Instruction manual

Cat. No. C15-2353-W0

Vertical & Horizontal Collision Apparatus

June 2022

⚠Safety Precautions

- **Wear safety glasses not to hurt your eyes with the rod of this product. Always mind the tip of the rod.**
- **Do not disassemble, repair, and remodel this product. The warranty will be void.**
- **Teachers or trainers must instruct students about the operating procedure and the safe ways of conducting experiments with this product before actually conducting experiments.**
- **Always carry students' experiments under the supervision of teachers/trainers.**
- **Do not use this product on an unstable place because it may collapse and hurt you.**

Product's Feature

All-in-one mechanical energy experiment set designed to quantify the potential energy of vertically falling object and kinetic energy of horizontally launched object by measuring how deep the center core bar of the pile-driver-like cushion mechanism (PDLCM) is compressed after collision with the object in millimeters using the built-in ruler. Possible for students to study the principle of mechanical energy conservation. The core units of the apparatus are PDLCM and Narika's BeeSpi V (speed measurement light gate). Whole apparatus is designed to quantify and verify the mechanical energy of a free-falling or launched object that compresses PDLCM by using the measured values of mass, velocity (measured by BeeSpi V) and impact of collision against PDLCM, which consists of a vertical collision part (see below [1]) and a horizontal collision part (see below [2]).

[1] Experiments of potential energy use the setting of free-fall motion to verify the relationship between below parameters (1, 2 and 3) of a free-falling object that is represented by the formula of F = mgh (where F is force, m is mass, g is gravitational constant, and h is height).
1) Height from which an object is released
2) Mass
3) Collision impact against the pile-driver represented by distance.

[2] Experiments of kinetic energy use the setting of the horizontal launcher to verify the relationship between below parameters (1, 2 and 3) of a launched object that is represented by the formula of K = 1/2 mv2 (where K is kinetic energy, m is mass, and v is velocity).
1) Mass.
2) Velocity (measured with the BeeSpi V, a speed measurement light gate, S77-1321).
3) Collision impact against the pile-driver represented by distance.

An object's mechanical energy (E) is a combination of its potential energy (U) and its kinetic energy (K) (see eq. 1). Eq. 2 can be obtained by Eq. 1 when no force acts on an object other than gravity. Then, Eq. 3 represents the state when all of the potential energy has changed to kinetic energy. Definition of "Work" is a measure of how much force is applied to an object over a certain distance when it moves in the same direction in which the force is exerted. The amount of "Work" is obtained from the difference between kinetic energy before work and the one after work (see eq. 4).

$$E = U + K \quad \text{———} \quad (1)$$

$$E = mgh + \frac{1}{2}mv^2 = \text{Constant} \quad \text{———} \quad (2)$$

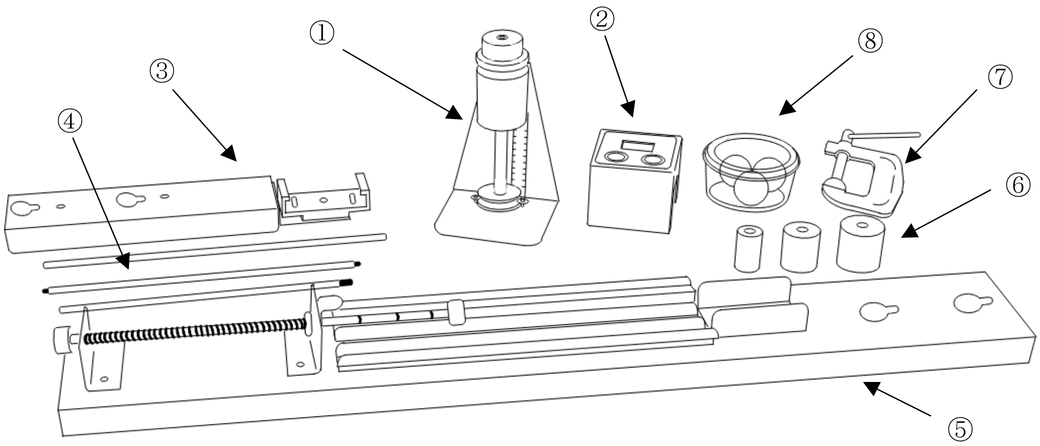
$$mgh = \frac{1}{2}mv^2 \quad \text{———} \quad (3)$$

$$W = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \frac{1}{2}m(\ v_2\ -\ v_1\ )^2 \quad \text{———} \quad (4)$$

