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Development of recycled PET fiber and its application as concrete-reinforcing fiber

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Abstract

We describe a method that can be used to produce concrete-reinforcing PET fiber from used PET bottles. Using this method, the concrete and PET fibers are easily mixed at a fiber contents as high as 3%. The primary characteristic of the PET fiber is that it is easy to handle. The issue of concern in the development of PET fiber is its alkali resistance; however, we encountered no problems when using the fiber in normal concrete. The wetting tension of PET was found to be lower than that of PVA but higher than that of PP. No toxic gas was generated during a combustion test of the PET fiber. We describe two example applications: a gateway support at Hishikari Mine, Japan, and the pavement of bush roads.

Keywords: Fiber-reinforced concrete; Recycled PET; PET fiber; Alkali resistance; Mixing; Strength

1. Introduction

Steel fiber [1], glass fiber [2], and plastic fiber [3] are used as concrete-reinforcing material for tunnels and underground structures [4,5]. The application of concrete-reinforcing fiber has been gradually expanded by making greater use of the individual characteristics of the fibers. Polypropylene (PP), polyethylene (PE), nylon, aramid, and polyesters are commonly used as synthetic fibers in this regard.

Polyethylene terephthalate (PET) analyzed in the present study belongs to the polyester group. PET has been used increasingly in recent years, including use as PET bottles. The following methods have been proposed to reuse PET bottles: conversion to unsaturated polyester and mixed to form polymer concrete [6], and mixing of fragments in concrete to be used as lightweight waste aggregate [7]. However, as the strength of conventional PET fiber is low and its alkali resistance is questionable [3], it has rarely been used as a concrete-reinforcing fiber.

In this study, we started with the development of a production method for concrete-reinforcing PET fiber. Pellets produced from PET bottles were melted and drawn to produce monofilaments; during this process, caution was taken to ensure that sufficient strength would be installed in the monofilaments. Subsequently, indents were marked on the monofilaments and they were cut to produce PET fiber. Temperature control of the monofilaments was found to be crucial for accurate indentation. After a period of trial and error, the appropriate temperature range was found to be 68–73 °C, which is close to the glass transition point of the PET fiber.

At this point, we tested the wetting tension, alkali resistance, and combustion gases of the produced PET fiber. In all tests, we obtained desirable results for the concrete-reinforcing fiber. Following this, the mixability of the PET fiber was examined by hand mixing; the PET fiber was found to mix very easily with concrete. The machine-mixing ability of the PET fiber with concrete was also found to be good. Next, we conducted a bending test of the

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PET-fiber-reinforced concrete; the measured JCI (Japan Concrete Institute) toughness was found to have increased greatly relative to that of the same material without reinforcement. A pull-out resistance test of the PET fiber was also conducted, and the adhesion of the fiber per surface area was found to compare favorably with that of PP fiber. Following the above-mentioned basic tests of the PET fiber, the PET-fiber-reinforced concrete was used to support a mine gateway and pave bush roads. In all cases, the PET fiber was applied without any problems.

2. Preparation of PET fiber

To minimize costs and contribute to material recycling, we used pellets recycled from PET bottles as the raw material for the production of PET fiber. The properties of plastic fiber vary widely depending upon the production method. In the normal process, pellets are melted, extruded from a nozzle, and drawn into fiber while warm. When melted plastic is drawn in this way, the polymer chains align along the longitudinal direction of the fiber. As a result, the strength of the fiber is increased by more than an order of magnitude.

After various considerations, we decided to produce monofilaments, which are used as the raw material for the PET fiber, using an extruder, as shown in Fig. 1. Pellets were placed in the extruder and melted; 20–100 fibers were then extruded from the nozzle at the tip of the extruder. The nozzle was disk-shaped and had numerous small holes. Through these small holes, fibers with a fineness of 60,000 dtex (decitex: grams per 10,000 meter length) were extruded. Temperature control during the extrusion process is generally very difficult. After some trial and error, the temperature inside the extruder was set at 250–280 °C and the temperature of the nozzle was set at 260–280 °C. The extruded fiber was pulled to the godet roll and hot-drawn to a fineness of 25,000 dtex. The fiber was further drawn in a water bath filled with cold water, and a fineness of 5000 dtex (diameter of ∼ 0.7 mm) was achieved when it reached the snub roll.

