Uniform ballast quality assessment criteria

This article describes the present state of the work carried out by the ERRI D 182 Committee. The main aspects of this question are quality assessment and delivery conditions of new ballast, and quality assessment of ballast in the track.

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The work carried out on current quality of ballast and acceptance conditions was reported in RP 1 in October 1991 [1]. Studies on assessment of ballast condition in the track were reported in RP 2 [2].

A comprehensive study on ballast durability has been carried out at the ETH Zürich using tri-axial laboratory tests and the results will be published in RP 3 [3], scheduled for September 1994.

A separate study has been carried out in which results of individual test methods (e.g. Los Angeles, Deval wet, Aggregate Impact Value or Impact Resistance tests) have been compared with Vibrogir results and the findings are to be published in a separate Technical Document, scheduled for the end of 1993 [4].

The D 182 question should result in proposals for standardised technical specifications and a description of a quality assurance system for ballast, which will be published in the final report, envisaged for autumn 1994.

Current ballast quality and specifications

A questionnaire conducted amongst the participating members of the D 182 Committee revealed that the principle problems with ballast concern fouling and increase in roundness. It appeared that a wide variety of sieve curves was used to determine ballast grading. Some of the results are presented in Fig. 1.

To draw up uniform criteria and develop one or more ballast testing methods it was necessary to look at the test methods in current use and compare the specifications of the various railways.

Most countries used test methods, standardised to some degree, to determine the quality of the different ballast materials. The dynamic tests most widely used by the railways are: the Los Angeles test (LA), the Deval wet test and the Aggregate Impact Value test (AIV) or the Impact Resistance test. Static testing consists in determining the compressive strength of a ballast sample. In addition, all railways have requirements concerning permissible fouling and resistance to freezing.

The D 182 Committee arranged for a large number of different types of stone to be subjected to impact tests in a single laboratory, with a view to establishing the relationship between the various test methods and service conditions.