By using this apparatus, it will be possible for students to study the relations represented by above formulas, especially, eq. 3 and eq. 4.

Note that the apparatus has a limited accuracy in measurement as it is educational science equipment for schools.

Specification



① "Pile-driver-like cushion mechanism" (Pile-driver) x 1 pc
② BeeSpi V x 1 pc
③ BeeSpi V holder for Vertical Collision unit x 1 pc
④ Guiding rod: Three-piece separatable rod with engraved scale per 100mm x 3 pc
⑤ Assembly type Horizontal launcher unit x 1 pc
⑥ Metal blocks: 3 cylindrical steel weights with different mass (50g, 100g, 150g) x 1 ea.
⑦ C-clamp x 1 pc
⑧ Balls: Steel: 67g, Aluminum: 22g, Plastic: 9g with 25mm dia. x 1 ea.

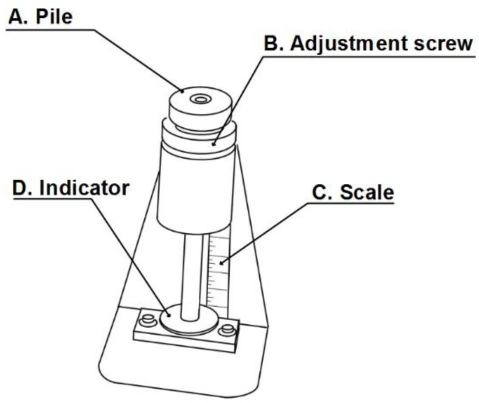
Experiment Guide for Vertical Collision

Description of Each Part Used

① Pile-driver

A. Pile assembly:

Pile assembly consist of a center bar with a through-hole for the guiding rod, a bumper, a shock absorber, and an indicator.



B. Adjustment screw:

If turning clockwise, friction force against the pile from the shock absorber increases. If turning anti-clockwise, friction force against the pile from the shock absorber decreases.

C. Scale:

Measures, in millimeters, how deep the pile is compressed after the collision with an object. Scale with 1 mm divisions. Size: 80 x 70 x 135 mm.

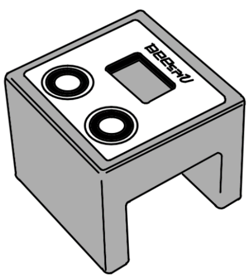
D. Indicator (Disc plate at the bottom of the pile):

Read where the disc plate points on the scale to know how deep the pile is being pushed in.

② BeeSpi V (S77-1321):

Speed Measurement Light Gate (see below specifications).

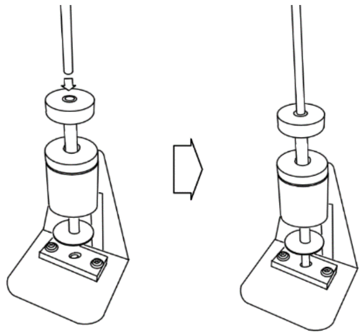
- Speed Measurement Range: 0 to 999.9 cm/s, o to 99.99m/s, 0 to 99.99 km/h
- Lap Time: 0 to 99.99sec
- Accumulated Lap Time: 0 to 99.99sec
- Power Source: Two size AAA batteries (sold separately)
- Size: 60 x 60 x 50mm (Inner Dimension: 40 x 30mm)
- Weight: 65g (excluding batteries)
- Extra functions: Memory function for saving up to 5 latest measured data.



