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# TESTING METHOD FOR TENSILE PROPERTIES OF GLASSFIBER REINFORCED CEMENT

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## ABSTRACT

The geometry of the specimen for the tensile test of glassfiber reinforced cement is proposed here from the test results. The specimen having dimensions of 1cm x 4cm x 38cm is reinforced with adhered steel, aluminum or plywood plates at both ends.


## INTRODUCTION

GRC is a new composite material composed of alkali-resistant glassfiber and cement or cement mortar having superb properties, not found in conventional cement material group. The development of GRC employed in the fields of construction and civil engineering works is expected. GRC is already in use as an interior and exterior construction material for its high strength and incombustibility. Design data and quality control are necessary for the use of GRC products, and for this purpose the preparation of a standard test method for the properties of GRC is required.

In this paper, the results of the tests conducted to determine the standard test method for tensile strength of GRC are reported.

## 1. BEHAVIOR OF GRC IN TENSILE TEST

Numerous results of the tensile tests of GRC have been reported so far. Despite some differences in test results due to differences in measuring methods, the sizes of specimens, and the composition of GRC specimens, the following region or points in tensile strain-stress relation are recognized for appropriately namufactured

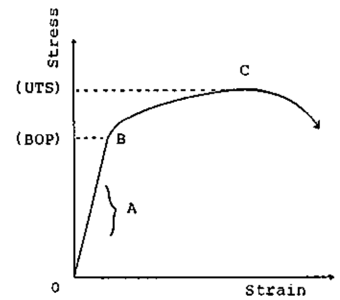


Figure 1. Tensile Behavior of GRC


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GRC on the market, in which alkali-resistant glassfiber effectively reinforces cement matrix.

* Initial linear elasticity — At initial loading, the relation between tensile stress and tensile strain shows a linear elasticity relations.

* Tensile proportionality limit — The relation between tensile stress and tensile strain becomes non-linear when cracks occur in the cement matrix. The point where the linear relation begins to fail is called the limit of proportionality (also called BOP, Bend Over Point).

* Ultimate tensile strength — After exceeding the BOP, the rate of increase of the tensile strain against the tensile stress is accelerated and the tensile stress reaches a maximum value. The maximum value of the tensile stress is called the Ultimate Tensile Strength (UTS).

Figure 1 explains the tensile behavior of GRC showing the initial linear elasticity at A, the BOP at B, and the UTS at C. The tensile stress decreases after reaching the UTS. There will be differences in tensile strain values depending on measuring methods. The differences are especailly prominent after reaching the UTS.

## 2. LOADING METHOD AND SIZE OF SPECIMEN

### 2.1 SELECTION CRITERIA

In the tensile test of GRC, the initial linear elasticity, the BOP, and the UTS, which are the factors of representing the tensile property of GRC, are the test items, and the tensile stress and the tensile strain produced in the specimen under tensile load are measured. The following four points are the bases for selecting the loading method and the size of specimen:

1) The specimen must have a standard shape representing GRC products.
2) The part to be measured must have uniform sections.
3) Rupture occurs at the part to be measured.
4) The behavior of the part to be measured must not be affected by the stress transmission mechanism.

### 2.2 CONVENTIONAL TENSILE TEST

The loading mehtod and shape of the specimen used for the tensile test of GRC and similar materials may be roughly classified into three: (1) Tensile load is applied by adhesion or friction at both ends in longitudinal direction of plate or column-shaped specimen, (2) Tensile load is applied mechanically by clamping both ends of a column-shaped specimen which is constricted in the middle, and (3) Compressed load is applied at the sides of a column-shaped specimen. In order to determine a standard test method for GRC products of different dimensions and shapes, it will be necessary to unify the specimens into a typical shape for testing GRC as a material,



since it is difficult to cut off a specimen from GRC products. A plate-shaped specimen may be used as a typical shape.

Table 1 shows a summary of the tensile test using a plate-shaped specimen of GRC and similar materials. Many of the tests employ methods of applying loads by mechanical or by friction clamping with chucks at both ends of the specimens, and some methods were tried in which the loading was done via bolts. In either case it is so designed that the ultimate rupture occurs at the part to be measured having a uniform section in the middle of the length of the specimen by reinforcing it with reinforcing material applied by adhesion to the ends of the specimen from where the load is transmitted to the specimen, or by making the width of the ends larger than the width at the middle.

