14 THE DEVELOPMENT OF HIGHLY FUNCTIONAL GRC

H. OKADA, Asahi Glass Building Wall Co Ltd, Tokyo, Japan

SUMMARY: Asahi Glass Building Wall has been developing highly functional GRC products. These include GRC panels for the prevention of wind noise on elevated structures. The GRC panels are used to cover radio transmission towers, high-rise buildings and apartments. GRC panels can easily be made with smooth edges, and these are used to cover any sharp edges that may otherwise cause wind noise.

TV electromagnetic wave absorption panels are another highly functional GRC product. High-rise buildings cause interference to TV transmission signals and this can result in a ghost image on the TV screen. In this case, we combine GRC, a TV electromagnetic wave absorber and reflection plate. With this combination we can prevent the ghost TV electric wave and the resulting ghost image on the TV screen.

In this paper, we present these applications and the manufacturing methods.
KEYWORDS: Functional GRC, GRC, transmission towers, wave absorber.

INTRODUCTION: REQUIRED FUNCTION OF THE FAÇADE WALL

The building structure must be safe against external forces, such as an earthquake, strong wind and snow loading.

In addition there are many performance requirements for both interior and exterior elements and materials of the building, which must be satisfied to ensure that the structure will not collapse under applied loads.

The performance requirements demanded of an outer wall and the measures of performance are shown in Table 1. Various evaluations have been performed with regard to safety, comfort, durability and environmental protection, and GRC has performed well. GRC is also used for decorative components including monuments, sculptures and ornamental components of buildings. However, in order for GRC to be used in populated areas, it is important to implement designs which consider the environment.

Table 1 - Façade wall performance

Performance of the outer wall		Design factor
Safety	Earthquake-resistance	Transformation between levels; inertia corner
	Wind resistance	Bending strength and deflection
	Combustibility and fire resistance	Combustibility and resistance in hours
	Impact resistance	Impact energy
Comfort	Waterproof	Water permeability
	Thermal insulation	Heat loss
	Sound insulation	Sound transmission loss
	Air-tight	Air permeability
Ambient surroundings	View and the beauty	Color
	Resist dirt and graffiti	Ease of cleaning
	Electromagnetic disturbance	Reflectivity and the permeability
	Noise fault	Wind noise
	Prevent glare	Reflectivity
Durability	Reversible thermal movement	Coefficient of linear expansion
	Moisture-induced movement	Water permeability and expansion
	Resistance to ultraviolet rays	Color loss and strength degradation
	Abrasion resistance	Resistance to wear
Environmental protection	Environmental load	CO_2 permeability
	Ease of replacement	Fixing method
	Take-ability	Recycling percentage
	Low maintenance	Ease of maintenance

1 WIND NOISE PREVENTION USING GRC LOUVRE

1.1 Effect of wind

There are many high-rise buildings in the densely populated urban areas of Japan and these buildings are required to harmonize with the environment. Louvres are commonly used as covers for roof-top air conditioning units, and also for decoration of buildings and apartments.

However, louvres installed in exposed situations are often the cause of wind noise, which can be a problem for residents.

In fact, there are generally three types of noise:

1.1(a) Continuous noise

This sound due to pressure change is caused by the wind turbulence itself. While the wind flows fast, the turbulent wavelength becomes high.

Examples of this are the noise created by a jet engine or the occurrence of the sounds at the jet nozzle.

1.1(b) Kalman whirlpool

This sound occurs when the air brushes and leaves the surface of an object when flowing smoothly. It is similar to the noisy sound which occurs when a typhoon approaches. At this point, the effect of the Kalman whirlpool will be added to the magnitude of vibration of the object, if they are close. Fatigue failure might happen from the vibration with both stick-type objects and needle-type objects.

1.1(c) Self-vibration

This sound is caused by the air current itself vibrating (as with a harmonica or a clarinet-type pipe).

The sound caused by the Kalman whirlpool effect is the one which affects the louvre.

It is possible to minimize the Kalman whirlpool effect by alteration of louvre shape and thereby disturb the turbulence intentionally.