③ BeeSpi V holder for Vertical Collision unit:

Exclusively designed holder for BeeSpi V to successfully measure a dropping speed velocity of a free-falling object.

④ **Guiding Rod:**



Three-piece separatable rod, with engraved scale per 100 mm, that functions as a guiding rod when falling the metal block. When assembled, the whole rod will have totally 4 engraved scales at intervals of 100 mm.
When setting up the assembled rod, screw the threaded end into the threaded hole at the upper surface on the base of Pile driver. Make sure the rod is securely fastened.

⑥ **Metal Blocks:**

Three cylindrical steel blocks with different mass ratio (ratio by weight = 1:2:3), masses (50g, 100g, 150g), and with a through-hole in the center of each block.

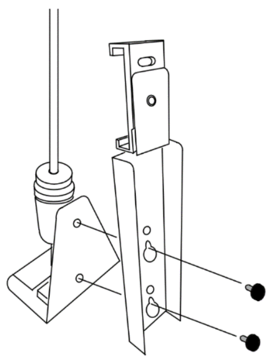
⑦ **C-Clamp**

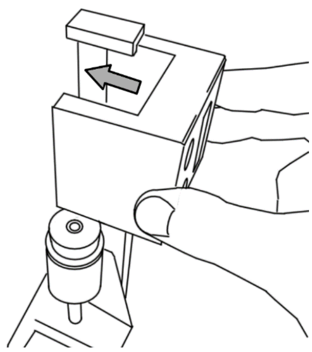
Make sure the pile driver is securely fastened to the lab bench using the C clamp in case of experiments of potential energy or "Work".

Relationship between Kinetic and Potential Energy

[How to fix BeeSpi V holder to Pile driver]

When measuring dropping velocity of a free-falling metal block, use BeeSpi V after attaching it to the holder. Firstly, fix the holder to the pile driver by securely turning the knurled screws that come with the product (see drawing below on the left). Secondly, fully fit BeeSpi V into the holder (see drawing below on the right). Prior to the measurement, check if the BeeSpi V is being set in correct position toward the rod with a sufficient space in between, so that the photogate of the BeeSpi V can successfully detect the free-falling block.





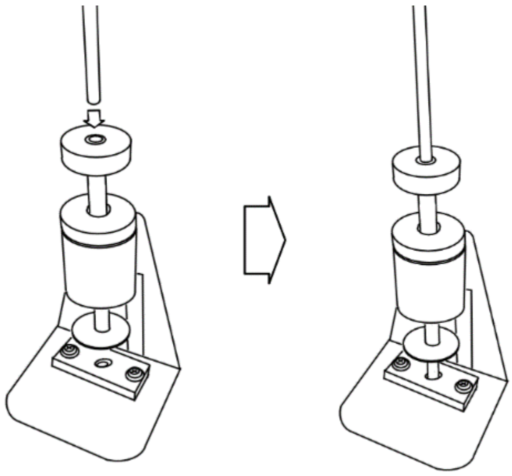
[Calibration of friction force acting on Pile]

Pile driver has a calibration function to adjust the friction force acting on Pile. The collision energy differs by the type of the block used and/or the height from which the block is dropped. Tighten/loosen the adjustment screw, so that the indicator is lowered by 50 (+/- 5) mm when the bottom surface of the heaviest block (150g) is dropped from the first notch from the top of the rod, which is the highest release point (actual height of 400 mm).

1. Insert the whole rod into the center hole of the pile, and then screw the one end into the threaded hole on the base of Pile driver (see the drawing on the right). Fully raise the pile.

2. Align the bottom surface of the metal block (150g) with the first notch from the top of the rod, and then release the block, so that it drops from a height of 400mm.

