High Zirconia Alkali-resistant Glass Fiber

ARG Fiber

Nippon Electric Glass Co., Ltd. is a manufacturer of specialty glass products including glass fiber reinforcements.

Nippon Electric Glass Co., Ltd.
Since its founding in 1949, Nippon Electric Glass Co., Ltd. (NEG) has been manufacturing a wide spectrum of technical glasses. The company entered the glass fiber arena in 1960 primarily as a material supplier, and eventually started production of glass fiber in 1975. High Zirconia (ZrO$_2$) alkali-resistant glass fiber (ARG Fiber), developed in cooperation with Kanebo, Ltd., was successfully put into mass production also in 1975 using the company’s own Direct Melt Method with an all-electric furnace. NEG provides ARG Fiber for use in building products and other engineering uses.

There are a variety of ARG Fiber products available including Continuous Roving, Chopped Strands, and Fabrics, all of which are used to strengthen cement and concrete products as well as calcium silicate products utilizing the spray-up and premix methods and so forth.
Spinning Process

Hundreds of filaments are drawn from tiny nozzles.
Continuous Roving is made by gathering 150 to 200 ARG Fiber filaments into a strand, then winding 20 to 50 strands to form cylindrical packages. Two types of Roving using different sizing are provided as Roving No.1 for H-103 and Roving No.2 for H-200. Continuous Roving is best suited to the spray molding process and is used in a wide range of products in building, civil engineering, etc.

- **Standard Specification**

<table>
<thead>
<tr>
<th>Type</th>
<th>Code</th>
<th>Tex</th>
<th>Strand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type1</td>
<td>AR2500H-103</td>
<td>2500</td>
<td>32</td>
</tr>
<tr>
<td>Type2</td>
<td>AR2500H-200</td>
<td>2500</td>
<td>32</td>
</tr>
</tbody>
</table>

Packaging  
44 lbs. in shrink-film

Recommended use  
Spray-up, centrifugal casting

- **Applications**

**Building**  
Exterior and interior walls, parapets, window frames, ceilings, roofings, sandwich panels, railings, acoustic panels, permanent formwork, electric utility products, etc.

**Civil engineering**  
Acoustic panels, GFRC pipes, cable troughs, water troughs, drain pipes, bridge deck formwork, etc.

**Others**  
Garden furniture, coping, fences, storage tanks, noise barriers, etc.
Continuous Roving

GFRC Applications using Rovings

GFRC spandrel panels (16 to 18 ft long) and column covers clad these 4-story light steel framed buildings. Light weight GFRC panels allowed the use of a spread footing instead of piles.

GFRC panels on this building allowed an accelerated time schedule and provided a total wall system.

GFRC panels duplicated ornamental terra cotta for the roof cornice.

The terra cotta was matched with GFRC panels for a two-story addition.

A bas-relief mural in GFRC.

The versatility of GFRC... fluted column covers... three dimensional spandrels.

Use of GFRC allowed reduction in size of the structural steel braced-frame. Panels can be removed to permit equipment installation.
GFRC reinforced with ARG Fiber has been used for various purposes in the fields of building and civil engineering. Recently, there has been a growing demand for the exterior walls of 30 to 40 floor high-rise buildings in the United States. Design, manufacture and installation of these GFRC panels were safely carried out in accordance with PCI's* guideline.

*PCI: Prestressed Concrete Institute
175 West Jackson Boulevard, Chicago, Illinois 60604, U.S.A.

Use of the lightweight panels helped the upper 24 stories to cantilever over a landmark low-rise structure.

GFRC Applications using Rovings

Addition of 36 stories around 16-story terra cotta structure. The use of GFRC and a steel stud frame to support the terra cotta shaved one year off a three-year construction schedule.
Applications for High-Rise Buildings

GFRC wall of 157,000 sq. ft having large smooth reveals and a medium textured exposed aggregate finish. Lightweight GFRC panels allowed the long spans.

An 18-story building uses column covers and spandrel panels of GFRC. False joints break up the surfaces into 8 ft by 8 ft blocks and give the desired architectural effect.

- **GFRC Panel Installation Method**
  First using ARG-contained mortar install flexible anchor rod to GFRC panel while it is wet. This anchor rod is to be welded to steel stud. Flexible anchor rod absorbs expansion or shrinking of the GFRC panel.

- **Characteristics of Installation Method**
  1. Flexible anchor allows size change of GFRC panel, leaving no constraint on the panel.
  2. Without ribs, light weight has been achieved.
  3. Both light-weight steel frame and the space of anchors give the superior wind pressure resistance required for 30 to 40 floor building.
  4. There is enough flexibility to withstand an earthquake.
Chopped Strands

High Integrity Type

High integrity-type Chopped Strands disperse keeping itself as strands in a matrix of calcium silicate slurry, cement slurry, etc.