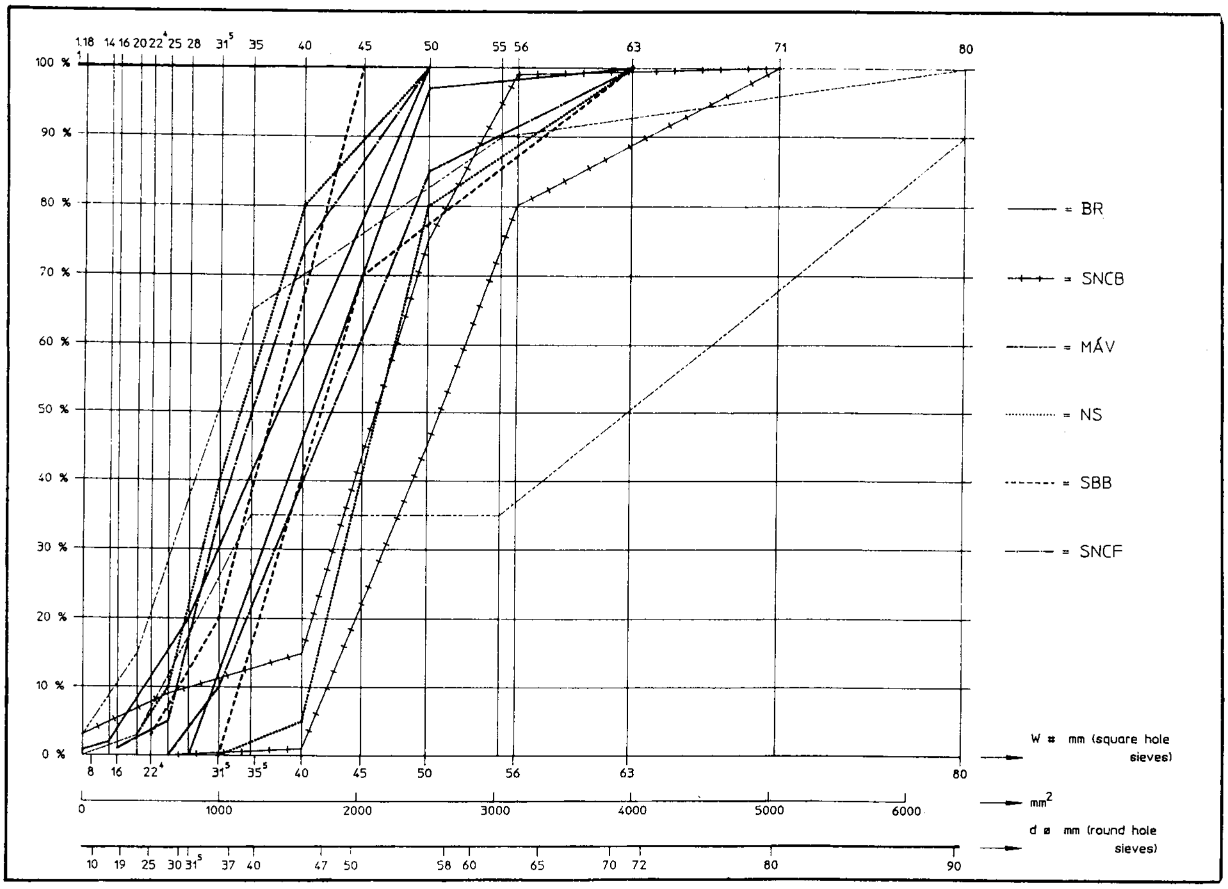

Fig. 1: Examples of ballast grading used by railways

The laboratory tests consisted of producing sieve curves, establishing the grain form, carrying out Los Angeles, Aggregate Impact Value and Deval wet tests, and a petrographic study. One benefit of the laboratory tests was that they highlighted links between the different test methods, as for instance shown by Fig. 2.

Vibrogir tests

Additional tests with the French Vibrogir were carried out to establish the effect of accumulated loads on the wear of ballast. The Vibrogir simulation machine enables periodic forces to be exerted on the sleepers similar to the on-line forces produced when an axle passes overhead. The machine is essentially composed of an unbalanced excitor generating a sinusoidal vertical force with an amplitude of 45 kN at a frequency of approx. 50 Hz. This force is transmitted onto the sleeper via a girder and two rails which are 12 m long. One hour of operation typically corresponds to a hauled tonnage of 3.6 MGT. The tests were carried out for 50 hours, equivalent to 180 MGT.

Fig. 3 summarises the results from the Vibrogir tests. The table gives the variation in weight for the different sieves and also indicates results from the LA, AIV, Impact and Deval wet tests. The Deval wet value (DH) was transferred to the value UDH = 40/DH to retain the comparable units.

The maximum variations can be seen to correspond to the 31.5 mm and 40 mm sieves and the variations are clearly more significant in the case of the two ballast mixtures composed of limestone rock. The tests also confirmed that the hard materials are more abrasive in their effect on concrete sleepers.