The resulting monofilament was a smooth fiber with a circular cross-section. Judging from our experience with steel fiber and based on the results of simple preliminary tests, we inferred that the fiber would be easily pulled out from the concrete if there were no indents on the fiber. Therefore, we developed a process to produce indents and incorporated this into a fiber-cutting apparatus, as shown in Fig. 2. The rolled monofilament is on the bobbin on the right side of Fig. 2, and it is pulled with the pinch roll #1 and gradually reeled out. We marked indents on

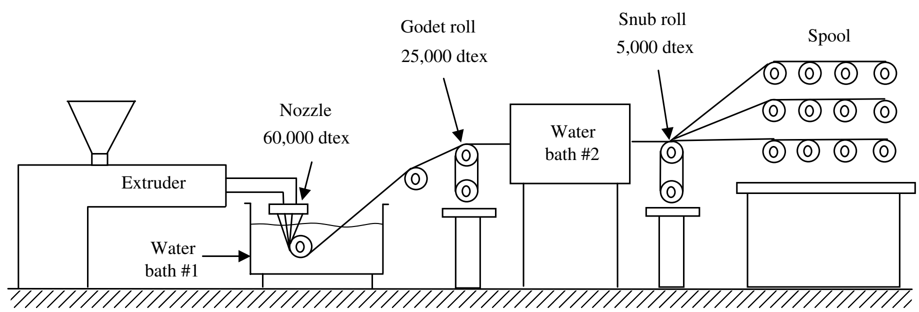

Fig. 1. Extrusion apparatus for monofilaments.

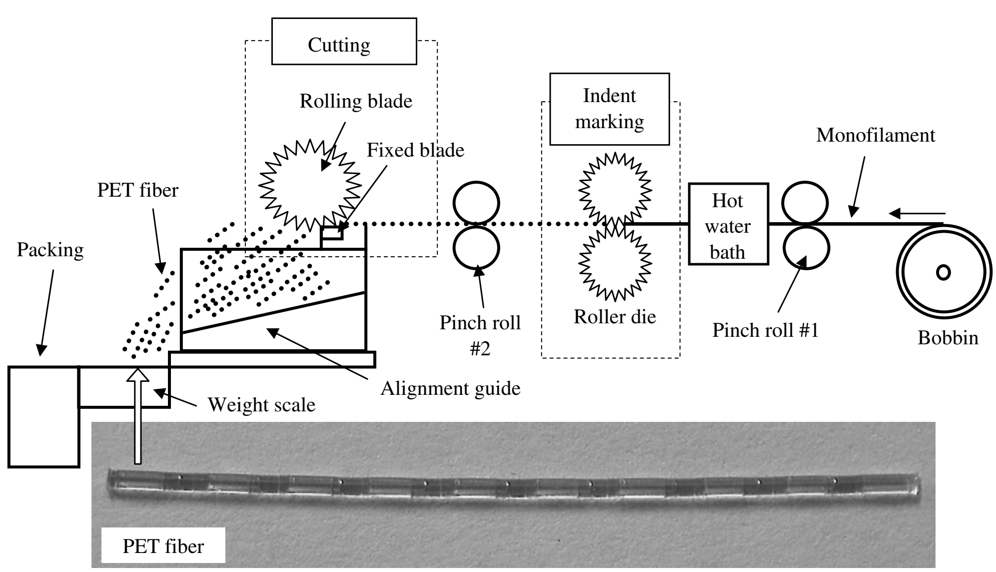

Fig. 2. Apparatus for the indent marking and cutting of PET fiber.

Table 1
Specifications of the PET fiber

Material	PET
Specific gravity	1.34 ± 0.02
Diameter (mm)	0.7
Length (mm)	30 ± 1 or 40 ± 2
Mass (mg)	15.2 ± 15% (30 mm length) or 20.3 ± 15% (40 mm length)
Surface	Indented
Tensile strength (MPa)	Above 450

the monofilament using an indented roller die. As temperature control is important to accurately mark consistently sized indents, the monofilament was preheated in a hot water bath. The temperature control range was set at 68–73 °C after a process of trial and error; this range is in the vicinity of the glass transition point of the PET resin. After marking indents, the PET fiber was cut to a length of 30 mm or 40 mm; these lengths were selected based on past experience, simple calculations, and preliminary experiments. The longer the fiber, the better the reinforcing effect; however, greater length makes mixing with concrete more difficult. The specifications of the PET fiber, including the allowable length errors, are shown in Table 1.