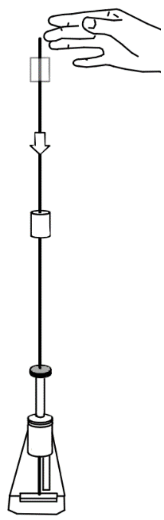
3. Check the numerical value indicated on the scale. Tighten/loosen the adjustment screw, so that the indicator is lowered by 50 mm. Throughout the experiment, do not change the friction force acting on the pile.



[Measuring how deep Pile will be compressed]

[Purpose & procedure]

It is the purpose of this experiment to study the relationship between kinetic and potential energy according to the result as hereinafter shown graphically. Measure how deep pre-calibrated pile will be compressed after collision with each of the metal blocks (50g, 100g, 150g) released from heights of 100mm, 200mm, 300mm, and 400mm respectively. Then, fill the measurement values in below table to calculate the average values. Plot those average values on a graph paper.



[Tips]

When determining the height from which a metal block is released, it is strongly recommended to align the bottom surface of the metal block with one of the engravings on the guiding rod. Otherwise, actual height (distance) the block drops will not be consistent throughout the experiment.

Table 1 Moving distances (depths) of pile compressed by a block (How deep is pile lowered after collision with a block?)

Weight (g)	Height (mm)	100			200			300			400		
150	Depth of Pile (mm)	16.0	17.0	16.0	32.0	31.0	30.0	45.0	45.0	42.0	53.0	52.0	55.0
	Advantage (mm)	16.3			31.0			44.0			53.3		
100	Depth of Pile (mm)	9.0	10.0	9.0	17.0	19.0	18.0	26.0	28.0	29.0	34.0	34.0	34.0
	Advantage (mm)	9.3			18.0			27.7			34.0		
50	Depth of Pile (mm)	4.0	4.0	4.0	8.0	7.0	7.5	10.0	11.0	10.0	14.0	14.0	15.0
	Advantage (mm)	4.0			7.5			10.3			14.3		

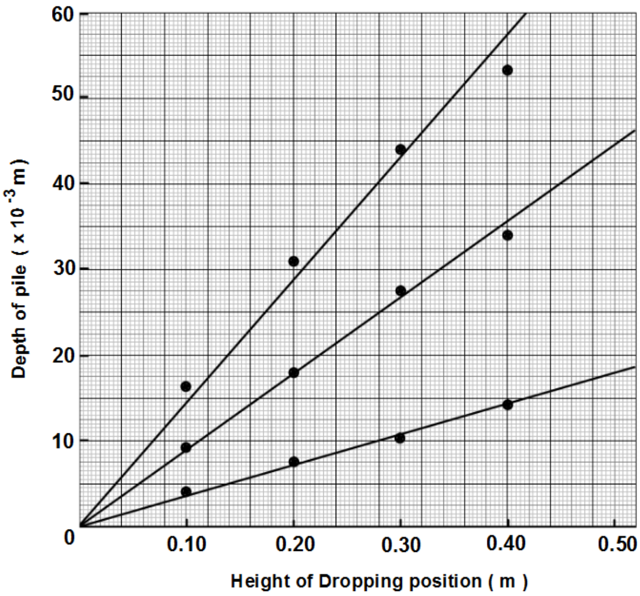


Fig. 1 Plotted average values of moving distances of Pile

Each of the straight lines shown in Fig. 1 represents that the relationship between the depths of pile and heights from which a block is released is drawn as a linear equation. On the other hand, theoretical formula (Eq. 5) is obtained by Eq. 1, 2 and 3. In this setting, moving distances (depths) of pile compressed by a block represent kinetic energy (K) of the block at the moment of colliding with pile, which is a direct function of the gradient (mg) and height (h).

$$K = mgh \qquad (5)$$

[Measuring velocity of a free-falling metal block]

[Purpose & procedure]

It is the purpose of this experiment to study the relationship between kinetic and potential energy according to the result as hereinafter shown graphically. Measure the velocity of a free-falling metal block, as well as how deep pre-calibrated pile assembly will be compressed after collision with each of the metal blocks (50g, 100g, 150g) dropped from heights of 100mm, 200mm, 300mm and 400mm respectively.

