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An evaluation of design factors and performance of groynes

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Abstract

Groynes are among the oldest structures in wide use today for controlling coastal erosion. Due to the complexities of the physical processes involved, predictions of groyne performance are not always reliable despite the prolific use of sophisticated numerical models. Site specific knowledge obtained from post-construction monitoring remains an indispensable source of knowledge for engineers in designing groynes. This paper reports the analysis of a recently conducted questionnaire survey on the most important factors which influence the design of groynes and perception of the performance of existing groynes. It was found that the greatest importance was placed on the effectiveness of groynes in holding sediment locally while the least importance was placed on the negative effects that building groynes can have on both the natural and human environments. It was also found that a large proportion of the existing groynes seemed to have achieved their design objectives with the rock groynes performing particularly well.

1 Introduction

Whether built as stand-alone structures or as a part of coastal protection scheme involving beach nourishment or seawalls, the groynes are designed to control longshore sediment transport and retain sediments on beaches. Due to the complexities of the physical processes involved, the design of groynes is still far from an exact science despite the prolific use of sophisticated numerical models in recent years (Walker et al. [1], Sukhodolov et al. [2] and Ouillon, & Dartus [3]). Very often, groynes were built as a quick fix soon after extremely severe storms and therefore, the design of these groynes tend to follow simple design guidelines and rely on experience rather than based on detailed process analysis and modeling (SPM, [4]). It is therefore important to check and update these guidelines using post construction data on the actual performance of the built groyne systems. Such data are also essential for validating probabilistic design methods and system analysis techniques which have been developed in recent years for designing coastal structures and quantifying uncertainties.

About twenty years ago, Brampton and Motyka [5] advocated that the engineers should make known both his successes and failures in using groynes for coastal protection so that valuable lessons can be learnt. This essential data need was addressed by the publication of the CIRIA Reports (CIRIA, [6], [7]) which were the first comprehensive survey on groyne performance in the UK. But since then, no similar work has been carried out.

This paper reports the analysis of a recently conducted questionnaire survey on the most important factors which influence the design of groynes and perception of the performance of existing groynes. It is hoped that for a complicated problem as groyne design, information from self-assessment will contribute to a well structured knowledge base and the development of a knowledge-based decision model.

2. Methodology

A two part questionnaire was designed for the survey. The first part is concerned with the factors that may influence engineers in groyne design while the second part is on the levels of performance achieved by the existing groyne systems as evaluated by the engineers. The questionnaire was sent to a large numbers of civil engineering companies and local government offices which have responsibility for a particular stretch of coast.

The purpose of building groynes varies greatly from site to site. Some are terminal groynes aimed at cutting-off longshore sediment transport completely while others may only intend too hold sediments on the upper beach. However, there exist a number of factors that are common in the design process of groynes. In consultation with engineers, six factors were identified to be most important which are:

- Cost;
- Predicted groyne performance;
- Availability of material;
- Aesthetics of groynes;
- Ease of construction;
- No detrimental effects on the environment.

The engineer responsible for each site was asked to rank these six design factors from one to six, with one being the most important and six being the least important. It is recognised that in certain cases the design factors could not be accurately known as the engineer filing in the form might not have been the engineer who designed the groyne. However, the engineer is expected to make a reasonable estimate of what the most important factors would have been. This will still allow the overall picture of the importance of specific design factors to be determined. Completed forms were returned for 27 sites in this part of the survey, located in areas from the north coast of Scotland to the south coast of England. The numbers given to each factor were then added up. The lower the score, the more important is the factor in the groyne design process.

The second part of the survey asked the engineers to give their views on how well the existing groynes have been performing. Completed forms were returned for 33 sites. In the CIRIA survey the performance of the groyne system was classed between one and six, with one being the least effective and six being the most effective. But in the present survey a broader performance classification was adopted (Poor, Satisfactory and Very Good). This is because that without morphological data it is difficult to differentiate 'Not contributing (CIRIA classification 1)' and 'Minor effect (CIRIA classification 2)' both of which are considered as Poor. For the same reason, Satisfactory and Very Good performance classifications are introduced to convert the CIRIA performance bands 1 - 6 to three broader bands as shown in Table 1.