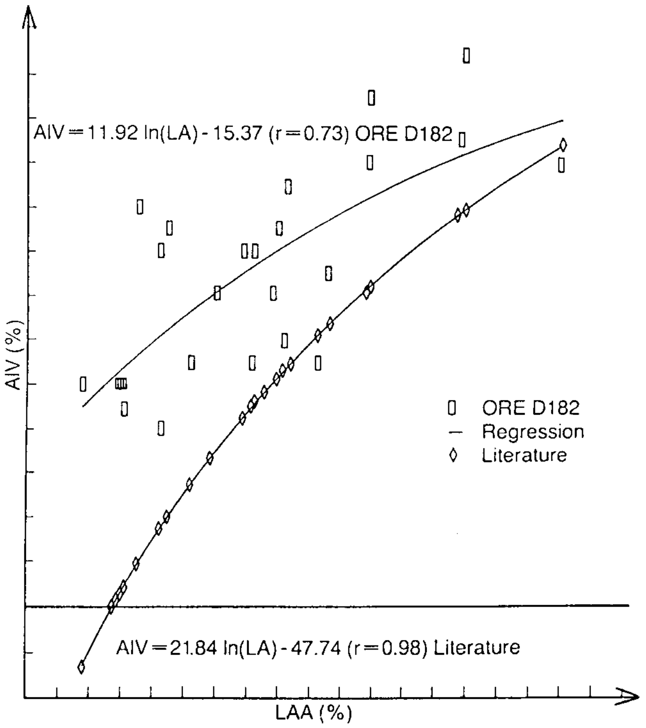

Fig. 2: Relationship between Los Angeles and Aggregate Impact Value

Assessment of ballast condition in the track

A reliable assessment of the ballast condition can be made at present only by taking samples of the material and screening it. The sample should be taken mechanically using a boring device or manually as a box sample using a sampling frame, in order to enable the proportion of fine grains to be accurately determined.

An enquiry was conducted in order to establish and evaluate the methods of assessing ballast condition in the track and the working methods used. It showed that the assessment of ballast condition in the track was based more on subjective impressions than on analyses.

Ballast is procured by the railways in accordance with technical specifications which stipulate the use of screens with graded square or round holes ranging from 20 – 70 mm. Each railway has its own specifications, allowing different volumes of very small particles.

To enable the experience gathered in practice by the various railways to be incorporated into a criterion for permissible ballast pollution, seven member railways each took an average of five to seven separate samples from an average of three different track sections which had been selected for ballast cleaning.

Sieve (mm)	NL1 - Basalt LA = 8.7 AIV = 10 Impact = 10.2 UDH = 3.9			F3 - Basalt LA = 9.5 AIV = 10 Impact = 11.7 UDH = 2.9			NL3 - Porphyry LA = 10.3 AIV = 10 Impact = 11.9 UDH = 3.6			B4 - Sandstone LA = 12.5 AIV = 11 Impact = 14 UDH = 4.1			CH2 - Limestone LA = 13.7 AIV = 15 Impact = 16.3 UDH = 4			B3 - Limestone LA = 23 AIV = 20 Impact = 21.3 UDH = 6.8		
	Before Test	After Test	Δ (%)	Before Test	After Test	Δ (%)	Before Test	After Test	Δ (%)	Before Test	After Test	Δ (%)	Before Test	After Test	Δ (%)	Before Test	After Test	Δ (%)
50	79.7	82.6	2.9	95.8	97.4	1.6	99.9	100	0.1	94	97.2	3.2	90.2	95.1	4.9	80.5	84	3.5
40	39.6	43.1	3.5	62.8	65.7	2.9	68.9	71.4	2.5	36.5	41.7	5.2	40.8	49	8.2	25.7	33.7	8
31.5	8.2	12.8	4.6	17.3	23.6	6.3	14.3	19.1	4.8	7.4	12.4	5	7.9	14.8	6.9	4	11.7	7.7
22.4	0.2	3	2.8	1.9	3.4	1.5	0.5	3	2.5	0.3	3.3	3	0.2	4.9	4.7	0.4	5.9	5.5
16	0	2.2	2.2	0	2.1	2.1	0	1.7	1.7	0	2.3	2.3	0	3.7	3.7	0	4.4	4.4
8	0	1.4	1.4	0	1.3	1.3	0	1.4	1.4	0	1.5	1.5	0	2.3	2.3	0	3.1	3.1
1.6	0	0.7	0.7	0	0.7	0.7	0	0.8	0.8	0	0.9	0.9	0	0.8	0.8	0	1.7	1.7
1	0	0.6	0.6	0	0.7	0.7	0	0.5	0.5	0	0.6	0.6	0	0.6	0.6	0	1.3	1.3

Fig. 3: Summary of results from Vibrogir tests

The specimens were screened by the different railways using the screens which they normally employ, thus determining the particle-size distribution curve of soiled ballast, of which Fig. 4 gives an example. The results were used to formulate a proposal for a preliminary criterion on track bed fouling, stating that the ballast of a track requires cleaning when the mean value of the samples shows that more than 30% of the particles, in terms of weight, are undersized on the basis of a screen with 22.4 mm square holes.

