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Chapter 1

Knowledge of Cranes and Other Lifting Equipment

Slinging is the work to secure a load or remove it from the hoisting accessory with sling gear.

1 Qualifications for the Slingers (p.1)

Any person to sling goods by crane, mobile crane, derrick or cargo hoist, is required by the applicable legislation to have either of the following qualifications, according to the maximum load which the lifting machine can handle:

Table 1-1 Qualifications for the Slingers

Type of machinery and equipment	Lifting load or limited load	
	1 ton and more	Less than 1 ton
Crane Mobile crane Derrick Cargo hoist	• Those who have completed the slinging skill training course • Those who have completed the special training course *1 • Those who have approved by the Minister of Health, Labour and Welfare*2	• Those who have completed the slinging skill training course • Those who have completed the special training course *1 • Those who have approved by the Minister of Health, Labour and Welfare*2 • Those who have completed the special education for the sling works

*1: The training course listed in the column of training courses of Appended Table 4 of the Enforcement Ordinance on the Human Resources Development and Promotion Act

*2: A person who has completed the training of crane operation course prescribed in the Ordinance on the Human Resources Development and Promotion Act

2 Overview of Cranes (p.2)

2.1 Definition of Cranes (p.2)

Cranes

“Crane” means any mechanical device designed to lift loads by power and carry the lifted loads horizontally, other than mobile cranes, derricks and cargo hoists. Accordingly, the crane does not include any of the mechanical devices which lift goods by human power. On the other hand, the crane includes those mechanical devices which lift goods by a power even if they rely on human power for the horizontal conveyance of the lifted goods.

Mobile Cranes

“Mobile crane” means any of those cranes which have built-in motors to move themselves to unspecified place.

Derricks

Derricks are those mechanical devices which are designed to lift goods by motive power, have a mast or a boom and are operated by wire ropes with motors installed separately.

Cargo Hoists

Cargo hoists are those mechanical devices which are attached to ships to load or unload the ships or move cargo in the hold.

3 Motions of Crane (p.3)

The following are the motions of a crane in lifting a load and carrying it to the desired place.

3.1 Lifting and Lowering

Lifting means a motion of the crane to move up a load and lowering is the reverse motion to bring the load down.

3.2 Traversing

Traversing is a motion of the crane to move its trolley (or hoist) along the girder of the overhead traveling crane/bridge crane, horizontal jib of the hammer-head crane, or rope of the cable crane. See Fig. 1-1.

3.3 Traveling

Traveling is the movement of the whole crane such as girder, jib and tower on its traveling rail or runway. See Fig. 1-1.

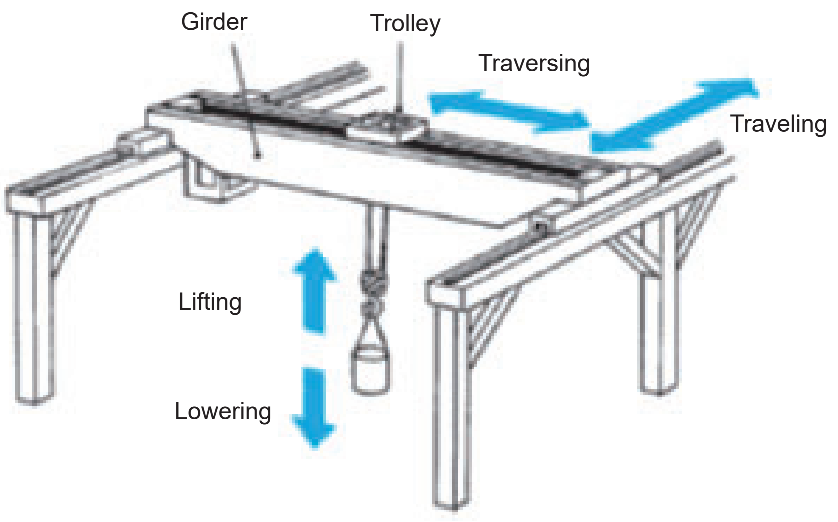


Fig. 1-1 Lifting, Lowering, Traversing, Traveling

3.4 Derricking

Derricking is the upward/downward movement of the job or boom from its end.

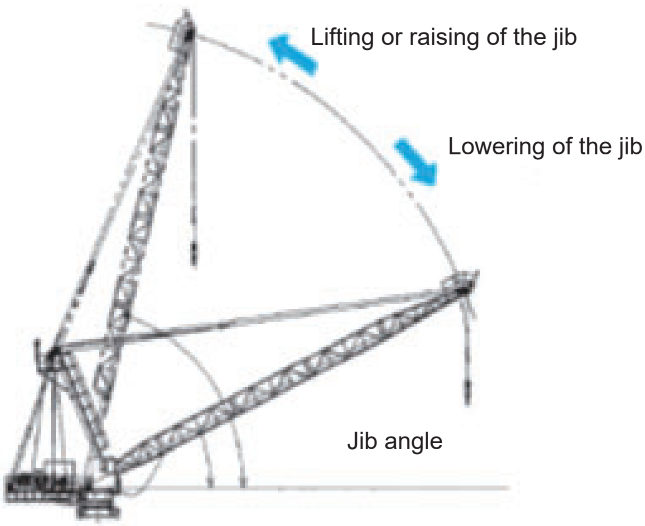


Fig. 1-2 Derricking

The motion of the jib in the direction that increases the jib angle (the angle between the centerline of the jib and the horizontal plane) is called the “lifting or raising of the jib”, while its motion toward a smaller jib angle is called the “lowering of the jib”. An ordinary jib crane, when derricking, brings the load up or down.

A structural improvement is provided to remove this undesirable motion so that the load can be held at a given height and moved horizontally during derricking. This improved motion is called “level luffing.” “Luffing in” means the movement of the load toward the jib and “luffing out” means the movement of the load away from it.

This level luffing does not include an upward or downward motion of the lifted load that may be involved in jib derricking.

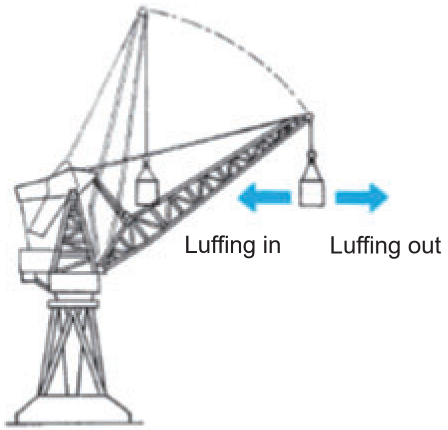


Fig. 1-3 Level luffing

3.5 Slewing

“Slewing” means the rotation of the jib or other similar component of the jib crane/mobile crane with its center of rotation as the axis.

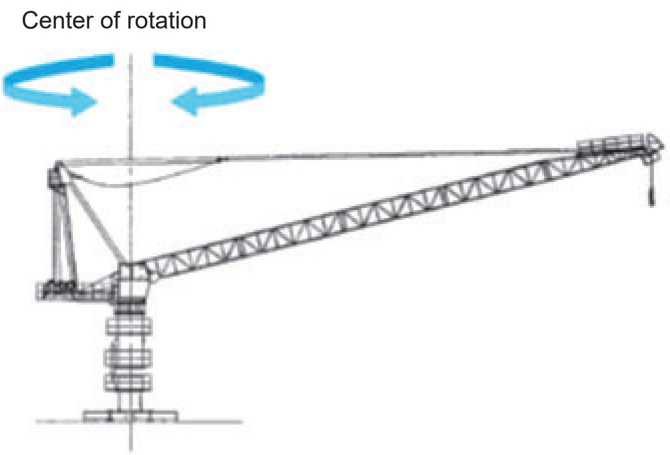


Fig. 1-4 Slewing

3.6 Telescopic Motion

This is a motion of the crane to change the length of the jib.

Increasing the length of the jib is called “extension” and decreasing its length is called “retraction.” (See Fig. 1-7: p.6.)

4 Technical Terms Relating to Cranes (p.6)

4.1 Lifting Load

The term “lifting load” means the maximum load that may be laid on a crane, mobile crane or derrick according to its construction and materials used. The lifting load includes the weight of the crane’s hoisting accessory such as hook or grab bucket.

4.2 Rated Load

The term “rated load” means the net weight after deduction of the weight of the hook, grab bucket or any other hoisting accessory from the lifting load for the cranes without jib and derrick.

For the cranes with jib or mobile crane/derrick with boom, it is the load after deduction of the weight of the hook, grab bucket or any other hoisting accessory from the maximum load that may be laid according to its construction or configuration (jib/boom angle and length, trolley position on the horizontal jib) and materials used.

4.3 Rated Gross Load

The term “rated gross load” means the maximum load that may be laid on the mobile crane according to its construction, component materials and jib angle or length.

For mobile cranes, the hooks are changed depending on the type of the operation. Even when the jib length and operating radius are the same, the rated load varies with a change of the hook. In general, the rated gross load (the weight of the hook or any other hoisting accessory is added to the rated load) is used. See Fig. 1-5.

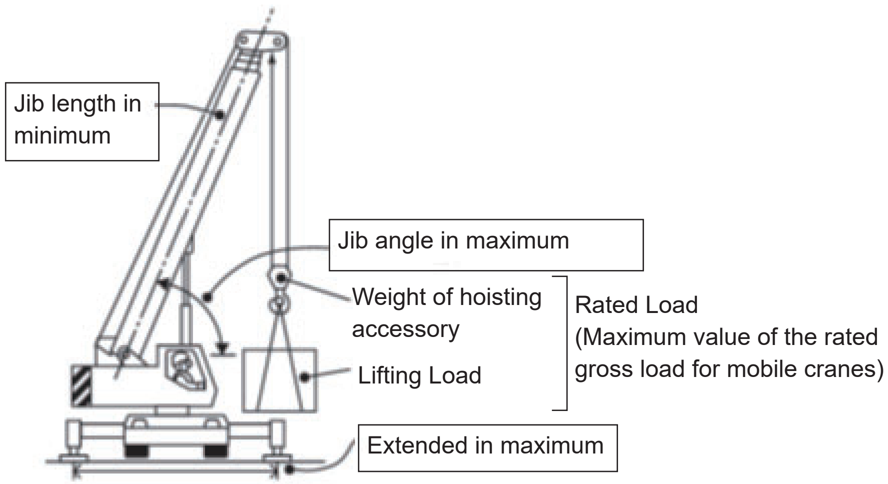


Fig. 1-5 Relation Between Lifting Load, Rated Gross Load, and Rated Load

4.4 Limit Load

The term “limit load” means the maximum load that may be laid on a cargo hoist according to its construction and materials used. The limit load includes the weight of the hoisting accessory such as hook or grab bucket.

4.5 Rated Speed

The term “rated speed” means the maximum speed at which a crane, mobile crane or derrick may perform such a motion as lifting, derricking, traversing, traveling or slewing with the rated load on its hoisting accessory.

4.6 Lift

The term “lift” means the distance between upper and lower limit that the crane can lift and lower the hook, grab bucket or any other hoisting accessory normally.

4.7 Operating Radius

The “operating radius” means the horizontal distance between the center of rotation of a jib crane and the center of its hoisting accessory. The operating radius is also known as the “slewing radius”, of which the largest limit is called the “maximum operating (or slewing) radius” and the smallest limit is called the “minimum operating (or slewing) radius”. (See Table 1-2: p.9)

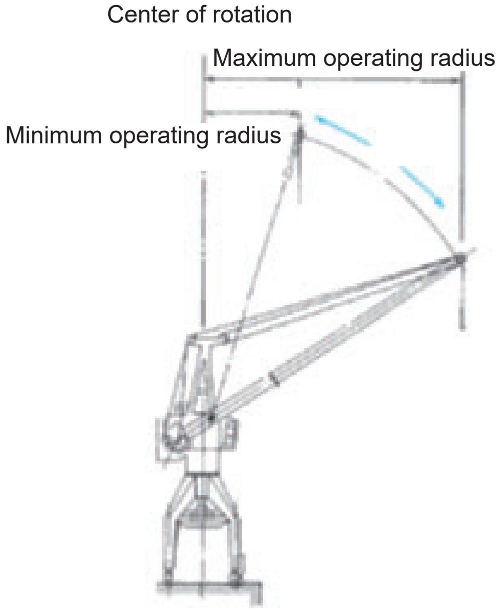


Fig. 1-6 Operating Radius

4.8 Operating Range

The “operating range” means the space within which the crane or any other hoisting device can move the load by each of the available combinations of motions such as traversing, traveling or slewing. For details about operating ranges of the combinations of general cranes and motions, refer to the textbook. (Fig. 1-12: p.40)

4.9 Sling Gears

The “sling gear” means any of the tools used for securing a load to the hoisting accessories of cranes or other hoisting devices. See Chapter 3: How to Select and Handle Sling Gear.

4.10 Liftoff

This means the motion of lifting the load slightly away from the ground, floor, and/or bearer blocks. For the slinging work, inching up the load slowly, stop once the load has been lifted off, and confirm the stability of the load and the safety of the sling gear.

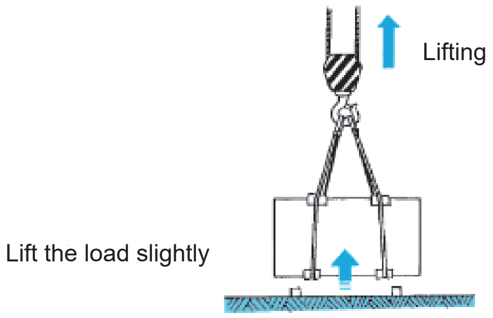


Fig. 1-7 Liftoff

4.11 Grounding

This means the motion to lower the load to the intended location. For the slinging work, check the conditions of the landing location and set up the bearer blocks for the load to stabilize. Inching down the load, then stop it once when the load is landed. After confirming the stability of the load, fully lower the load, remove the sling gears.