3. Basic properties of PET fiber

This study investigated the basic properties of the PET fiber, including wetting tension, which is important in terms of the adhesion between fibers and concrete, alkali resistance, which is important in terms of durability, and the toxicity of combustion gas, which is important in terms of safety during exposure to fire. Polypropylene (PP) and polyvinyl alcohol (PVA), which have been used in the past as concrete-reinforcing fibers, were used for comparison where appropriate. The specifications of the fibers are shown in Table 2.

3.1. Wetting tension

In the wetting tension test, we used test mixtures with wetting tension values in the range of 30–45 mN/m. The obtained wetting tensions were ca. 40 mN/m for PET, 35 mN/m for PP, and more than 45 mN/m for PVA. Thus, the wetting tension of PET is lower than that of PVA but higher than that of PP.

Table 2
Test results for alkali resistance

Fiber	Diameter (mm)	Length (mm)	Tensile strength (MPa)		Strength ratio[a] (%)
			Before exposure	After exposure for 120 h	
PET	0.75	30	352	348	99
PP	1.21	30	170	147	86
PVA	0.71	30	360	202	56

[a] Strength after exposure/Strength before exposure.

3.2. Alkali resistance

An immersion test was conducted in an alkaline solution that was prepared by dissolving 10 g of sodium hydroxide in 1 dm^3 of distilled water. The immersion time was 120 h, and the temperature during the immersion was kept at 60 ± 2 °C. Although immersion temperatures of 40 °C or 80 °C can be used, 60 °C was chosen, as this is the most common practice in Japan. The measured results of the tensile strength before and after immersion are shown in Table 2. The tensile strength of the PET after immersion was 99% of that before immersion; thus, minimal deterioration occurred. For PP, the tensile strength after immersion was 86% of that before immersion. In the case of PVA, the tensile strength after immersion was 56% of that before immersion; thus, significant deterioration occurred. Judging from these test results, PET has sufficient alkali resistance as a concrete-reinforcing fiber.

3.3. Combustion gas

The combustion test of the PET fiber was conducted to answer the following two questions. If the fiber is exposed to high temperatures during fire, is toxic gas emitted from the PET fiber in the concrete? If toxic gas is generated, is it in a range that is harmful to humans? Analysis of the generated gas revealed that carbon dioxide was the main component. Although a trace amount of carbon monoxide was generated, no toxic gas was detected. The PET fiber consists of the elements C, H, and O; thus, no toxic gas is generated.

4. Mixability of PET fiber

From a practical viewpoint, the mixability of concrete-reinforcing fiber and concrete is very important. For example, it is necessary for the fiber to be uniformly dispersed in the concrete without forming fiber balls. Thus, the mixability was investigated by both hand mixing and machine mixing.

4.1. Hand-mixing test

A hand-mixing test was conducted for the blend shown in Table 3. Measured volumes of cement and fine aggregates were thoroughly mixed in a bucket; the mixture was then mixed with a shovel for 8 min while water was gradually added up to a predetermined amount. The PET fiber was then added in 3–4 loads to the obtained mortar until the fiber content was 0.76%; the mixture was then mixed for a further 8 min. The mixed state was carefully observed, and neither fiber balls nor any abnormalities were observed.