Table 1: Rating conversion

Band	Performance Rating
1-2	Poor
3-4	Satisfactory
5-6	Very Good

It should also be pointed out that there are some differences regarding the performance criteria used in the two classifications. CIRIA 135 classed the groyne performance on the basis of the volume of sand collected, while the present questionnaire defines the performance on the basis of whether the groyne systems have, in the opinions of the respondents, performed as designed. Despite this difference both criteria are expected and proven to give consistent results. Therefore, in order to ensure that the sample size is statistically significant and to eliminate the influence of the construction time, the samples from the present survey and that from CIRIA were pooled together to bring the size of the samples to 73. By carrying out a comprehensive analysis on these data, it is expected that the most effective type of groynes may be identified.

3. Results and discussions

3.1 Design factors

A representation of the results can be seen in Figure 1 noting that the higher the score the lesser the importance of the design factor. It can be seen that the 'Predicted groyne performance' is the most important design consideration, with the 'Cost' of the groyne system the second most important. The second least important factor was the groyne system having 'No detrimental effects on the environment'.

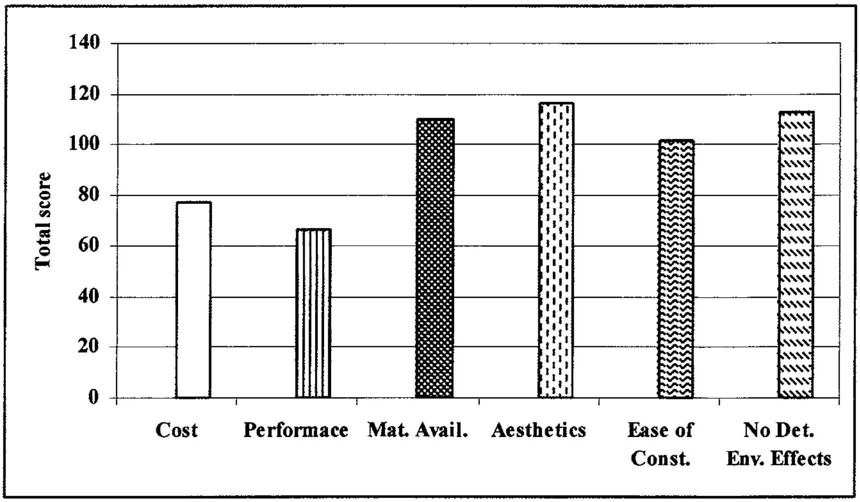

Figure 1: Scores of the design factors

The above results can be further quyantified in terms of the relative importance index defined as

$$\text{Relative importance index} = \frac{\text{The score of individual design factor}}{\text{The score of predicted performance}} \times 100 - 100$$

The results of these calculations can be seen in Table 2.

Table 2 Relative importance index

DESIGN FACTORS	% LESS IMPORTANT THAN PREDICTED GROYNE PERFORMANCE
Cost	17
Ease of Construction	55
Availability of Material	67
No Detrimental Effects on The Environment	72
Aesthetics	76

In the table, the cost factor is 17, meaning that the cost of building the groynes is 17% less important than the predicted performance. It can also be seen that all other design factors are less than half as important as the predicted performance of the groyne system. It is worth noticing that little importance has been placed by the design engineers on the negative effects that building groynes can have on both the natural and human environments. This is more a reflection of historical design practice than what is actually happening at the present time.

3.2 Groyne performance

The overall performance of all types of groynes on all types of beaches is shown in Figure 2.

Figure 2: Overall performance rating

It can be seen that 78 % were classed as performing satisfactorily or very good. This high success rate is of no surprise as the performance is strictly local and functional. Any possible adverse effects of the groyne systems on the adjacent coastlines have not been included in the assessment.

In order to find out the factors or parameters that are more likely to contribute to an effective (satisfactory or very good) classification, further examination on the variations in groyne materials and beach types and their relation to the performance of the groyne systems was undertaken.

