# Evaluation of A Newly Developed Crack Width Measurement Instrument

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## ABSTRACT

A new portable instrument that is based on optical principles and is quantitatively able to measure crack width on a structural surface has been developed to deal with the increasing problem of crack width measurement in existing buildings and structures.

The instrument's accuracy and applicability were evaluated to determine its suitability for practical use. The results of the experimental evaluation are as follows:
1) The instrument is generally applied to ordinary building materials but cannot be used for clear glass structures or materials.
2) It is essential to apply an opaque sheet when the material surface being measured around the crack is blue or a deeply colored ceramic tile.
3) Careful measurement is necessary when an undulation on the measured material surface extends over the crack width and the magnitude of the undulation exceeds 1.0 mm.
4) The region around the crack on the measured material surface has to be at an angle of under 41 degrees and must have no defects at the corners.
5) The operator's experience with the instrument and individual skill affect the measurement result. However, they do not affect the results after measurement has been conducted a few times by the same operator. Furthermore, using an auxiliary sheet for the measurement gives a better measurement result.
6) In cases where it is difficult to determine whether the instrument can be applied to some material, the instrument can be used for measurement if it can be confirmed that there are no differences between measurements made with a loupe and the instrument.

As the above shows, the newly developed instrument can measure crack width more accurately and can decrease operator error except under certain conditions related to color, undulation and unevenness of the measured material surface.

## KEYWORDS

Building diagnosis, Crack width measurement, Deterioration inspection, Optical instrument

## 1 INTRODUCTION

In Japan, existing buildings and structures have deteriorated over the time that has elapsed since their completion. Therefore, structure diagnosis is becoming increasingly important and the need to conduct crack width measurement in existing buildings and structures has become more pressing.

Against this background, a new portable instrument that is based on optical principles and is quantitatively able to measure crack width on a structural surface has been developed

The measurement accuracy and the range of application must be clarified if the instrument is to come into wider use, and an objective evaluation is therefore required.

## 2 OUTLINE OF THE CRACK WIDTH INSTRUMENT

A plastic film with a graduation has generally been used for measuring the width of cracks in concrete structures. It is named the plastic film crack scale in Japan.

This instrument has been developed as a replacement for the conventional crack scale. The instrument is pressed against the crack on the concrete surface and it indicates the magnitude of the crack width instantly. It is portable and can be used to measure cracks from 0.05 – 2.0 mm in 0.05 mm increments.

### 2.1 Shape and size of the instrument

The dimensions of the instrument are 100 X 70 X 25 mm and it weighs 105 g. The appearance and name of each part are indicated in Fig. 1.

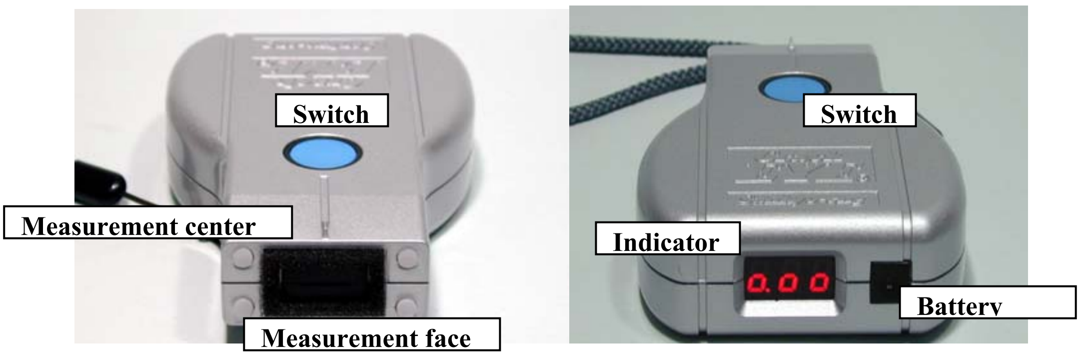


**Fig. 1. Appearance and part names**

### 2.2 Measurement method

The measurement method is shown in Fig. 2.
The instrument radiates a beam of light from both sides of the measurement face and the beams cast shadows of each side of the crack onto its opposite face. The shaded part (A in Fig. 2) is detected with a charge-coupled device (CCD) and the crack width is indicated. The instrument measures the difference in contrast between the surfaces illuminated by the beam and the dark depths of the crack.

