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Fiber Reinforced Plastics Grid Reinforcement for Concrete Structures

Grillage en matière plastique renforcé de fibres pour les structures en béton

Faserarmierte Plastiknetze als Betonbewehrung

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SUMMARY
Fiber-reinforced plastic grid reinforcement is a new composite material for reinforcing concrete, which is composed of high strength continuous fibers impregnated with resin and formed in grid shapes. It has many excellent characteristics such as non-corrosive, lightweight, non-magnetic. In this paper, the latest application cases of fiber reinforced plastics grid reinforcements to various kinds of concrete structures are described.

RÉSUMÉ
Le grillage d'armature en matière plastique renforcé de fibres est un nouveau matériau composite servant à renforcer le béton; il est composé de fibres continues à haute résistance imprégnées de résine et disposées en forme de grillage. Ce matériau possède les excellentes caractéristiques suivantes: non corrosif, de poids faible et non magnétique, etc. Cette contribution décrit les derniers cas d'applications des grillages d'armature en matière plastique renforcés de fibres dans diverses structures en béton.

ZUSAMMENFASSUNG
Faserverstärkte Plastiknetze sind ein neuer Baustoff, zur Bewehrung von Beton. Sie bestehen aus mit Hartz imprägnierten hochfesten, kontinuierlichen Fasern, die zu Netzen verarbeitet die folgenden Eigenschaften aufweisen: es korrodiert nicht, ist sehr leicht, ist nicht magnetisch usw. In diesem Aufsatz sind die neuesten Anwendungsbeispiele von faserarmierten Plastiknetzen in diversen Betonstrukturen beschrieben.

1. INTRODUCTION

Recently in Japan, reinforced concrete structures have sometimes been seriously deteriorated owing to the corrosion of reinforcing steel bars. This problem is a significant topic of concern. A thick concrete cover to protect steel bars is not economical, because the sections of concrete members become large and the weight of the structure increases.

In order to improve the durability of concrete structures and make them light in weight, we have developed the New Fiber Composite Material for Reinforcing Concrete (NEFMAC), which is composed of fiber reinforced plastics (FRP) and formed in grid shapes. Through various series of experiments [1], the practical application cases of NEFMAC have increased in number. And those to the tunnel supports have already been presented in another paper [2]. The latest application cases of NEFMAC to the other concrete structures are described in this paper.

2. CHARACTERISTICS OF NEFMAC

Table 1 Characteristics of NEFMAC

* Non-corrosive	* Improve durability of concrete structure under severe condition
* Use of continuous fibers	* Effective use of fibers
* Enough strength at cross point of grids	* Sufficient bond and anchorage to concrete * Lap splice joint
* Light in weight (specific gravity ≒ 2) * Formed in complicated shapes	* Improve work productivity in site
* Non-magnetic	* Applicable to concrete structure required non-magnetic

NEFMAC is a new composite material for reinforcing concrete, which is composed of high strength continuous glass and/or carbon fibers impregnated with non-corrosive resin and formed in flat or curved shapes by the filament winding method [1]. NEFMAC has many excellent characteristics as listed in Table 1. For instance, it has enough strength at the cross point of grids, it provides good bond and anchorage to concrete, therefore lap splice joints are made possible. Furthermore, it is not only light in weight but also non-magnetic.

