handed segment was 30-40m and for the right handed segment, 50-80 m for the range of wave conditions tested. The left handed segment is shorter as the topography of the existing reef influenced the shoaling and breaking process. The shoaling coefficient of waves with incident periods of 10 and 12 s was 1.6.

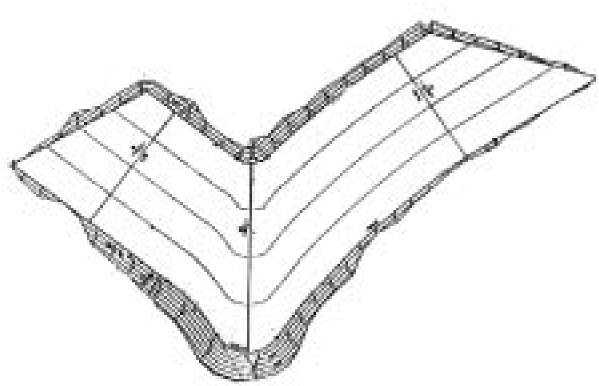

Figure 4 – Final design of the Cable Station artificial surfing reef.

The breaker heights and peel rates obtained for the existing reef are shown on Figure 5. The limits of surfing have been extracted from the 'Walker' diagram (Figure 2). As expected most of the waves lie below the surfable limit proposed by Walker (4). In contrast, with the design reef, the much wider spread of breaking wave heights and peel angles can be observed (Figure 6).

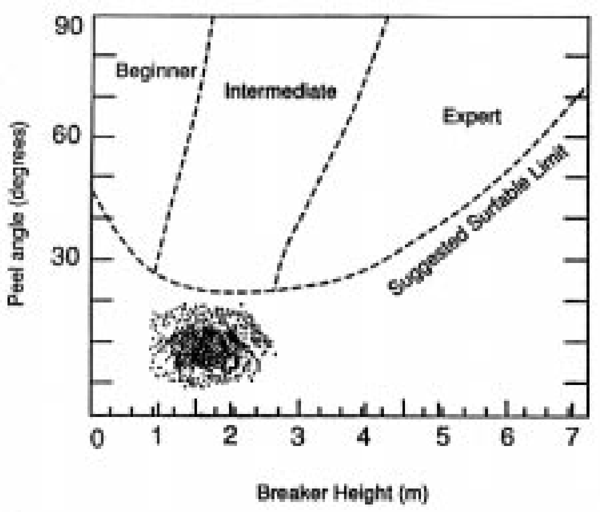

Figure 5 – Performance of the existing reef at Cable Station.

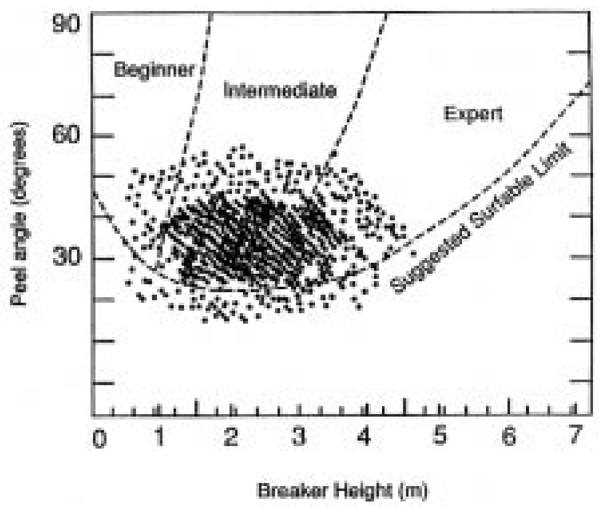

Figure 6 – Performance of the proposed artificial surfing reef at Cable Station.

4. DISCUSSION AND CONCLUSION

The results of the physical modelling indicated that it is feasible to construct an artificial surfing at the Cable Station site. The design presented in Figure 4 has been accepted after numerous reviews and civil engineering design for construction. The location of the reef in relation to the shoreline is given is Figure 7. Construction of the reef, the first of it's kind in the world, was started in February 1999. The reef is being built using rock (granite) and construction is due to be completed by April 1999. A video camera located at the shore provides real time images of the reef located through the internet (the URL is: http://www.coastaldata.transport.wa.gov.au/coastcam/cam_cables.html.

