SUPER DUCTILE PVA-FIBER REINFORCED CEMENT BOARD

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ABSTRACT

Super Ductile Cement Board (SDB) is made of cement, new PVAfibers called " REC7 ", pulps and other additives by Hatzeck. SDB is suitable for permanent formworks, panels and other thin applications. It is very similar to traditional fiber cement board but most different characters of this SDB are the strain-hardening behavior and micro/multiple cracking dispersion with over 12N/mm2 of high tensile strength. And also it has a good durability, i.e. freezing and thawing, penetration, fire resistance and etc. One of the useful properties of SDB is handling. It can be enable easy drilling, nailing and cutting SDB on site. And the second is durability of ductility. After the big earthquake at Niigata many SDB was used for tunnel lining.

INTRODUCTION

PVA-fiber has good alkaline resistance, high tenacity and high modulus and are often used for the replacement of asbestos as the recent worldwide restriction. On another front of cement board products, there required much more ductility for the reliability. However, it is difficult to apply the high amount of fibers for Hatzeck-processed cement boards, so there is not enough ductility. We developed new PVA-fiber called "REC7"and succeeded to produce ductile cement board with multiple and micro-cracking fracture toughness made by Hatzeck process. And also SDB is enabled to produce commercially.

GENERAL SPECIFICATIONS OF HPB

Production Process

Typical process of SDB is shown in figure 1. And SDB composition and New PVA fiber properties are shown in table 1 and table 2. To produce SDB, 1) uniform slurry will be prepared and supply into the stock tank. 2) Wire cylinders are rotating in the stock tanks and these cylinders percolate the slurry to the solid sheet. Then, the solid sheet is transferred onto the felt belt. 3) After that, the solid sheet is transferred onto the laminating roll and this process is repeated and multiple layer sheets are laminated until desired thickness to make SDB. 4) Laminated green SDB is pressed to dehydration. Initial curing is usually done at 50 celcious degree and 24hours. After that, more than 1weeks of natural curing will be done. This process is suitable for SDB in productivity, product quality and thin/light weight/high strength.

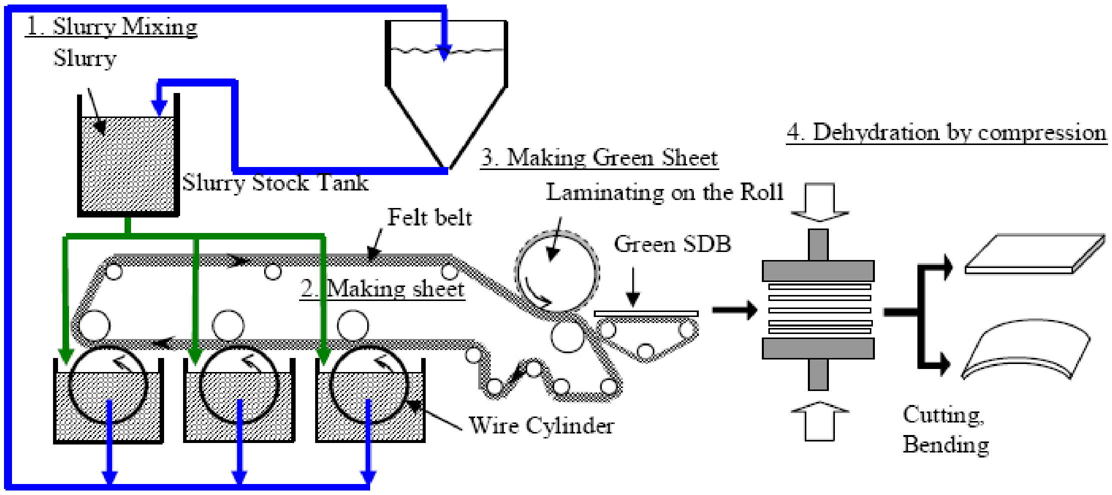


Figure 1. Typical SDB process

Table 1. Typical SDB composition

	Cementitious	Inorganic Fiber	Pulp	PVA-fiber	Additives
Weight %	92	1.5	3	3	0.5

Table 2 New PVA fiber : REC 7 x 6 mm

Type	Diameter	Length (mm)	Tenacity (MPa)	Young Modulus (GPa)
REC 7	26	6	1700	37

Physical Properties of SDB

Physical properties of SDB are shown in table 3. SDB shows high ductility and high flexural and tensile strength. Figure 2 shows the multiple and micro cracks on the tensile fractured specimen surface. Figure 3 shows the typical strain-stress relationship in tensile fracture. From the figure 2, multiple and micro cracks are mostly less than 0.05mm width on the HPB surface. And also figure 3 shows SDB shows strain-hardening behaviour under the tensile fracture process.