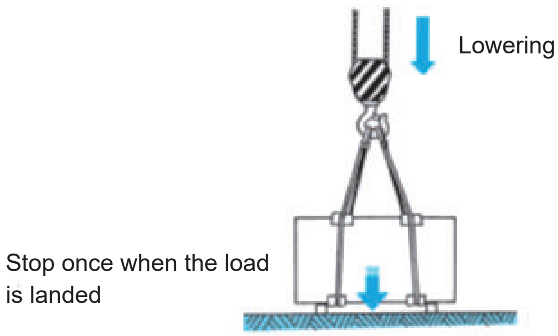


Fig. 1-8 Grounding

Chapter 2

Knowledge of Dynamics Necessary for Slinging Crane Loads

1 Topics Relating to Force (p.35)

1.1 Three Elements of Force, Action and Reaction (p.35)

Refer to the textbook.

1.2 Composition and Decomposition of Forces (p.36)

As shown in Fig. 2-1 a, when two people pull the stump with a rope, the stump is pulled in the direction of the arrow. Thus, when two forces are acting on an object, these two forces can be replaced with one resultant force (combined forces) having the same effect.

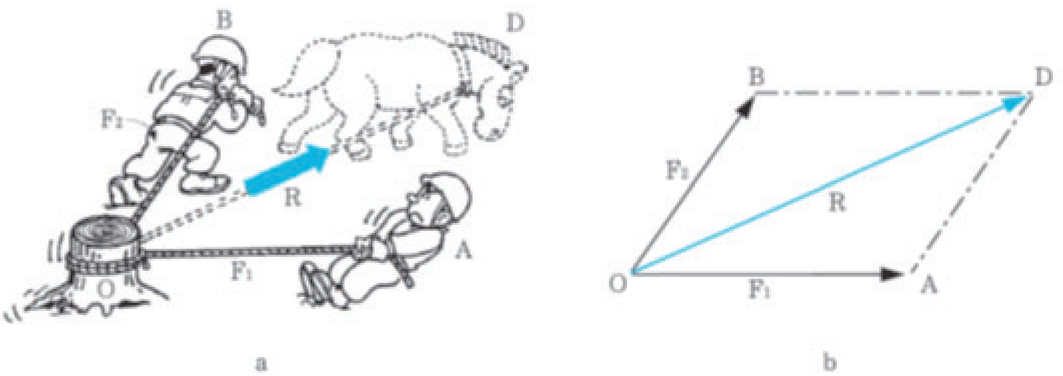


Fig. 2-1 Composition of Forces

Fig. 2-1 b explains the method of finding a resultant force. The resultant of the forces F1 and F2, which work on the point O from two different directions, can be determined by drawing a parallelogram (OADB) with these forces on its two sides. The diagonal R in the figure represents the magnitude and direction of the resultant force to be determined. This is called the parallelogram law.

The “decomposition of force” is the process of dividing a force working on an object into two or more forces at an angle to one another. Each of the portions into which a force is thus divided is called a “component” or a “component force” of the original force. To find a component of a force, the parallelogram of forces described in the “composition of forces” is used in reverse sequence to divide the force into two or more forces at an angle to one another.

Let us look at a man dragging a sled as shown in Fig. 2-2 a by way of example. Since he pulls the rope forward at an angle to the ground, i.e., somewhat upward, the sled is hauled horizontally (longitudinally) but, at the same time, vertically. So we have to find the magnitude of the force that actually draws the sled horizontally.

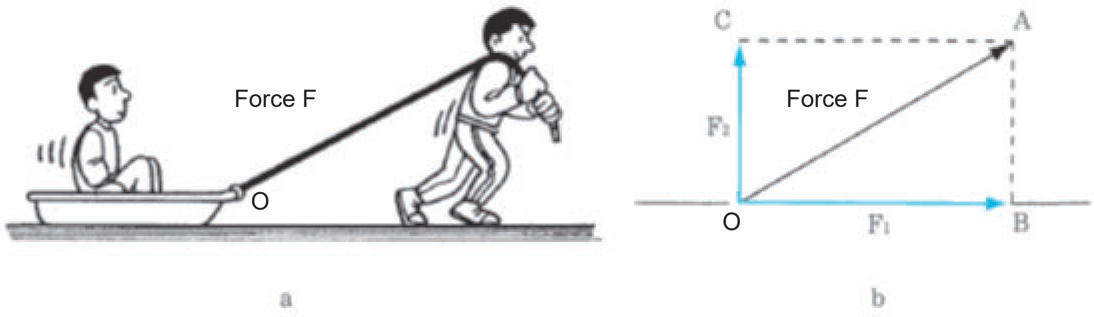


Fig. 2-2 Decomposition of Forces

As shown in Fig. 2-2 b, the force F (OA) is divided into F1 (OB) and F2 (OC) using by the parallelogram law. This is the decomposition of force and it can be found that the horizontal force of the sled becomes F1 (OB).

1.3 Moment of Force (p.38)

The moment of a force is the work of the force to turn an object.

In turning a nut with a spanner wrench as in Fig. 2-3, a smaller force is required when you hold the wrench near the end of the shaft than when yon hold it in the middle of the shaft. This example indicates that the turning work of force is related not only to the magnitude of the force but also to the distance between the center of the axis of rotation and the line of action of the force (i.e., the length from the axis of rotation O to the F1 or F). This distance (L1 or L in Fig. 2-3) is called the “length of arm”.

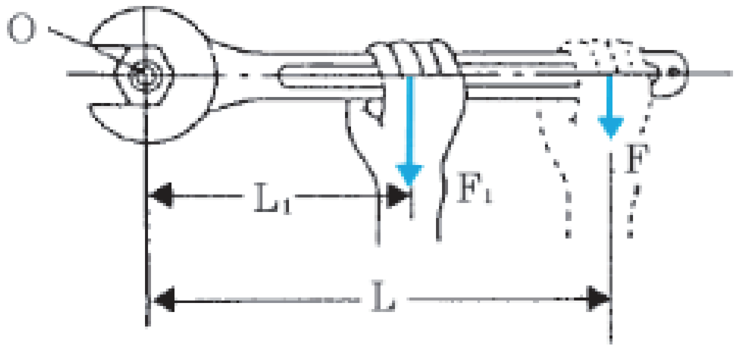


Fig. 2-3 Relationship between Magnitude and Arm of Force

In lifting a heavy load with a lever as shown in Fig. 2-4, the nearer the grip is to the fulcrum, the greater the required force becomes.

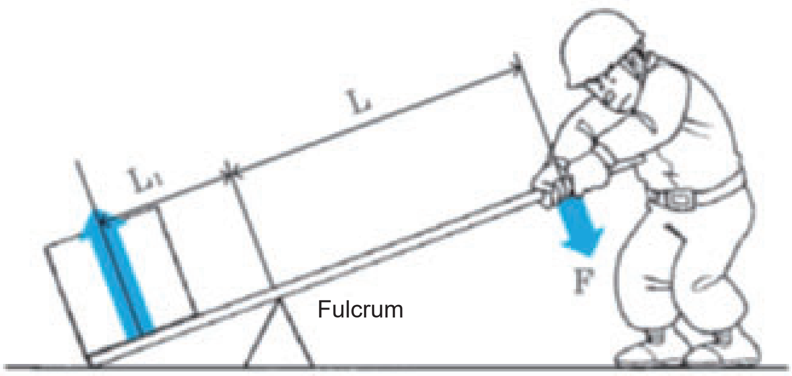


Fig. 2-4 Moment of Leverage

With the magnitude of a force given as F and the length of arm given as L, the moment of the force M can be written as M = F x L. Where the magnitude of the force F is stated in N (newton) and the length of arm L in m (meter), then the moment of the force M can be represented in N·m (newton meter).

If this is applied to the lifting of a load by a jib crane, as described in Fig. 2-5, the moment working to make the crane fall when the jib carrying the load (m) to the position A differs from when the jib comes further to the position B. The lengths of arms from the fulcrum O (or the axis of rotation) at the jib positions A and B are given as L1 and L2, respectively, in the diagram. Accordingly, each moment (M1 and M2) can be written as follows:

$M1 = 9.8 \times m \times L1$, $M2 = 9.8 \times m \times L2$

By comparing these two lengths, you can find L1 < L2, and therefore, the moment M1 is smaller than the moment M2.

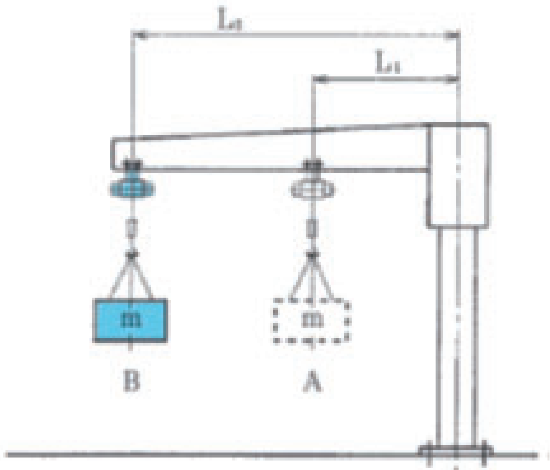


Fig. 2-5 Moment Working on Jib Crane

Usually moment works to turn an object either clockwise or counterclockwise. To find the sum or equilibrium of two or more moments, therefore, you have to take into account the rotational direction of each of them.

1.4 Equilibrium of Forces (p.40)

Equilibrium of Parallel Forces

Fig. 2-6 shows a worker carrying a couple of loads on the ends of a pole. To keep it level on the shoulder, the pole should be held right in the middle when the two loads are equal in weight, but when their weights differ, the pole should be held at a point nearer the heavier load. This is because of the need to equilibrate the moments of forces.

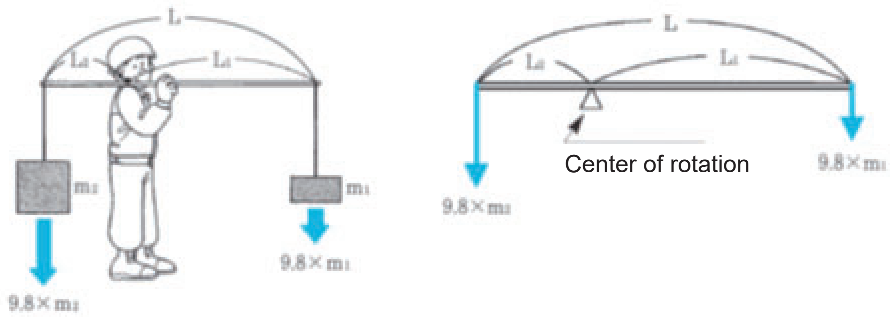


Fig. 2-6 Equilibrium of Parallel Forces

In this diagram, let us examine the moments of forces with the worker's shoulder as the axis of rotation. With the weights of the two loads given as m1 and m2 and with the load-supporting places on the pole (horizontal distances between the loads and the shoulder) given as L1 and L2

The clockwise moment: M1 = 9.8 x m1 x L1

The counterclockwise moment: M2 = 9.8 x m2 x L2

The moments around the axis of rotation are kept in equilibrium as below:

$9.8 \times m1 \times L1 = 9.8 \times m2 \times L2 \qquad (1)$

$m1 \times L1 = m2 \times L2 \qquad (2)$

$m1 \times L1 = m2 \times (L - L1) \qquad (3)$

$m1 \times L1 = m2 \times L - m2 \times L1 \qquad (4)$

$m1 \times L1 + m2 \times L1 = m2 \times L \qquad (5)$

$L1 \times (m1 + m2) = m2 \times L \qquad (6)$

(Note that L = L1 + L2)

Needless to say, the worker's shoulder serves as the axis of rotation that supports the weight of the loads (m1 + m2).

Equation (6) can be rewritten as:

$$L1 = \frac{m2}{m1 + m2} \times L$$

Accordingly, the loads will be equilibrated if the pole is held at the point determined by internally dividing the pole in inverse proportion to the weights of the loads m1 and m2.

2 Weight and Center of Gravity (p.43)

2.1 Weight (p.43)

The weights of objects made of different materials may differ even if they are exactly equal in volume. For instance, aluminum is heavier than wood and iron is lighter than lead.

Table 2-1 shows approximate weight in tons (t) of different materials per cubic meter (m^3). Based on this table, you can find the weight of a specific material body if its volume (in cubic meters) is known.

The weight of a load to be lifted (W in tons), for instance, can be found by multiplying the volume of the load (V in cubic meters) by the numerical value in the table indicating the weight of its material per cubic meter (d in tons):

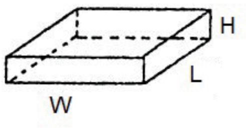
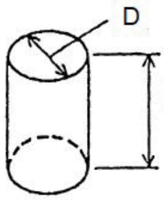
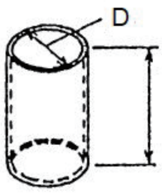
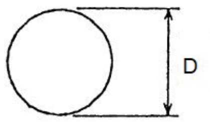
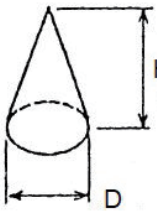
Table 2-1 Weight of Material Bodies per Cubic Meter

Material	W t/m^3 (t)	Material	W t/m^3 (t)
Lead	11.4	Sand	1.9
Copper	8.9	Coal dust	1.0
Steel	7.8	Coal	0.8
Cast iron	7.2	Coke	0.5
Aluminum	2.7	Water	1.0
Granite	2.6	Oak	0.9
Concrete	2.3	Cedar	0.4
Earth	2.0	Cypress	0.4
Gravel/sand	1.9	Paulownia	0.3

Note: The weight of wood is based on the condition that it has dried in the atmosphere. The weight of earth, sand, etc. is apparent weight.

Simple equations for calculation of volume are shown in Table 2-2.