The assumption for sectional shapes is shown in Figure 1.

Figure 1 - Shape of cross-section to minimize noise

Metal, GRC, ceramics and GFRP can all be used to achieve these shapes, but each has advantages and disadvantages. The characteristics of each type of material are compared in Table 2.

Metallic profiles are generally used to produce the louvre. However, metal is unsuitable to make special shapes, and there is also a possibility that metal might cause heat around a place such as a radio wave tower.

Ceramics are non-magnetic and have excellent durability but it can be dangerous to use ceramic at high elevation due to its fragility, and the serious consequences of an accident.

GFRP does not have problems like metal and ceramics. It is very easy to use, but is combustible, and is therefore not suitable to use in large quantities for exterior applications. There is also the risk of deterioration due to ultraviolet light.

Comparing all these materials, GRC is non-magnetic and has good weather resistance. It is possible to make small numbers and a variety of shapes. Therefore, GRC is the best material for the louvre.

Table 2 - Characteristics of each material for the louvre

Material	Merit	Defect
Metal	High-precision, smooth surface, the R ones are expensive	It is necessary to be standardized; possibility of corrosion; dielectric; a mold is necessary
GRC	Non-magnetic, high-variety, low-volume manufacturing possible Toughness for which it is possible to manufacture R one Non-combustible	Surface variation (possible to correct this with a coating)
Ceramics	Non-magnetic, durable, corrosion-resistant, non-combustible	It is necessary to be standardized; brittleness; a mold is necessary
Glassfiber reinforced plastic (GFRP)	Corrosion-resistant, non-magnetic	Combustibility, and poor resistance to ultraviolet

1.2 Experiment in noise

Modelled on an actual transmission tower, an experiment was conducted in a wind tunnel to verify the noise of a GRC louvre. Figure 2 shows the mockup.

Figure 2 - Mockup of GRC louvre

The wind speed was adjusted from 8m/s to 50m/s, to simulate a wide range of exposure conditions.

As a result of this experiment, it was confirmed that there was no problem for the sound pressure level even at high wind speeds.

In low wave noise area, however, the noise from Kalman swirl was observed.

This may be the result of an interaction between the character of materials and GRC itself.

Strain gauges installed in the GRC indicated a maximum stress of approximately 2.16N/mm2. This is generally considered as a permissible long-term stress for GRC. Because of little information on fatigue strength, additional tests were performed.

1.3 GRC fatigue characteristics

Figure 3 shows a device to measure fatigue characteristics of GRC. This allows a high stress to be applied from either side.

Figure 3 - Test scenery

Vibration was set for 30Hz, amplitude ± 0.01cm, and stress levels of 5N/mm^2, 4N/mm^2 and 8N/mm^2 by changing the span of the sample. This is because the limit of proportionality (LOP) of GRC is generally 10N/mm^2. GRC was cyclically loaded a maximum of 3,000,000 times with these stress levels. Samples were then cut and tested for bending strength in compliance with GRC industry standards (see Table 3).

Table 3 - Bending strength test result (N/mm^2)

Cyclic stress level	LOP		Modulus of rupture (MOR)		Young's modulus $\times 10^3$	
	Value	Standard deviation	Value	Standard deviation	Value	Standard deviation
0	12.0	0.38	15.8	9.0	21.0	0.7
2.5	7.9	0.82	20.8	7.6	21.7	1.1
4.0	10.1	0.49	13.0	2.5	15.2	2.5
8.0	16.7	1.47	17.9	2.2	21.0	2.4

The results of the test show that the strength of GRC did not reduce after the cyclic loading.

There is a probability of a Kalman whirlpool effect causing resonance at a wind speed of more than 30m/sec. This wind velocity is expected 10.3 times and for 103 minutes in 100 years. In this case the stress and the frequency of vibration become 1.1N/mm^2 and 52Hz, respectively.

Taking account of the ratio of frequencies 52Hz/30Hz = 1.7 and time duration factored accordingly, 103 minutes × 1.7 = 175 minutes, the number of vibrations is equivalent to approximately 315,000.