3.2.1 Beach types

Different types of beach were classed on their material content and grouped into three categories: Shingle Beach, Sand Beach and Mixed Beach. Nineteen shingle beaches were in the combined database and generally groyne systems on these beaches had performed effectively. As shown in Figure 3, only 10.6% of them had Poor rating. This set of results is slightly worse than the shingle beach results of CIRIA 135 which found none to be classified as poor. However the

CIRIA report only contained a small number of samples (7 sites). Had they sampled one more beach and found it to have a poor performance rating, it would have given a 12.5% Poor rating. Nevertheless, it can be safely concluded from the present result that groyne systems built on shingle beaches are generally effective.

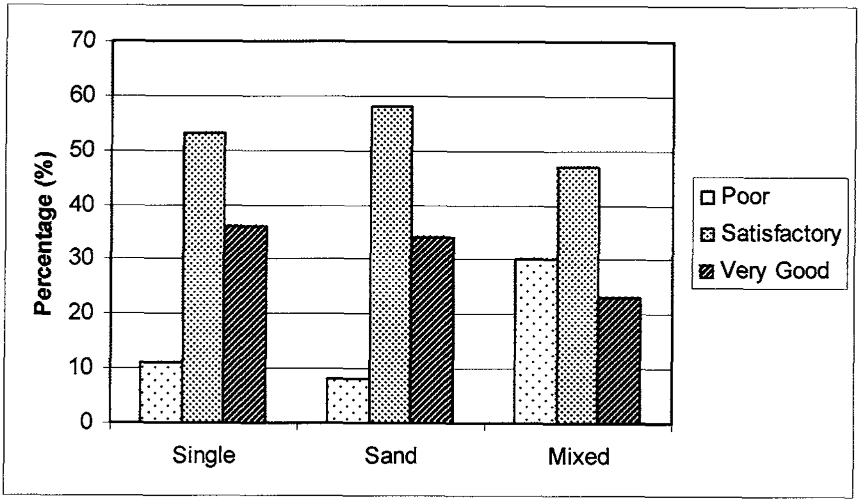

Figure 3: Performance according to beach type

Fourteen sand beaches were surveyed and it was found that, unlike the CIRIA report which rated the performance of sand beaches as the most variable of all beaches and had 20% of the groyne systems classed as poor, only 7.2% of the groyne systems in the combined data set had the Poor rating. This is believed to be due to the fact that many groynes in the current survey are built recently and they all have performed well so far but whether they will continue to do so is unknown. Further discussions will be given in later sections.

The Mixed Beach classification comprises both Shingle Upper/Sand Lower beaches and Shingle/Sand mixed beaches. In the CIRIA survey these two mixed classifications were considered separately. A single mixed beach classification was used here to facilitate quick and easy completion of the survey. This was the largest survey group and comprised 40 sites. The performance classification of this beach type was found to be the most varied of the three and it also has the greatest percentage of groynes which were classified as poor (30%). Intuitively the variability of the beach constituents is the obvious reason for the high number of groynes with a poor performance rating. Designers of groynes have found difficulties in designing for a beach which is made up of one material, so it should not be surprising that when two or more materials are present both the design uncertainty and the percentage of Poor performance increase.

3.2.2. Groyne types

Information on groyne types was obtained for 70 sites in this category. The main groyne materials used are rock and timber. The groynes built with steel piles and timber planks have been included in the timber groyne classification due to the fact that this type of groyne works exactly like a timber groyne although being held in position by the steel piles. Because of the small numbers involved, it is reasonable to group the groynes constructed of a mix of materials or groyne fields consisting of different types of groynes were grouped into a single third category.

