

# ROLLING CHARACTERISTICS OF WEDGE LOCK SCAFFOLDINGS DURING USE

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Leading handrail frames for scaffoldings have recently been used in construction work sites in Japan. Since then, the Ministry of Health, Labour, and Welfare has recommended the adoption of this safety method to prevent falling accidents. Meanwhile, wedge lock scaffolding has been increasingly used because of its versatile range of applications. Wedge lock scaffolding systems are considered more flexible structures than frame-type scaffoldings. To elucidate the advantages offered by the former, we compared the rolling characteristics of wedge lock scaffoldings equipped with different leading handrail frames during workers walked on catwalks. The test results show that the perception of rolling effects is influenced not only by rolling amplitude, but also by worker's walking speed and manner of walking (i.e., type of steps taken). On a scaffolding with ledgers (longitudinal struts) on both sides, rolling occurs synchronously with the movement of the entire scaffolding. On scaffoldings with pre-installed handrails on both sides, the rolling amplitude in individual scaffoldings is high but the movement of each scaffolding does not extend to the adjacent scaffolding because of the looseness of the connecting mechanism.

## Introduction

Leading handrail frames for scaffoldings (denoted as scaffold) have recently been used in construction work sites in Japan to prevent falling accidents. Wedge lock scaffolds, approved as safe by the Scaffolding and Construction Equipment Association of Japan (SCEA), have gradually been used as attachments to pre-installed handrails. Typical wedge lock scaffolds equipped with leading handrail frames are shown in Figure 1. According to the SCEA's technical standards, wedge lock scaffolds should be equipped with wedge lock ledgers on both sides of longitudinal planes. Scaffolds with pre-installed handrails on one side and wedge lock ledgers on another are used because of easy handling in situ. However, in this case, these scaffolds should be verified in confirmation tests as being as strong as ordinary scaffold systems. Workers have increasingly demanded the use of scaffolds with pre-installed handrails on both sides of longitudinal planes given the flexible application that these scaffolds offer. The SCEA experimentally validated that the aforementioned scaffold systems have sufficient strength for different construction needs. This development prompted the organization to revise its technical standards to include the use of scaffolds with pre-installed handrails on both sides of longitudinal planes. During the review of the SCEA standards, construction workers indicated that the aforementioned scaffolds exhibit higher rolling than do scaffolds with wedge lock ledgers on both sides. To verify these observations, we carried out an experiments intended to determine the rolling characteristics of wedge lock scaffolds during use.

## Measurement of the rolling movements of scaffolds in use

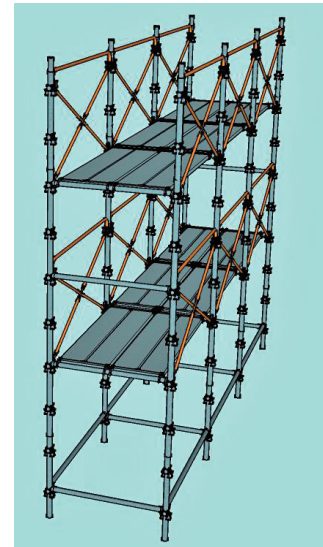
### Specimens

The tested scaffolds were equipped with four different connecting mechanisms (Figure 2). Four types of scaffold systems were selected, in which the deformations measured during a horizontal bending resistance test were considered. The test shows that the A-type, B-type, C-type scaffolds exhibit maximum, moderate, and minimal deformation, respectively. The D-type was that wedge connecting mechanisms are located on uprights outside the longitudinal planes.

### Test procedure

#### 1. Tested scaffolds

Scaffolds consisting of 2 stages and 3 spans were tested. Targets ( $\varnothing=15\text{cm}$ , painted yellow and black) were attached to the scaffolds to measure their rolling movements. The movements of these targets were recorded using a video camera while a worker walked along the top catwalk (Figure 3). The movements were measured by the image processing method using the Dipp-Motion Pro 2D program. The displacements of the targets were compared to determine the rolling characteristics of the tested scaffolds.