[Tips]

When determining the height from which a metal block is released, it is strongly recommended to align the bottom surface of the metal block with one of the engravings on the guiding rod. Otherwise, actual height (distance) the block drops will not be consistent throughout the experiment.

Measure how deep pre-calibrated pile will be compressed after collision with each of the metal blocks (50g, 100g, 150g) dropped from heights of 100mm, 200mm, 300mm and 400mm. Experimental results shown in Table 2 show that velocity is determined only by the height from which the block is released, not by its mass. As an example, the upper curve line shown in Fig. 2 represents the relationship between the dropping velocity and height from which the 150g metal block is released, while the lower curve line represents theoretically calculated velocity values.

On the other hand, Eq. 3 can be converted into Eq. 6 and Eq. 7 that represents a quadratic function of height and velocity.

$$v^2 = 2gh \qquad (6)$$

$$h = \frac{v^2}{2g} \qquad (7)$$

Both curve lines shown in Fig. 2 represent quadratic functions in accordance with Eq. 7. The upper curve line based on the measured values is almost identical with the lower line based on theoretically calculated values.

Table 2 Moving distances (depths) of the pile compressed by a block & Velocities of each block released from different height.

Heigth(mm)	100		200		300		400	
Weight of Block	Depth of Pile	Velocity (m/s)	Depth of Pile	Velocity (m/s)	Depth of Pile	Velocity (m/s)	Depth of Pile	Velocity (m/s)
150 g	13	1.18	28	1.82	34	2.27	50	2.66
	14	1.17	29	1.83	40	2.31	43	2.62
	15	1.18	28	1.83	34	2.28	39	2.61
Ave.	14.0	1.177	28.3	1.827	36.0	2.287	44.0	2.630
100g	9	1.20	18	1.83	23	2.29	33	2.67
	10	1.21	18	1.84	25	2.30	31	2.65
	10	1.19	16	1.85	25	2.30	30	2.67
Ave.	9.7	1.200	17.3	1.840	24.3	2.297	31.3	2.663
50g	3	1.2	8	1.84	12	2.32	13	2.68
	3	1.19	8	1.84	11	2.27	14	2.72
	4	1.21	8	1.84	11	2.31	13	2.62
Ave.	3.3	1.200	8.0	1.840	11.3	2.300	13.3	2.673