If, for example, a black line is printed on a white background, the width of the black line can be measured by this instrument.

The sensitivity of the instrument can be controlled with a measurement aid sheet applying the above principle.

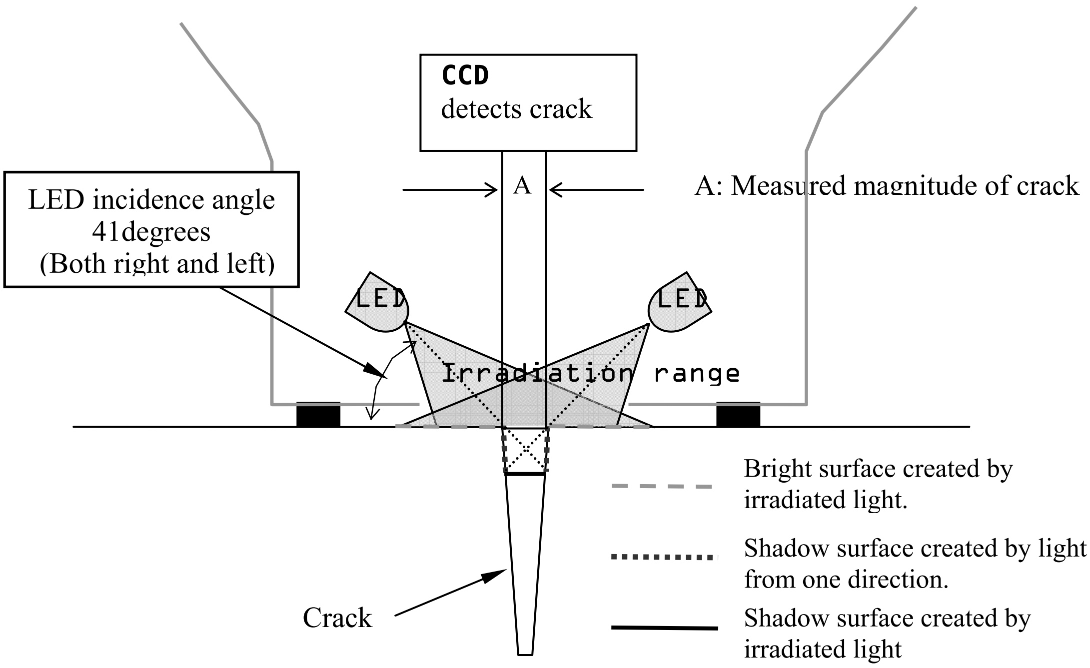


**Fig. 2. Crack width detection method**

### 2.3 Control of measurement sensitivity

The measurement sensitivity of the instrument is controlled by using the attached measurement aid sheet indicated in Fig. 3. It provides a standard width of 1.0 $\pm$ 0.01 mm. If the error of three measurements of the standard is within $\pm$ 0.05 mm, the instrument is working normally. Any differences in the power of the light-emitting diode (LEDs) and the sensitivity of the CCD are corrected for by calibration with this 1.0 mm wide line, to minimize any difference between instruments.

The measurement aid sheet is made by a film process, because it is difficult to achieve the required $\pm$ 0.1 mm design accuracy with ordinary printing. The thermal expansion of the measurement aid sheet is 1.0 X $10^{-3}$ %/C° and its stability are excellent at ordinary temperatures, though it may be degraded at temperatures above 70 C°.

If the instrument is tilted when held against the crack, the tilted width is measured, which includes some depth as well as width, and is thus likely to be larger than the true value.


**Fig. 3. Measurement with the aid sheet**

## 3 EVALUATION OF THE INSTRUMENT

### 3.1 Measurement of several types of specimens

Measurements of cracks in ordinary building materials (concrete, steel and textured sprayed finish) are shown in Fig. 4. It was judged that the results were equivalent to measurements obtained with crack scale or loupe for all the specimens examined. As the crack width grew, the difference in the results increased. However, It is necessary to take into account those errors peculiar to crack scale and loupe measurements, which increase with the size of the reading.