**Figure 1. Scaffoldings with both pre-installed handrails**



A-type



B-type



C-type



D-type

**Figure 2. Four types of wedge connecting mechanism**

#### 2. Walking patterns used in the test

Three walking patterns were used: slow, normal, and fast. Two workers made one round trip each on the 3-span catwalk. Details on the height, weight, and experience of the workers are listed in Table 1.

**Table 1. Worker profile**

Worker	Age	Gender	Height(cm)	Weight(kg)	Experience (years)
A	24	Male	175	62	1
B	27	Male	171	70	4

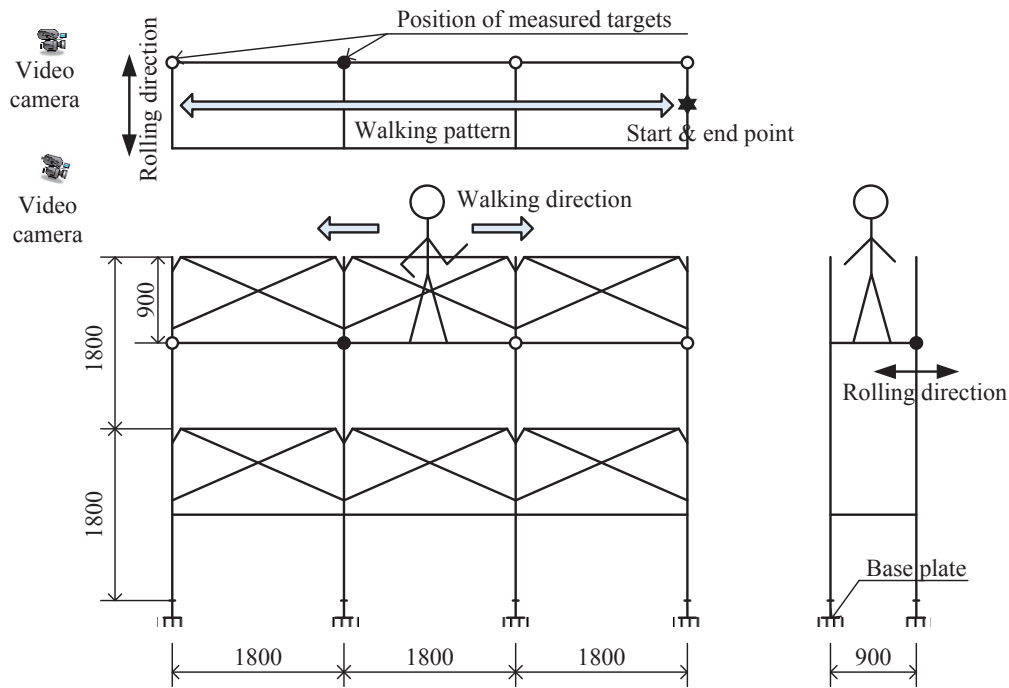
#### 3. Structures of the tested Scaffolds

The structures of scaffolds were 2 stages and 3 spans. Each scaffold was set up using prefabricated scaffold elements produced by the same manufacturer. The scaffolds were test under conditions (a), (b), and (c):

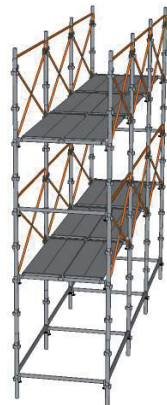
- Pre-installed handrails were attached on both sides of scaffolds (denoted as PH+PH) (Figure 4);
- A pre-installed handrail was attached on one side and a wedge lock ledger was attached on another (denoted as PH+LS) (Figure 5);
- Wedge lock ledgers were attached on both sides of scaffolds (denoted as LS+LS);

The SCEA standards stipulate that wall-anchored ties must be attached within 5 m in the vertical direction and near the putlog (transverse strut). Thus, wall-anchored ties need not be attached on the 2-stage scaffold (whose height is about 4 m). This condition is considered the most flexible, because only bases of scaffolds are anchored.

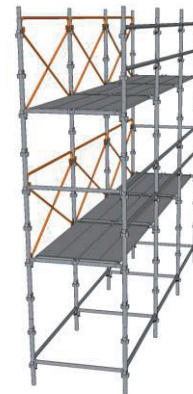
Here after, PH and LS represents pre-installed handrails and wedge lock ledgers, respectively.