Table 1. Tensile Test of GRC and Similar Materials Using Plate-shaped Specimen

| Material | Specimen | | Loading Method | Test Items* | Remarks |
|---|---|---|---|---|---|
| | Shape | Example of Size (mm) | | | |
| G R C | Uniform Section | 150 x 25 x 10 | Chuck(friction) | U T S | Reference 1) |
| S F R C | | 450 x 100 x 16 | Bolt(mechanical) | U T S, $E_t$ | Reference 2) |
| P F R C | | 300 x 50 x 6 | Chuck(friction) | U T S, B O P | Reference 3) |
| W O O D | Constriction in the Middle | 390 x 20 x 5 | Chuck(friction and partially mechanical chuck) | UTS, BOP, $E_t$ | JIS Z 2112 |
| M E T A L | | 400 x 50 x 9 | | U T S, (B O P) | JIS Z 2201, Z 2241 |
| PLASTIC | | 120 x 25 x 2 | | U T S, B O P | JIS K 6911, K 6745, K 7113 |

* UTS:Ultimate Tensile Strength, BOP:Bend Over Point, $E_t$:Tensile Young's Modulus

### 2.3 PRELIMINARY TEST ON SHAPE OF SPECIMEN

A 1cm thick plate-shaped specimen is considered to be a standard GRC specimen for the sake of preparation. The width of the part to be measured should preferably be about 4cm, which is equal to, or larger than the length of the alkali-resistant glassfiber considering its two dimensional homogeneity.

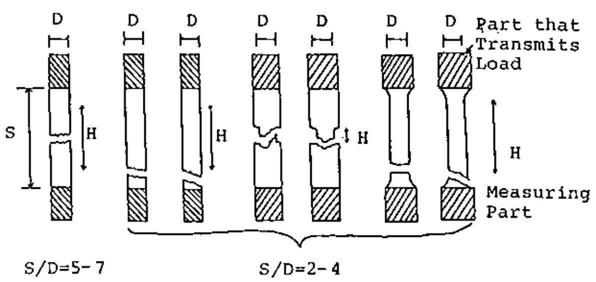


Figure 2. Preliminary Test

Figure 2 shows some of the specimens for the preliminary test conducted to study the shape of the specimen. Even in the test using specimen having a constriction in the middle ruptures occurred for the small number of the specimen at the positions to be measured when the load transmitting distances S (called span) of the specimens are 2 to 4 times as long as the width D. On the contrary, specimens having a uniform rectangular section with the span remarkably larger than the width D ruptured in the middle, which is subject to measurement, in many instances. In order to have the rupture in the middle, therefore, it is important to design the span remarably larger than the width D rather than to provide constriction in the middle. Therefore, the specimen may be of plate shape, 1cm thick and 4cm wide, with a uniform section. The value of the span is an important factor.

## 2.4 TEST OF LOADING METHOD

Five kinds of load transmitting methods using plate type specimens with a uniform section are shown in Figure 3. Tensile tests were carried out on the specimen having different span/width ratios to investigate the relation between the position of rupture and the span/width ratio, and the results are shown in Figure 4. In the method where the ends of the specimens were clamped by chucks without reinforcement, many specimens ruptured at the ends as symbolized by X in Figure 4. This loading method is not appropriate. Clamping tightly with inserted rubber sheets is not suitable as a standard loading method, because it is time-consuming in preparation and the rubber sheets tend to slip when loading. Loading through bolts by adhered plywood or steel plate and loading by friction clamping with chucks the ends reinforced by adhered aluminum plate are considered to be standard methods because these methods produced ruptures in the middle part of the specimens with a large span, which is the subject for measurement. As for standard methods, steel plates or aluminum plates having a high rigidity are preferred. Adhered plywood may be used as a supplementary measure when steel or aluminum plates are not available, because plywood is easy to obtain and easy to cut.

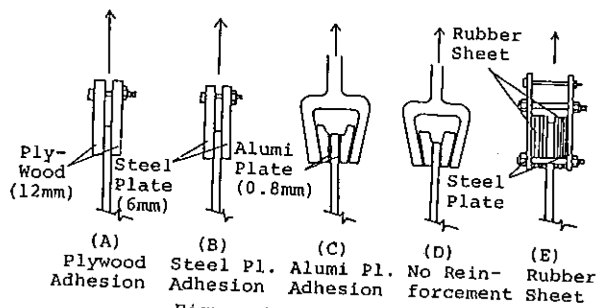


Figure 3. Loading Method

Standard loading methods:
reinforced with
adhered Steel plate
adhered Aluminum plate

Supplimentary method:
reinforced with
adhered Plywood plate

## 2.5 TEST FOR SPECIMEN SIZE

Stress distribution is disturbed at the ends where steel, aluminum or plywood plates are adhered to reinforce the ends of the specimens for better load transmission. Figure 5 shows the results, or stress disturbance analysis at the ends, and