To prepare test specimens for investigating fiber orientations, the mixed PET-fiber-reinforced mortar was cast with a shovel into two molds with a diameter of 75 mm and a height of 150 mm, and into one mold with a diameter of

Table 3
Blend of concrete constituents

		W/C (%)	Mixtures (kg/m^3)				Volumetric content of fiber (%)	Fiber length (mm)	Max. size of aggregate (mm)	Slump (cm)
			Cement	Water	Fine aggregate	Coarse aggregate				
Mixing test	Hand mixing	50	681	341	1129	0	0.76	30	–	–
	Concrete mixer	69	325	225	992	789	0, 0.5, 1.0, 1.5	30	15	18.5[a]
Bending test		65	334	217	973	743	0	30	15	16.5
							0.5			16.0
							1.0			3.5
							1.5			4.0
		60	358	215	947	754	0	30	15	9.5
							0.5			
							1.0			
							1.5			
		55	389	214	918	761	0	30	15	7.0
							0.5			
							1.0			
							1.5			
Hishikari mine		40	538	215	973	585	0.3	30	10	18.0
Bush road pavement		64	285	182	890	898	0.75	40	20	8.0

[a] Plain concrete.

100 mm and a height of 200 mm. The fluidity on this occasion was good, and uplifting of the PET fiber was not observed even when the mold was hit with a wooden hammer to create compaction.

The three test specimens of the PET-fiber-reinforced mortar were removed from the molds after hardening. They were then cut into seven round slices. As the PET fibers in the mortar are not visible, the PET fibers exposed on the cross-section were colored and counted. The cross-sections of the three test specimens were observed, and the PET fibers were found to be evenly dispersed. The number of fibers exposed on the six cross-sections and the orientation factors of the test specimens in the direction of specimen height are shown in Table 4. The orientation factor P is defined here as the average length of the projection on the longitudinal axis of all fibers crossing a section, divided by the fiber length [8,9]; it can be approximated by the following equation [8,9]:

$$P = \alpha A/V$$

where α, A, and V indicate the number of fibers per unit cross-sectional area, the cross-sectional area of an individual fiber, and the volumetric content of fibers, respectively.

The fibers were evenly distributed except for cross-section 1 of test specimen #2. The orientation factors for all test specimens were lower than 0.64, which is the theoretical value for two-dimensional random orientations, and close to 0.5, which is the theoretical value for three-dimensional random orientations. Thus, the fibers are considered to be randomly oriented.

After the moulds were cast for the investigation of fiber orientations, 46.9 g of additional fiber was added to the remaining PET-fiber-reinforced mortar (ca. 2 dm^3), and the mixture was blended together. The fiber content of the mixture in this case was ca. 3%; however, no fiber balls were generated. Although the viscosity increased, fluidity was maintained. The fiber was easily mixed with concrete at a fiber content as high as 3%.

Table 4
The number of fibers exposed on the cross-section and the orientation factor

Samples		#1	#2	#3
Cross-sectional area (cm^2)		44	44	79
Number of fibers counted on a cross-section	Cross-section 6	31	52	73
	Cross-section 5	20	52	78
	Cross-section 4	31	60	73
	Cross-section 3	43	42	91
	Cross-section 2	51	44	75
	Cross-section 1	37	14	67
	Average	36	44	76
Average fiber density[a] ($1/cm^2$)		0.81	1.00	0.96
Orientation factor[b]		0.47	0.58	0.56

[a] Average number of fibers per unit cross-sectional area.
[b] (Average fiber density)(Cross-sectional area of a fiber)/(Volumetric content of fibers) [8,9].

Based on the above results, the dispersion of the PET fibers in mortar following hand mixing is considered to be good.

4.2. Machine-mixing test

The machine-mixing test was conducted for the blend shown in Table 3. Initially, measured amounts of cement and fine aggregates were mixed in a 55 dm^3 concrete mixer for 15 s. Following this, a predetermined amount of water was added and the mixture was mixed for 30 s. Next, coarse aggregates were added and the mixture was mixed for an additional 60 s. The obtained concrete was cast into three molds with dimensions of 100 × 100 × 400 mm to prepare test specimens (plain concrete with 0% of PET fiber) for the bending test. Next, a predetermined amount of the PET fiber was poured into the concrete mixer, during mixing of the remaining concrete, for a period of 45 seconds. The prepared PET-fiber-reinforced concrete was cast into a mold to prepare test specimens for the bending test. The mixed state was carefully observed, and neither fiber balls nor any abnormalities were recognized; the fluidity was also good during the mold casting.

Based on the above results, the mixability of the reinforcing PET fiber and concrete by machine mixing is considered to be good.