**Figure 3. Schematic diagram of rolling test**



**Figure 4. Both side were pre-installed Handrail**



**Figure 5. One side was pre-installed handrail and another side was ledge**

### *Test results*

The test results are shown in Table 2 and Figure 6. The vertical and horizontal axes represent the horizontal displacement (mm) of the targets and elapsed time (sec), respectively. After the walking test, worker A revealed that the scaffold exhibiting the strongest rolling is the A-type scaffold with LS+LS. By contrast, worker B pointed out the D-type scaffold with PH+PH shows the strongest rolling. The analysis of the test results on rolling amplitude indicates that even though a worker detects strong rolling, such assessment does not necessarily translate to a high-rolling amplitude.

For example, the worker evaluated the A-type scaffolds with PH+PH and LS+LS as “steady” and “having the strongest rolling”, respectively. However, minimal difference was found in the rolling amplitude of both scaffolds, as shown in the analysis (the scaffold with LS+LS exhibits a maximum rolling amplitude of 8 mm; the scaffold with PH+PH shows a maximum rolling amplitude of 7 mm). Numerous irregularities were observed in the rolling movements of the scaffolds with LS+LS. This irregular rolling drove worker A to assess the scaffolds thus: “It was not easy to walk because it is rolling”. The rolling amplitudes of scaffolds do not always correspond with the assessments of workers. Worker B, who is more skilled than worker A, walked fast along the scaffolds by taking wide steps.