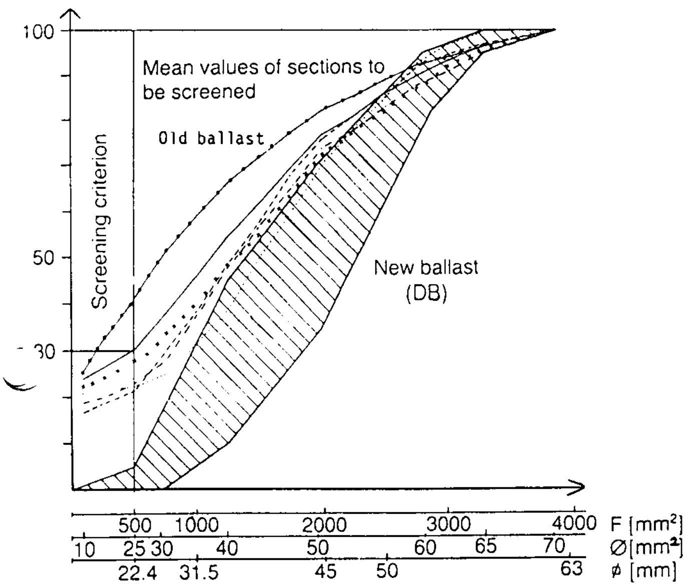

Fig. 4: Summary of old ballast analysis for DB sections

Tests carried out at the TU-Zürich

Large-scale tri-axial tests were carried out at the Institute for Geotechnology (Institut für Geotechnik) of the ETH in Zürich, Switzerland, on behalf of ERRI, in order to explain how the ageing process affects the most important mechanical properties of ballast.

The basic material used in the research was a typical type of used ballast, removed from a SBB/CFF track. The material was reduced to fractions and then combined into specimens with varying degrees of fouling. The tests were carried out in stages, in three separate research phases, involving a total of 27 dry large-scale tri-axial tests.

In order to achieve as realistic a situation as possible in terms of the material's grain structure, the specimens were first prestressed by subjecting them to 100,000 load reversals. The quasi-static cycles run after these load reversals serve to determine the mechanical properties of the specimen materials and to establish the relationship between fouling and mechanical properties. Finally, each specimen was subjected to a tri-axial shear test to the point of fracture.

The most significant results can be summarised as follows:
— the density of the material increases as the level of fouling increases. A maximum is reached at approx. 70% fouling;
— only at fouling levels over 50% does rigidity drop substantially;
— new ballast contracts when subjected to load reversals; highly soiled material, on the other hand, dilates;
— the energy absorption of the material remains virtually unaltered up to a level of fouling of approx. 50%. At higher levels of fouling, the energy absorption increases markedly;
— the shear angle remains virtually unaltered up to a level of fouling of approx. 70%, while at higher levels of fouling it falls sharply.

The results show that the mechanical properties of the ballast studied alter dramatically at fouling levels of approx. 50 – 70% and above.

Conclusions

The main conclusion in the work published so far was the criterion on track bed fouling of 30% passing through a 22.4 mm sieve. The studies carried out at the ETH-Zürich are in line with this conclusion.

The final report, envisaged for publication in autumn 1994, will propose guidelines for a quality assurance system for ballast and formulate ballast delivery conditions. This implies, among other things, the proposal of standards for:
— upper and lower limits for grading curves;
— grain shape;
— testing methods;
— resistance to frost;
— rock powder and fine particles.

D 182 is in regular consultations with the related CEN Committees in order to maintain consistency.

References

[1] ERRI D 182 RP 1: Studying the current quality of ballast and acceptance conditions, October 1991.
[2] ERRI D 182 RP 2: Assessment of ballast condition in the track, October 1991.
[3] ERRI D 182 RP 3: Determining the criteria for ballast durability using tri-axial laboratory tests (due to be published in September 1994).
[4] ERRI D 182 RP 4: Examining the test methods for determining the properties of ballast material using a simulation test with Vibrogir (due to be published at the end of 1993).