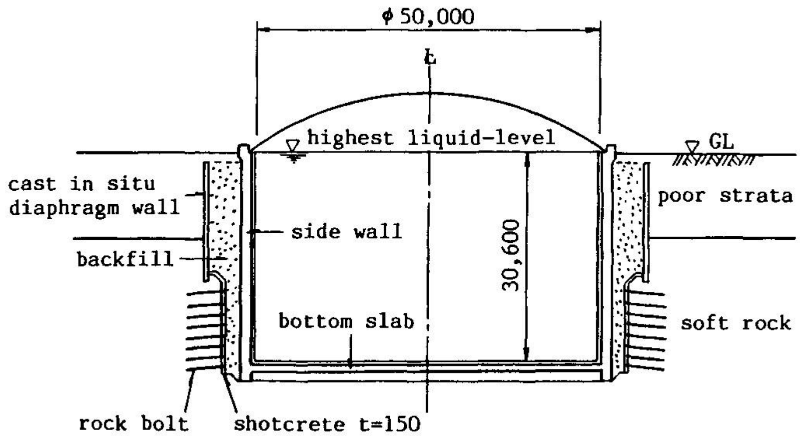

Fig. 1 Cross-section of LPG inground storage tank

3. SHOTCRETE FOR LANDSLIDE PROTECTION OF LPG INGROUND STORAGE TANK

NEFMAC has been widely used as reinforcing grids for shotcrete of tunnels and slopes, because it can curtail the amount of the secondary shotcrete compared with welded wire fabrics when it secures the same cover from the surface of the secondary shotcrete [2]. Lately, it was adopted as reinforcing grids for shotcrete of landslide protection of a liquid petroleum gas (LPG) inground storage tank in the gas company. Figure 1 shows the vertical cross-section of the tank. The side wall and the bottom slab are made of reinforced concrete as one body. And its capacity is 60,000 m^3.

The soft rock, which is the foundation bed of the tank, was excavated with a backhoe while it was reinforced with shotcrete of 15 cm thick and rock bolts. Approximately 4,300 m^2 of NEFMAC was used for reinforcing the shotcrete. Its dimension was 3.0 m x 1.7 m and it was set between the primary and second layers of the shotcrete (See Fig. 2). NEFMAC was lapped each other with one grid. Since it is light in weight and easy for handling, a large size can be used. Consequently, the setting rate became much higher than that of conventional welded wire fabrics.

Fig. 2 Reinforcing grids for shotcrete

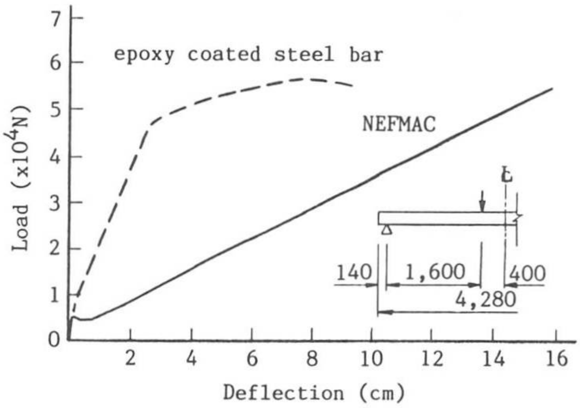

Fig. 3 Load-deflection relationship of specimen

4. FENDER PLATES FOR BOATS INSTALLED IN THE FRONT OF PIER

At low tide, boats accidentally went under the pier and damaged it with the wave motion. To prevent this kind of accident, reinforced concrete fender plates had been proposed to be installed in the front of the pier. Since these fender plates should be installed between the high and low tide zone, ordinary reinforcing steel bars would be corroded by the salt attack of sea water. Thus, epoxy coated steel bars had been selected to be used at first.

In order to apply non-corrosive NEFMAC to the fender plates in place of epoxy coated steel bars, the bending test of the concrete beams which were reinforced with two kinds of reinforcements respectively was carried out and their mechanical behavior was compared. The

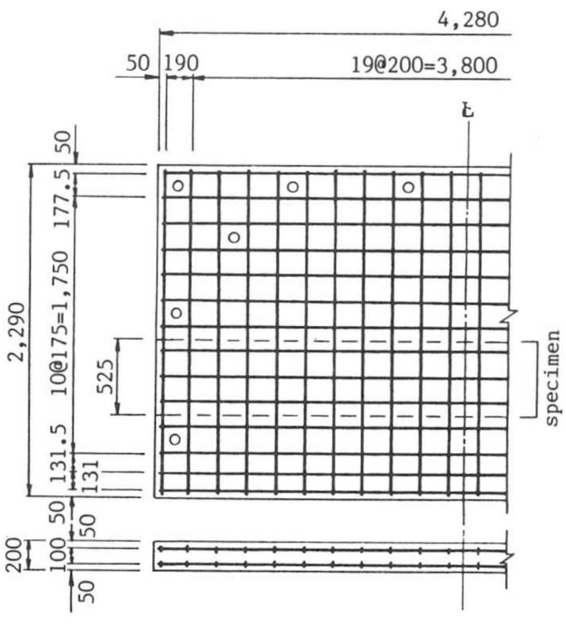

Fig. 4 Reinforcement of fender plate

relationship between the load and the deflection at the midspan is shown in Fig. 3. After the appearance of flexural cracks, the deflection of the beam reinforced with NEFMAC became approximately five times larger than that of one with the epoxy coated steel bars. Thus, it was confirmed that the former beam had a large capacity of absorbing the impact energy. Incidentally, the former beam failed in compression but the latter one failed in tension after yielding of the lower steel bars under the bending moment. Nevertheless, their flexural capacity was almost equal.