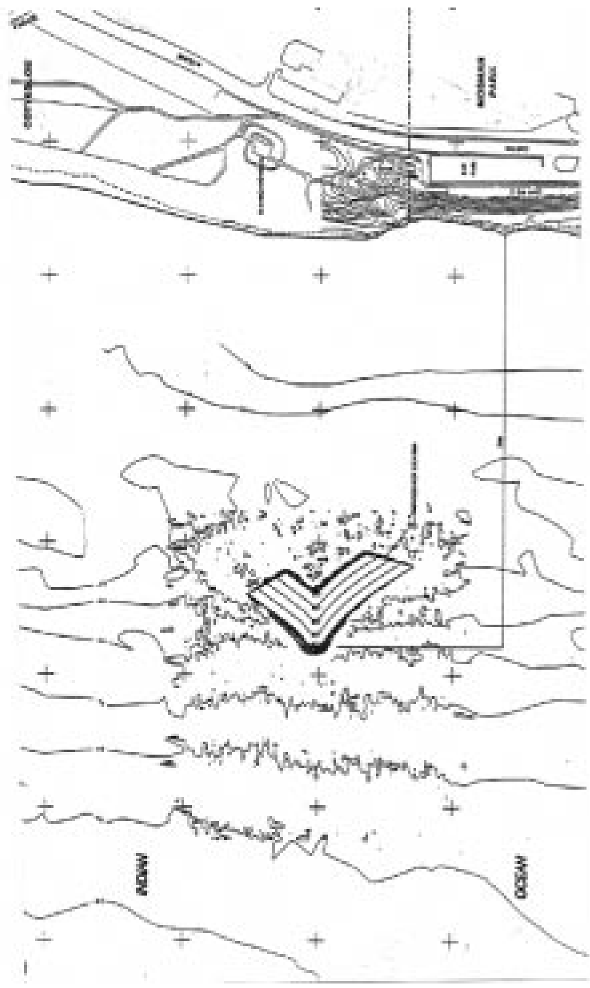

Figure 7 – The geographic location of the the proposed artificial surfing reef at Cable Station.

ACKNOWLEDMENTS

The development and the concept of building an artificial surfing in Western Australia began in the early 1970's. Several individuals have associated with the project over this time, In particular, John Balgarnie, Keith Campbell, John Furmann, Nello Siragusa, Ian Eliot were instrumental in getting this project through various obstacles. The Chairpersons of the WA Artificial surfing reef committee over the years, Graham Burkett, MLA, Norm Marlborough, MLA, Mr Mike Board MLA and Arthur Marshall MLA ensured that the project received continuous WA government support. The laboratory tests were performed by Mark Button and Matt Lyons.

REFERENCES

1. Pattiaratchi C.B., Masselink G. and Hurst P. 1999. Surfability of the Perth Metropolitan Coastline: An Assessment. Ports & Coasts'99 Conference, Perth. (in press).
2. Dally W.R. 1990. Stochastic modelling of surfing climate. Proc 22nd International Conference on Coastal Engineering.
3. Battjes J.A. 1974. Surf similarity. Proc 14th International Coastal Engineering Conference, 466-480.
4. Walker J.R. 1974. Recreational surf parameters. University of Hawaii, Look Laboratory Rep No. 30, 311pp.
5. Hegge B. 1994. Anticipated environmental impacts of the proposed artificial surfing reed, Cable Station. Unpubl report submitted to the Artificial surfing reef committee.
6. Button M 1991. Design studies for an artificial surfing reef. Unpubl Hons dissertation. Department of Civil Engineering, University of Western Australia.
7. Lyons M. 1992. Design studies for an artificial surfing reef. Unpubl report. Department of Environmental Engineering, University of Western Australia.
8. Hurst P. 1996. Characterisation of surfing wave climate of Metropolitan Perth Unpubl Hons dissertation. Department of Civil Engineering, University of Western Australia.

This is Centre for Water Research reference ED1483CP.