5. Mechanical properties of PET-fiber-reinforced concrete

5.1. Bending test

For this test, three water–cement ratios (65%, 60%, and 55%) were selected, and four volumetric content percentages of PET fiber (0%, 0.5%, 1.0%, and 1.5%) were selected. Thus, the four-point bending test was conducted for a total of 3 × 4 = 12 conditions. Five specimens were tested for each parameter setting. The blend of concrete constituents is shown in Table 3. The dimensions of the test specimens were 100 × 100 × 400 mm.

The bending strengths for the case in which the water–cement ratio was 60% are shown in Fig. 3. The vertical line in Fig. 3 indicates the standard deviation; according to the standard deviation, the variation in the bending strength is large. As seen from this figure, the bending strength varies little up to a fiber content of 1%; however, the bending strength increases significantly at a fiber content of 1.5%. This trend is the same as that observed for steel-fiber-reinforced concrete [10], in which the length and cross-sectional area of the steel fibers are 25 mm and 0.3 mm^2, respectively, and the water–cement ratio is 0.6. The bending strengths for all conditions are shown in Table 5. The trend of variation in bending strength with changing content of PET fiber was qualitatively similar for all cases with different water–cement ratios.

The load–deflection curves for the test specimen with a water–cement ratio of 60% are shown in Fig. 4. When the fiber content is 0% (plain concrete), the maximum load is at a deflection of ca. 0.2–0.3 mm (deflection at the load point); following this, the load suddenly decreases. When the fiber content is 1.5%, cracks form at the same deflection point at which the maximum load was reached for plain concrete; however, since the load is supported with the

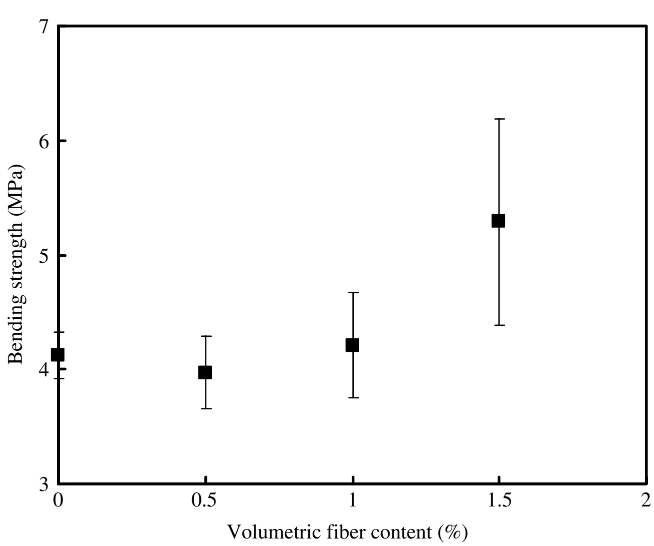

Fig. 3. Change in the bending strength with respect to the fiber content for concrete with a water–cement ratio of 60%. The vertical line indicates the standard deviation.

Table 5
Results of the bending test

W/C	Volumetric content of fibers (%)	Bending strength (MPa)	Absorbed energy[a] (Nm)	Toughness index[b] (MPa)
65%	0.0	3.82	4.3	0.62
	0.5	3.72	13.7	2.01
	1.0	4.12	22.1	3.24
	1.5	4.80	32.8	4.82
60%	0.0	4.12	4.4	0.64
	0.5	3.97	17.9	2.63
	1.0	4.21	25.1	3.68
	1.5	5.29	33.0	4.86
55%	0.0	4.21	4.3	0.67
	0.5	4.41	16.5	2.42
	1.0	4.85	25.6	3.76
	1.5	5.73	35.7	5.24

[a] Energy absorbed at the mid-span deflection of 2 mm.
[b] (Absorbed energy)(Span) divided by (Deflection)(Width)$(\text{Height})^2$.

