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CURRENT STATUS OF REBOUND HARDNESS TEST BLOCKS IN JAPAN AND OUTLOOK

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Abstract – Currently, about 30,000 high-precision, standardized hardness blocks are supplied to the Japanese market each year, and are available in about 140 different types. The history of hardness blocks in Japan can be traced back more than 70 years to the development of the Shore hardness block ($\phi 64 \times t 15$ mm) by Shoichi Yamamoto. In Japan, the Shore block has the largest share of the market for rebound hardness test blocks. Recently, however, the Leeb hardness block has also been increasingly used for rebound hardness testing, and the R type ($\phi 115 \times t 33$ mm) and P type ($\phi 90 \times t 56$ mm) Leeb hardness blocks are produced exclusively in Japan.

The successful expansion of the Shore hardness test in Japan is due to the use of Vickers hardness values, which are more reliable than Shore values, and the VHS conversion method adopted by the Japan Industrial Standards (JIS).

This paper discusses how differences in geometry between the R- and P-type Leeb hardness blocks influence Leeb hardness values. Based on hardness measurements using the Vickers and Leeb (HLD and HLE) hardness scales with these Leeb blocks, a method for converting Vickers hardness values into Leeb values is also discussed. As a result, no influence from geometric differences on the Leeb (HLD and HLE) hardness measurements is found, and conversion from Vickers to Leeb hardness can be defined by the same formula for both R- and P-type blocks.

1. INTRODUCTION

Currently, about 30,000 high-precision, standardized hardness blocks are supplied to the Japanese market each year, and these are available in about 140 different types. The history of hardness blocks in Japan can be traced back more than 70 years to the development of the Shore hardness block by Shoichi Yamamoto. In Japan, the Shore hardness block (Fig. 1 Left: $\phi 64 \times t 15$ mm, 380 g) has the largest share of the market for rebound hardness test blocks. Recently, however, the Leeb hardness block has also been increasingly used for rebound hardness testing.

Viewed from its force application curves, rebound hardness testing might be considered to be a form of indentation testing in which deformations occur at a high velocity. In practice, however, rebound hardness testing is

clearly distinguished as a convenient and speedy hardness testing method that differs from static indentation testing.

Rebound hardness testers are mostly light and compact for portability, therefore, they are available for on-site testing of large structures and plant equipment for strength and deterioration, which is difficult with stationary indentation testers. Easy and speedy testing processes and relatively low initial costs are among the benefits of rebound hardness testing.

2. INCREASING THE ACCURACY OF REBOUND HARDNESS TEST BLOCKS

Rebound hardness testers have distinctive issues to be considered, including friction between indenter—a hammer or an impact body—and measuring cylinder, and the effects of a specimen's mass on the measurements obtained, or so-called mass effect. It is, therefore, not recommended to establish absolute standard (reference) values using a standard hardness tester for which the friction and mass effects differ from those of hardness testers generally used in the field. Rather, it is important to set more practical standard values that are suitable for general hardness testers to monitor the accuracy of rebound hardness values.

To establish a practical standard for Shore hardness, Dr. Takeo Yoshizawa, the first chairman of Material Testing Research Association of Japan (MTRAJ), recognized the importance of clarifying the average status of general Shore hardness testers. For that purpose, Yoshizawa took hardness measurements on a high-accuracy Vickers hardness block ($\phi 64 \times t 15$ mm) developed by Shoichi Yamamoto with many general

Shore hardness testers (Fig. 2) actually used in the industrial world. Based on the results of these measurements, Yoshizawa developed a method for determining standard values of Shore hardness by converting Vickers hardness values. The method was then introduced into JIS as the cubic Vickers-to-Shore (VHS) conversion formula shown in Equation (1).

$$VHS = \{1.7026(HV/1000) - 0.9224(HV/1000)^2 + 0.2291(HV/1000)^3\} \times 100 \quad (1)$$



Fig. 1 Appearance of standard blocks for rebound hardness

Later minor improvements were introduced to produce a quartic version of the formula. In Japan, all general Shore hardness testers, whether Type C or Type D, require not only direct verification, but also indirect verification using test blocks and the VHS conversion method. The minor variances of hardness measurements detected through indirect verification are addressed by adjusting (random polishing) the spherical tip of the diamond indenter with a diamond to correct hardness values.