Compared with the 3,000,000 vibrations, and 8.0N/mm^2 stress in testing, it can be concluded that the performance is satisfactory.

1.4 Conclusion on wind noise prevention

Through this experiment, it was verified that GRC louvres for the prevention of wind noise are effective, and also their influence on vibration.

2 TV ELECTROMAGNETIC WAVE ABSORPTION PANELS

2.1 The purpose of electric wave absorption

Most areas in Japan receive TV signals by a terrestrial analogue wave. Reception can be made difficult by buildings and topography. There are two different types of wave in terrestrial broadcasting. One is known as a direct wave, which comes directly from the broadcast station to an antenna of each resident. The other is called a reflected wave, which reflects off buildings.

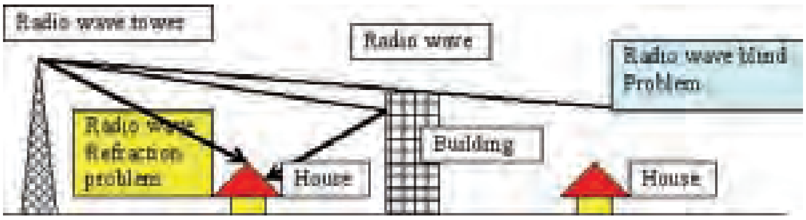

Figure 4 - Example of the electric wave interference

The antenna receives both direct waves and reflected waves. The reflected wave travels further and therefore arrives at the antenna later.

The image is altered according to the number of reflected waves.

If it is difficult to receive direct waves behind a building, it is possible to use a common antenna. However, if it is possible to predict the occurrence of a reflection problem, there are some effective ways to prevent it at the design stage by (1) changing the form of a building or (2) absorbing the reflection wave into the structure or exterior of the building.

In more detail:

1. Changing the direction in which a building faces, or changing its shape. Reflecting the electromagnetic wave up and down.
2. Implanting an object to absorb electromagnetic interference into a wall. Changing wave energy into heat energy.

Indicated below are examples of electric wave interference.

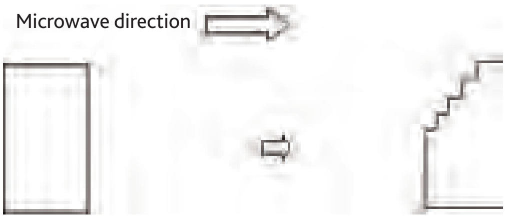

Figure 5 - Example of changing the shape of the building

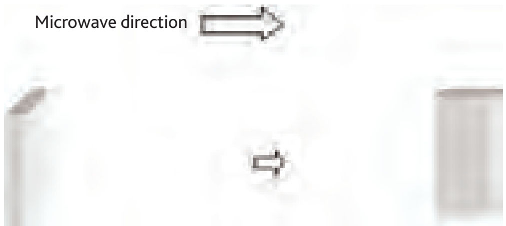

Figure 6 - Example of changing the direction of the building

Figure 7 - Example of absorbing it into a building

2.2 The electric wave absorption panel with GRC

The basic section in the electric wave absorption with a GRC panel is shown in Figure 8.