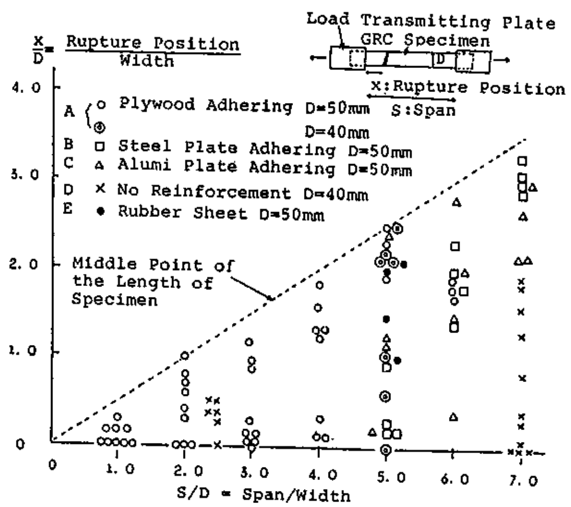


Figure 4. Rupture Position and Span/width Ratio



shows 1% or less disturbance at a location distant by D, the width of the specimen, from the end where the reinforcement plates were adhered. The fact that the stress distribution becomes uniform at a distance as same as the width is supported by the Saint-Venant Theory 4). It, therefore, is rational to adopt as the tensile strength of GRC only when the rupture has occurred at a location apart from the reinforcement plates as much as or more than the width of the specimen, and measurement has been taken at this position.

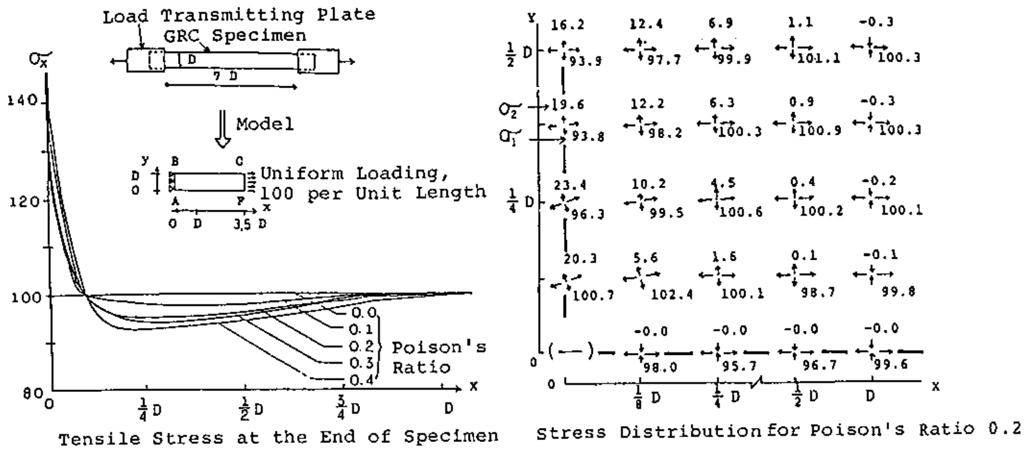


Figure 5. Stress Disturbance at the End of Specimen

In the methods employing adheard steel, aluminum or plywood plates with the span S 6 - 7 times as much as the width D as shown in Figure 4, the ruptured position is away from the adhered reinforcement plates as much as or more than the width of specimen. Many specimens where the span S is less than 5 times as much as the width D rupture at positions near the end of the reinforcements. From the above, it is considered appropriate for the specimen to keep the necessary length, for the span length 7 times as much as the width. Considering the space for the cross head of the testing equipment, the size shown in Figure 6 is suitable for a standard specimen for the GRC tensile test.

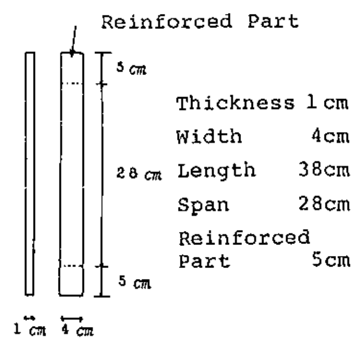


Figure 6. Standard Size of Specimen

## CONCLUSION

It is essential to use a specimen having a remarkably larger span than the width rather than a specimen having a small span/width ratio as in the case of conventional test methods in order to have rupture in the middle position of a specimen, which is the measurment point. A standard specimen is 38cm long, 4cm wide, and 1cm thick with a uniform section with 5cm long reinforced load transmitting parts at both ends. Adhered steel or aluminum plates are considered to be suitable for the standard loading methods, and plywood plates are supplementary reinforcement. Stress distribution disturbance caused by the reinforced end parts considerably decreases as the distance from the reinforced part becomes greater than the width of the specimen.

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