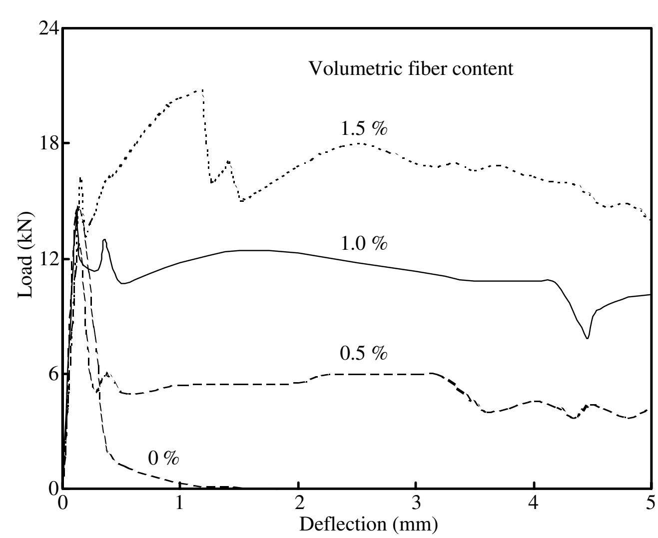

Fig. 4. Load–deflection curve for concrete with a water–cement ratio of 60%.

PET fiber, the load increases. Subsequently, the load repeatedly increases and decreases, and the load is 14 kN even when the deflection is 5 mm, indicating high toughness. Regardless of the fiber content, the load–deflection curves show similar behavior until cracks are formed. Thereafter, the sustained load is approximately proportional to the fiber content, as shown in the figure. This behavior is the same as that of steel-fiber-reinforced concrete [10]. The bending strength of all samples was 4–5 MPa, which is comparable to that of steel-fiber-reinforced concrete [10]. Even when the water–cement ratios were varied, we observed the same trend for the different fiber contents.

In conducting the bending test, it is important to know how much energy is absorbed at the point of destruction. Table 5 lists the energy required to reach a mid-span deflection of 2 mm and the JCI toughness [11,12] calculated using that amount of energy. In all cases, the absorbed energy and the JCI toughness increased markedly by mixing the cement with the PET fiber.

5.2. Compression test

The number of test specimens for the compression test was 12, as was the case for the bending test. The test specimen was a cylinder with a diameter of 100 mm and a height of 200 mm, with four strain gauges attached to it. The uniaxial compressive strength, Young's modulus, and Poisson's ratio, as obtained from the experimental results, are shown in Table 6. Although some variation exists, for all water–cement ratios there is no significant variation in these values associated with varying PET fiber contents. For all samples, the strain at the maximum load barely changed with varying water–cement ratios and different PET fiber contents. The vertical and horizontal strain were ca. 0.4% and ca. 0.2%, respectively.

5.3. Pull-out resistance test for fiber

The concrete-reinforcing effect of fiber is considered to reflect the pull-out resistance created when the fiber is pulled out from the matrix concrete. Thus, we decided to conduct a pull-out resistance test for the PET fiber, and for comparison, a PP fiber; this test is used relatively frequently for reinforcing.

Table 6
Results of the compression test

W/C	Volumetric content of fibers (%)	Compressive strength (MPa)	Young's modulus (10^4 MPa)	Poisson's ratio	Specific gravity
65%	0.0	32.1	2.13	0.20	2.35
	0.5	31.4	2.13	0.20	2.27
	1.0	34.8	2.22	0.21	2.28
	1.5	34.1	2.23	0.20	2.27
60%	0.0	34.8	2.65	0.16	2.28
	0.5	38.8	2.63	0.28	2.28
	1.0	39.6	2.15	0.20	2.27
	1.5	38.8	2.15	0.20	2.26
55%	0.0	45.1	2.16	0.16	2.30
	0.5	45.6	2.09	0.20	2.31
	1.0	47.8	2.33	0.20	2.28
	1.5	43.7	2.25	0.20	2.28

