South Africa, who had observed that old anchors dredged from harbor bottoms tended to interlock. Merrifield felt that the principle could be applied to breakwater design to improve reliability. His idea was to develop a unit which would lock together *due* to wave action and offer a surface that would absorb a large proportion of the wave energy. The memory of the interlocked anchors led to a configuration that resembled old sea anchors, and three years of research were needed to determine the exact proportion of lengths and thicknesses to produce the interlocking effect needed for high stability. It was this completed design which resembled the goats' knuckles, and dubbed "dolos." The success of these efforts is recorded in the number of breakwaters around the world using the design; for more than a decade the dolos has been the mainstay of breakwater design.

However effective the dolos has been, the need for further research has been intensified, particularly with the time constraints put on basic research by the demands of commerce. This has left the coastal engineer with the choice of designing for nearly maximum conditions, a costly solution, or building at minimum original cost and accepting the expense of repairs when storms damage the breakwater.

The Nova Scotia study is an excellent example. The work led to the questioning of the test parameters used by previous researchers. Mr. Joe Ploeg, Section Head of the Laboratory, contends that the old criteria for testing must be revised to include any significant movement of the armor unit. "Since the weakest point in a breakwater structure is a single armor unit," he says, "then the rocking of any one of them renders the whole assembly suspect." Because a dolos in an unstable condition may be more likely to move than the tetrapod, its capacity for damage could be greater. Where the stability of the dolos was once thought to be as much as three times that of the tetrapod, the investigations of the Hydraulics Laboratory may reduce the stability level to one-third that of its competitor.

Examination of the condition of those dolosse-protected breakwaters around the world tends to support the NRC findings. Off-shore drilling and power generator sites needing wave protection are on the increase, demanding still more research in breakwater design. New devices for breakwater armor will therefore need to be developed and evaluated. □

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COST/PERFORMANCE

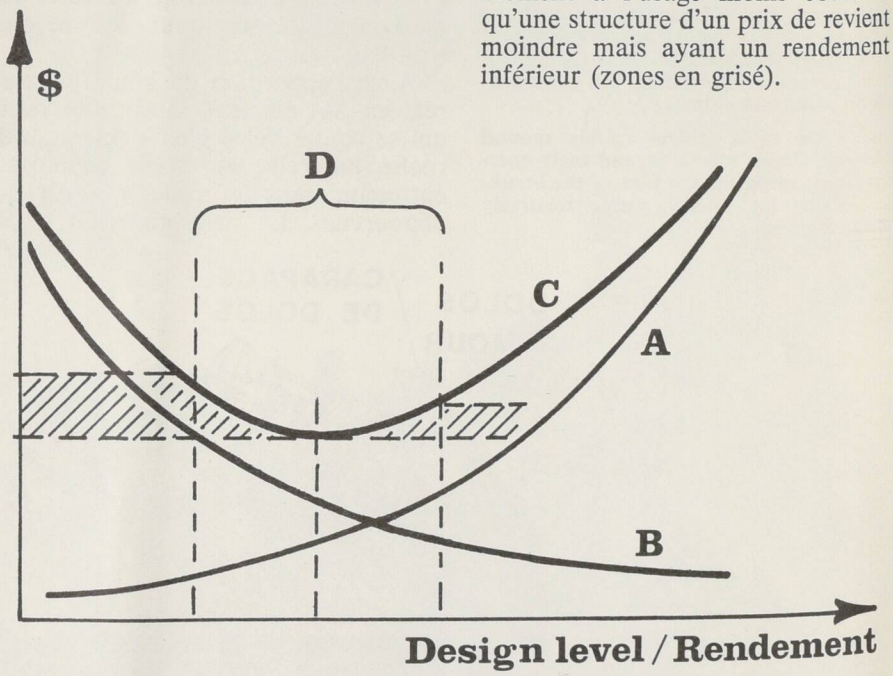
In order to construct a rubble mound breakwater, an impossible mystery must be solved. The designer must determine what manner of waves will assault the structure, what will it cost to build, and if waves tear it down, how much in time, money and possibly, lives lost, will be the result of the failure. None of these criteria can be considered independent of the others. No building codes or design handbooks exist for breakwater design. Experience, and to a large degree, intuition must guide coastal engineers planning protection for harbors.

The graph portrays the dilemma facing the breakwater engineer. Basic parameters are the relationship of total dollars involved and "design level" of the structure, the latter derived from a lengthy series of calculations of its own. Curve "A" is the "capital cost", a combination of building and financing costs for a given design level. Curve "B" represents operational costs — continuing maintenance, breakdown of the structure, time lost by the harbor facilities and so on. Curve, "C", represents totals with the optimum range of designs (D), shown by dashed lines. Note that a slight "over design" will probably prove less costly than the saving in building cost an underdesign would offer (shaded areas).

QU'EN COÛTE-T-IL?

Avant de pouvoir construire un brise-lames en enrochements il faut résoudre un problème particulièrement ardu. L'ingénieur doit déterminer les caractéristiques des vagues qui viendront s'y briser, le coût de la construction et, si les vagues le détruisent, les conséquences de cette destruction en matière de temps, d'argent et éventuellement de vies perdues. Aucun de ces critères ne peut être étudié indépendamment des autres. Comme il n'existe aucun code ou manuel de construction, l'ingénieur doit faire appel à son expérience et, dans une large mesure, à son intuition pour planifier la protection des ports.

Le diagramme illustre le dilemme auquel il doit faire face. Les paramètres de base sont le rapport existant entre la dépense totale prévue et le «rendement» de la structure, ce dernier facteur étant lui-même dérivé d'une longue série de calculs. La courbe «A» représente «l'investissement», qui combine les frais de construction et de financement pour un rendement donné. La courbe «B» représente les frais d'exploitation, c'est-à-dire d'entretien, de réparations, de temps perdu pour les installations portuaires, etc. La courbe «C», quant à elle, représente les totaux avec la plage optimale de rendements (D), indiquée en traits interrompus. Remarquons qu'une structure ayant un rendement légèrement supérieur se révélera probablement à l'usage moins coûteuse qu'une structure d'un prix de revient moindre mais ayant un rendement inférieur (zones en grisé).



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