Table 2-2 Simple Equations for Calculation of Volume

Shape of object		Equation
Shape	**Illustration**	
Rectangular parallelepiped		Height x Width x Length (H x W x L)
Circular cylinder, solid		$(D)^2$ x H x 0.8
Circular cylinder, hollow		D x Wall Thickness x H x 3.1
Sphere		$(D)^3$ x 0.53
Circular corn		$(D)^2$ x H x 0.3

[Exercise]

Calculate the weight of steel plate (thickness: 0.05 m, width: 1.5 m, length: 3.0 m)

[Answer]

Volume of steel plate: V = 0.05 x 1.5 x 3.0 = 0.225 m^3

From Table 2-1, weight of steel per cubic meter is 7.8.

Accordingly, weight m = 7.8 x 0.225 = 1.755 (t)

2.2 Specific Gravity (p.44)

The specific gravity of a material body is the ratio of its weight to the weight of an equal volume of pure water at 4°C. Mathematically it can be written as:

Specific gravity = Weight of a material body / Weight of an equal volume of pure water at 4°C

2.3 Center of Gravity (p.45)

The point of action of such resultant is called the "center of gravity" (COG) which is located at a fixed point in the case of certain material bodies. In other words, the location of the COG of any of these bodies remains unchanged wherever and whatever way the body is placed. Also notable is that the COG is not necessarily located inside the body (See Fig. 2-7).

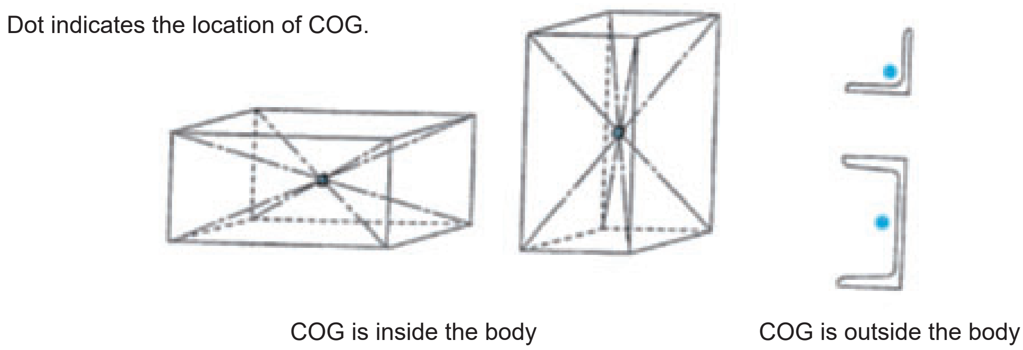


Fig. 2-7 Location of COG

How to Find COG

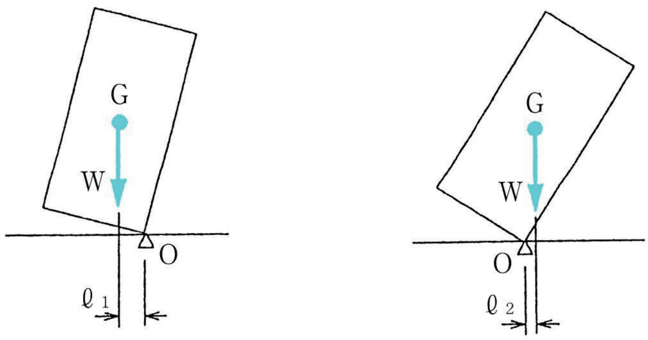
The COG of a material body can be found based on the phenomenon that when the body is suspended with a string, the line of action of force passing through the COG becomes perpendicular, resulting in the location of the COG right under the spot of the body by which it is suspended. More specifically, you can determine the COG by suspending the material body by two different spots on it and finding the point at which the lines of action of force supporting the body in the two instances crosses each other. (Fig. 2-19: p.46)

2.4 Stability (p.47)

A material body is considered stable if it tends to return to its original position when let go after being tilted a little by hand while it is standing still. Conversely, if it tends to fall on its side, it is considered unstable.

If, for instance, an object sitting on a level surface is tilted as in Fig. 2-8 (a) and then let go, it returns to its original position. This is because the gravity acting on the COG G generates the moment of a force which, with the center of rotation O as a fulcrum, works to right the tilted object. However, if the object is tilted so far that the perpendicular passing through its COG comes outside its base as shown in Fig. 2-8 (b), it falls on its side instead of returning to its original position.

Accordingly, the diagram (a) is in a stable state, and (b) in an unstable state.



(a) Stable (b) Unstable

Fig. 2-8 Stability of Material Body

An important consideration in setting an object in a stable state is to let it have a greater base area and a lower COG.

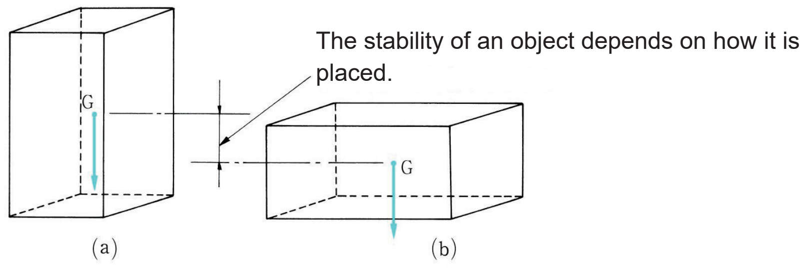


Fig. 2-9 Stability of Material Body when Placed in Different Way

3 Motion (p.48)

3.1 Velocity (p.49)

Speed is a quantity indicating how rapidly an object moves. It is represented by the distance the object moves in a unit length of time.

If an object in uniform motion moves 50 meters in 10 seconds, its speed can be expressed as 5 m/s. The speed of an object in uniform motion is expressed by the result of dividing the distance the object has moved in a certain period of time by the required number of unit lengths of time, as written below:

$$\text{Velocity (v)} = \frac{\text{Distance (L)}}{\text{Time (t)}}$$

Among commonly used units of speed are meters per second (m/s), meters per minute (m/min) and kilometers per hour (km/h).

In determining the motion of an object, however, it is hardly sufficient to think of its speed alone. We have to find the direction of its motion as well, and the term “velocity” is often used as a quantity indicating both the direction and speed of motion.

3.2 Inertia (p.50)

A material body has a tendency to remain at rest if at rest, or, if moving, to continue moving in the same direction, forever in either case, unless it is affected by some external force. This tendency is known as “inertia”, and the force that works on a material body because of inertia is called the “force of inertia”.

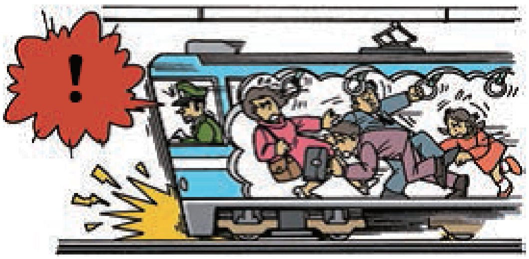


Fig. 2-10 Inertia

3.3 Centripetal and Centrifugal Forces (p.51)

When a hammer thrower, after turning the hammer quickly to give it a circular motion, releases his hold of the ring, the hammer flies in a direction tangent to the circle at the point of the release. To make the hammer continue a circular motion, the athlete has to keep pulling it toward the center of the circle.

The force which thus sets an object in circular motion is called “centripetal force”. In this connection, a force that is equal in magnitude but opposite in direction to centripetal force is called “centrifugal force”. (See Fig. 2-11.)

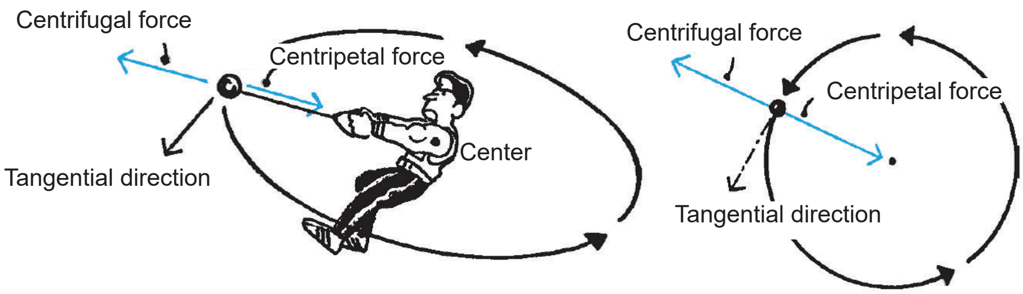


Fig. 2-11 Centripetal and Centrifugal Forces

As shown in Fig. 2-12, the faster the lifted load turns, the greater the centrifugal force becomes, resulting in the movement of the load further outward. Compared with the situation where the lifted load is at rest, this condition increases the moment of a force that works to make the jib crane fail. Under some extreme conditions, it is not unlikely that the crane will fall actually.

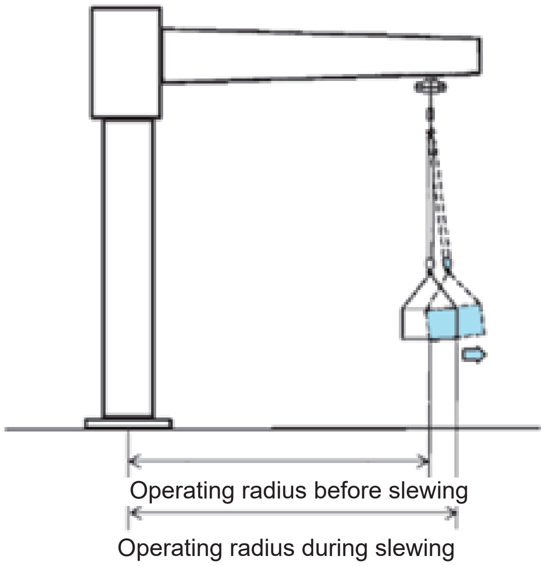


Fig. 2-12 Outward Movement of Lifted Load and Changes in Operating Radius due to Centrifugal Force

4 Pulley Blocks (p.53)

“Pulley block” is a general term for assemblies consisting of a combination of sheaves. These assemblies can be divided into the following categories:

4.1 Stationary Pulley (p.53)

This type of pulley is fixed at a specified place as shown in Fig. 2-13. All you have to do to lift a load by stationary pulley is to pull the other end of the rope downward. In other words, this device changes only the direction of inputted force, leaving its magnitude unchanged. To lift a load by 1 meter, for instance, you only have to pull down the rope by 1 meter.

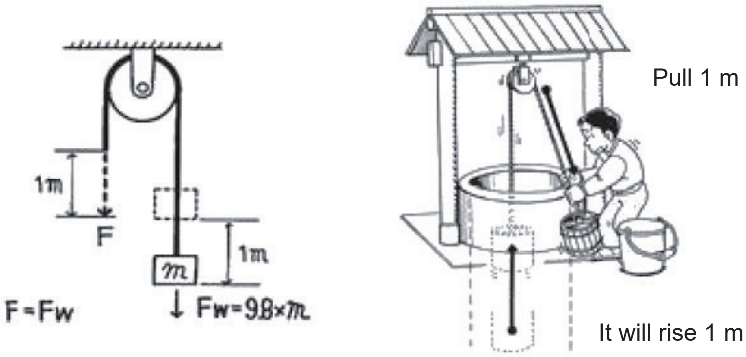


Fig. 2-13 Stationary Pulley

4.2 Movable Pulley (p.54)

This is the same type of pulley as those used for the hook blocks of cranes. As shown in Fig. 2-14, a movable pulley is operated by moving up and down one end (A in the diagram) of the rope that runs on its wheel or wheels, with the other end fixed. The pulley itself moves up and down carrying a load, according to the vertical motion of the rope end A. You can lift a load by this device with a force equivalent to half the weight of the load (assuming that the pulley is free from any friction), but when the rope is pulled 2 meter, for example, the load moves up only 1 meter - half the length by which the rope is pulled. In other words, the pulley requires a smaller input force to lift a given weight of load but so much greater length of rope has to be pulled.

Meanwhile, the direction of inputted force remains unchanged as the rope is pulled up whenever a load is to be lifted.

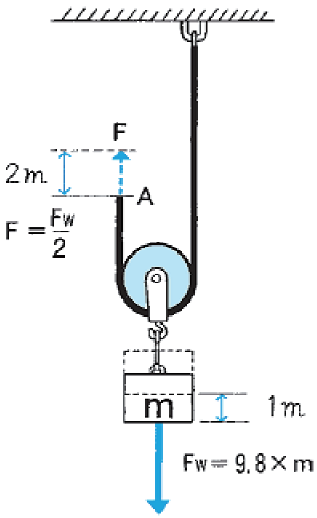


Fig. 2-14 Movable Pulley

4.3 Combination Pulley (p.55)

A combination pulley block, made by combining several movable and stationary pulleys, can lift or lower a very heavy load with a relatively small force. A combination of three movable pulleys and three stationary ones, as described in Fig. 2-15, is capable of lifting a load with a force equivalent to only one sixth of the weight of the load, assuming that the pulley system is free from any friction. However, it can lift a load only one sixth of a meter for every one-meter length of the rope pulled. This means that the velocity of a lifting or lowering load is also one sixth of that of the inputted force.

$$F = \frac{1}{2 \times n} \times Fw$$

F: Force to pull rope

Fw: Weight of load

$$Vm = \frac{1}{2 \times n} \times v$$

Vm: Winding speed

v: Lifting speed of load

$$L = 2 \times n \times L$$

L: Winding length

Lm: Lifting distance of load

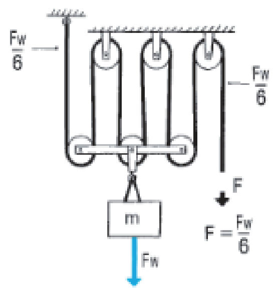


Fig. 2-15 Combination Pulley (Three Movable Pulleys)

Given in Fig. 2-16 is an example of combination pulley systems for cranes.