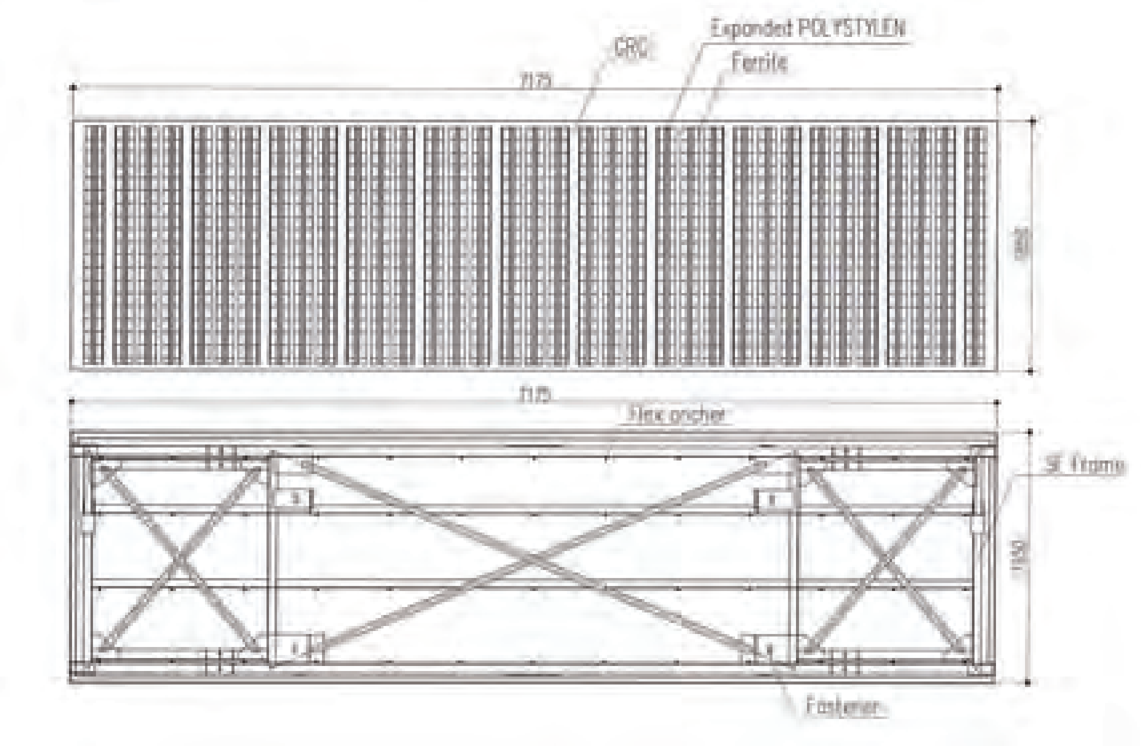

Figure 8 - Electric wave absorption GRC basic section

There are some points to consider when using GRC panels for electric wave absorption.

In Japan, 90~222MHz of TV wave is VHF, and 470~770MHz is UHF. The scope of electric wave absorption covers a wide range of 90~610MHz. The GRC panel structure must not be damaged by electric wave absorption.

1. Capability of electric wave absorption:
   - 100-200MHz: more than 14dB absorption'
   - At 600MHz: 10db, absorption with 2-3dB tolerance

2. In the penthouse of a building, the size of a panel may be as big as 7.2m width × 2m height, with a stud frame structure. And the absorption material is implanted within it.

To fulfil these requirements, a simulation was performed to determine:

- GRC dielectric character;
- Ferrite tile dielectric character (implanted in the panel);
- Distance between the metal stud frame elements.

As a result, it was proved that high quality GRC was required and that the thickness of GRC in front of the ferrite tile (the main unit of the electric wave absorption) should be 8mm thickness, with a tolerance of + 0, – 1mm.

Because of the guarantee of absorption capability required for every panel, they have been tested by constructing facilities for electric wave absorption performance measurement on site.

To fulfil these requirements, the processes of manufacture were developed and trial GRC panels were made.

1. Surface of GRC
   To keep thickness tolerance to + 0, – 1mm is very difficult. If the thickness varies widely the electric wave absorption would be unstable. Therefore, the jig was checked, and thickness control was performed very carefully.

Ferrite tile
The size of ferrite tile is 50 × 100mm. The tiles must be placed quickly to avoid a cold joint to the surface of the GRC before hardening. Because the laying arrangement influences absorption performance, thickness management on the back side of the ferrite tile was measured with measured at a 50mm pitch quickly. Moreover, it is necessary that they be in contact with each other. The measurement was done from edge to edge of the ferrite tile after laying the tiles.

Reflection line
The manufacturing control standard must be ± 1.0mm. It was made by using a stud frame.

2. Panel water content
To ensure electric wave absorption performance, it is necessary to control the water content of GRC to less than 5%.

In order to do this the panels were dried and the water content checked in more than 12 locations per panel.