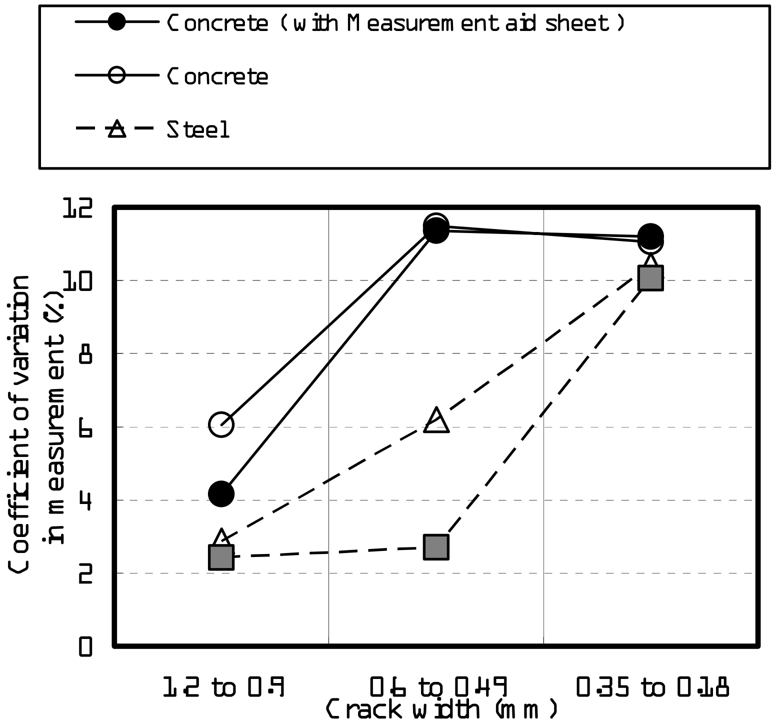


**Fig. 4. Measurement result for ordinary building materials**

On the other hand, when several operators made 10 measurements at the same place on the specimen in a short time, the results were repeatable, with only a small scatter around the mean value. This takes into account the specific characteristics of the instrument. If the measurement aid sheet is used, the dispersion in measurement is decreased and this may be useful when high accuracy is required from a few measurements.

It is recognized that there will be dispersion in measurements made on a textured sprayed finish, which is an uneven surface, even if the aid sheet is used. Therefore, it is necessary to avoid making measurements on a continuously uneven surface, and the instrument must be placed on a stable surface. Also, measurements should be made only after the measured surface has been tested for smoothness, because a projection angle of over 41° presents problems due to the geometry of this instrument.

### 3.2 The operator effect

*3.2.1 Experience and number of measurements*

The experiment used concrete specimens with cracks 0.65 and 0.25 mm wide, and a concrete wall with a 0.7 mm width crack as measured by a crack scale. An operator measured these cracks 5 – 30 times using the instrument, but without using the measurement aid sheet.

The effect of the number of measurements made by the operator is shown in Fig. 5.
Measurements made just 5 times have the largest dispersion, and subsequent measurements tended to become stable.

It is considered that the effect of the number of measurements made by an operator is negligible after the operator has gained practical experience by using the instrument more than 5 times in trial measurements.