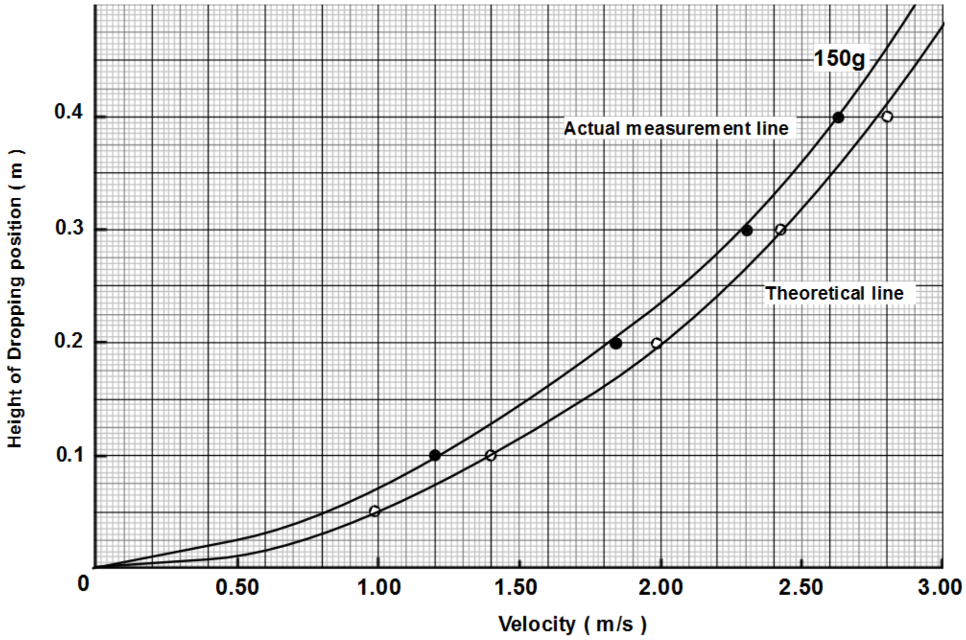
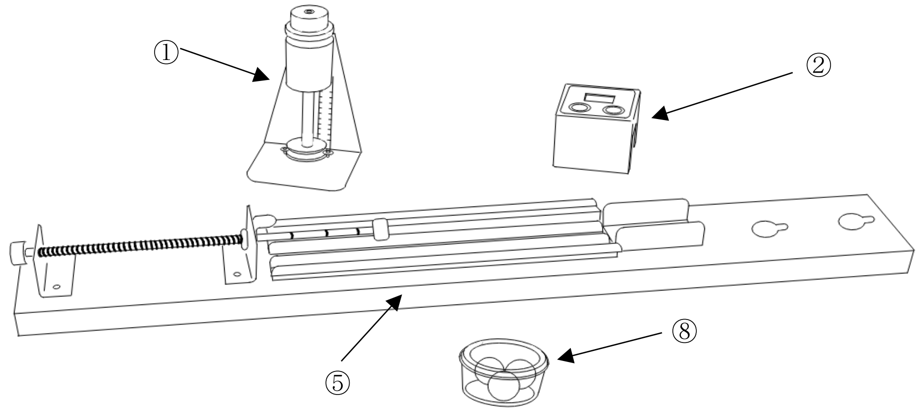


Fig. 2. Plotted average values of velocities of a block released from different heights.

Experiment Guide of Horizontal Collision

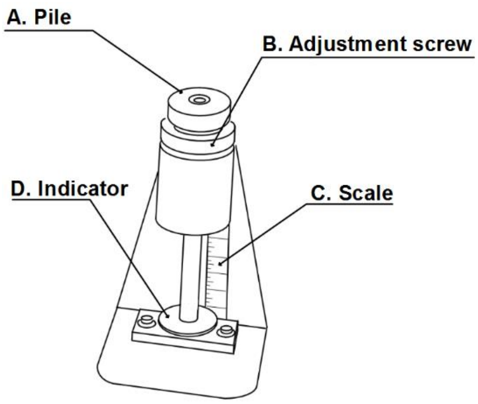
Description of Each Part Used



① Pile-driver-like cushion mechanism with a built-in ruler

A. Pile:

Pile of Pile-driver with a through-hole for the steel stem includes a bumper, a shock absorber and an indicator.



B. Adjustment screw

If turning clockwise, friction force against the pile (the shock absorber) increases. If turning anti-clockwise, friction force against the pile (the shock absorber) decreases.

C. Scale:

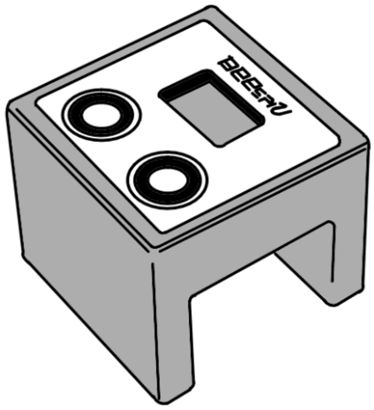
Measures, in millimeters, how deep the pile is compressed after the collision with an object. Scale with 1 mm divisions. Size: 80 x 70 x 135 mm

D. Indicator (Disc plate at the bottom of the pile):

Read where the disc plate points on the scale to know how deep the pile is being pushed.