Table 3. Physical properties of SDB

	Standard	Unit	Scores	Notification
Compressive Strength	JIS K 6811	N/mm2	>85	
Flexural Strength	JIS A 1408	N/mm2	>32	
Tensile Strength	(no std.)	N/mm2	>12.0	
Shear Strength	JIS K 7058	N/mm2	>25	
Coefficient of Linear Expansion	JIS A 1325	10-6/K	9.3	
Sharpy Impact Strength	JIS K 7111	kJ/m2	6.46	
Fire Resistance	JIS A 1321	Class 1		

Figure 2. Multiple and micro cracking on the surface of tensile specimen of SDB

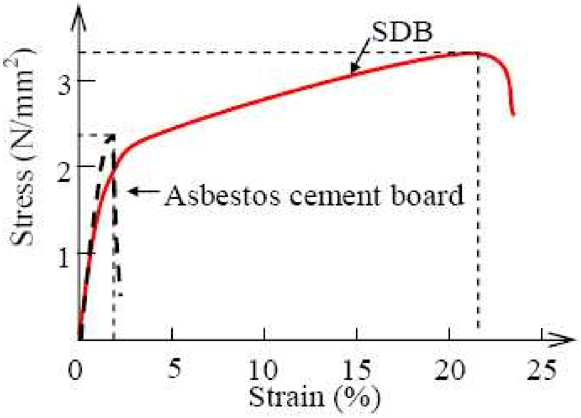


Figure 3. Typical strain-stress relationship of SDB at tensile fracture

Figure 4 Bendable sheet (2mm thickness)

Figure 5. Excellent Impact Resistance

DURABILITY OF SDB

SDB is made with over 90% of fine inorganic particles and compression process is applied. Then, SDB has uniform and dens structure and its good durability will be anticipated.

Abrasive resistance

SDB has dens and uniform structure and it causes good abrasive resistance. Figure 6 shows the results of rotary abrasion test, ased on ASTM C-779. High amount of reinforced fibers causes apparent matrix cohesive force and good abrasive resistance.

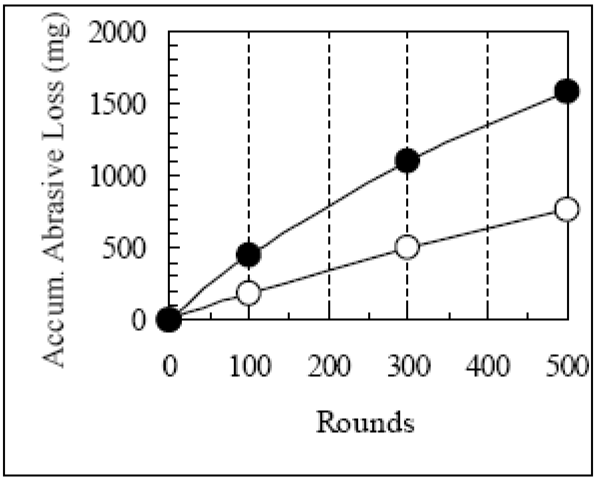


Figure 6. Accumulative abrasive loss by rotary abrasion test: ASTM C-779

Neutralization resistance

SDB was placed in 5% of carbon dioxide atmosphere at 20 celcious degrees and 65%R.H. to accelerate the neutralization. After the 60days of exposure, SDB shows not only little or nothing neutralized but also stable flexural strength, modulus and toughness. 60days of acceleration is to be 28years of on site exposure.