2.3 Electric wave absorption

Figure 9 shows the effect of water content on electric wave absorption. It proves that performance of electric wave absorption is reduced with higher water contents.

Also, Figure 10 shows the relation between percentage of water content in the GRC and the dielectric constant. The higher the water content, the higher the dielectric constant. It turned out that electric absorption declined qualitatively.

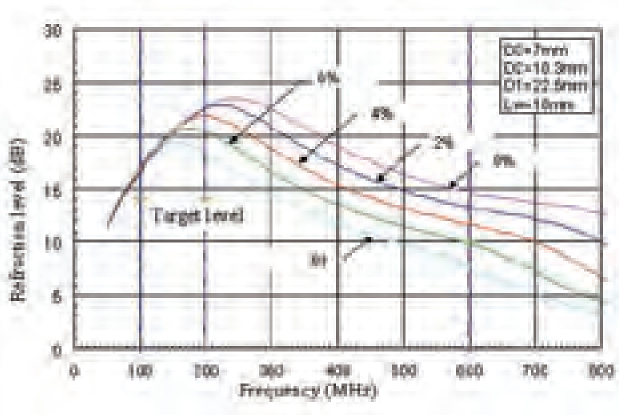

Figure 9 - Electric wave absorption level with changes in GRC water content

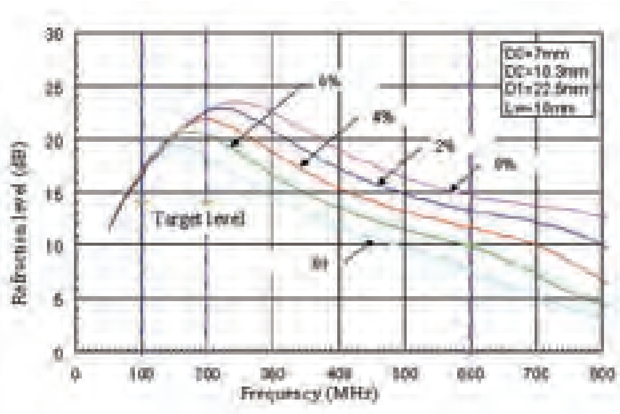

Figure 10 - Result of GRC dielectric constant

Figure 11 - Full-size panels

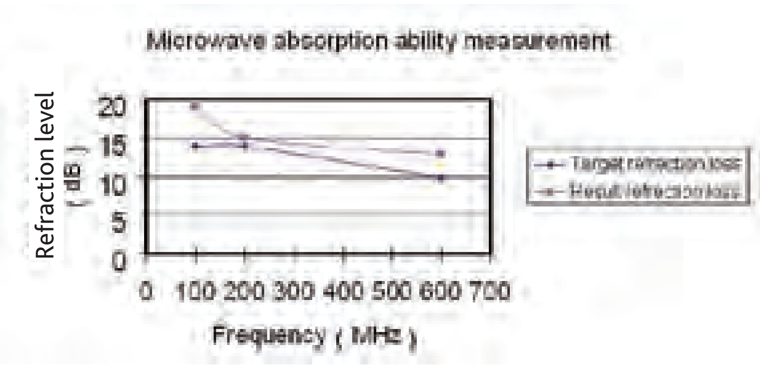

Figure 12 - Result of electric wave absorption in full size panel

Figure 12 shows the results of measurements. It accomplished the required absorption performance in all areas, though absorption at 200MHz is a little lower than at others. As a result, there was no problem with any panel that was tested.

2.4 Conclusion of electric wave absorption

It is possible to make GRC panels with the ability to absorb electromagnetic waves of both VHF and UHF.

CONCLUSION

GRC has been proven effective in the prevention of wind noise in the application of GRC louvres. In this case, the vibration that is involved does not adversely affect the GRC.

Also, the possibility of making GRC panels with the function of absorbing electromagnetic waves of both VHF and UHF was verified. In Japan, high quality and skills are often required to suggest a solution to an environmental problem.

Asahi Glass Building Wall Co., Ltd believes that GRC is a high quality material that can satisfy customers' demands and provide economic solutions to environmental problems.

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