Measurement of Soil Hardness of Floor Surface for a Reconstruction of Activity Patterns in a Prehistoric Dwelling

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The hardness of the soil is one of the most important characteristics to observe in the stratigraphy of archaeological sites. The hardness is especially useful in detecting the floor surface of prehistoric dwellings where the surface had gradually been hardened by the pressure exerted by the people who had lived in the dwelling.

The hardness of the floor surface is not homogeneous within a dwelling pit. It is commonly observed that an area surrounding the fireplace had a tendency to be hard, while areas near the dwelling walls usually tended to be relatively soft. This variation is thought to be due to the different frequencies of activities on different parts of the dwelling. Thus the distribution of hardness of a living surface will assist in reconstructing the floor plans of dwellings where activities took place.

Exact measurement of the hardness will be required for this purpose. The penetrometer (Baker and Webley 1978) measures the soil strength assessment, which occurs when the instrument is inserted deeply into the soil. In contrast, Nakayama's hardmeter (Fig. 1) enables measurement of the reacting pressure of the soil at the surface, which is more suitable for examination of the hardness of a living surface (Council for Physical Analyses of Soil 1970). Moreover, the hardmeter is portable, and can take measurements on sloping or vertical surfaces as well as on level surfaces.

In this report, methodological problems in measuring the hardness of the soil on the dwelling floor will be discussed using data obtained from a pit house of the Kofun Period excavated recently in Tokyo (Excavation Project of Ishikawa-Amano Site 1981).

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NAKAYAMA'S HARDMETER

As shown in Fig. 1, the retraction of the probe cone of Nakayama's hardmeter gives the soil hardness. The distance from the top of the cone to the brim is 40 mm, and the angle of the cone is 12°40'. When the instrument is gently pushed onto the soil surface, the cone retracts and the spring is compressed. The hardmeter must be inserted into the soil until the brim has been attached firmly onto the soil surface.

The degree of hardness is read as a distance of retraction of the cone, that is compression of the spring. Absolute hardness \( (H \text{ mg/cm}^3) \) can be calculated as the volume of the inserted part of the cone based on the compression of the spring \( (x \text{ mm}) \).

Where \( H = k \cdot x/(4 - x)^3 \), \( k \) is a constant of the spring, 4.718 in this portable hardmeter (Yamanaka and Matsuo 1962).

MEASUREMENT OF FLOOR HARDNESS IN A DWELLING PIT AT THE ISHIKAWA-AMANO SITE

The dwelling pit examined (4C–64) was a typical dwelling of the late Kofun Period (ca. A.D. 800) having a rectangular plan, 4.8 m in the north-south axis and 4.4 m in the east-west axis. An oven made of clay had been built on the middle of the northern wall, opposite was a storage pit in the southern wall (Fig. 2).

The dwelling pit was excavated by the usual techniques until a fill of 5 cm thickness remained on the surface of the dwelling. Then exposure of the floor itself was started at the center of the dwelling, spreading toward the walls. The exposed surface of the floor was never trodden upon in order to avoid alterations to the hardness in the dwelling pit due to excavation activities. Because of the effects of moisture on soil hardness the dwelling pit was covered with waterproof sheets, except during the actual excavation, to protect from rainfall and night frost.
Fig. 2 Partial data of the hardness for the first measurement of dwelling pit 4C-64 in Ishikawa-Amano Site.
After the entire floor of the dwelling had been exposed, hardness was measured using Nakayama's hardmeter on 9 and 10 October 1981. The dwelling was disturbed by cultivation in a large area along the east-west axis, and by tree roots at the central eastern area. Other small disturbed spots were also detected all over the dwelling. These disturbed areas were not analyzed. The remaining area was measured for hardness at intervals forming a 10-cm grid (Fig. 2). The number of measured points totalled 2060, covering about 80 percent of the possible points.

Careful excavation revealed that the surface of the living floor was not smooth but undulated, with small bumps of 5 to 10 cm in diameter. Loam soil characteristically displays an uneven surface when frequently trodden. These bumps made it difficult to measure the hardness of the surface with the hardmeter, because the close fit of the brim to the analyzed surface is important for accurate measurement. Consequently the points to be measured were moved onto the bumps within the grid, and inadequate measurements were not used in further analyses.

The second measurement of the hardness of the dwelling floor was carried out on 29 October, 20 days after the first measurement, when the survey of the oven and four postholes and a drawing of the dwelling plan were finished. The aim of the second measurement was to examine influences of the excavation activities on the hardness of the soil. The points for measurement were set on a 50-cm grid along the same axes of the first measurement. Besides the measurement of the 50-cm grid, the hardness profile along the central axis connecting the oven and storage pit was measured in 10-cm intervals in order to examine the hardness of burnt loam in the oven.