Figure 4 shows the arrangement of NEFMAC for the fender plate. After the fender plates had been produced in the precast yard, they were transported to the site by a pontoon and installed in the front of the pier with bolts through rubber bearing (See Fig. 5). At present, their fatigue behavior caused by the wave force has been under investigation.

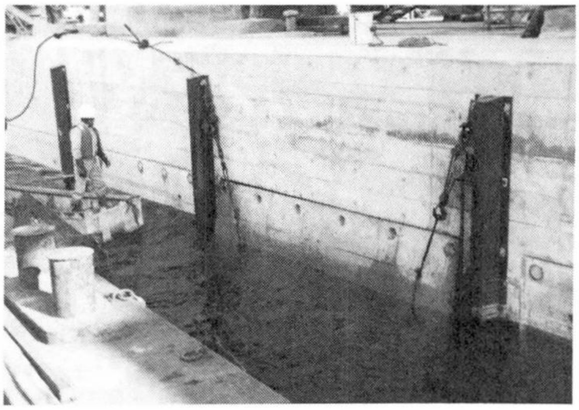

Fig. 5 Installing work of fender plate

5. FREE ACCESS FLOOR TILES FOR OFFICE AUTOMATION

According as the development of the office automation for intelligent buildings, free access floor tiles have been widely introduced. Since glass fiber reinforced cement mortar (GRC) floor tiles are beneficial for thermal insulation, comfortable for walking and have a good cost performance, they have begun to replace conventional die cast aluminum floor tiles.

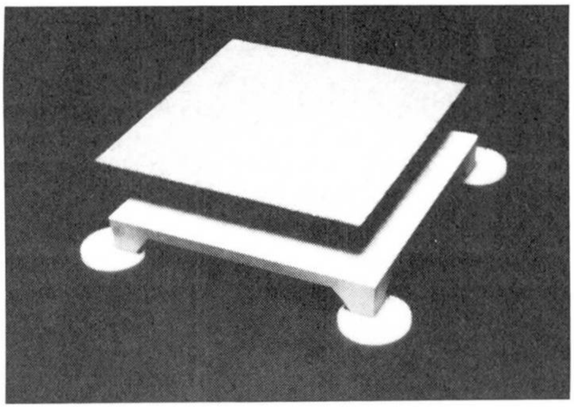

Fig. 6 New GRC free access floor tile

Ordinary GRC floor tiles have enough strength for a static load, but not for a dynamic (especially impact) one. To improve the impact resistivity, the new GRC floor tiles have been developed, which are composed of premix GRC and NEFMAC (See Fig. 6 and Fig. 7).

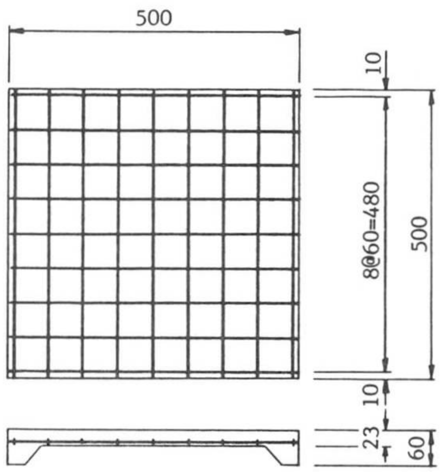

Fig. 7 Reinforcement of new GRC floor tile

Figure 8 shows the relationship between the load and the deflection at the center of the new GRC floor tile under the bending test [3]. It was confirmed that the impact resistance and toughness were increased approximately five times higher than that of the ordinary GRC floor tile by reinforcing with NEFMAC. Furthermore, NEFMAC is neither magnetic nor electric conductive, and it does not have a bad influence on the office automation equipment, thus it has been widely applied.