- **Standard Specification**
  - **Type**  | **Code** | **Length**
  - High Integrity | ACS○○PH-901X | 0.5, 0.75, 1.0 in (13, 19, 25mm)
  - ACS○○H-530X | 1.5 in (38mm)
  - ACS○○H-350Y | 0.5 in (13mm)

○○ = Cut length in mm

**Packaging** — 44 lb Bags. Total pallet weight varies according to fiber length.

**Recommended use** — Premix, casting.

**Applications**

- **Building** — Railings, parapets, flooring, roofing, ceiling, stucco, surface bonding, etc.
- **Civil engineering** — Cable troughs, soil reversion unit, etc.
- **Others** — Garden furniture, artificial stones, coping, fences, calcium silicate board, external lending, etc.

Dispersible Type

Dispersible-type Chopped Strands disperse into filaments in a matrix of calcium silicate slurry, cement slurry, etc.

- **Standard Specification**
  - **Type**  | **Code** | **Length**
  - Dispersible | ACS○○S-750 | 0.25, 0.5 in (6, 13mm)

○○ = Cut length in mm

**Packaging** — 44 lb Bags.

**Recommended use** — Hatschek method, casting.

**Applications**

- **Building** — Fire-proof drain pipes
- **Others** — Calcium silicate heat insulator, asbestos replacement products

GFRC Applications using Chopped Strands
Fabrics

Net

In case of GFRC production by the spray-up or premix methods, net is used to reinforce the areas which need mechanical strength to prevent sagging.

- **Standard Specification**

<table>
<thead>
<tr>
<th>Code Number</th>
<th>Weight (oz/ft²)</th>
<th>Length (yards)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS5 × 5</td>
<td>0.26</td>
<td>55</td>
</tr>
<tr>
<td>TD10 × 10</td>
<td>0.26</td>
<td>110</td>
</tr>
<tr>
<td>TD5 × 5</td>
<td>0.48</td>
<td>55</td>
</tr>
<tr>
<td>LW110</td>
<td>0.36</td>
<td>110</td>
</tr>
</tbody>
</table>

Note: TS = single-strand  TD = double-strand

**Width** 3.3 feet

**Recommended use** Spray-up or spray-up with combination of premix.

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Stadium ceiling  
Buddhist temple gable  
GFRC Applications using Fabrics
What is ARG Fiber?

Developed by Nippon Electric Glass, Co., Ltd. in cooperation with Kanebo, Ltd., ARG Fiber is a high-quality alkali-resistant glass fiber containing a high percentage of Zirconia (ZrO₂). The alkali resistance of glass fiber used as a reinforcing material for cement is determined by the Zirconia (ZrO₂) contents in the glass. The higher the ZrO₂ content, the greater the alkali resistance. (See Figure 1.)

NEG's ARG Fiber contains min. 19% ZrO₂, as shown in Fig.1, which was made possible by its original glass composition as well as the unique Direct Melt Method using an all-electric furnace.

![Figure 1: Alkali-resistivity of Glass and ZrO₂ Contents](image)

The figure shows the range of compositions which ensure the stable manufacture of high-Zirconia glass. The stable manufacturing zone is shown as the inside of the polyhedron. When Zirconia content exceeds 17% it causes difficulty in glass manufacturing. However, when Li₂O and K₂O coexist in a certain ratio, the manufacture of alkali-resistant glass fiber with 19% Zirconia becomes possible. (U.S.A. PATENT 4,140,533)

![Figure 2: Comparison of Alkali Erosion in ARG Fiber and E-type Glass Fiber](image)

**Table 1 Properties of NEG's ARG Fiber**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>pcf</td>
<td>170</td>
</tr>
<tr>
<td>Fiber Diameter</td>
<td>inch</td>
<td>0.00053</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>psi</td>
<td>more than 1.85×10⁶</td>
</tr>
<tr>
<td>Young's Modulus</td>
<td>psi</td>
<td>1.1×10⁷</td>
</tr>
<tr>
<td>Strain</td>
<td>%</td>
<td>more than 1.5</td>
</tr>
<tr>
<td>Alkali-resistivity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight¹ Loss</td>
<td>ARG Fiber</td>
<td>%</td>
</tr>
<tr>
<td>E-type glass fiber</td>
<td>%</td>
<td>10.5</td>
</tr>
<tr>
<td>Tensile² Strength Retention</td>
<td>ARG Fiber</td>
<td>%</td>
</tr>
<tr>
<td>E-type glass fiber</td>
<td>%</td>
<td>14</td>
</tr>
</tbody>
</table>

1) Weight loss rate (% of strand, held at 176°F for 200 hours in saturated cement solution

2) Tensile strength retention rate (% of cement paste applied strand, held at 122°F for 300 hours in 100%RH
Characteristics of GFRC

GFRC, alkali-resistant glass fiber reinforced cement, has many superior properties compared to ordinary cement products. It is widely used as a building and civil engineering material.

