The Use of Cellular Plastic in Swedish Railways To Insulate the Track Against Frost

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Presented in this paper is a description of current practice in the use of cellular plastic (polystyrene) for insulation against frost in railways. In the first part of the report the history of the use of insulation against frost in railways is briefly described. In the second part, the properties of the best material currently available—extruded cellular plastic of polystyrene (Styrofoam, Styrodur, Ecoprim)—are described. A material intended for insulation against frost that is laid in the soil under the permanent way in a railroad must fulfill the three following requirements: (a) it must have adequate compressive strength, (b) it must not take up moisture to such an extent that the insulating properties deteriorate unacceptably, and (c) it must not be affected by time (e.g., bacteriologically or chemically) in the soil. Stress-strain curves are also detailed, showing the highest limits allowed for deformation and the lowest breaking force allowed for material in a railway track. Dynamic tests and tests with different petroleum products are also described. Part three deals with the application of the material to the track. Finally, the value of extruded cellular plastic as insulation against frost damage with different applications is reviewed. In this respect it is noted that only prescribed qualities are used and that the materials are continuously controlled at delivery.

The problem of the need for insulation in buildings and on traffic routes is an old one in Sweden. Even in the eighteenth century damage was observed on culverts and bridge abutments on the stagecoach roads. It is reported that brush mats were used in northern Sweden in the 1870s as protection against frost lift. At the end of the 19th century peat was also used as a protection fill under the track, principally in northern Sweden. Today these fills have been damaged by the increased weight of trains and drains. In 1910, sleepers of wood were put on the track on the Karungi-Övertorneå line. In 1965 (more than 50 years later) the insulation was inspected. The wood in the sleepers was still in good condition. The weight of the trains gradually increased, further reducing trafficability.

In the 1920s some countries with cold winters began to investigate the problem of frost action in soil. In Sweden the leader of this area of study was Gunnar Beskow. In 1935 he published a summary of his findings *(1)*, which is now well-known throughout the world. Based on these theories, practical solutions to the problems of frost action were developed. The methods used by the Swedish State Railways (SJ) are described by Sandegren 1972 *(2)*.

Because it is costly to insulate to full frost penetration depth, the problem was to find a highly effective insulating material with such a high strength that it could be laid immediately under the ballast. In the early 1960s, G.A. Leonards was the first to use extruded cellular plastic. In Norway, S. Skaven-Haug employed this method in 1964, but used a bead plastic. In 1968, SJ laid the first test section (200 m) also using a molded bead plastic.

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PROPERTIES OF CELLULAR PLASTIC

SJ has tested both molded and extruded cellular plastic. A cellular plastic used to insulate against frost action in the soil must fulfill the following requirements:

1. Have the necessary strength.
2. Be so nonabsorbent that its insulating ability does not decrease significantly with time.
3. Be so resistant (e.g., to bacteria or chemicals) that it is not affected in the soil.

The second point is difficult to fulfill for molded bead plastic. Nowadays only extruded cellular plastic is used with bead-board being used previously. The material must also carry the load of the traffic, including the dynamic contribution within the elastic stage.

The International Union of Railways (UIC) lists specifications for the insulating material in its Code 719 R (see Figure 1) *(3)* as follows:

Axle load (kN)	<200	200–220	>220
Dry density (kg/m)	30 to 35	35 to 40	40 to 50
Deformation limit (%)			
0 kPa	<1	<1	<1
350 kPa	<5	–	–
400 kPa	–	<5	–
450 kPa	–	–	<5
Breaking force (kPa)	>250	>350	>450

These specifications must be used when the insulation slabs are 0.3 m below the underside of the sleeper and of 4 m width. They can be relaxed when the slabs are at a greater depth.

The insulation slabs must be placed at least 0.3 m below the sleepers to be protected during maintenance work. Figure 1 shows these given limits and also the curves for material normally used by SJ. The key to data in Figure 1 is as follows:

1 = Styrofoam HD 300 (according to a Dow Chemical letter);