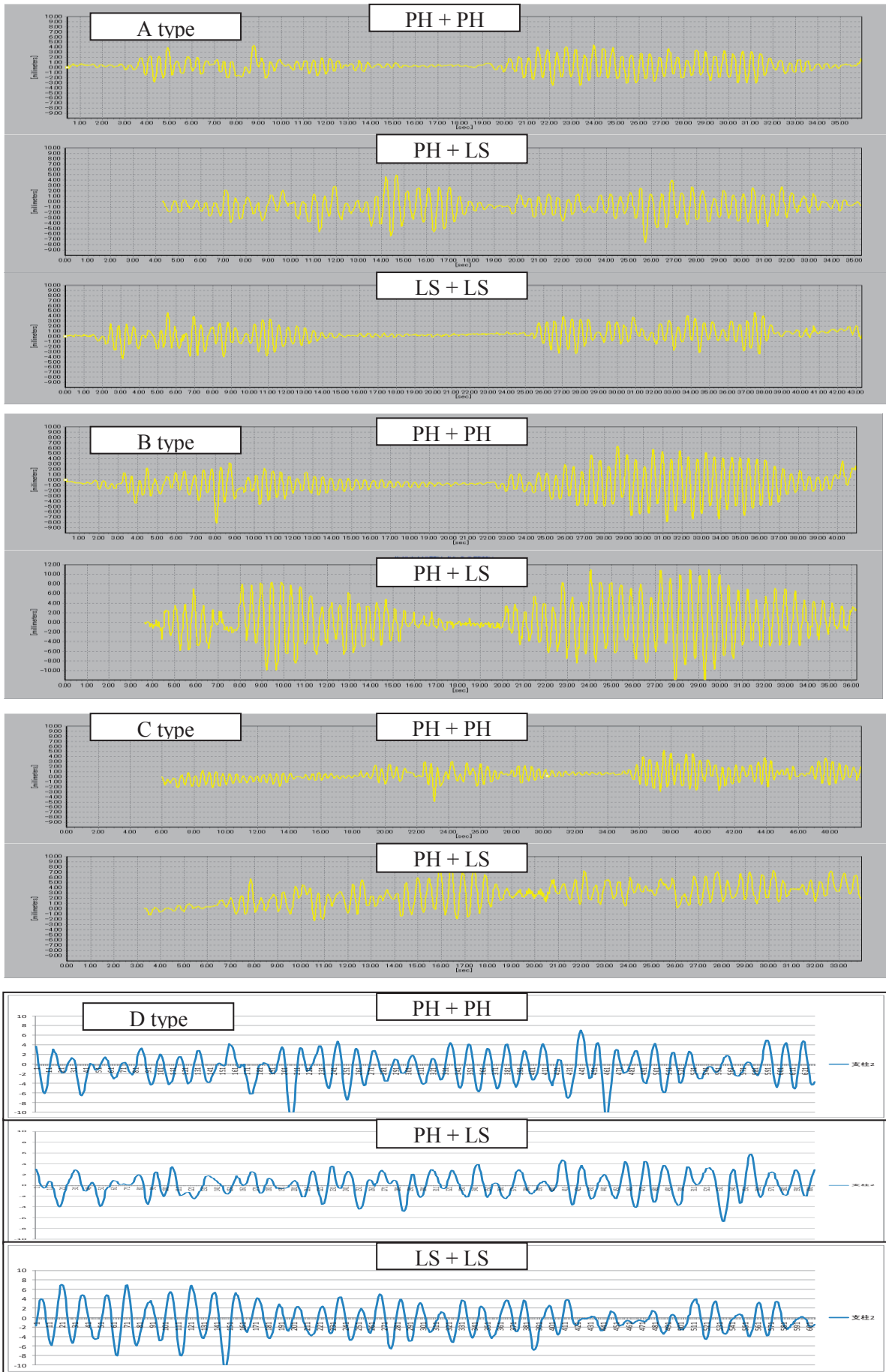


Figure 6. Shapes of rolling at walking test

**Table 2. Maximum rolling amplitudes scaffolds at walking test**

<b>Combination of leading handrails</b>	<b>PH + PH</b>	<b>PH + LS</b>	<b>LS + LS</b>
A type (flange type)	7.0	8.0	8.0
B type (pocket type)	13.0	21.0	---
C type (flange type)	11.5	9.5	---
D type (pocket type, outside)	15.0	8.5	17.0

Consequently, the rolling becomes to increase. Worker B assess the scaffolds was not difficult to walk even though high rolling of scaffold, because he has considerable experience walking on catwalks and high rolling occurred relatively constant pitch. Most of the pre-handrails were attached by inserting a wedge into the pocket of an upright for flexibility during work. Therefore, scaffolds essentially have low resistance to rolling because of the looseness of the connecting mechanism. This looseness of locking affects the manner by which worker's walk along such structures. These results indicate that the workers assessed the scaffolds as rolling because the irregular rolling movements disturbed the worker's walking pitch. The graph of each scaffold shows clear and undisturbed waves, indicating relatively high rolling amplitudes. Conversely, unclear and disturbed waves demonstrate the tendency of the scaffolds to generate low rolling amplitudes.

### *Discussion*

A number of human factors influence the rolling of the scaffolds.

- (1) The speed with which unskilled workers walk is slow, in which case a worker attempts to walk in accordance with the rolling pitch of a scaffold.
- (2) The steps taken by unskilled workers are narrow, a situation that a worker tries to rectify by walking also in accordance with the rolling pitch of a scaffold.
- (3) A worker's skill level influences characteristics 1 and 2; thus, an unskilled worker slows down his pace to walk carefully. The differences in walking speed and steps taken are reflected by a worker's skill level.

From a structural,

- (4) Pre-installed handrails are attached on both sides of a scaffold, so that the strength of a wedge lock component affects scaffold rolling.
- (5) A wedge lock can be strike or insert type. The former exhibits a small rolling width.

If the structure and strength of scaffolds are more rigid, then the rolling amplitudes of such scaffolds would be reduced. Nevertheless, the perception of rolling effects is influenced not only by rolling amplitude, but also by walking speed and steps taken, among other similar factors.

## **Displacement of scaffolds due to horizontal loading**

### *Specimens*

The tested scaffold systems were the B-type and D-type scaffolds, which have high rolling amplitudes.

### *Test Procedure*

A horizontal load test was conducted (Figure 7). In the test, a horizontal load acted on upright no.2 at the height of upper catwalk surface, and the horizontal displacement at the horizontal load reaches 489 N (50 kgf). The horizontal displacements of the uprights at the opposite side of a loaded upright were measured by LVDT. For the scaffolds with PH+LS, the loading point was applied on the pre-installed handrail side.