② BeeSpi V (S77-1321):

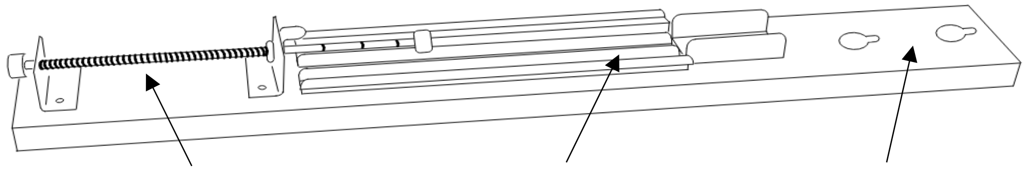
Speed Measurement Light Gate.



⑤ Assembly type horizontal launcher unit (AHLU)

Size: 590 x 80 x 55 mm, Material: Steel

AHLU, composed of two built-in components (A. Spring plunger and B. Guiding rail) and the area for mounting PDLCM (C.), is a setting for experiments of kinetic energy generated by a horizontally launched and colliding object.



A. Spring plunger B. Guide rail C. Pile driver setting place

A. Spring plunger

Mechanism for launching a ball (sphere). Magnitude of launching a sphere is adjustable in three levels if equally spaced shallow cuts (grooves) on the shaft are used. Set the plunger at one of the three levels.

Depress the spring plunger with your finger at one of the three levels and latch the plunger (see Fig. 3).

Hit the latch with a pen or something similar to release the spring plunger (see Fig. 4).

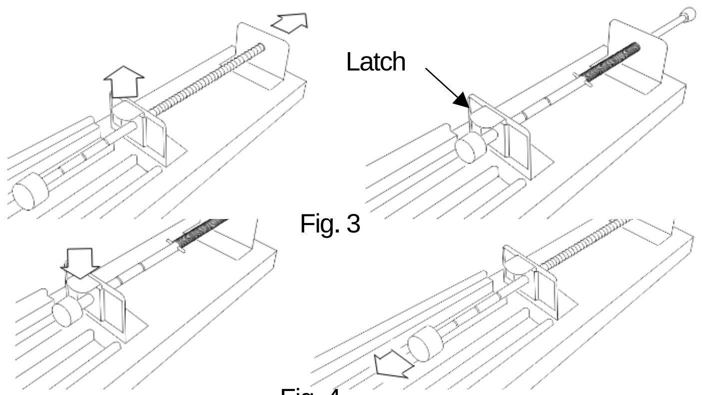


Fig. 3

Fig. 4

B. Guiding rail

Track to lead the sphere straight toward the pile and to provide proper area to place BeeSpi V at the point farthest from the plunger, so that the velocity of a sphere just before colliding with the pile can be successfully measured.

Size: 230 x 65 mm

C. Area for mounting the pile-driver

Attach the pile driver on the area with knurled screws (see Fig. 5 & Fig. 6 on the next page).

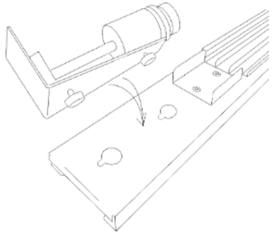


Fig. 5

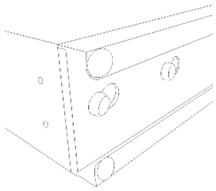


Fig. 6

⑧ Spheres x 3 pcs (Aluminum, Steel, Plastic)

Aluminum:	Mass: 22 g,	Diameter: 25 mm
Steel:	Mass: 67 g,	Diameter: 25 mm
Plastic:	Mass: 9g,	Diameter: 25 mm

Relationship between Kinetic Energy and Velocity

[How to set the pile-driver and BeeSpi V on AHLU]