- **Features of GFRC**
  1. Good bending strength
  2. Good impact strength
  3. High toughness and cracking resistivity
  4. Light weight due to thin forming
  5. Allows free design

- **Properties of GFRC**

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Spray-up Method</th>
<th>Premix Method</th>
<th>Plain Mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Percent</td>
<td>wt.%</td>
<td>5</td>
<td>3</td>
<td>—</td>
</tr>
<tr>
<td>Specific Gravity (dry state)</td>
<td>psf</td>
<td>110-120</td>
<td>103-120</td>
<td>120-145</td>
</tr>
<tr>
<td>Bending Strength</td>
<td>psi</td>
<td>3500-5000</td>
<td>1400-2800</td>
<td>700-1100</td>
</tr>
<tr>
<td>LOP*</td>
<td>psi</td>
<td>1000-1500</td>
<td>1000-1500</td>
<td>700-1100</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>psi</td>
<td>1400-2100</td>
<td>850-1500</td>
<td>400-700</td>
</tr>
<tr>
<td>UTS*</td>
<td>psi</td>
<td>700-1000</td>
<td>700-1000</td>
<td>400-700</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>psi</td>
<td>8000-14000</td>
<td>5000-11000</td>
<td>5000-8000</td>
</tr>
<tr>
<td>Share Strength</td>
<td>psi</td>
<td>3500-5000</td>
<td>1400-2800</td>
<td>250-700</td>
</tr>
<tr>
<td>Chargr. Impact strength</td>
<td>lb/ft²</td>
<td>80-140</td>
<td>50-110</td>
<td>5-10</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td></td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Water</td>
<td>%</td>
<td>10-15</td>
<td>10-16</td>
<td>9-14</td>
</tr>
<tr>
<td>Shrinkage Ratio</td>
<td>%</td>
<td>0.1-0.2</td>
<td>0.1-0.2</td>
<td>0.05-0.15</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>BTU/h·F</td>
<td>0.5-0.5</td>
<td>0.5-0.5</td>
<td>0.5-0.9</td>
</tr>
<tr>
<td>Heat</td>
<td></td>
<td>4-7</td>
<td>6-7</td>
<td>6-7</td>
</tr>
<tr>
<td>Fire</td>
<td></td>
<td></td>
<td></td>
<td>Incombustible building material</td>
</tr>
<tr>
<td>Fire Test</td>
<td></td>
<td>1250</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Test at Scorlab</td>
<td></td>
<td>250</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Mustash Institute of Technology</td>
<td>1000</td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td></td>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Stress-strain Curves of GFRC**

GFRC acts as an elastic solid up to point A (Limit of Proportionality). The curve between A (LOP) and B (MOR) illustrate the fact that only glass fiber contributes to the reinforcement, which is the main characteristic of GFRC's high impact strength.

- **Bending Strength of GFRC Used with Net**

1. **Comparison in Direct Spray-up Method**

   | Thickness of GFRC | 0.4 inch Glass Fiber | Chopped in 1 inch 5 wt.% |
   | Location of net  | 0.08 inch from tensile side |
   | No. of sheets of net | 2 sheets in parallel position |
   | Age              | 28 days, standard composition |

2. **Comparison in Premix Method**

   | Thickness of GFRC | 0.4 inch Glass Fiber | Chopped in 1 inch 5 wt.% |
   | Location of net  | 0.08 inch from tensile side |
   | No. of sheets of net | 2 sheets in parallel position |
   | Age              | 28 days, standard composition |
Overseas Subsidiary:

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URL: http://www.neg.co.jp/arg/index_en.html

Glass Fiber Division, Production of Nippon Electric Glass Co., Ltd. is certified to comply with the requirements of ISO9001 of Quality Management System regarding the design, development and manufacture of continuous glass fiber products, such as rovings, chopped strands and yarns. Certificate No. JQA-CM4854

The Otsu, Fujisawa, Shiga-Takatsuki, Notogawa, and Wakasa-Kaminaka Plants, and the Precision Glass Center of Nippon Electric Glass Co., Ltd. are all certified to comply with the requirements of ISO14001 of Environmental Management System. Certificate No. JQA-EM0906

Specifications are subject to change without notice.