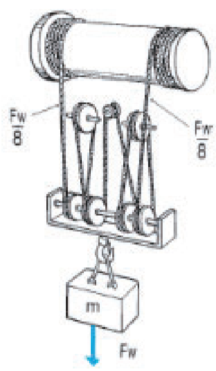


Fig. 2-16 Combination Pulley (Four Movable Pulleys for Crane)

5 Load, Stress, Strength of Materials (p.56)

5.1 Load (p.56)

Load is a force working on an object from outside (i.e., an external force). It can be categorized in different ways according to how such force works on the object involved.

Classification by Direction of Force

Tensile Load

Tensile load pulls a rod by the force F that works on the longitudinal axis of the rod. A typical example of it can be found in the load on a wire rope by which cargo is being lifted.

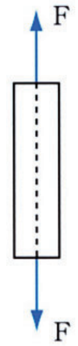


Fig. 2-17 Tensile Load

Compressive Load

Compressive load works in a direction opposite to tensile load, as indicated in Fig. 2-18, to compress the rod longitudinally with the force F. You can find a typical example of it in the force working on the ram of a jack.

Fig. 2-18 Compressive Load

Shearing Load

A reamer bolt may, when exposed to the force F as described in Fig. 2-19, be cut along a sectional plane parallel to the direction of F if this force is very strong. Such action of force is called “shearing load”.

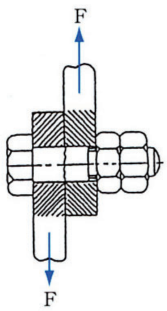


Fig. 2-19 Shearing Load

Bending Load

A beam supported at both ends may bend if the force F perpendicular to its longitudinal axis works on it as shown in Fig. 2-20. This action of force is known as “bending load”. An example of it can be found in the weight of a load or the trolley working on the girder of an overhead traveling crane.

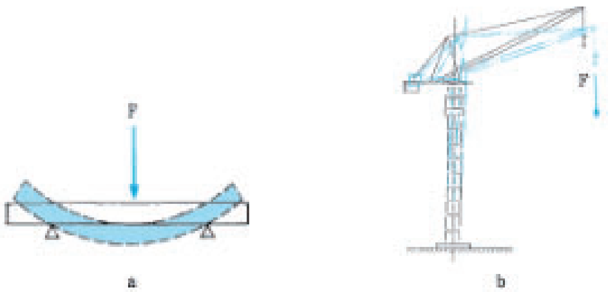


Fig. 2-20 Bending Load

Twisting Load

A shaft may be twisted if one end of it is fixed and the other is exposed to the force F working in two opposite directions on its circumference, as described in Fig. 2-21. Such work of force is called “twisting load”. You can find an example of this load in the instance where the shaft of a winch is pulled and twisted by the wire rope.

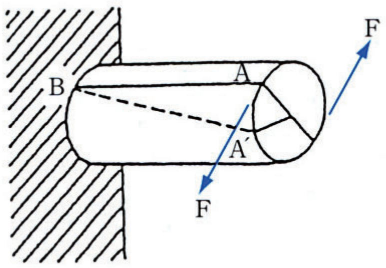


Fig. 2-21 Twisting Load

Compound Load

Mechanical components of a crane are affected more often by a combination of the loads described above rather than by their individual actions. For instance, the wire rope and hook are both subject to a combined action of tensile and bending loads, while power unit shafts in general are subject to a combination of bending and twisting loads.

Classification by speed of load (Fig 2-37)

Static Load

Static load means a fixed or standing load that has invariable magnitude and direction of force like the dead weight of crane structure.

Dynamic Load

Dynamic load, which is variable in magnitude, is classed under two categories. One is repeated load that continually varies with time, and the other is impact load that suddenly applies force to an object for a very short period of time.

Repeated load can be further divided into single-acting load and double-acting load, of which the former always works in the same direction but varies in magnitude with time like the load on such crane components as the wire rope and winch bearings, while the latter varies with time both in direction and magnitude like the load on gear shafts.

Machines or structures may break under any of these dynamic loads even if its magnitude is far smaller than static load. This phenomenon is called “fatigue fracture” which, arising from the fatigue of materials, accounts for a substantial percentage of fractures that occur actually.

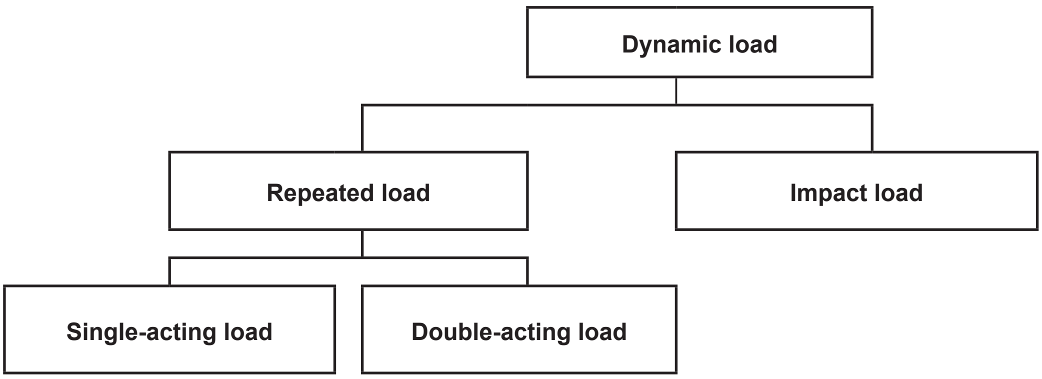


Fig. 2-22 Classification of Dynamic Load

Other Classifications

Load can also be classified, according to the state of its distribution, into concentrated and distributed loads of which the former focuses on a single spot or a very small area while the latter works on a wide area.

5.2 Stress (p.58)

Any object, when under load, generates a force in it (internal force) that works to resist and counterbalance the applied load as shown in Fig. 2-23. This internal force is called “stress”, whose intensity is represented by the magnitude of force per unit area.

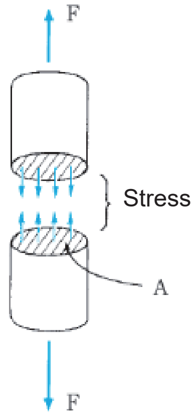


Fig. 2-23 Stress

Stress can be divided into tensile, compressive and shearing stresses, of which the first occurs under tensile load, the second under compressive load and the third under shearing load. With the sectional area of the structural member under load given as A and the tensile load working on the member given as F kg, the tensile stress can be written as:

$$\textbf{Tensile stress} = \frac{\textbf{Tensile load applied to the structural member (N)}}{\textbf{Sectional area of the structural member (mm}^2\textbf{)}} = \frac{F}{A}\ (\mathrm{N/mm^2})$$

6 Strength of Wire Rope, Chain and Other Sling Gear (p.60)

Wire ropes, chains or other sling gear may differ in strength, depending on their materials, even if they are in the same size and shape. These articles are also subject to a much greater force than the weight of the lifted load itself because such weight dynamically works on them.

Taking these factors into account, steps are taken generally to set a reference standard below the load at which the selected sling gear, such as wire rope or chain, may break. Then an arrangement is made to avoid using the sling gear above the reference load and to provide an effective means of directly comparing the reference load with the actual load to be born by the sling gear, so that lifting work can be carried out safely and smoothly.

6.1 Safety Factor and Safe Load of Wire Rope, Chain (p.60)

Breaking Load

The breaking load is the maximum load at which single wire rope breaks. (Unit: kN)

Safety Factor

The ratio of the breaking load of the wire ropes and chains to the maximum load applied to them is called the “safety factor”.

The safety factor is defined taking the type, shape, material and using method of the sling gear into consideration. The safety factor for sling gears are stipulated as follows in the Safety Ordinance for Cranes.

- Wire rope: 6 or more
- Chain: 5 or more, or 4 or more when certain conditions are met
- Hook, shackle: 5 or more

Standard Safe Load

The standard safe load (or standard working load) is the maximum load that can be lifted vertically using a single wire rope, taking this safety factor into consideration. The value can be calculated by the following equation.

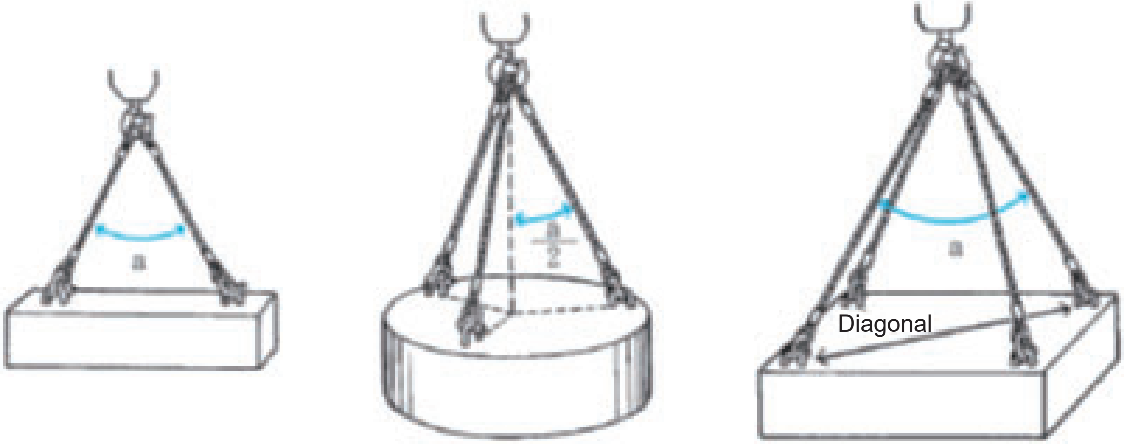
Standard Safe Load (t) = Breaking load (kN) / (9.8 x Safety Factor)

Safe Load

The safe load (or working load) is the maximum load (t) that can be lifted vertically using a wire rope or chain, according to the number of ropes and sling angle. Some sling gears indicates the safe load as a rated load or working load.

Number of Ropes and Sling Angle

The number of ropes are represented as One-rope slinging with two-point, Two-rope slinging with two-point, Three-rope slinging with three-point, Four-rope slinging with four-point or such, depending on the number of slinging points at the load. The sling angle (angle between the sling wire ropes attached to the hook) is shown in Fig. 2-24.



Two-rope slinging with **two-point** | Three-rope slinging with three-point | Four-rope slinging with four-point

Fig. 2-24 Number of Ropes and Sling Angle (a = Sling angle)

When the load is lifted using two wire ropes as shown in Fig. 2-25, the force to support the weight m of the load is the resultant force (F) of the tensions (F1, F2), which are each larger than the value of F/2. For a load of a given weight, the tensions F1 and F2 increase when the sling angle is increased.

In addition, the horizontal component P of the tensions F1 and F2 also increases with the sling angle. This horizontal component P acts as a compressive force on the load, and it pulls the sling wire ropes inward. Careful attention is therefore required when the sling angle is large.

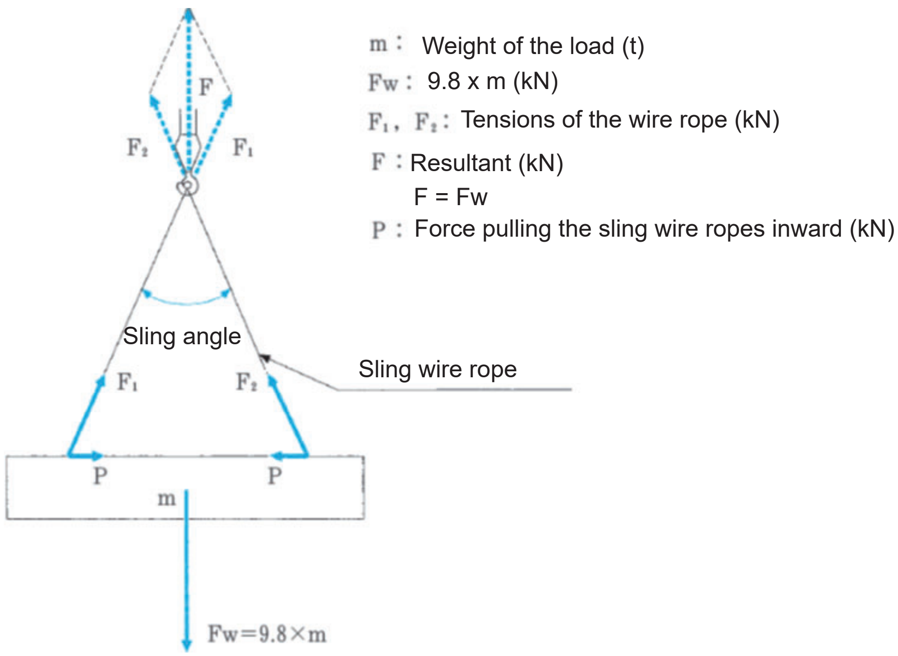


Fig. 2-25 Tension of Sling Wire Ropes

Tension Factor

Tension factor is the value to calculate the load (tension) applied to single wire rope for each sling angle. The load (tension) to the single wire rope can be calculated by finding tension factor and number of ropes even the number of the ropes are changed. For the relation between the sling angle of the wire rope and tension, refer to the textbook (Table 2-4: p.63).

Fig. 2-26 show the relationship between the sling angle and the tension of wire ropes, indicating that as the sling angle increases, thicker wire ropes have to be used even if the weight of the load remains unchanged, since the tension applies to the wire rope increases.