1. Set and attach the pile-driver onto the right area of AHLU (see Fig. 5 and Fig. 6).

2. Place BeeSpi V at the point on the guiding rail farthest from the plunger (see Fig. 7).

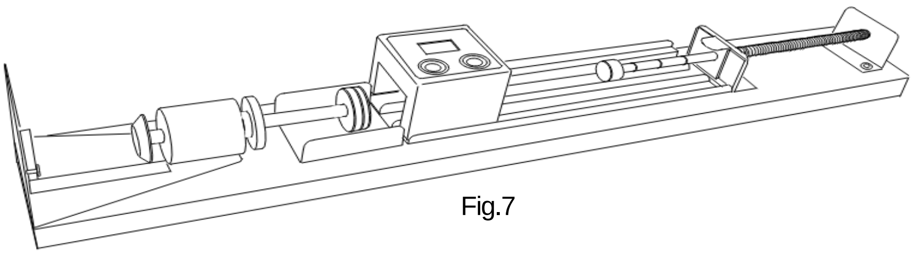


Fig.7

[Calibration of friction force acting on Pile]

The pile-driver has a calibration function to adjust the friction force acted on the pile in accordance with the collisional energy conveyed by the launched sphere.

1. Loosen the adjustment screw and pull the pile from the pile-driver to the full extent, after setting the pile-driver and BeeSpi V (see Fig. 7),

2. Depress the spring plunger with your finger and latch it using the 3rd cut (the furthest one from the latch) on the shaft to maximize the force magnitude generated by the plunger. Then, place a steel sphere (67g) on the guiding rail and make sure that it is in contact with the plunger.

3. Hit the latch with a pen or something similar to release the spring plunger and launch the steel sphere for colliding with and compressing the pile.

4. Repeat above steps, while tightening/loosening the adjustment screw, until the indicator is moved by 25 - 35 mm.

[Measuring the velocity of a sphere and moving distance of the pile after the collision]

1. Pull the pile from the pile-driver to the full extent.

2. Place BeeSpi V at the point on the guiding rail farthest from the plunger (see Fig. 7).

3. Depress the spring plunger with your finger and latch it using one of the three cuts on the shaft. Then, place one of the three types of the spheres on the guiding rail and make sure that it is in contact with the plunger.

4. Hit the latch with a pen or something similar to release the spring plunger and to launch the sphere to collide with and compress the pile. Calculate average of the measured values.

5. Read the pile depth measured and the velocity displayed on BeeSpi V, then record it in your notebook. Repeat those procedures at least three times for each sphere. Calculate the average of measured values.

6. Repeat above steps until obtaining measurement results of all the combinations of the spheres and force magnitude generated by the plunger.

Tips: Using a data table and drawing lines on a graph paper is recommended.

Each curve line shown in Fig. 8 represents a quadratic function in accordance with Eq. 3, which is a formula for the relationship between kinetic energy and velocity of a launched object.

Table 3. Moving distances (depths) of the pile compressed by a sphere & Velocity of the sphere

Spring Plunger Position		1 (Weak)		2 (Middle)		3 (Strong)	
Mass of Sphere		Depth of Pile (mm)	Velocity (m/s)	Depth of Pile (mm)	Velocity (m/s)	Depth of Pile (mm)	Velocity (m/s)
67 g (Steel)	1	3	0.77	17	1.45	36	1.98
	2	2	0.74	17	1.45	36	1.97
	3	3	0.74	17	1.45	36	1.97
	Ave.	3	0.75	17	1.44	36	1.97
22 g (Aluminum)	1	3	1.20	9	1.99	17	2.60
	2	3	1.20	10	1.97	18	2.61
	3	3	1.20	10	1.96	17	2.62
	Ave.	3	1.20	10	1.97	17	2.61
9 g (Plastics)	1	2	1.39	5	2.22	9	2.88
	2	2	1.40	6	2.22	9	2.87
	3	2	1.39	5	2.21	9	2.88
	Ave.	2	1.39	5	2.22	9	2.88

Fig 8. Plotted average depths (moving distances of the pile) & velocities of each type of blocks.