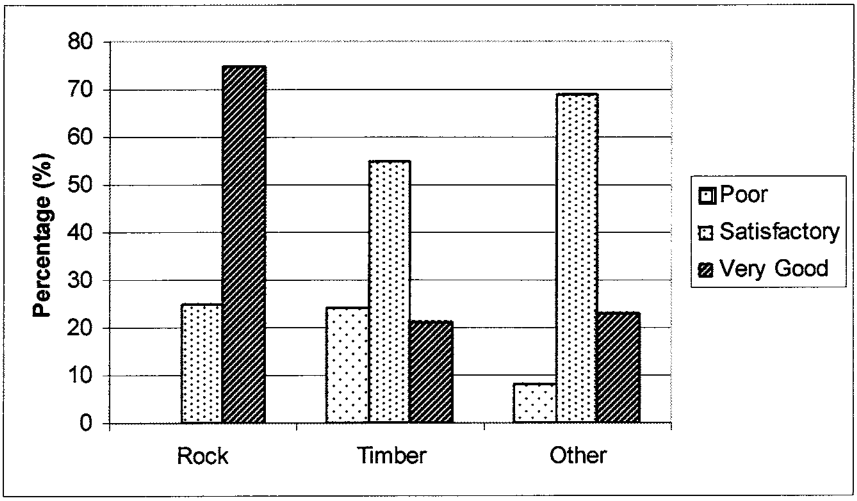

Figure 4: Performance according to groyne type

Rock groynes have only recently become popular in the UK as a material for constructing groynes (Bull et al. [8]). There are eight sites in this survey which have rock groynes (in the CIRIA report there were none). Of the eight sites, seven were built in the 1990's, while the remaining one was built in 1985. 75% of these groynes are classified as having a Very Good performance, while the remainder has a satisfactory rating. There could be a number of possible explanations for their excellent performance. The main reason is the intrinsic properties of rock groynes in dissipating wave energy and its low reflection. But another possible reason could be the improvement in the design tools available nowadays to the engineers, which are capable of providing more accurate information on design conditions and parameters. Nevertheless, these results prove very promising for rock groynes. Clearer picture will emerge in the near future with more rock groynes being built and their performance recorded.

Timber groynes constitute the largest sample in the survey with 49 sites all around the UK. Timber groynes were the most commonly built groynes up until

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the 1980's and since then its popularity started to decline. For example of the eight groyne sites built in the 1990's in the survey only one was a timber groyne system. The combined survey shows considerable variety in the performance. Although three-quarters of them are classed as effective only 20% of them are rated Very Good, but 24.5% rated as Poor. This distribution of results is very similar to that found in the CIRIA survey and represents an accurate picture of the performance of timber groynes to date.

The third category consists of many different types of groynes such as concrete and steel as well as mixtures of different types of groynes within one system. Almost 70% classed as Satisfactory with 23% having a Very Good performance. That groynes in this category have performed so well (a lower percentage with Poor ratings than that of timber groynes) may seem a little surprising considering their being less popular than timber groyne. Perhaps, the real reason is that groyne fields with different types of groynes in them are generally built as the results of improvements being made to existing timber groyne systems. This allows any defects or specific local problems to be addressed so as to produce a system which functions better.

4. Conclusions

The factors that influence engineers in designing groyne systems have been analysed quantitatively. It was found as expected that the functional performance and cost dominate over other factors. The fact that insufficient consideration has been given to the Environmental impact is the most concerning although not expected.

As to the performance of the groynes, it was found that over a fifth of all groyne systems in the combined database had performance rating as Poor but 90% of groyne systems constructed on sand and shingle beaches were found to perform effectively. In comparison, only 70% of those built on mixed material beaches fall into the same category.

It is generally accepted that no two beaches are the same and consequently, there does not exist a single design criteria which is universally applicable to the groyne design. Despite this fact, rock groynes were found to be effective on all types of beach. As only a few non-shingle beaches were surveyed in this study, more research is required to determine if the excellent performance of rock groynes found in this study is also repeated on sand and mixed material beaches. Notwithstanding this limitation, the finding is considered significant. As the use of rock groynes becomes more widespread its advantages over the more traditional timber groynes will be come more apparent. Until the evidence contrary to the present finding emerges, it is suggested that rock groynes should be encouraged where suitable material is readily available while timber groynes should only be used where the cost of rock construction is considered too high and the potential performance of other groynes too unpredictable.

The performance of timber groynes was found to be more varied than those of rock groynes, with over 20% classed as having a Poor performance rating on both shingle and sand beaches, increasing to almost 30% for mixed material

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beaches. However, over 30% of timber groynes built on either shingle or sand beaches were found to have a performance that was Very Good. This indicates perhaps that the reason for the poor performance of some of the sites is due to poor design and not necessarily due to the groyne type. However, the undesirable properties of timber groynes such as high reflection and generation of rip channels definitely have some bearing on the groyne system performance.

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