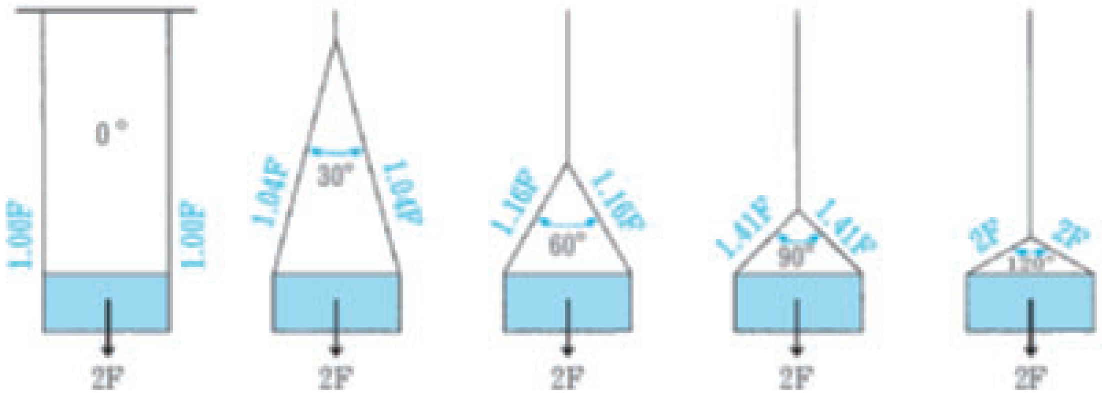


Fig. 2-26 Relationship between Sling Angle and Tension

Mode Factor

The ratio of the safe load of the wire ropes to the standard safe load at a certain number of ropes and sling angle is called the “mode factor”. (See Table 2-5: p.61.)

This value varies depending on the actual sling angle, however, the sling angles are classified into certain ranges, and a certain value is shared in each range for practical use.

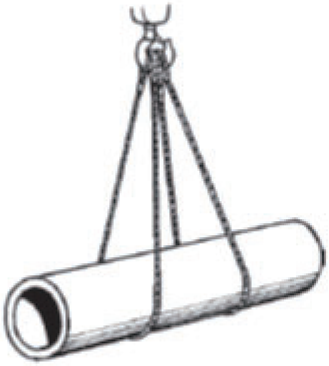
6.2 Calculation for Selecting Sling Wire Ropes (p.64)

To calculate the safe load for selecting the sling wire rope, tension and mode factors are used.

Calculation by Tension Factor

The standard safe load required for single wire rope can be calculated by the following equation.

Standard safe load required for single wire rope = (Weight of Load / Number of ropes) x Tension Factor



Sling angle: 40 °
Weight: 8 t

Fig. 2-27 Single-turn Slinging with Two-rope and Four-point

Calculation by Mode Factor

The standard safe load required for single wire rope can be calculated by the following equation.

Standard Safe Load = Weight of Load / Mode Factor

Chapter 3

How to Select and Handle Sling Gear

Wire ropes, chains, belt slings, hooks, and shackles are used as sling gears for slinging with the crane, depending on the weight and shapes of the load. The safety factor for these sling gears are stipulated as follows in the Safety Ordinance for Cranes (Article 213 and 214).

- Sling wire rope: 6 or more
- Wire sling chain: 5 or more, or 4 or more when certain conditions are met
- Hook, shackle: 5 or more

Clamps and hackers are also used, and the use of fiber ropes such as belt slings and round slings has also become more common. Although the safety factors for these items are not stipulated in the regulations, the Japan Crane Association Standard has specified the safety factors indicated below.

- Clamp and hacker: 5 or more
- Belt sling, round sling: 6 or more

1 Wire Rope (p.67)

1.1 Overview of Wire Rope (p.67)

Construction of Wire Rope

Wire rope is produced by twisting several strands together, each of which is prepared by intertwisting tens of seamless wires drawn from superior carbon steel.

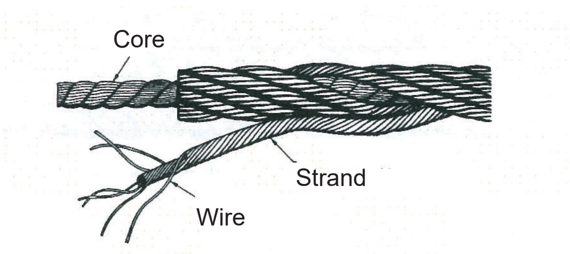


Fig. 3-1 Construction of Wire Rope

The material at the center of the wire rope is called the “core”, and it works to keep the rope shape, provide the flexibility, and absorbs the shocks and vibration to prevent the stands from breaking. The core is made of fabric fiber or wire. For slinging purposes, six-strand wire ropes are used widely. (See Table 3-1: P.68).

The wire rope filled with the wires (filler wires) inside the strand is called “filler type”.

The construction of wire rope is usually indicated by a structural code (the number of strands x the number of wires contained in each strand), such as 6 x 24 or 6 x 37.

Among different wire ropes of a given diametric size, those made with a larger number of smaller wires in general have greater flexibility, and those prepared with a core at the center of each strand in particular are still more flexible and easier to handle.

Types of Lays

Fig. 3-2 shows types of lays used for wire ropes. The “ordinary lay” has the twist of wire rope and that of strands in opposite directions, while the “lang lay” has the twist of rope and strands in the same direction. Each of these lays is further divided into right and left-hand lays (Z and S). Compared with a lang-lay product, an ordinary-lay wire rope wears away sooner but is easier to handle because it is less liable to untwist or kink. For slinging, ordinary-lay Z (right-hand) wire ropes are used widely.

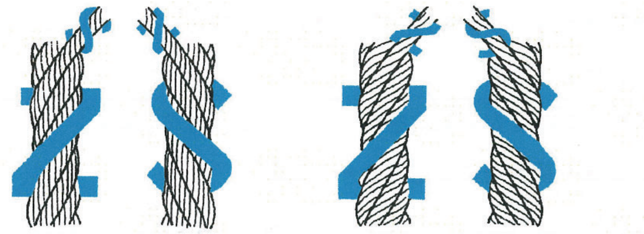


Fig. 3-2 Types of Lays

Wire Rope Diameter

The diametric size of wire rope is represented by the diameter of a circle circumscribing its cross section. It is determined by measuring the diameter of wire rope with slide calipers in three directions at a given cross section as described in Fig. 3-3 and then averaging the measured results. The tolerance against the nominal diameter determined at the time of production must be 0 to +7 percent (note that for the wire rope below 10 mm diameter is 0 to +10 percent).

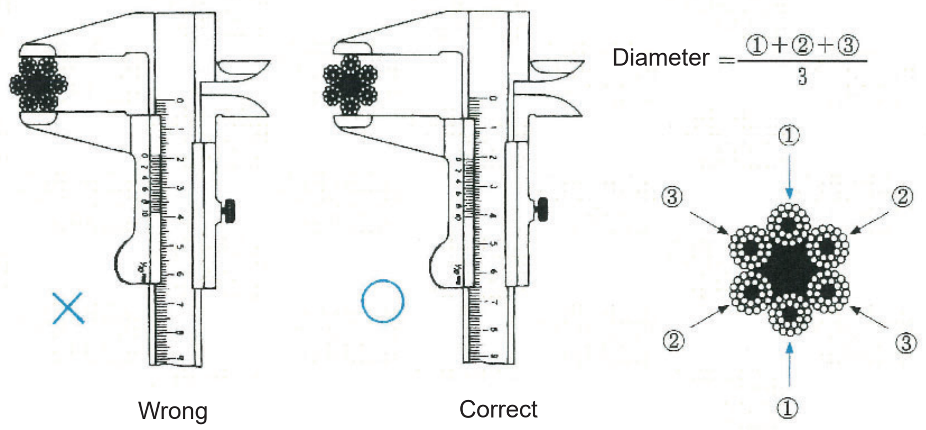


Fig. 3-3 Measuring Method for Diameter of Wire Rope

1.2 Safe Load for Sling Wire Ropes (p.70)

Safe Load

The safe load is the maximum load (t) that can be lifted according to the number of ropes and sling angle.

The safe load can be calculated by using the tension and mode factors and the table of safe load.

- Calculation by Tension Factor
  Safe Load = Standard Safe Load x (Number of ropes / Tension Factor)
- Calculation by Mode Factor
  Standard Safe Load = Standard Safe Load x Mode Factor
- Calculation by Safe Load Table

When the safe load table for the sling gear to be used is available, refer to the table to find the safe load. (Table 3-7 (a) - (d): p.75 - p.78) For example, the sale load can be calculated easily by finding the single angle and number of ropes when the type of the wire rope is specified.

For the technical terms related to the load of the wire rope, see Chapter 2: Strength of Wire Rope, Chain and Other Sling Gear.

Tension Factor

Tension factor is the value to calculate the load (tension) applied to single wire rope for each sling angle.

Table 3-1 Tension Factor and Sling Angle of Wire Rope

Sling angle	Tension factor
0°	1.00
30°	1.04
60°	1.16
90°	1.41
120°	2.00

Mode factor

The ratio of the safe load of the sling gear to the standard safe load at a certain number of ropes and sling angle is called the “mode factor”. (See Table 3-3, p.72.)

Breaking Load of Wire Rope

The strength of wire rope is rated G grade, A grade or others according to the pulling strength of wires used. (Table 3-4: p.72)

For the breaking load for G and A grade wire ropes of 6 x 24 and 6 x 37, which are most widely used for slinging, refer to the textbook. (Table 3-5: p.73)

Standard Safe Load for Sling Wire Ropes

The safety factor for sling wire ropes is stipulated as 6 or more in the Safety Ordinance for Cranes. The standard safe load is the maximum load that can be lifted vertically using a single wire rope, taking this safety factor into consideration. (See Table 3-6: p.74.)

The approximate standard safe load for a 6×24 wire rope can be calculated using the following equation:

Standard safe load (t) $\approx 0.008 \times$ (Wire rope diameter)^2

Note that the unit of wire rope diameter is mm.

Standard Safe Load for Sling Wire Ropes by Number of Ropes and Sling Angle

Sate Load for Two-rope Slinging with Two-point

For the safe load of wire ropes of 6 x 24 and 6 x 37 in each nominal diameter, refer to the textbook. (Table 3-7 (a): p.75, Table 3-7 (b): p.76, Table 3-7 (c): p.77, Table 3-7 (d): p.78)

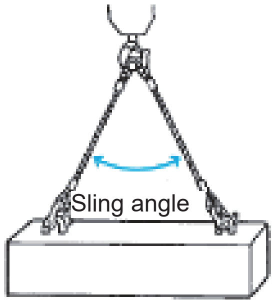


Fig. 3-4 Sling Angle for Two-rope slinging with Two-point

Sate Load for Three-rope Slinging with Three-point

When the load is applied evenly to all three sling wire ropes as shown in Fig. 3-5, the sling angle is twice as large as a/2, and the safe load is 1.5 times the value that was determined from (Table 3-7), which shows the safe loads for two-rope slinging with two points.

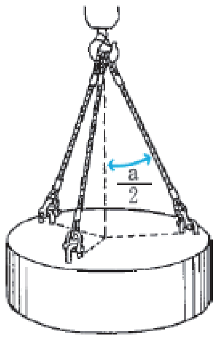


Fig. 3-5 Sling Angle for Three-rope Slinging with Three-point

Safe Load for Four-rope Slinging with Four-point

For four-rope slinging with four points, the safe load is twice as large as that for two-rope slinging with two points. Therefore, the safe load is twice as large as that of the corresponding loads shown in (Table 3-7). If it is difficult to apply the load evenly to four ropes due to slight variations in the shape of the load or the lengths of the sling wire ropes, it is safer to calculate the safe load based on the mode factor for three-rope slinging.

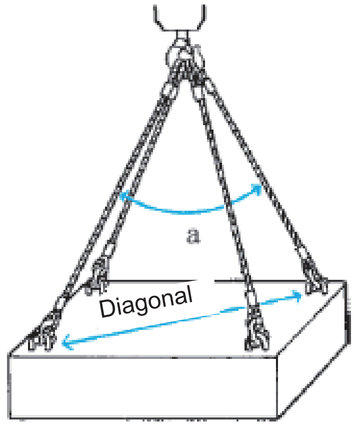
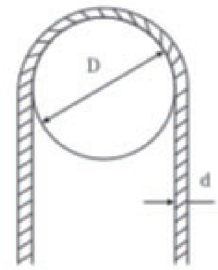


Fig. 3-6 Sling Angle for Four-rope Slinging with Four-point

Decreased strength of wire rope due to bending

Since the safe load decreases according to the ratio (D/d) of the diameter D of gear such as hooks and shackles, to the diameter d of the wire rope, the diameters must be taken into consideration when selecting the equipment to use for the work.

(Reference)



(%)

Construction of rope \ D/d	1	5	10	20
6 x 24	50	30	25	10
6 x 37	45	22	10	5
6 x Fi (25), Fi (29)	45	25	15	4

Example of Decreased Strength of Wire Rope due to Bending (Japan Wire Products Association)

1.3 Finishes of Rope Ends (p.83)

It is required that wire ropes used as sling gear be endless or provided with hooks, shackles, rings or eyes at both ends. Fig. 3-7 shows wire ropes generally used for slinging.

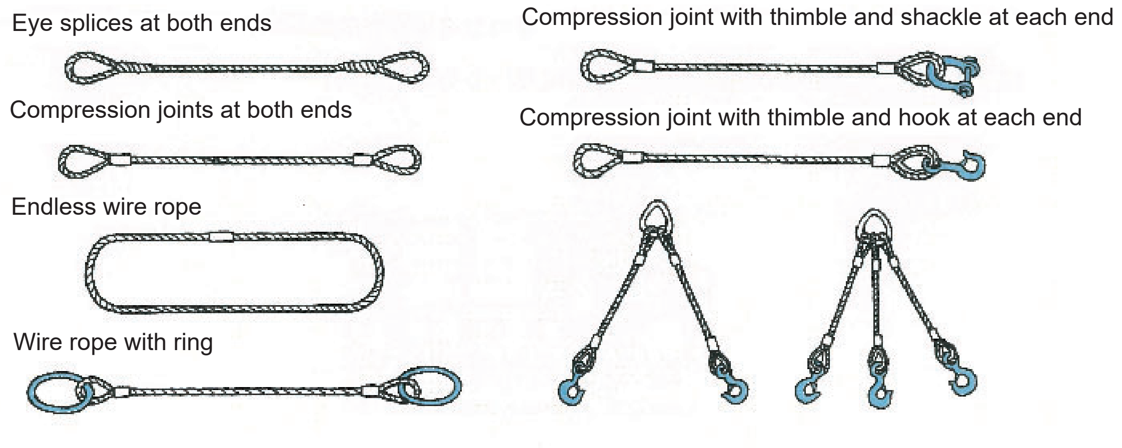


Fig. 3-7 Sling Wire Rope

“Makisashi” (winding insertion) is easier to make than “kagosashi” (split insertion), but when used in a situation where the load works to turn the wire rope, this splice may untwist and come loose.