The successful introduction of the VHS conversion method is regarded to have resulted in persistently stronger demand for Shore hardness testing in Japan, compared to other developed nations¹⁾.

Subsequent to the successful management of standard values of Shore hardness testing using the VHS conversion method, the Roll Hardness Committee of MTRAJ studied the relationship between Vickers and Leeb hardness with the cooperation of Proceq SA, and successfully introduced the Vickers-to-Leeb (VHLD₁ and VHLE₁) conversion formulas²⁾.

Table 1 Leeb hardness values of HL R-type blocks with/without anvil

Nominal hardness HLD (HV)	880 (920)	730 (540)	540 (250)
HLD with anvil (cast iron, 26.5 kg)	871.5	725.7	540.5
HLD without anvil	870.2	726.9	541.7

More recently, the Roll Hardness Committee developed a Proceq version of the Leeb hardness block (Fig. 1 Right: $\phi 90 \times t 56$ mm, hereinafter the “P-type block”), in addition to the conventional Roll Hardness Committee-version of the Leeb hardness block (Fig. 1 Middle: $\phi 115 \times t 33$ mm, hereinafter the “R-type block”), and performed a comparative study. As a result, it was found that, despite the significant difference in thickness of the two, there was no mass effect because their masses were almost equal at about 2.7 kg, even when the R-type block was used, as shown in

Table 1. Needless to say, it is proven that the hardness uniformity of the P-type block is as high as that of the R-type block²⁾. Table 2 shows major specifications of Shore and Leeb hardness testers.

3. REVIEW OF HLD AND HLE HARDNESS AND THEIR RELATIONSHIP WITH HV HARDNESS (VHL)

Due to the background stated above, R-type Leeb hardness blocks on which Vickers-converted HLD and HLE hardness values are indicated have been used conventionally. However, this VHL conversion formula is based on measurement results obtained by testing mostly R-type blocks with initial Leeb testers of the Roll Hardness Committee and Proceq SA.

Taking the opportunity of the development of the P-type hardness block, the Roll Hardness Committee reviewed the relationship between Vickers and HLD/HLE hardness by testing R-type and P-type blocks with three of the latest Equotip testers (HLD and HLE). The results are shown in Fig. 3 and Fig. 4. The HV-HL conversion results showed good agreement between VHLD₁ and VHLE₁, but a slight difference in a high hardness range. Considering 20 years of progress of testers, the new HV-HL conversion formulas should be developed based on the latest measurement results in the near future. These formulas will be under review by the Roll Hardness Committee for official adoption.

4. OUTLOOK FOR REBOUND HARDNESS TEST BLOCKS

Theoretically, it is almost impossible to rely on actual Specimens when establishing a hardness standard, but a hardness test block, which has to function as a provisional hardness standard, must be able to provide the most reliable hardness values possible.