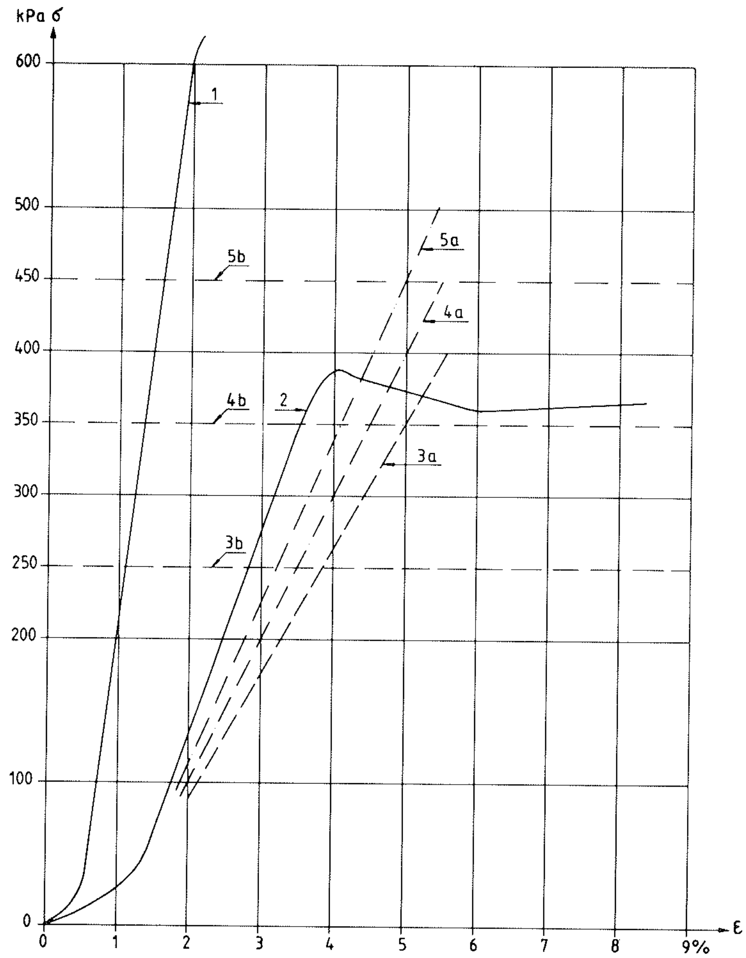

FIGURE 1 Specifications according to the UIC Code 719 R and stress-strain diagrams for different cellular plastics used by Swedish State Railways.

2 = Styrofoam HI 50 (mean value, according to a Dow Chemical letter);
3a, 4a, 5a = deformation limits according to UIC Code 719 R by axle load *3a* = < 200 kN, *4a* = 200 to 220 kN, and *5a* = > 220 kN; and
3b, 4b, 5b = the lowest-allowed breaking force by the same axle loads.

The dynamic behavior of the materials is of great interest. Many dynamic endurance tests in a repeated dynamic-stress testing machine were performed. First of all, testing between the load 30 kPa and the different highest loads was undertaken until the material could endure $2 \cdot 10^6$ repeated impacts. Today the material is tested between 10 and 150 kPa during $2 \cdot 10^6$ repeated impacts. The allowable deformation must then be < 5 percent. Three different materials are used for normal railroad lines: Ecoprim 937-00 from Rockwool, Styrodur 4000 S from BASF, and Styrofoam HI 50 R from Dow Chemical. They all have a deformation < 5 percent by a load of 350 kPa, a density > 38 kg/m and a thermal conductivity of about 0.033 W/mK. For lines with more than 220 kN axle load, the slabs are either laid deeper or Styrodur 5000 S or Styrofoam HD 300 E are used, which can also be used under highly loaded bridge abutments. The resistance of cellular plastic to petroleum products is in some cases low (e.g., petrol rapidly destroys even a high-class extruded cellular plastic). Diesel fuel also has the same effect but it does not happen as fast.

To investigate how spills from tank cars might affect the slabs in a track, petrol, diesel fuel, and heavier oils such as lubricating oils and gear oils have been tested both on ballast over the slabs and directly on the slabs. The tests show that spills on the ballast do not harm the slabs but a direct outflow in a track (e.g., by a derailment) will destroy the slabs. The probability for a derailment on an insulated part of the line is, however, very low. A more complete report on the philosophy of the use of high-insulation materials and performed tests is given by Sandegren 1978 *(4)*.

THE USE OF CELLULAR PLASTIC ON THE TRACK AS INSULATION AGAINST FROST

When cellular plastic was first used as insulation against frost, the choice of dimensions was rather limited and the slabs had no shiplaps. The length was limited to 2.0 m and the breadth was 0.6 m. As the width of the insulating area under the ballast should be at least 4.0 m, the slabs could be laid parallel with or perpendicular to the track. As the joints do not coincide, the slabs must be staggered in two layers. If the slabs are laid parallel to the track, the total width is 4.2 m (7 × 0.6 m). However, the practice showed that it was better to lay the slabs perpendicular to the track. Therefore, a layer of two slabs with 2.0-m lengths were first laid out and on this a layer, with one slab 2.0 m long in the middle and two slabs 1.0 m long outside, this slab was placed. However, after some time it was possible to get slabs with a length of 2.5 m. One slab with 2.5 m and one with 1.5 m length were then laid in the first layer and in the second layer one with 1.5 and one with 2.5 m length were added.