Eye splicing is performed by hand, so the strength may vary depending on the splicing skill level. While sling wire rope is supplied for load-lifting purposes, anchoring wire is provided to fasten things to stationary matters. (Fig. 3-14: p.84)

Compression Joint

Compression jointing, also called “locking,” is a method of forming a wire rope end into a ring by fitting and compressing a special metallic piece at the neck of the eye. But care should be taken to use compression-jointed wire ropes supplied by a reliable special factory because the quality of these products varies, depending on the method of processing. Compression-jointed sling wire ropes have a disadvantage in that while the wire rope is being pulled out from under a load, its end may get caught by the load.

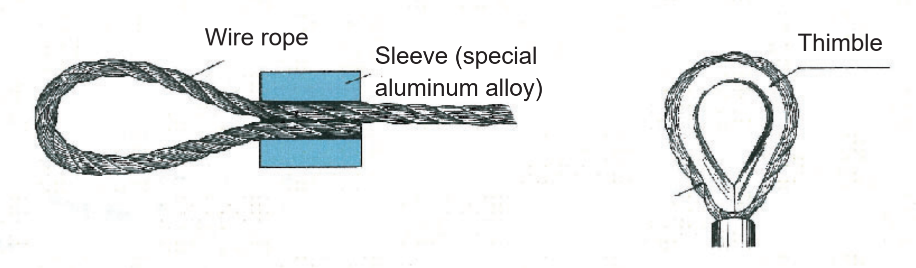


Fig. 3-8 Compression Jointing Method

Precautions for usage

To use the sling wire rope safely, careful attention should be paid to the following precautions.

- Ensure that all loads will be lifted at a proper sling angle and with a safety factor of 6 or more.
- Always pad damageable parts of the wire rope.
- Do not use any rope that has worn away or has a kink or any other damage.
- Avoid slinging high-temperature goods as far as possible.
- Preferably, use plated wire ropes (G grade) if the job site is located in a coastal area or any other place where damage from salt is likely to occur.
- Avoid single-rope slinging wherever possible. The turning of the load may untwist the wire rope, and the load may fall off. (See p.135)
- When storing wire ropes, group them by category of uses and keep them in order at a well-ventilated place free from high humidity, heat, dust, acid and other undesirable elements.
- Do not bend or fasten the endless wire rope at the joint part.
- Do not soak the wire rope with aluminum alloy into sea water.
- (If it is used for a long time, aluminum alloy may be damaged and the tightening force may decrease.)
- Do not let the opening angle of the eye part of the sling wire rope with compression joint exceed 60 degrees.

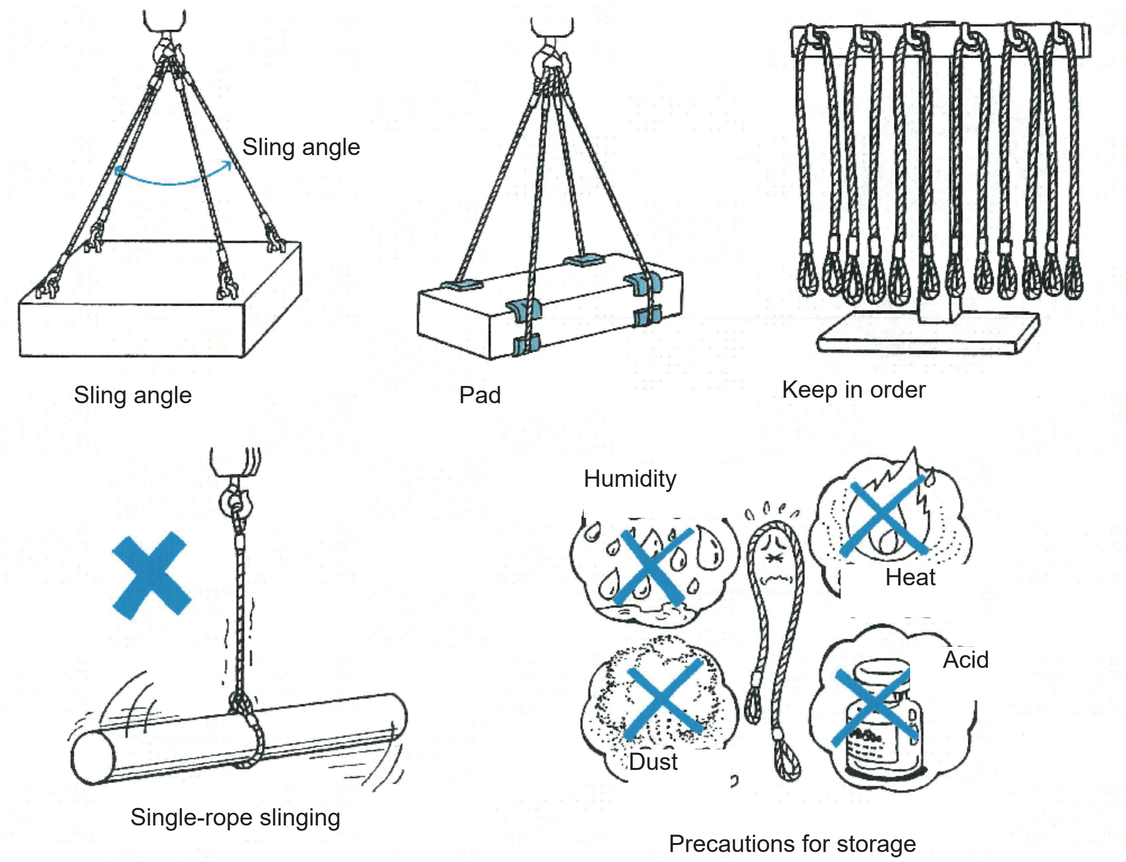


Fig. 3-9 Precautions when Using Sling Wire Rope

2 Chain (p.87)

Chain is often used for slinging high-temperature goods or some other special jobs because of its desirable qualities, specifically greater resistance to heat, corrosion and deformation, compared with wire rope.

The size of chain is represented by the diameter of the component round steel bar (mm), which is called the “nominal diameter” of chain. There is a wide variety of chains but the most widely used of them is link chain, and sometimes stud-link chain is used for slinging heavy loads.

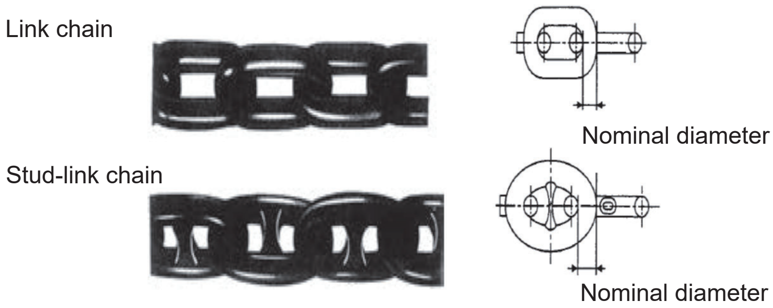


Fig. 3-10 Types of Chain

Usually chain sling is comprised of chain with hooks, rings or some other pieces of metal attached to both ends as described in Fig. 3-11.

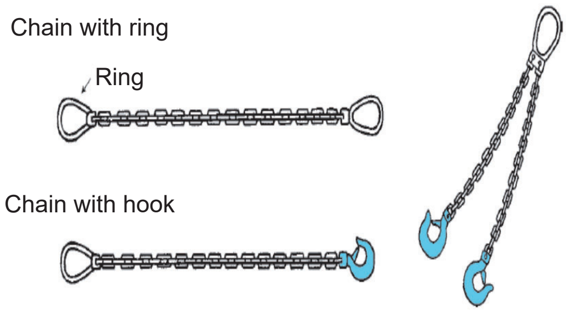


Fig. 3-11 Chain Sling

Precautions for usage

To use the chain safely, careful attention should be paid to the following precautions.

- Choose those sling chains for which the working load is known. (Working load tag is attached to the ring part for some products.)
- Ensure that all sling chains will be used at a proper sling angle with a safety factor of 5 or more.
- Remove any twist before using it.
- Take care not to let any sling chain fall from an elevated place.
- Avoid directly exposing sling chains to heat.
- Do not pull out chains from under the load.
- Do not thrust the end of a hook, pin or any other article into a link in the chain to reduce its length.
- When using sling chains in a cold place, take great care to avoid giving them any shock.
- Do not use any scaffolding chain for slinging loads to be lifted. (Fig. 3-20: p.89)

3 Fiber Rope (p.89)

Fiber ropes are lighter in weight and easier to handle than wire rope or chain, and in addition, they seldom damage the goods lifted with them.

3.1 Belt Sling (p.89)

For belt sling, select the one with the belt part and metal fitting of safety factor 6 or more and 5 or more respectively.

Types and Maximum Working Load (Standard Safe Load)

The belt slings are defined by the grade, type and width, and it is displayed on the tag. Two types of belt slings with the different width are available.

For the maximum working load for each type, refer to the textbook. (Table 3-11: p.92, Table 3-12: p.92)

Precautions for usage

To use the belt sling safely, careful attention should be paid to the following precautions. (Fig 3-22: p.93)

- Select and use the applicable belt for its purpose. Avoid using the one made of polypropylene outdoor. When using new chemical materials or unknown solvent, consult the manufacturer.
- Do not use the belt with use limit indication.
- When using the belt out of the temperature range (between -30 °C and 50 °C), check the working load with the manufacturer. Do not use it in temperatures that exceeds 100 °C.
- If the belt gets wet or oil is attached, it slips easily.
- Be sure to put pads on the edges of the angular load to protect the load and the belt sling and also to prevent sideway slipping.
- When a choke hitch is used, sling the load tight noosing of the belt sling.
- The crane operator must not leave the operating position while the load is lifted.
- Do not use the belt if it is twisted excessively, or tied or pulled each other.
- When pulling out the belt sling under the load, be careful not to damage it.
- Do not drag the belt on the ground or floor. Do not let the belt sling fall with the metal fittings from a high place.
- Do not leave the belt under the load (for a long time).
- When using the belt with other sling gears or hoisting accessory, care should be taken not to damage it at the connecting part.
- Keep the belt away from heat, chemicals and direct sunlight.
- For the belt sling used for the chemical products, wash it thoroughly before storage.
- If the belt becomes dirty due to attachment of oil or dust, wash it with neutral detergent before storage.
- If the belt sling or metal fittings are decided to be discarded after inspection, do not repair for reuse.
- When using the belt sling in uncommon situation, consult the manufacturer.

Working Load of Belt Sling

In actual slinging work, it is important to consider the mode factor and sling angle to select the proper belt sling.

For the working load and slinging method of grade III products, refer to the textbook. (Table 3-13: p.94, Table 3-14: p.94) To secure safety, using it with the sling angle less than 60 degrees is recommended.

3.2 Round Sling (p.95)

Round slings consist of a core material made of twisted strands of synthetic fiber yarn, covered by an outer layer of surface cloth. The safety factor is the same as that of belt slings.

Appearance

Core material

Fig. 3-12 Round Sling

Type of round sling

The types of round slings are classified according to the type of yarn used in the core material, the shape of the sling, and the maximum working load. (Table 3-16: p.96)

The JIS B 8811 standard defines the color codes used for the surface cloth to indicate the maximum working load, as shown in the table below. However, some products may use different color codes due to agreements between companies.

Maximum working load (t)	0.5	1.0	1.6	2.0	3.2	5.0	8.0
Color of surface cloth	Gray	Purple	Blue	Green	Yellow	Red	Dark blue

Precautions for usage

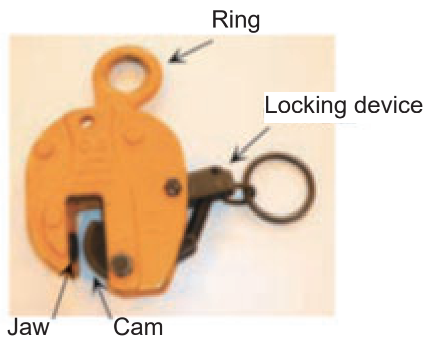
Although the precautions for using round slings are mostly the same as those for belt slings, pay particular attention to the points below.

- Round slings for general use must not be used with chemicals or when heat resistance is required.
- When you perform inspection and find slight damage only to the surface cloth, ask the manufacturer to perform repairs.

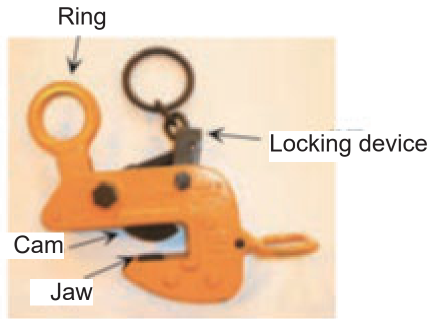
4 Other Sling Gear (p.97)

4.1 Clamps (p.97)

Because its clamping force is proportional to the weight of the load, the cam-type clamp is apt to loosen and let the load fall when the load is lowered to the floor or ground or inadvertently comes in contact with another thing, temporarily resulting in a no-load state. Therefore, most of the cam-type clamps now in wide use are provided with a safety lock, as shown in Fig. 3-13, to preclude inadvertent loss of their hold on the load.