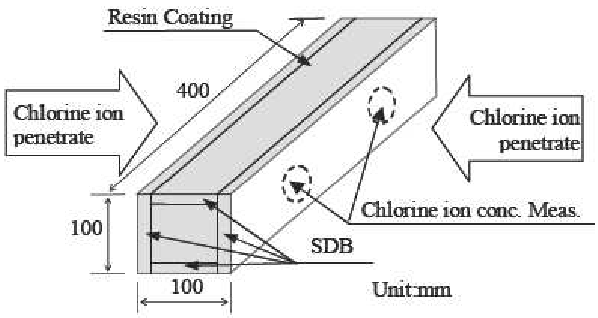
Table 4. Accelerated neutralization test results of SDB

	Unit	Acceleration		
		0days	30days	60days
Flexural strength[1)]	N/mm^2	38.5	44.5	39.7
Flexural modulus[1)]	$x10^4 N/mm^2$	1.50	2.14	1.74
Flexural toughness[2)]	N/mm^2	30.4	36.4	32.4

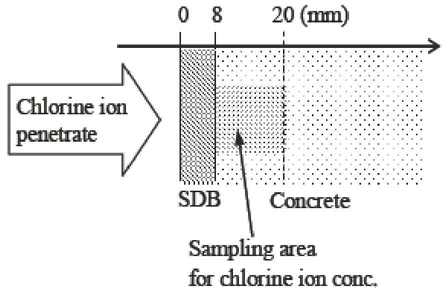
1) Flexural test: 3point flexural test – W=250mm Span=250mm, JIS A 1408
2) Flexural toughness: integrated the area of strain - stress till maximum flexural strength.

Chlorine ion permeation resistance

Chlorine ion permeation resistance was studied for the coverage use of RC structures. Specimen for chlorine ion permeation resistance is shown in figure 7. 8mm thickness of SDB was cut and built into the structure of 100x100x400(mm) outer size and ordinary concrete, composition is shown in table 5, was poured into this mould. Plain concrete specimen was also prepared. After the 38days of under water curing and 7days of aerial drying were applied, resin coating was applied at 4 faces for confining permeating faces. These specimens were soaked into the 20celcious degrees of artificial seawater with 1.8% of chlorine ion concentration. After 30 or 60days of soaking, chlorine ion concentration of the concrete part of the specimen was estimated by potentiometric titration, JCI method. Figure 8 shows the results of chlorine ion permeation status corresponded with the distance from the penetrating surface. SDB covered concrete avoids chlorine ion penetrating and it enables to prevent steel rebar from corrosion.



7-a): Dimension of specimen



7-b): Chlorine ion concentration measured area

Figure 6. Specimen for chlorine ion penetration resistance

Table 5. Ordinary Concrete Composition

W/C	S/a	Unit weight (kg／m^3)				
		C	W	S	G	Ad
0.48	0.438	357	171	753	1034	0.714

C: Ordinary portland cement, Ad: Superplasticizer

Freezing and thawing resistance

Freezing and thawing resistance was studied for the coverage use of ordinary concrete structures. Specimen for freezing and thawing resistance is shown in figure 9. SDB was cut and built into the structure of 100x100x400(mm) outer size and ordinary concrete, composition is shown in table 5, was poured into this mould. Plain concrete specimen was also prepared. The specimen was applied to the freezing and thawing test, based on ASTM C-666 B-method, after the 38days of under water curing. Relative dynamic modulus of elasticity is shown in figure 10 and the aspects of the specimens after 300cycles of freezing and thawing durability test in figure 11. SDB coverage endures 300cycles of freezing and thawing test and realizes less damage for the structures.