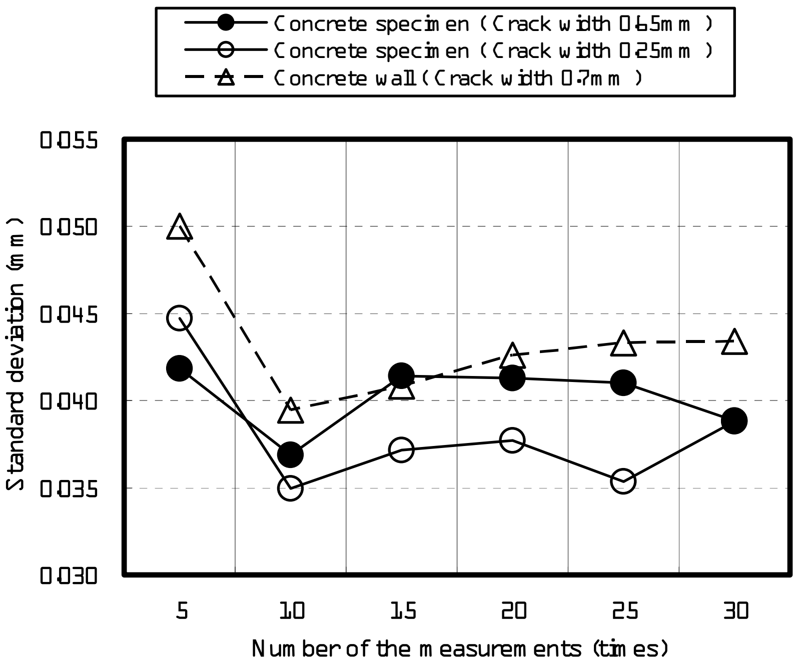


**Fig. 5. The effect of operator experience on the measurement**

*3.2.2 Individual skill*

The experiment used concrete specimens with cracks 0.4, 0.55, 0.9, and 0.95 mm wide as measured by a crack scale. Three operators with actual experience measuring crack widths made a mean of three measurements of these cracks using the instrument but without using the measurement aid sheet.

The result of the experiment is shown in Fig. 6. For each specific operator, the dispersion of measurement values and the difference from values measured with a crack scale are recognized, and the dispersion between operators is significant. However, the coefficient of variation is decreased for all three operators when the measurement aid sheet is used.

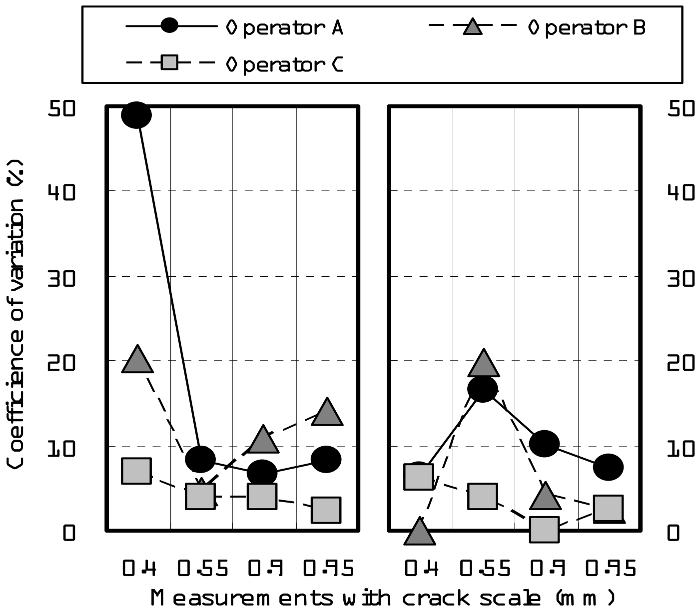


**Fig. 6. The effect of the individual operator's skill on the measurement**

*3.2.3 The calibration tool*

The targets were cracks 0.35, 0.6 and 1.2 mm wide as measured with a crack scale, which had been extracted at random from concrete structural elements. An operator with actual experience measuring crack width measured the cracks with the instrument, with and without using the calibration tool.

The results are shown in Fig. 7. The dispersion in measured values can be decreased at all crack widths by using the calibration tool.

It is considered that the usefulness of the calibration tool can be seen in the measurements made by the experienced operator, and also that it helps even an unskilled operator achieve consistent accuracy.