Vertical



Horizontal

Fig. 3-13 Cam-type clamps

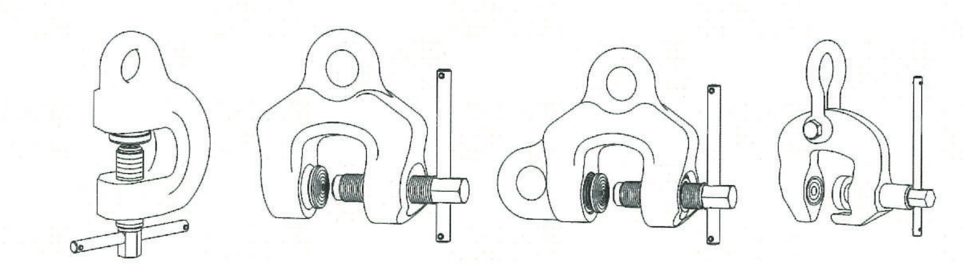


Fig. 3-14 Screw-type clamps

Recently, screw-type clamps are used widely.

Precautions for usage

To use the clamp safely, careful attention should be paid to the following precautions.

- Use the vertical or horizontal clamp according to the type of work. (Multiple type clamp for vertical and horizontal slinging is also available.)
- Be sure to use the clamps within the specified working load (minimum and maximum) and plate thickness.
- Ensure that the sling angle is 60 degrees or less, and that the angle between adjacent slings is 30 degrees or less. (Fig 3-27)
- Avoid one-point slinging as the clamp may come off due to the load swing, even it is slung at the COG.
- When installing the clamp to the load, be sure to insert it to the end of the opening, and apply the safety lock.
- If the installation part of the load is slanted, consult the manufacturer before use.
- When the cam and jaws are clogged, be sure to remove them before use.
- Do not use the worn cams and jaws (according to manufacturer standards).
- Before slinging a load, be sure to completely remove oil, coating, rust or scales, if any, from its surfaces.
- Be careful not to apply an impact load to the load or clamps.
- Do not use the clamps to sling high-temperature objects of 150 °C or higher.
- Do not lift loads with two or more stacked or a load with pads applied.
- Be sure to use a shackle instead of inserting a wire rope directly into the ring.

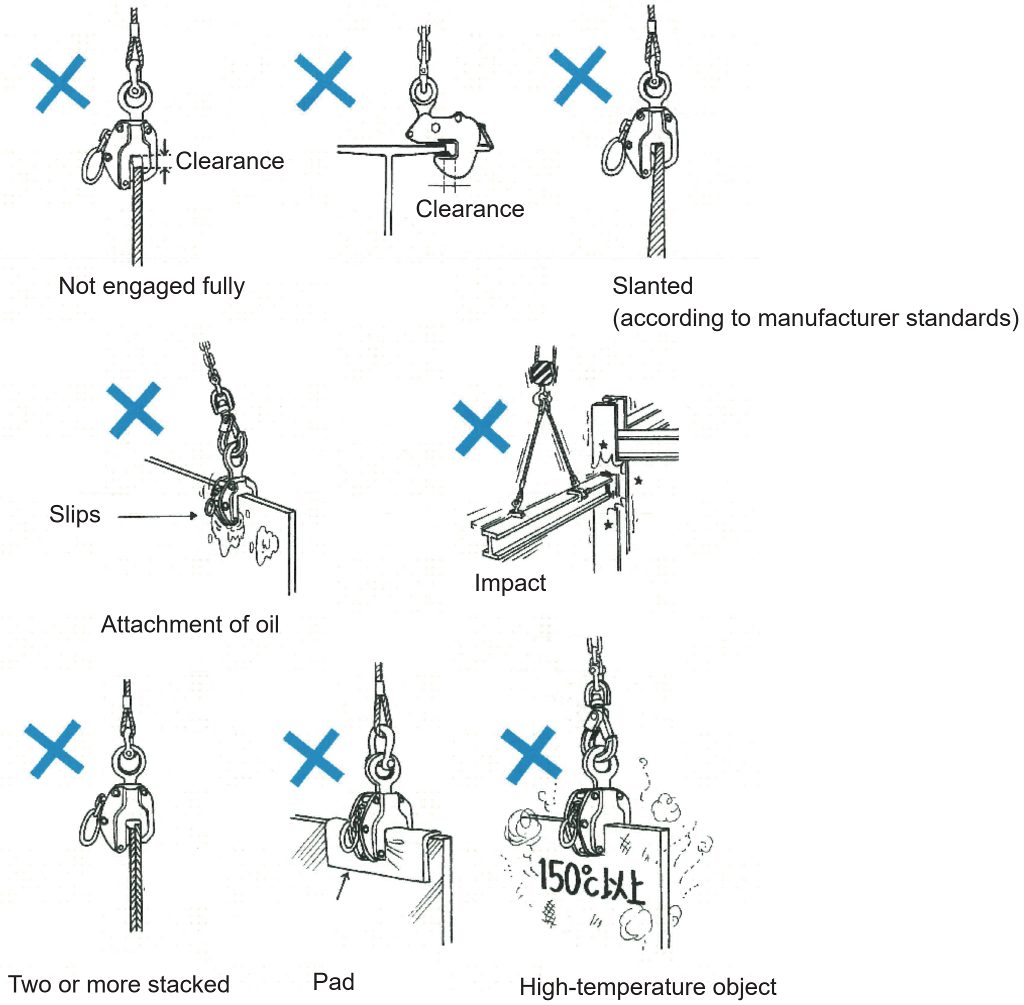


Fig. 3-15 Unacceptable Method to Sling with Clamps

4.2 Hackers (p.99)

Hacker is the sling gear that has one or two claws on its end to hold the products such as steel plates, shaped steels, or pipes for conveyance.

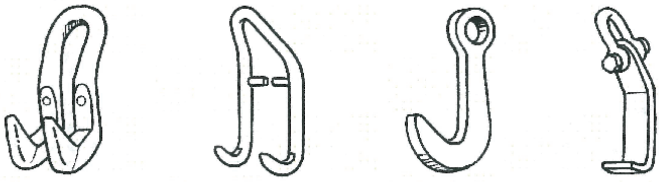


Fig. 3-16 Hackers

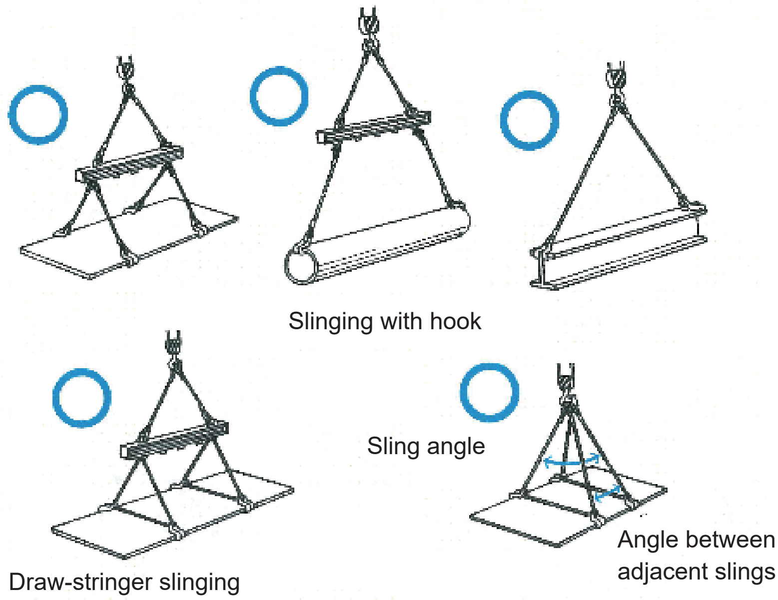
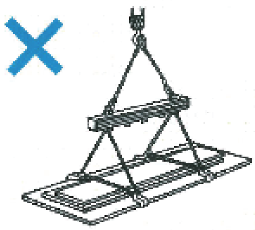
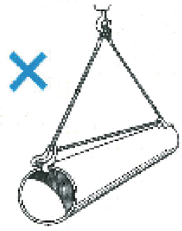


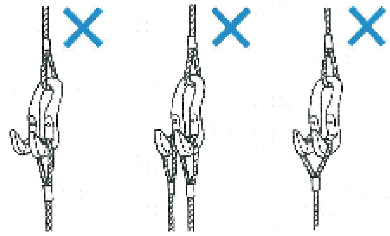
Fig. 3-17 Slinging with Hackers



Do not use hackers when lifting stacked items with different dimensions.



Do not use only one of two claws.



Do not put the sling wire ropes to the claw.

Fig. 3-18 Unacceptable Method to Use Hackers

Precautions for usage

To use the hacker safely, careful attention should be paid to the following precautions.

- Select hackers that are appropriate for the shape, weight, and thickness of the load. (Fig. 3-30)
- Do not use hackers when lifting stacked items with different dimensions.
- Ensure that the sling angle is 60 degrees or less, and that the angle between adjacent slings is 30 degrees or less.
- Find the COG of the load correctly, and use 2 or more hackers to hold the COG securely.
- Insert the hacker securely into the end of the claw.
- Do not use only one of two claws.
- Do not put the sling wire ropes to the claw.
- Do not use the hackers to sling high-temperature objects of 150 °C or higher, or at the cold district where ambient temperature is lower than - 15 °C. (Japan Crane Association Standard Inspection Manual for hackers)
- Do not use the hackers that are modified or repaired by welding.

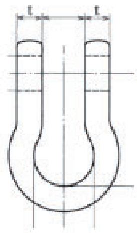
4.3 Others (p.101)

In addition to those described above, the following devices are used for slinging.

Shackles

Shackles used for slinging comprise bow and straight shackles which are further subdivided by type of bolt or pin.

The grade of shackle is classified into M, S, T or V, depending on the pulling strength of the material used. (Fig. 3-32: p.101, Fig. 3-33, Table 3-17: p.102)



t shows the nominal diameter.

Fig. 3-19 Nominal diameter of shackle

Precautions for usage

To use the shackle safely, careful attention should be paid to the following precautions.

- Select the proper shackles according to the specified working load and usage.
- When using the screw-type shackle, connect the shackle bolt to the eyes of the sling wire rope as shown in Fig. 3-20.
- Do not put the wire rope through the bolt side of the shackle as in Fig. 3-21. The bolt may rotate.
- Ensure that no bending force will work on the shackles themselves.
- Do not use a heated or repaired (by hitting) shackle.

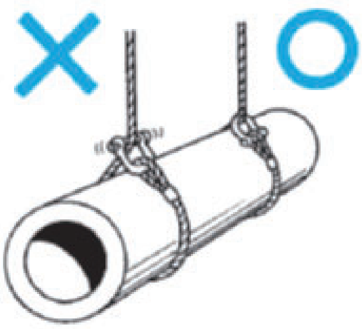


Fig. 3-20 Position of Shackles

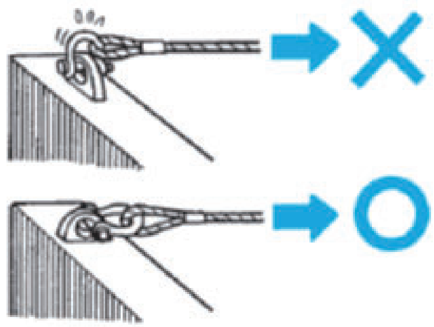


Fig. 3-21 Example of Using Shackles

Eyebolts and Eyenuts

Eyebolts and nuts are bolts and nuts with rings as shown in Fig. 3-22 and Fig. 3-23. Attach them to the machinery or its components in advance so that they can be easily slung when lifting.

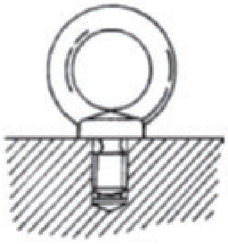


Fig. 3-22 Eyebolt

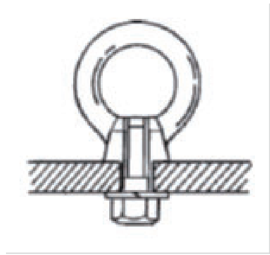


Fig. 3-23 Eyenut

Precautions for usage

To use the eyebolt and eyenut safely, careful attention should be paid to the following precautions.

- Select the appropriate eyebolts and eyenuts according to the type of the load.
- Avoid exposing eyebolts to a lateral force, which reduces their strength very significantly.
- Make sure that the seating surfaces are in close contact. If the eye orientation does not match due to close contact, use the washer to adjust.

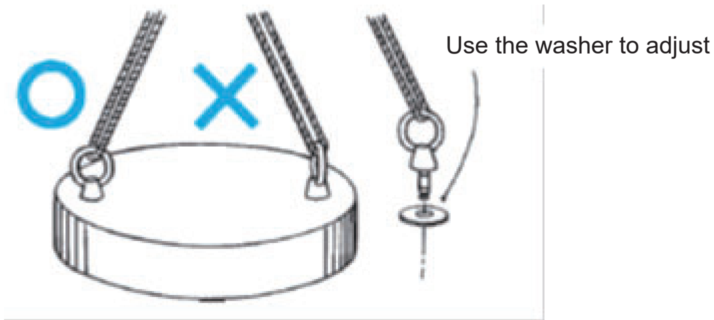


Fig. 3-24 Example of Using Eyebolts

Lifting Beam

The lifting beam is used to lift a long object, or to lift a wire rope vertically so as not to damage the load.(Fig.3-39: p.104)

Precautions for usage

To use the lifting beam safely, careful attention should be paid to the following precautions.

- Select the appropriate lifting beam according to the type of the load.
- For multipurpose lifting beams, check the slinging points and loading conditions beforehand.
- When using a lifting beam for multipoint slinging, which involves uneven distribution of load among the slinging points, take into account such unevenly distributed load.

Wire Net Sling

4.4 Sling Accessories (p.105)

In slinging goods for conveyance by crane, such sling accessories as pads and bearer blocks are used to protect the sling gear or the goods to be lifted or to make the slinging work easier.

Pad

When an angular or fragile product is to be lifted, pads are used to protect the wire rope or the load from being damaged.