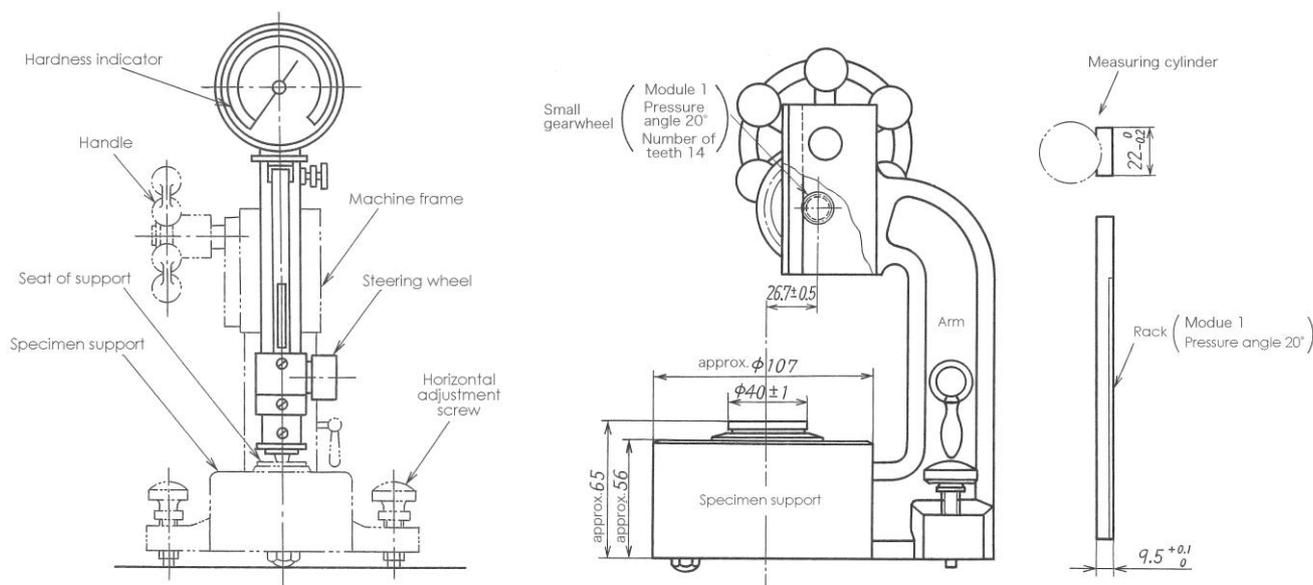


Fig. 2 Testing machine and machine frame with anvil of the HS tester (JIS B 7727)

Table. 2 Specifications of rebound hardness testers

		Shore hardness		Leeb hardness	
		HS C	HS D	HLD	HLE
Indenter	Material	Diamond		Cemented carbide	Diamond
	Mass (g)	≅ 2.5	≅ 36.2	5.45 ± 0.05	
	Radius (mm)	≅ 1			
	Falling height (mm)	≅ 254 (10 inch)	≅ 19 (3/4 inch)		
Impact	Energy (mJ)	(6.2)	(6.7)	11.5	
	Velocity (m/s)	2.0–2.2			

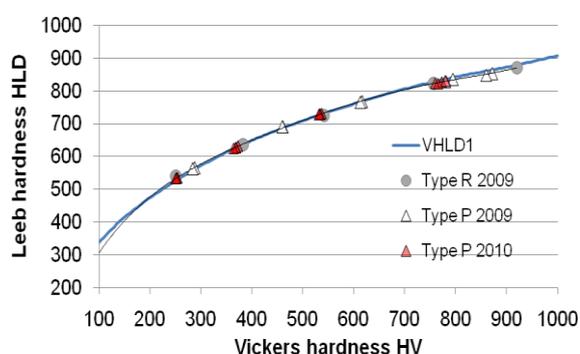


Fig. 3 Relation between HV and HLD values

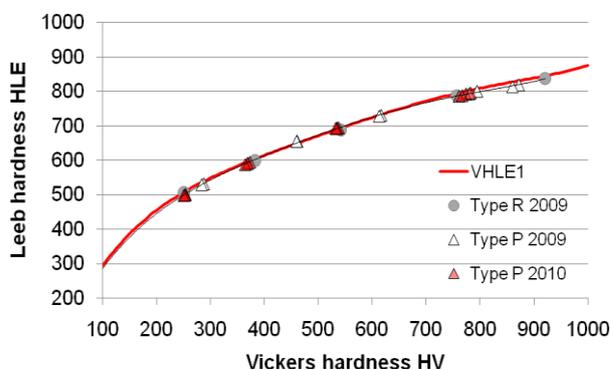


Fig. 4 Relation between HV and HLE values

For this reason, Shore hardness test blocks rely on Vickers hardness—with which the reliability of test results is higher than those of rebound hardness tests—to establish standard values by monitoring the difference ΔHS from actual measurements of Shore hardness testing. In Japan, the standard for Leeb hardness testing was also established by converting from Vickers values (R-type test block). When using Leeb hardness measurements to establish a standard as specified by DIN, it is recommended to monitor minor fluctuations of Leeb hardness by taking Vickers hardness measurements³⁾.

As mentioned above, it is difficult to avoid the mass effect with rebound hardness tests. Therefore, it is required

in Japan for indirect verification of a Shore hardness tester to be performed by testing a hardness block (φ64 × t15 mm) on a JIS-defined 8 kg machine frame integrated with a specimen support, as shown in Fig. 2. This allows the use of a highly accurate test block as small as φ64 × t15 mm, without being limited to large blocks.

For Leeb hardness testing, large blocks with a mass of about 2.7 kg are currently on the market, and the DIN requires a thickness of 54 mm or more and a diameter of 90 mm or more for Leeb test blocks. However, it is desirable for Leeb test blocks to become available in a wider range of sizes and masses by equipping a Leeb hardness tester with a machine frame and a specimen support as is the case with a Shore hardness tester.

REFERENCES

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