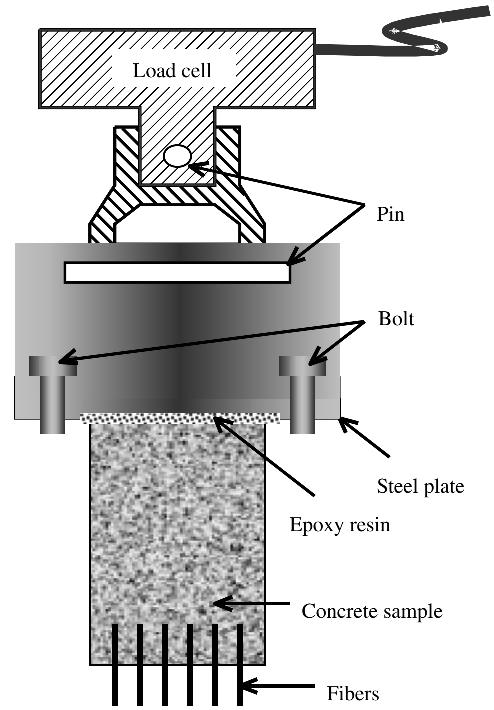

Fig. 5. Apparatus used for the pull-out resistance test.

Concrete was poured into a cylindrical mold with a diameter of 50 mm and a height of 100 mm. A 15 mm length of the fiber, which is a half of the total length of 30 mm, was embedded into the concrete. The test specimen, after air curing, was put on a 10 kN universal testing machine as shown in Fig. 5. The maximum load was measured when the fibers were pulled out individually.

The pull-out resistance test was conducted when the age of the mortar was 7 days, and 10 tests were conducted for each fiber. The adhesive strengths per unit area for PET and PP fibers were 2.8 and 2.9 MPa, respectively. Here, the adhesive strength was calculated by dividing the maximum pull-out load by the bonded area of the fiber. Judging from these test results, PET fiber has comparable adhesive strength to that of PP fiber.

6. Application examples of PET-fiber-reinforced concrete

6.1. Application to mine construction

Based on the results of the basic study described in the previous sections (Sections 2–5), we considered that the PET fiber had good mixability and that its reinforcing ability was satisfactory. Accordingly, concrete (shotcrete) mixed with the PET fiber was installed at Hishikari Mine, Japan, operated by Sumitomo Metal Mining Co. Ltd. The results are described in the following section.

Hishikari Mine is a gold mine located in Kagoshima Prefecture, which is one of Japan's leading gold-producing areas [13]. In the past, steel-fiber-reinforced concrete was sprayed onto a gateway with a cross-sectional area of 4×4 m; however, this was unsatisfactory because the mixing of steel fiber and concrete was difficult, and the steel-fiber-reinforced concrete often blocked the sprayer. The PET-fiber-reinforced concrete was applied on a trial basis from January 2004, and the workability of the concrete and its supporting ability were evaluated.

The prerequisite condition stipulated by the mining company was that a loose rock with a weight of 24 kN should be supported after 2 h of spraying. To satisfy this requirement, the standard specifications of the concrete (shotcrete) were set as shown in Table 3.

Actual spraying was conducted at the mine gateway, and the operation proceeded smoothly and was completed without any problems. The rebound rate (rebound weight/sprayed weight) of the PET-fiber-reinforced concrete was 14% by weight.

Observation of the sprayed surface revealed that the PET fibers were adequately dispersed, there was no uplifting and deviation, and the surface was relatively smooth. One year later, a survey of the sprayed location was conducted. The sprayed surface had no cracks, and an excellent supporting ability appeared to have been achieved.

At mines, bedrock can be marked by local weaknesses. There are also locations, such as a 4-way entry and 3-way entry, that are very difficult to support and the roof is susceptible to collapse. In these cases, there is a long-standing demand to increase the support by increasing the fiber content; however, in the case of steel-fiber-reinforced concrete, the formation of fiber balls has prevented the use of higher fiber contents. When the PET-fiber-reinforced concrete was used, the fiber content was increased as necessary. Even when the fiber content was more than 1%, uniform PET-fiber-reinforced concrete could be obtained within the normal mixing time. In addition, pipe clogging during concrete pumping or poor concrete adhesion did not occur. It is a noteworthy characteristic of the PET fiber that the fiber content can be freely changed in situ without fiber-ball formation and pipe clogging.

6.2. Pavement of narrow areas

Passages in tunnels under construction, passages through underground structures, urban alleyways, and bush roads are commonly narrow, winding, and steeply. It is desirable to apply fiber-reinforced concrete to the pavement of such narrow sections of road; however, steel fiber can puncture tires, and there are workability concerns about this conventional fiber. Thus, it has not been used previously to pave narrow sections of road in Japan. In this study, we decided to use PET-fiber-reinforced concrete to pave bush roads to make use of its easy workability.

