Development of a New Concrete Armor Unit for High Wave: R-A Block

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ABSTRACT
The Concrete Armor Unit (CAU) is an artificial structure to reduce the intensity of wave energy. Hundreds of different shapes of concrete armor units have been developed since 1950. Recent development of armor units focused on cost, constructability besides stability. Research necessity of a new CAU for high waves is increased due to climate change. We developed the new CAU which protected against significant waves height of 10 m and was suitable for single layer such as Accropode and Core-Loc. The new CAU called Reverse-A (R-A) was analyzed and verified in laboratory tests. It had excellent stability in hydraulic tests with high waves but difficulties in fabrication and installation.

KEY WORDS: Concrete Armor Unit; high wave; breakwater; single layer; experiment

INTRODUCTION
As human life is getting bigger and bigger along the coast, the demand for a new technology to control incident waves is also increasing. Many new types of breakwaters and technologies have been developed, the required weight of quarried stone is also increased against higher waves. Because it is difficult to find qualified heavy quarried stones, artificial structures are applied to dissipate wave energy instead of them in the armor layer. The artificial structure is called Concrete Armor Layer (CAU).

CAU begins with simple shape Cube and widely used Tetrapod is developed in the 1950s. Dolos and Accropode are developed in 1963 and 1980, respectively. Because they have been verified in many constructions, they are still popular comparing recently developed CAUs. Dolos is practical as a repair for other CAUs and rubble stone in breakwater. Their shapes are shown in Fig. 1. Though hundred shapes of CAU have been developed over the past 60 years, only a few of them have been done after the year 2000.

Melby and Turk (1997) develop Core-Loc and mention optimal armor engineering characteristics for the design of CAU. Core-Loc has very high Hudson stability coefficient and it is useful for a repair unit to Dolos (Turk and Melby, 1994).

There are two representative artificial structures to prevent attack of incident waves. One is CAU and the other is a concrete caisson. Existing CAU is economical and its wave limit is 7 or 8 m in height comparing with a concrete caisson. The purpose of the study is developing of a new CAU against waves of higher than existing one. We analyzed the most popular CAUs and applied their advantages to a new CAU. Laboratory experiments were conducted to verify hydraulic characteristics and structural stability in a 2-dimensional wave tank. The new developed CAU is stable in waves of 10 m and its shape is modifying to get better stability using FEM.

NEW ARMOR UNIT
Previous blocks mainly focus on stability of breakwater but many factors need to be considered together in development of a new CAU. They are economical, constructability, size of yard, handling, stocking, recycle of steel form, material, number of layer, and so on. Therefore it is very difficult to develop a new CAU considering above factors. Because hundred shapes of CAU are already developed, a birth of a new CAU is impossible without conflicting of patent violation.

Most of past CAUs have been analyzed and there are four basic shapes in Fig. 1. They are Cube, Tetrapod, Dolos and Accropode. They are divided into two types by number of layers. Three blocks (Cube, Tetrapod, Dolos) are double layer and Accropode is single layer. Single layer starts with Accropode in 1981 and it becomes a new trend for new developed CAUs after then. Werren et al. (2002) described that two placement techniques and importance of packing density for Core-Loc. Turk and Melby (1997) said that the special placement was designed on toe area for single layer Core-Loc. We also followed single layer design for a new CAU due to many advantages.

A new CAU, called R-A block, was based on interlocking between blocks (Fig. 2). The shape of the block is a reverse of alphabet A and zigzag shape placement is easy to dissipate incident wave energy. It is a completely different shape comparing with the above four conventional CAUs. Because it should be economical, slender type and single layer were required. It is difficult shape to make a simple steel form due to two legs on the bottom. Because angular faces are efficient for dissipation of wave energy, they were applied to R-A block. The two legs were weak point in structural stability and it would be modified.