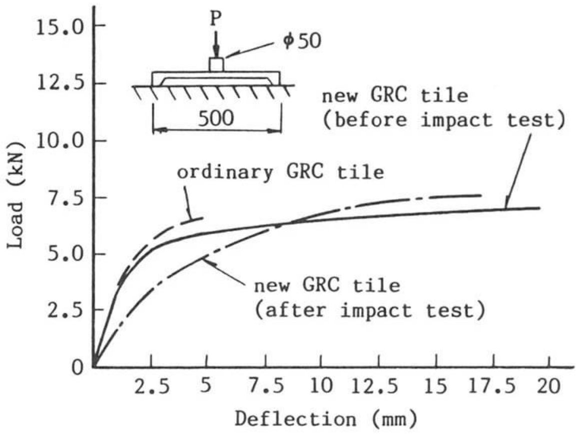

Fig. 8 Load-deflection relationship of GRC floor tile

6. PRESTRESSED CONCRETE SLAB OF PEDESTRIAN BRIDGE

The modulus of elasticity of FRP prestressing tendon is generally lower than that of a steel tendon. Thus, FRP tendon has an advantage of a small loss of prestress owing to the elastic shortening of concrete produced by prestressing, creep and shrinkage of concrete. Furthermore, NEFMAC has enough strength at the cross point of grids and provides good anchorage to concrete. Therefore, it can be used as a prestressing tendon for the pretensioning system, and the transfer length is extremely short [4].

For the practical application of NEFMAC to prestressed concrete members, we have constructed a full-scale pedestrian bridge in our factory as a trial, which is composed of the prestressed concrete slab with NEFMAC.

As shown in Fig. 9, NEFMAC was used as tendons at the lower position and as reinforcements at the upper one in the prestressed concrete slab. Figure 10 shows a new prestressing system with NEFMAC. First, concrete was placed at the both ends of NEFMAC which was longer than the slab and

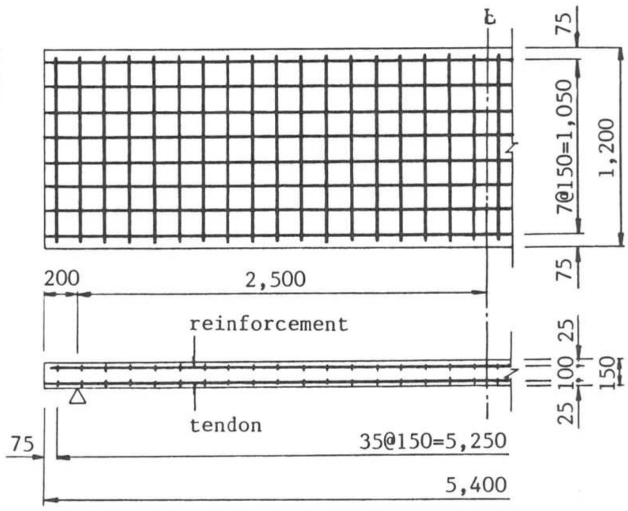

Fig. 9 Tendon and reinforcement of prestressed concrete slab

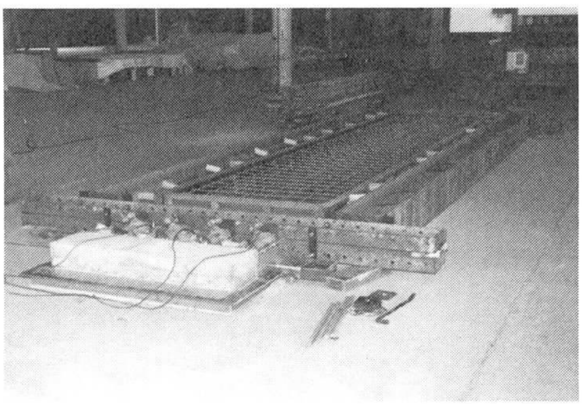

Fig. 10 New prestressing system with NEFMAC

Fig. 11 Prestressed concrete pedestrian bridge

contained another four distribution reinforcements. After the concrete blocks had sufficient strength, a stretching force was applied to NEFMAC by pushing them apart with four mechanical jacks through load cells. The initial tensile force of each tendon was approximately 40 percent of its ultimate tensile capacity (= 106 kN).

After the prestressed concrete slab had been set on the concrete abutments reinforced with NEFMAC, the pedestrian bridge was completed by installing guardrails and slopes (See Fig. 11). Many people walk on it everyday. The success of the construction of this pedestrian bridge gave a great hope to the future application of NEFMAC to prestressed concrete structures.

7. CONCLUDING REMARKS

In this paper, the latest application cases of NEFMAC to various kinds of concrete structures. Currently, NEFMAC is mainly composed of glass fibers because of its reasonable cost performance. In the near future, the cost of high modulus carbon fibers will become low, NEFMAC is expected to be more widely applied.

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