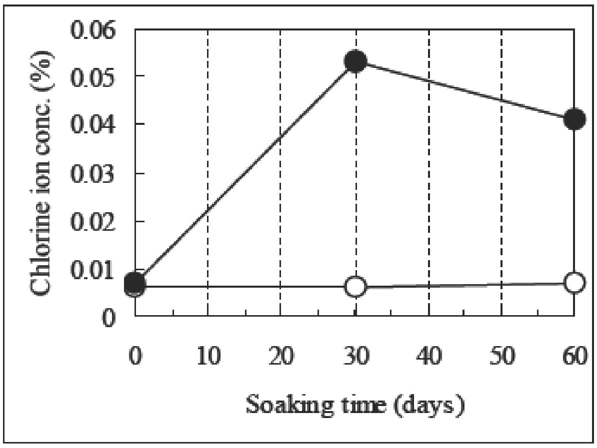


Figure 8. Chlorine ion concentration after artificial seawater soaking
Measured at 9 to 20mm depth from penetrating surface

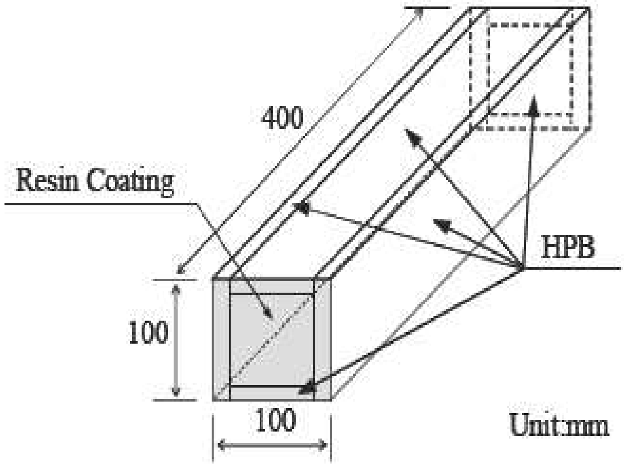


Figure 9. Dimension of freezing and thawing test specimen

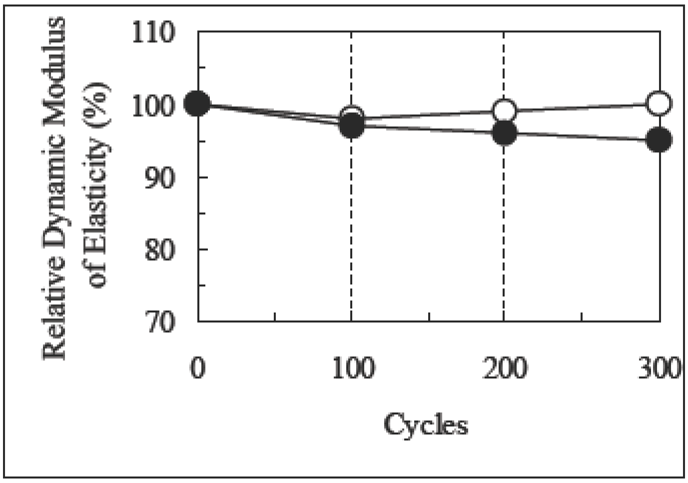
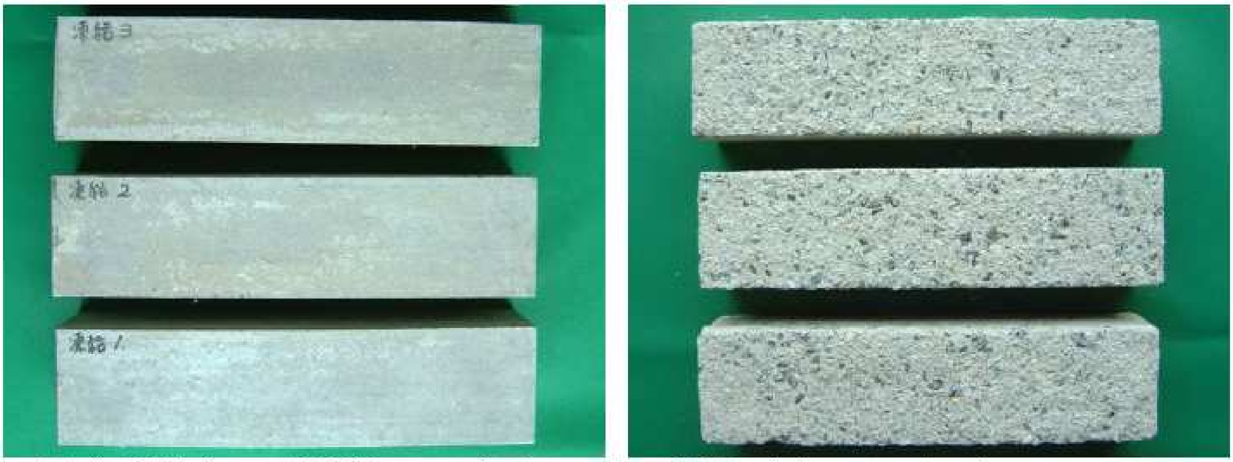