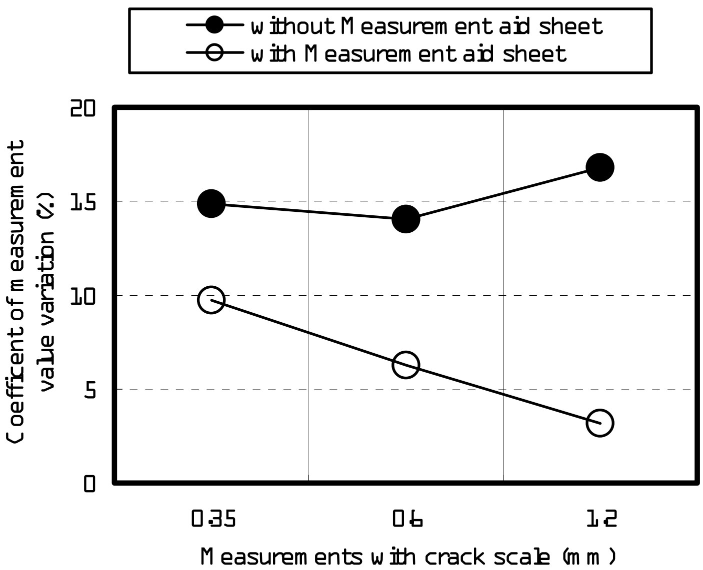


**Fig. 7. The effect of the acid sheet on the measurement**

### 3.3 The measurement for structures

It is considered that an uneven surface or lack of a sharp edge on the crack may affect the measurement results with this optical instrument. In this experiment the crack width was measured with both a crack scale and the instrument for two shapes of crack.

Experimental results are shown in Fig. 8.

It is judged that measurements made with the instrument do not differ from those measured with a crack scale, even with unevenness and surface level differences. On the other hand, the lack of an edge did have an effect on the results. It is difficult to measure the crack width exactly because the irradiation depth of the light varies. However, this characteristic may not be a problem unique to this instrument, because the crack scale showed a similar problem in measuring the true crack width.

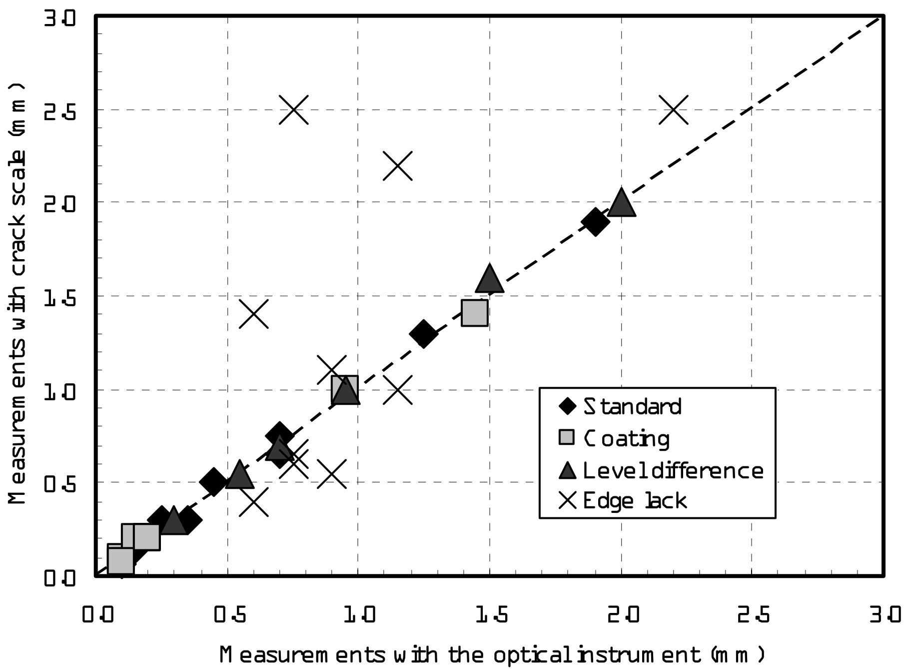


**Fig. 8 The effect of the surface conditions on the measurement**

### 3.4 Background Color

The detection error in the crack width tends to increase if the material is blue or green, because these are complementary to the red color of the LED light source, so they absorb the illumination, which decreases the contrast of the illuminated area.

In an extreme case, the background color simply appears as black as the crack, and it is impossible to measure the crack.

Also, in actual practice, if the surface is a dark color but the inner walls of the crack are nearly white, the instrument's error may be larger.

## 4 CONCLUSION

A new portable instrument has been developed to deal with the increasing problem of crack width measurement in existing buildings and structures. Its function is based on optical principles and it can measure crack width quantitatively on a structural surface.

This paper describes the experimental evaluation of the instrument, as it measures actual cracks. The results show the capabilities and limitations of the instrument.

## 5 ACKNOWLEDGMENTS

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The authors would like to express their heartfelt thanks to other committee members.

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