HARDNESS DISTRIBUTION OF THE FIRST MEASUREMENT

As the complete measurement data have already been given in the excavation report (Koike 1981a), examples of the measurements are shown in Fig. 2. Comparison of measurements among adjacent points showed that they had a rather wide variation, even between neighboring points. The coefficient of correlation among neighboring points was 0.35, showing only a weak correlation.

The histogram of the hardness (Fig. 3–A) ranged from 9.0 to 32, a wider range than that of soft loam in a standard geological profile (Endo et al. 1981). The mean value was 21.6 mm, with standard deviation of 2.5 mm.

Distribution of the hardness over the floor of the dwelling is illustrated in Fig. 4, where measurements were divided into five classes: the hardest class (hardest 2.5 percent points, more than 26.0 mm), the harder class (harder 15 percent points, from 24.0 to 25.9 mm), the medium class (medium 65 percent points, from 19.0 to 24.0 mm), the softer class (softer 15 percent points from 18.9 to 16.6 mm), and the softest class (softest 2.5 percent points, less than 16.5 mm).

Points of the hardest class were distributed in the central zone along the main axis connecting the oven and the storage pit, especially in the area between 1 m from the oven and 1 m from the storage pit. Points of the harder class had a distribution similar to those of the hardest class, but spread toward the walls. These harder points were found mostly inside the area bounded by the postholes and were concentrated on the western side of the oven. The softer points were found outside the postholes in a zone 1 m wide from the dwelling wall. The softest points were found close to the dwelling wall.
HARDNESS DISTRIBUTION OF THE SECOND MEASUREMENT

The histogram of hardness of the second measurement also had a wide range, varying from 15 to 31 mm with a mean value of 23.3 mm (Fig. 3-B). These measurements were clearly higher than the first measurement. Softer values, less than 18 mm, had almost disappeared, and harder values, more than 25 mm, increased in the second measurement. These data indicated that excavation activities on the dwelling floor would have a significant influence on the hardness of the soil.

Comparison between the first and second measurements in the same grid (Fig. 5) showed a weak similarity. Coefficient of correlation was 0.30, slightly smaller than that of neighboring points. Although the absolute hardness values increased in the dwelling floor, they had a pattern similar to that of the first measurement, with a harder area in the central part bounded by the postholes (Fig. 6).

The hardness profile along the central axis of the dwelling (Fig. 7) showed softer values near the storage pit, increasing sharply toward the center about 1 m from the edge of the storage pit, and highest when passing beside the postholes. As a whole, the central area was relatively hard, but individual measurements had a rather wide variation. At the oven, where the burnt loam had changed into red-brown, the soil was softer; the partly burnt soil at the end of the oven, where the heat morphogenesis was relatively weak, was rather harder than the average hardness of the dwelling surface.

DISCUSSION

Measurement of soil hardness by means of Nakayama’s hardmeter enables a quantitative analysis of the prehistoric dwelling floor (Koike 1981b). Although the hardness of neighboring points on the floor had a wide variation, showing that the
Fig. 4 Distribution of ranked hardness for the first measurement of the dwelling floor.
hardness of the soil surface on the dwelling floor was not homogeneous, distribution of ranked hardness showed a distinct pattern reflecting the intensity of activities of prehistoric residents. The measurement of the dwelling floor in the Ishikawa–Amano Site showed that harder points were distributed at the central area of the dwelling, especially within the area bounded by the postholes. The hardness suggests that most daily activities took place in the central area, while the outer area around the dwelling walls might have been used as resting places. The data further indicate another aspect of activities within the dwellings. Archaeologists have assumed that the entrance to the dwelling would have been at the side opposite the oven, possibly employing a boardwalk over the storage pit. The profile of hardness along the central axis showed that the hardness of the floor increased sharply at about 1 m from the storage pit, where residents entering the dwelling would have stepped off the boardwalk and continued to the central area of the dwelling.

The second measurement showed that excavation activities affected the hardness
Fig. 6 Distribution of the ranked hardness for the second measurement of the dwelling floor.

of the soil surface. Although the distribution pattern was similar to the first measurement, absolute hardness values increased. Therefore, it is important to take care not to tread upon the excavated living floor until after measurement.

Since moisture also affects the hardness of soil, plastic sheets were always used to cover the soil in order to keep a relatively constant moisture level, except during excavation. If small amounts of fill remained on the floor, the hardness values would decreased markedly from the actual hardness of the floor surface. Accurate excavation of the living surface is also important in order to obtain good results.
Fig. 7 Hardness profile along the central axis of the dwelling.

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