Figure 10. Relative dynamic modulus of elasticity, ASTM C-666 B-method
Open: SDB covered prism, filled: plain concrete



11-a): SDB faces of SDB covered prism 11-b): plain concrete prism

Figure 11. Aspects of the specimen after 300cycles of freezing and thawing durability test.

TYPICAL APPLICATION OF SDB

Reinforcement of concrete structures

The reinforcement of concrete structures is one of the useful applications of SDB. It is good example of this application that retrofitting of damaged beams by filling of concrete or mortar in the coverage of SDB. Figure 12 shows the dimension of the specimen for the simulation of the damaged beam retrofitting by SDB. This specimen simulates the cover concrete with SDB. Third point flexural test, based on ASTM C-78, was done with this specimen and figure 13 shows the results. Plain concrete shows poor strength and ductility but SDB-concrete hybrid structure shows just like twice of flexural strength and high ductility.

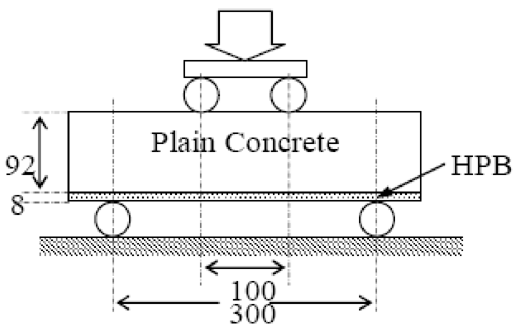


Figure 12. Dimension of SDB retrofitting test specimen

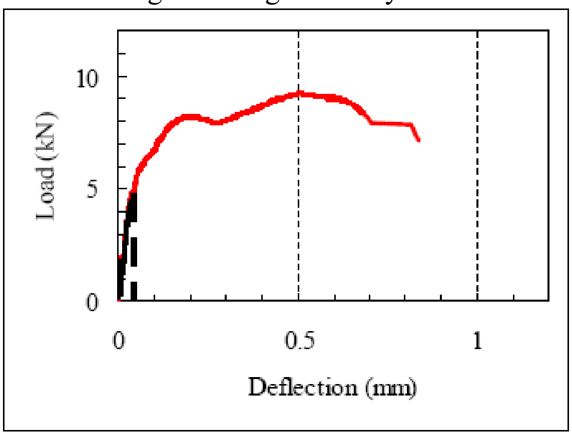


Figure 13. Load-deflection relationship of SDB-concrete hybrid structure: Real: SDB-concrete hybrid, broken: Plain concrete

Architectural products

Architectural application is one of the important possibilities for SDB. Thin, lightweight, fire resistance and permeation resistance are suitable properties for this application. And also high ductility enables structural wall materials made by SDB.

Permanent formworks

The permanent formwork is one of the useful applications utilizing good durability, high strength and high ductility of SDB. SDB is easy to assemble on site by its workability and enables to shorten the construction work in comparison with pre-cast concrete formwork. In 2006 there was big earthquake at Niigata in North-East Japan and got big damage at Uonuma Tunnel (Figure 14 and 15). Japan East succeeded to repair the tunnel within 2 months by using SDB for permanent formwork shortened considerably the construction work.

Figure 14 Niigata-Chuetsu earthquake

Figure 15 Big damage for Uonuma Tunnel

Figure 16 a

Figure 16 b

Figure 16a,b. SDB permanent formwork for tunnel lining

CONCLUSIONS

- Kuraray Co.,Ltd developed new PVA fiber called " REC7 "for SDB.
- SDB can be made by standard Hatzeck process and it shows high strength, high ductility, high durability .
- SDB will be used for many civil engineering application because of light weight and easy handling.

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