### *Test result*

The scaffolds with PH+PH are characterized by large displacements and the scaffolds with PH+PH exhibit stiffness smaller than that generated by the other types of scaffolds. To compare

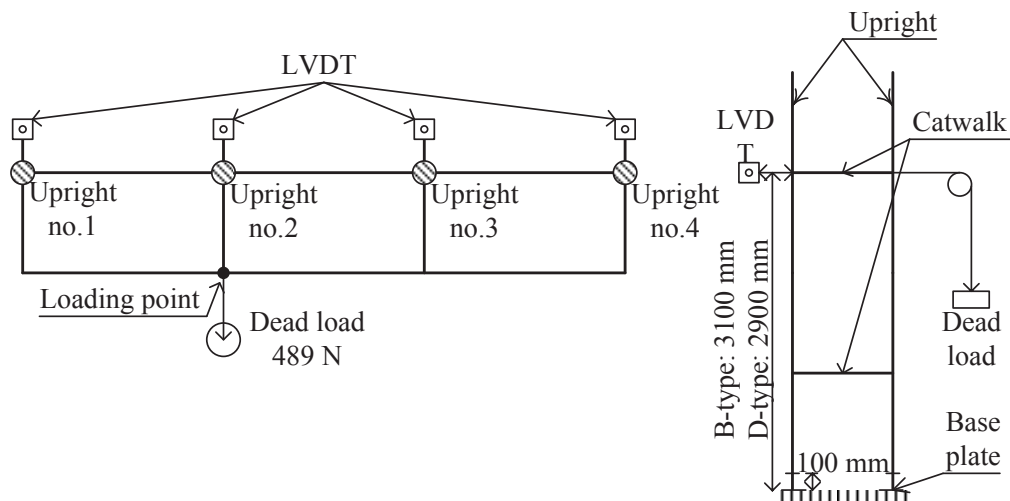


Figure 7. Schematic diagram of horizontal load test

Table 3. Horizontal displacements of B-type and D-type scaffoldings (mm)

Upright no.	1	2	3	4	Upright no.	1	2	3	4
PH + PH	7.6	24.9	12.2	3.1	PH + PH	14.2	30.7	13.4	3.6
PH + LS	16.6	21.8	10.4	4.2	PH + LS	17.6	24.3	12.5	6.1
LS + LS	16.9	17.1	10.4	4.9	LS + LS	17.6	17.9	12.0	6.3
B type (Pocket type)					D type (Pocket type)				

the stiffness of entire scaffold structures, the displacements of each upright were also compared (Table 3). In both LS types of scaffolds, the loaded upright and adjacent uprights exhibit a small difference in displacement. Conversely, both PH type scaffolds show a considerably large difference in displacement. The stiffness of the connecting mechanism in the LS type scaffolds is larger than that in PH type scaffolds. In the LS type scaffolds, the stiffness of the entire structures increases because the connecting wedges were placed in position using a hammer.

### Discussion

In both LS type scaffolds, rolling occurs synchronously with scaffold movement because even under high rolling, workers experience difficulty traversing across such components. In both PH type scaffolds, the amplitude of individual scaffolds is high but the movement of one scaffold does not extend to the adjacent scaffolds because of the looseness of the connecting mechanism. The uneasiness that the workers felt as they walked across the scaffolds may be attributed to their misassumption that small rolling waves occur along the ledgers.

### Conclusions

The conclusions derived from the experiment are summarized as follows.

- (1) If the structure and strength of scaffolds are more rigid, then the rolling amplitudes of scaffolds would be expected to reduce. Nonetheless, the perception of rolling effects is influenced not only by rolling amplitude, but also by walking speed and steps taken.
- (2) On scaffolds with ledgers on both sides, rolling occurs synchronous with an entire scaffold's movement.
- (3) On scaffolds with pre-installed handrails on both sides, the amplitude of individual scaffolds is high but the movement of each scaffold does not extend to the adjacent scaffolds because of the looseness of the connecting mechanism.

### Reference

Yoshida, I (1956). *Wooden scaffolding and metal tubular scaffolding*. Tokyo: Maki Shoten