Later slabs 4.0 m long were developed. The last step to make it possible to lay the insulation in one layer was to introduce shiplaps. The effective width of the slabs thereby diminished to 0.54 m (see Figure 2). Thus the insulation was placed in one

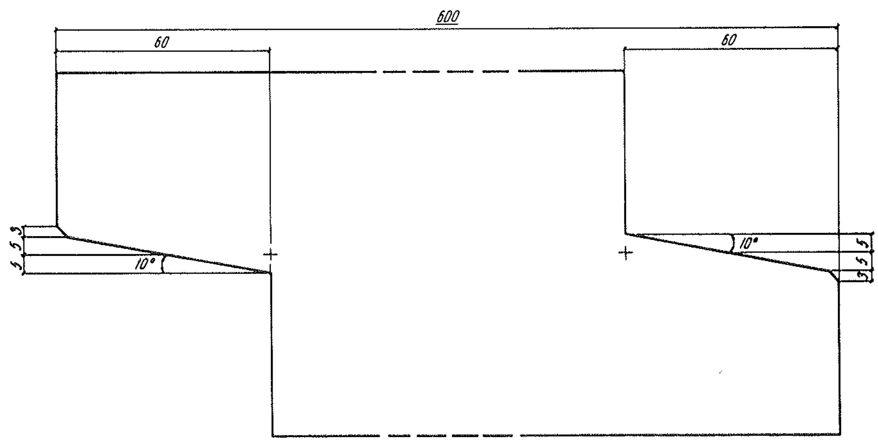

FIGURE 2 Shiplap for insulating slabs in track.

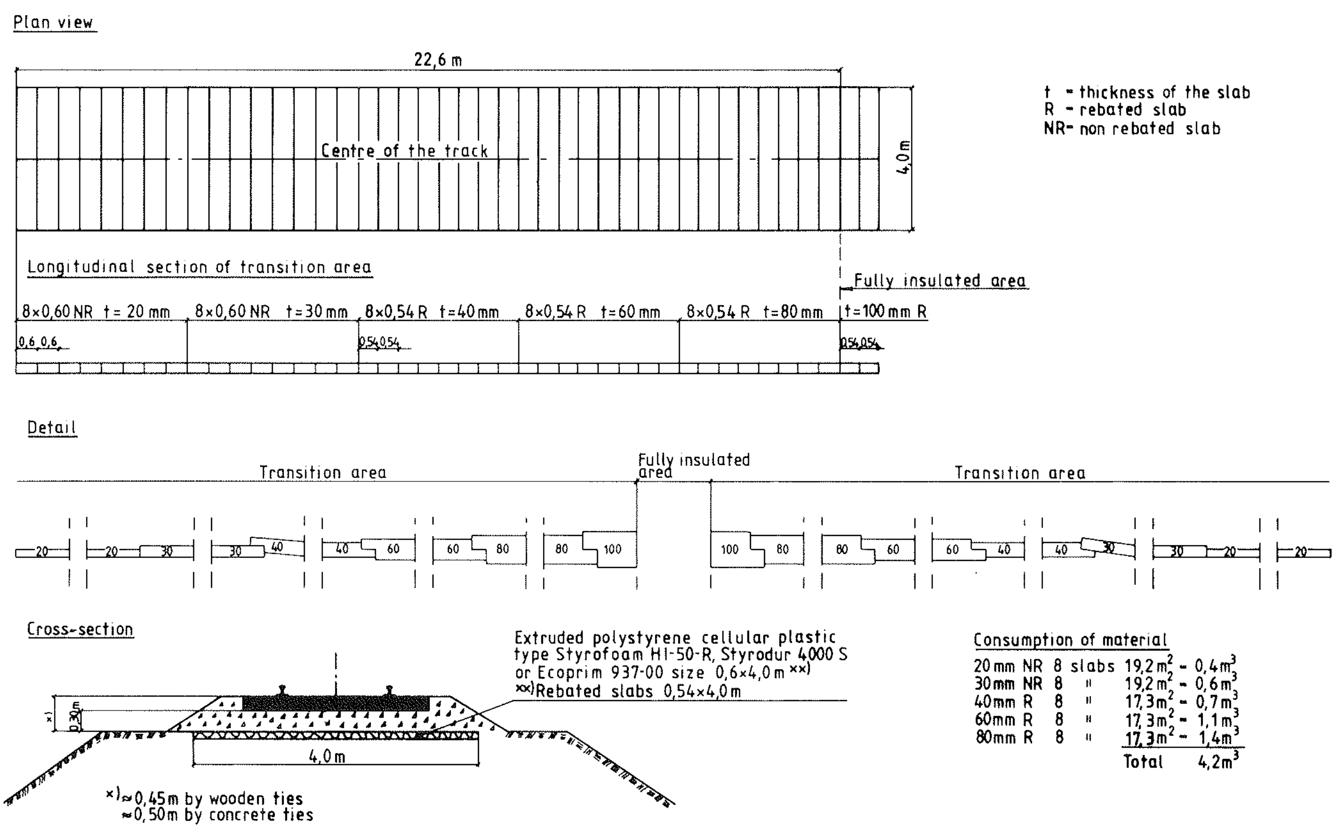

FIGURE 3 A transition area for 100-mm-thick slabs with shiplaps.