PET-fiber-reinforced concrete was applied to a bush road between Hayatogawa and Kanazawa, Kanagawa Prefecture, Japan. On March 26 2004, a road with a length of

Table 7
Installation processes and necessary time for bush road paving

	PET fiber-reinforced concrete	Wire mesh-reinforced concrete
Area (m^2)	41	48
Depth (cm)	13	15
Process	Concrete placing	Concrete placing #1 Wire mesh placing Concrete placing #2
	Finishing	Finishing
Worker-hours	4.4	9.7
Man-hours (m^{-2})	0.11	0.20

Table 8
Example applications of the PET fibers

Starting date	Prefecture	Location	Sprayed/placed	W/CM (%)	Fiber length (mm)	Volumetric content of fibers (%)	Remark
January 2004	Kagoshima	Mine gateway	Sprayed	50	30	0.3	Replacement of steel fiber. First trial to use PET fiber in Japan. Found to be very easy to handle
March 2004	Kanagawa	Bush road	Placed	64	40	0.75	Replacement of wire mesh. Considerable laborsaving
October 2004	Ibaragi	Bush road	Placed	64	40	1.0	Applied successfully to road with 10% gradient
March 2004	Ehime	Slope	Sprayed	50	30	0.3	Replacement of steel fiber on the sea front
August 2004	Fukuoka	Tunnel	Placed	52	40	0.3	Applied to tunnel support for the first time
February 2005	Tottori	Tunnel	Placed	52	40	0.3	A new fiber content analyzer was developed and used
September 2005	Kanagawa	Bridge pier	Placed	50	30	0.3	Crack extension was substantially decreased
October 2005	Shiga	Tunnel	Placed	52	40	0.3	A new fiber injector was developed and used
In the planning stage	–	Underground storage for LNG	Sprayed	50	30	0.75	Replacement of wire mesh to prevent rust for longer service life

20 m and a width of 3.6–4.9 m was paved. The PET fiber was gradually added to the agitator of an agitator truck and combined with the ready-mixed concrete. The mixed PET-fiber-reinforced concrete (see Table 3) was applied on the bush road to a pavement thickness of 13 cm. For comparison, a conventional composition using welded mesh as reinforcement was also used. For the conventional composition, plain concrete was installed to a predetermined thickness of 15 cm. The processes and necessary time for installation using the PET fiber method and the conventional method are listed in Table 7. As seen from the table, the application of PET-fiber-reinforced concrete is efficient and laborsaving. A follow-up survey was conducted half a year later; flaws such as cracking or chipping were not observed in the pavements constructed by either method.

Previous applications of PET fiber are summarized in Table 8. Applications such as slope spraying, tunnel support, and application to a bridge pier have been performed previously; in all cases, the PET-fiber-reinforced concrete has shown easy handling and has been highly appreciated.

7. Summary

In this study, we developed a method to produce recycled PET fiber to be used as reinforcing in concrete. A mixing test was conducted by hand-mixing concrete with the produced PET fiber (described in Section 4); the concrete and PET fibers were easily mixed. It is interesting to note that the concrete and PET fibers were mixed easily even when the volumetric content of the PET fibers was gradually increased to ca. 3%. As evident from this result, the primary characteristic of the PET-fiber-reinforced concrete is that it is easy to handle. We conducted a follow-up survey at Hishikari Mine, where we first applied PET-fiber-reinforced concrete, and found that it was highly appreciated on the site because of its easy manageability.

The issue of most concern in the development of the PET fiber has always been alkali resistance; however, after careful analysis it was found that there was no problem when used in normal concrete.

To expand the use of PET fiber, the cost will need to be considered. At this stage the market price is comparable to that of steel fiber, when the same volumes are being compared. At present, PET fiber is used in Japan for spraying and lining tunnels, including expressway tunnels, and future use is expected to increase. Future applications include not only general tunnel support, but also underground structures that are located in harsh environments, such as near the coast or under the sea. In addition, its use as pavement on narrow, winding, and steep roads can be considered.

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