

# Degradation behavior and application of recycled PVC sheet made of floor sheet for railway vehicle

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## Abstract

A floor sheet made of plasticized poly(vinyl chloride) (PVC) is used as interior material for railway vehicle. Some of the floor sheets mainly used in Express and Shinkansen vehicles were layered by vulcanized surface to protect against the fire. Therefore, these floor sheets have been considered as inappropriate material for recycling. In this paper, some varieties of recycled sheets made of these floor sheets have been studied with respect to a long-term stability which is necessary for practical application. Through the weathering test, these recycled sheets indicated suitable mechanical properties for long-term outdoor use; however, at the beginning of weathering test, the elongation was reduced by the rapid flow out of plasticizer. The mechanical strength was closely related to the plasticizer concentration. Based on the plasticizer concentration, the tensile strength could be estimated without dependence of specimen preparations and the slope of the elongation was related to the content of the floor sheet. To prevent flowing out of plasticizer, virgin PVC was laminated to the surface of recycled sheet. The laminated sheet was set up at the outdoor to be used as an anti-weed sheet. For more than five years, the laminated sheet has kept on preventing overgrowth of weed and flow out speed of plasticizer has decreased by the effect of virgin PVC lamination. It is presumable that the laminated sheet was estimated to be used as the anti-weed sheet for more years.

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**Keywords:** Poly(vinyl chloride) (PVC); Material recycling; Floor sheet for railway vehicle; Long-term stability; Anti-weed sheet

## 1. Introduction

In railway field, many kinds of polymer products are applied, among these products; many polymer materials can be seen in railway vehicles. For example, water tank, piping, lavatory unit and interior. A colorful and designed sheet made of plasticized poly(vinyl chloride) (PVC) is used as the floor sheet of interior for railway vehicle. For example, as shown in Fig. 1, some of the floor sheets mainly used in Express and Shinkansen vehicles in Japan were layered by vulcanized surface for improving the appearance and protecting the scorch mark by fire [1]. The vulcanized surface that was treated PVC by dithiol derivatives turns to thermosetting resin;

therefore, these floor sheets have been considered as inappropriate material for recycling and disposed as industrial waste without any studies to reuse. There are many studies concerning with material and chemical recycling of PVC [2–4]. However, these studies were based on only thermoplastic PVC. In recent years, from the ecological viewpoint, reusing and recycling of the floor sheets with vulcanized surface have been requested strongly. On the other hand, many cable sheaths were also disposed from railway field. The cable sheath is a major product of plasticized PVC. Therefore, some varieties of recycled sheets made of these floor sheets mixed with plasticized PVC for cable sheath were produced. These recycled sheets are expected to be used as anti-weed sheets that prevent the overgrowth of weeds adjacent to track or level crossing area [5]. The use of the herbicide is an ordinary way to remove overgrowth of weeds. However, to keep weeds out condition, the herbicide is necessary to be sprayed regularly.

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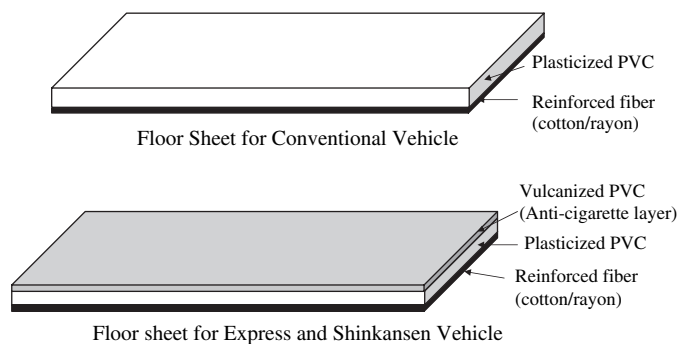


Fig. 1. The outlines of the floor sheet for railway vehicle.

Furthermore, the herbicide is closely related to contamination of soil and groundwater. The anti-weed sheet simply covers the weed area; therefore, the use of anti-weed sheet is a more appropriate method for ecological issues. However, for ensuring practical application as the anti-weed sheet, it is necessary to evaluate a degradation behavior and a long-term stability of the recycled sheets. For the anti-weed sheet, the longer service life, at least more than five years was desirable for saving a maintenance work. In this paper, the artificial weathering test was performed to study the degradation behavior of the recycled sheets by measuring plasticizer concentration, tensile properties and penetration resistance force. The penetration resistance force was an important property to evaluate the performance of the anti-weed sheet [6]. Furthermore, based on these results, proper product component of the anti-weed sheet is also proposed.

## 2. Experiment

### 2.1. Materials

Table 1 shows the components of a series of test specimens. Ten years old floor sheet with vulcanized surface (No. 130 Lonseal Corp.) was ground into chips less than  $\phi 4$  mm and afterward, reinforced fiber was removed by blowing. The floor sheet chip, plasticized PVC for cable sheath, calcium carbonate and HAF grade carbon black were mixed in Banbury mixer. Table 2 shows the compounds of respective materials. Subsequently, the test specimens were molded by calendar roll in the form of 1.5 mm thickness. The appearance of Specimen C is shown in Fig. 2.

Table 1  
Preparations of specimens

Specimen	Recovered floor sheet with vulcanized surface (wt%)	Plasticized PVC for cable sheath (wt%)	CaCO <sub>3</sub> (wt%)	Carbon black (wt%)
A	4.9	47.2	47.2	0.7
B	9.9	44.7	44.7	0.7
C	24.8	37.2	37.2	0.7
D	49.7	24.8	24.8	0.7

Table 2  
Compounds of respective materials

	phr
<i>Ordinary floor sheet with vulcanized surface (1980s)</i>	
PVC (include vulcanized PVC)	100 (40)
Plasticizer (DOP, TCP)	66
CaCO <sub>3</sub>	145
Metal oxide	2
Stabilizers	5
Total	318
<i>Plasticized PVC for cable sheath</i>	
PVC	100
Di-sec-octylphthalate (DOP)	35
Lead sulphate, tribasic	4
Total	139

### 2.2. Artificial weathering test

Artificial weathering test was carried out with use of a Suga Sunshine Weather meter (WEL-6X-HC-BEC). Table 3 shows the test condition of weathering. Irradiation of the xenon lamp and cyclic spray of the pure water to the one side of the specimen sheet were carried out. The specimen of approximately  $200 \times 155 \times 1.5$  mm was applied to the artificial weathering test. Subsequent to the artificial weathering test, the specimens were preserved in an auto-desiccator more than 72 h in order to control a specimen condition.

### 2.3. Measurement of plasticizer concentration

The specimen was cut to a size less than  $1 \times 1 \times 1$  mm. To extract the plasticizer, the ultrasonic extraction was carried out for 60 min with Bransonic ultrasonic cleanser (Branson-1200) using a solvent of tetrahydrofuran/isopropyl alcohol = 1:1. After ultrasonic extraction, the solid specimen was separated by filtration. To remove the solvent, the filtered solution was evaporated. Acetonitrile was added to the residue. An insoluble oligomer was separated by filtration. The filtrate was diluted to 10 mL. The plasticizer contained in this solution



Fig. 2. The appearance of recycled sheet (Specimen C).

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