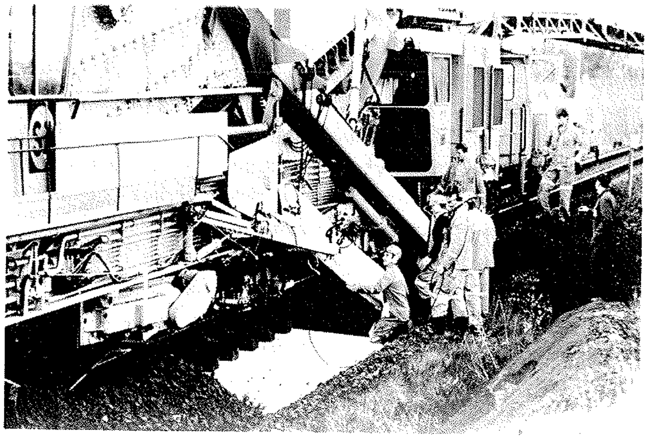

FIGURE 4 The ballast-clearing machine lifting the track and digging out the ballast to make it possible to put in the insulating slabs.

layer with 4.0-m long slabs perpendicular to the track. The thickness depends on the amount of cold (–°Ch) in the winter at the actual place and ranges from 60 mm in southern to 140 mm in northern Sweden. See also work by Sandegren *(4)*. Great care must be taken with the transition areas at the ends of a stretch of insulated track because the material is so highly insulating. The lengths required range from 16 m in southern to 38 m in northern Sweden. An example of a transition is shown in Figure 3.

From 1972 to 1974 all slabs were laid by hand. The rails were either taken away one bearing at a time or the sleepers only were removed. The old ballast was then removed with an excavator. It was time-consuming work. In March 1974, a ballast-clearing machine [hired from the Norwegian State Railways (NSB), a Plasser and Theurer machine type RM 82] was used for the first time (see Figure 4). The machine first removed the old ballast and, during cleaning, the slabs were put

TABLE 1 RANGES OF APPLICATION FOR HIGH-INSULATION MATERIALS FOR INSULATION AGAINST FROST

Material / Range of application	Extruded cellular plastic compressive strength kPa			Molded cellular plastic (beadplastic) compressive strength kPa		Rockwool	
	≥450	≥350	≥250	≥350	≥250	821	817
Railways with axle load >220 kN	X						
Railways with axle load 200 to 220 kN		X					
Railways with axle load <200 kN			X				
Under foundations for buildings and bridge abutments							
Load >200 kPa	X						
" 200–100 "		X					
" <100 "			X				
Outside and along buildings							
dry condition			X	X	X	X	X
wet "			X	X			

in under the track by hand and the cleaned ballast was replaced on the slabs. After the ballast was replaced and tamped down, the track was fit for traffic again. The outcome of the test was so good that new machines were not only rented but purchased for the improvement work. However, it was still time-consuming work to transport the slabs to the track, lay them out, and then put them in by hand. Thus the idea was conceived of modifying the machine so that the slabs could be automatically transported from the freight wagons to the machine and down under the track.

In April 1984, the prototype, RM 80-SPX, was ready to work. The machine did all the work except putting in the slabs under the track. The new machine worked successfully and the work in southern Sweden ended in November. In 1985 the crew was so experienced that it could insulate about 900 m during a shift of 8 hr at its best.

During the winter of 1985 to 1986, the machine was again modified slightly to make it possible to lay the slabs under the track automatically. In 1986 this modification was tested. During the first months there were some problems but later it worked satisfactorily (see Figure 4).

CONCLUSIONS

After working with high-insulation materials for nearly 20 yr, it is concluded that extruded cellular plastic is the best material and that it can help to solve different types of frost problems on the railroads. However, in special cases, other highly insulating materials can also be used. Table 1 shows present recommendations.

Molded material (bead plastic) cannot be used in soil under a bearing construction (abutment or foundation), as chance of the possibility of augmented moisture ratio accrues because the material in this position cannot breathe.

To insulate with high-insulation materials is both an economical as well as a technically sound solution if the right material is chosen for the right purpose. However, it is a required condition that if only prescribed kinds of material are used, these kinds are continuously controlled at delivery.

REFERENCES

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