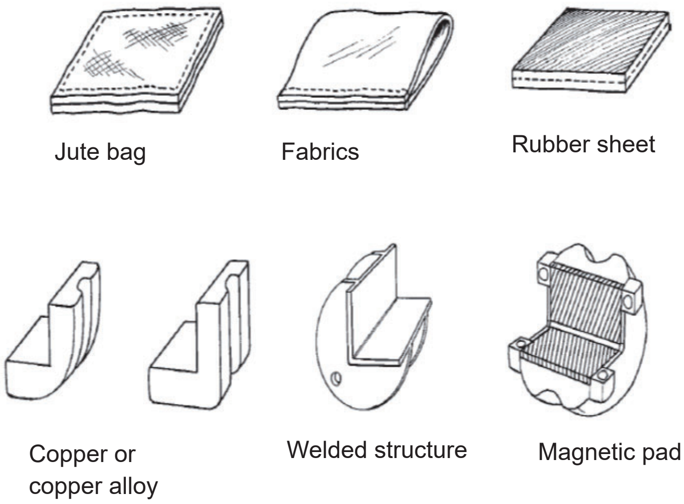


Fig. 3-25 Pad

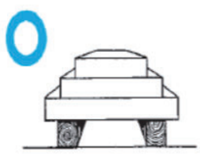
Bearer Blocks

Bearer blocks are used to protect the wire rope and load as well as to ensure that slinging work will be carried out efficiently and safely. Take care not to get your foot jammed under the load.

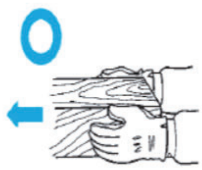
Precautions for usage

To use the bearer blocks safely, careful attention should be paid to the following precautions.

- Use blocks of equal size. If blocks with different height are used, the load becomes unstable.
- For wood blocks, use the ones without crack or damage.
- Hold a block from two sides with both hands. Do not put your hand on its top.
- When adjusting the position of the bearer blocks under the load, be sure to hold the left and right side of the block.

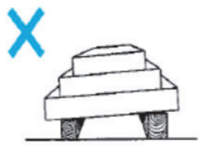


Use blocks of equal size.



Hold a block from two sides with both hands.

Hold the left and right side of the block.



The load becomes unstable.

Do not put your hand on its top.

Fig. 3-26 Bearer Blocks

5 Checkups on Sling Gear (p.106)

Sling gear must be checked regularly and as necessary to keep it in good working order. Failure to carry out these checkups would lead to a serious accident. Before they are used for the day's work, all articles of sling gear have to be checked carefully to make sure that they are in order. In addition to daily routine checkups, these articles have to be inspected periodically, e.g., once a week or a few times a month, depending on their operating conditions, because their service life is affected by such factors as how often they are used daily and how heavy a load is carried at each lifting. Also when they are resuming their service after being stored for a long time, they have to be examined very carefully.

The Safety Ordinance for Cranes defines the standards for prohibiting the use of inadequate sling gear. For details on factors such as the amount of wear or deformation, refer to "Guidelines for Periodical Self-Inspection of Overhead Traveling Cranes".

In addition, for items that are not stipulated in the regulations, follow the standards that are specified in the instruction manual provided by the manufacturer. If any irregularity is found with sling gear by a checkup, which must cover breaks, deformation and other damage, the affected sling gear has to be immediately repaired or removed from service. What is important here is that necessary measures be taken to preclude retired sling gear from being ever used again.

5.1 Wire Rope (p.107)

Inspection Points for Wire Rope

- Broken wires
- Decreased diameter and wear
- Kinks deformation
- Corrosion
- Irregularities in end finishes and other joints

Standards for Determining Unacceptable Wire Ropes

- Wire ropes of which more than 10 percent of the total number of wires (excluding filler wires) contained in any one twist are broken.

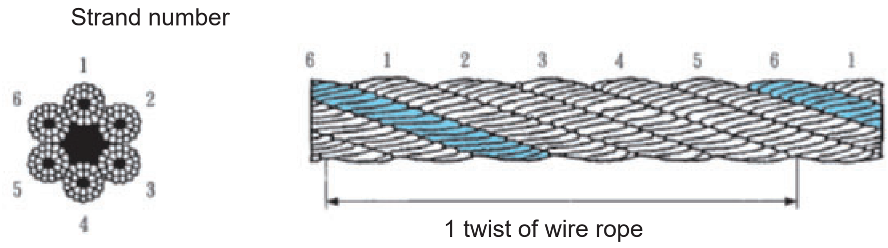


Fig. 3-27 1 twist of wire rope

- Eye part of which more than 5 percent of the total number of wires (excluding filler wires) contained in any one twist are broken. (Reference: Guideline related to Safety of Slinging Operation)
- Those which has decreased in diameter by more than 7 percent of the nominal diameter.
- Those which have any kink. (Do not repair to use it again.)

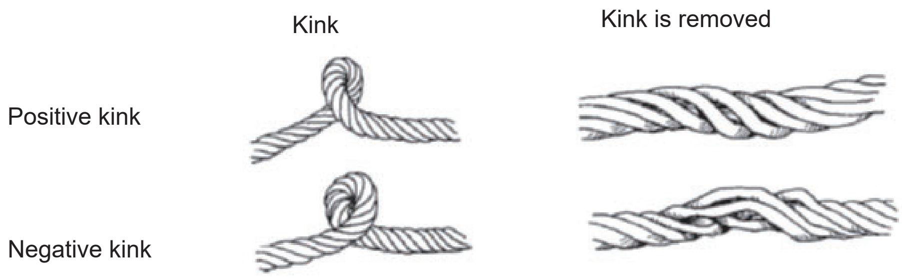


Fig. 3-28 Kink

- Those which are severely deformed or corroded.
- Those which have any irregularity at either of the finished ends or compression joint. (The braided part of eye splice or the metal sleeve of the compression joint.)

These are the criteria set under the applicable legislation for determining the wire ropes to be discarded as such. It is desirable that wire ropes with broken wires or an appreciable decrease in diameter be replaced with new ones sooner before they reach the criteria specified above. A wire rope affected by a combination of any two or more of such troubles as deformation, wear and tear, and broken wires may have to be removed from service when the combined total damage from these causes reaches a certain level even if their individual damage is below the replacement criteria.

5.2 Chain

Inspection Points for Chain

- Elongation
- Wear
- Cracks
- Deformed or twisted links
- Irregularities in the welded or forge-welded parts

Standards for Determining Unacceptable Chains

- Those chains which have elongated by more than 5 percent of their original length as determined immediately after they come off the production line.
- Those which have any link whose sectional diameter has decreased by more than 10 percent of the original size as determined immediately after they come off the production line.
- Those which have any crack
- Those which have any defect or irregularity in the welded or forge-welded parts or are deformed appreciably.

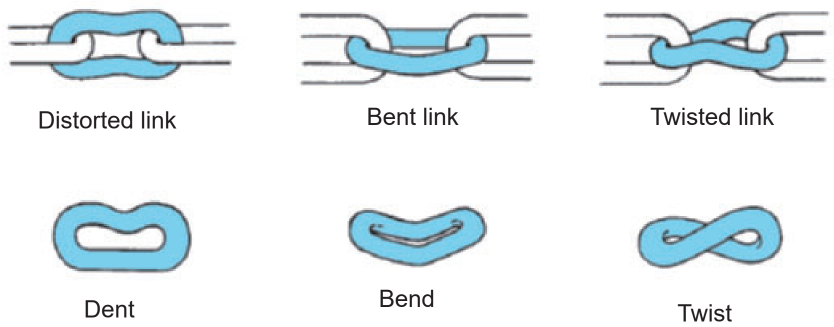


Fig. 3-29 Deformation of Chain

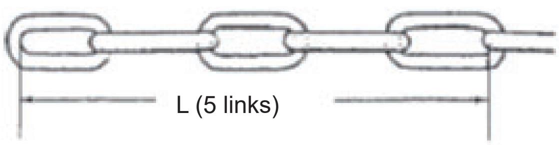


Fig. 3-30 Standard Length of Chain

The elongation of links is found by measuring the length of five links in the most severely elongated part of the chain in service and then calculating the difference between this length and the original length of any five links in the chain determined at the time of production, which serves as a reference standard or standard length. See Fig. 3-30. Since this process involves measuring the dimensions of a new chain and comparing them with those determined later while the chain is in service, arrangements should be made to keep the measurements of every new chain recorded in a ledger.

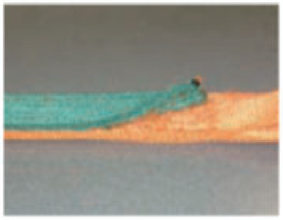
5.3 Fiber Rope (p.110)

It is difficult to estimate the deterioration with time of fiber ropes and belts or to set a reference standard for their strength. Accordingly, particular attention should be given to the following items for inspection:

Belt Sling

Inspection Points

- Damaged condition: Wear (fuzz), scratches, broken thread of sewn part, peeled surface
- Abnormal appearance: deterioration, coloring, melting, dissolution, dirt
- Metal fittings: deformation, scratches, cracks, wear, corrosion



Peeling off at sewn part

Peeling off at body part

Broken thread at eye part

Fig. 3-31 Peeling off at belt

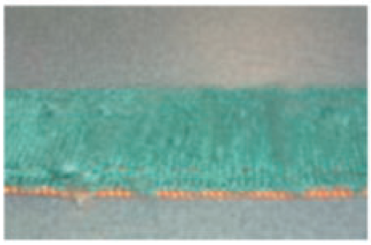


Fig. 3-32 Fuzz at body part

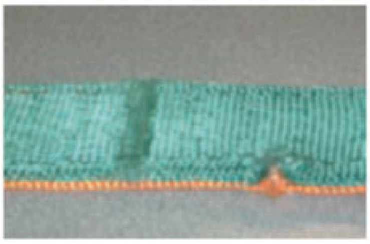


Fig. 3-33 Damage on the end loop

Standards for Determining Unacceptable Fiber Rope and Belt

- When the texture of the sling cannot be recognized due to fuzz, and the sewing thread is damaged or broken. When the sewing thread is peeled away longer than the width.
- Those which have cuts or scratches equivalent to 1/10 of the width in the width direction or 1/5 of the thickness in the thickness direction.
- When the sewing part and body part are peeled away.
- Those which have the use limit indication, and the use limit is exceeded.
- Those which have significant discoloration, coloring, melting, or dissolution due to heat or chemicals.
- Those which have cracks, bends, twists, distortion, and scratches on the metal fittings.
- When there is noticeable wear on the metal fitting. (the amount of wear exceeds 10% of the original size)
- When there is corrosion on the entire metal fitting, or there is significant corrosion on the part of the metal fitting.
- When the service life is exceeded (Reference: 7 years indoors, 3 years outdoors)
- Those which have damage on the end loop.

Round Sling

Inspection Points

- Damaged condition: Wear, scratches, broken thread of sewn part
- Abnormal appearance: deterioration, coloring, melting, dissolution, dirt
- Abnormal core: Core part is hardened partially, uneven thickness

Standards for Determining Unacceptable Round Sling

- When the surface cloth is broken and the core can be seen
- When the thread at the joint part is frayed and the core can be seen
- When excessive fuzz, discoloration, dissolution, melting, corrosion is caused by friction, heat or chemical products.
- When it is too dirty to use
- When the core is hardened partially
- When the core thickness becomes uneven
- When the service life is exceeded (Reference: 7 years indoors, 3 years outdoors)

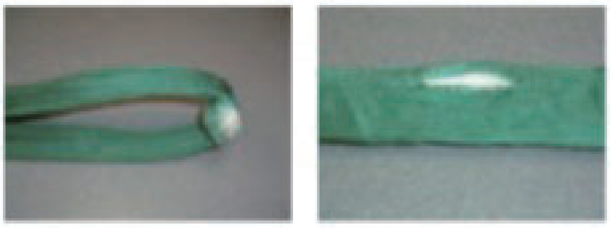


Fig. 3-34 Damage on surface cloth

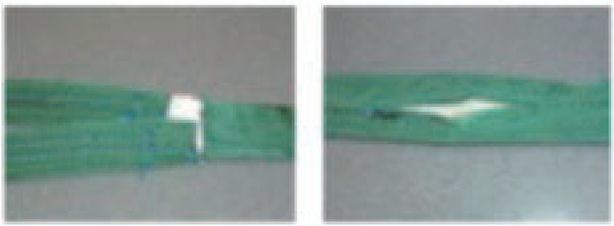


Fig. 3-35 Damage on the thread

Fig. 3-36 Dissolution, melting

Fig. 3-37 Dirty

5.4 Other Sling Gears (p.112)

Hooks, Shackle, Ring

Inspection Points

- Worn state
- Cracks
- Damage
- Elongation, deformation

Standards for Determining Unacceptable Hook, Shackle, Ring

- Opening of the hook is too wide
  Measure the dimensions on Fig. 3-38 and the value exceeds the specified range set by the manufacturer.
- Ring is deformed excessively and can be recognized visually.
- When cracks are found in visual check
  For the hook, it is desirable to periodically inspect for cracks by color check or magnetic particle test.
- Those which have noticeable wear (the amount of wear exceeds 5% of the original size).

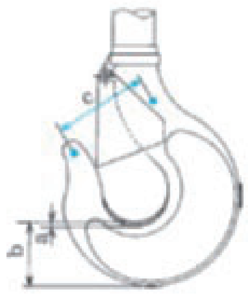


Fig. 3-38 Opening and wear of hooks

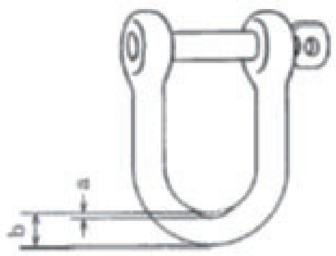


Fig. 3-39 Wear of shackles

Clamp

Inspection Points before Work

- Appearance (clogged teeth)
- Function (locking device, ring, link, cam)
- Wear, cracks, and chipping of the cam and jaw
- Deformation, loosening or falling off of the bolts and nuts

Standards for Determining Unacceptable Clamps

- Those which working load is unknown.
- Those which have wear, cracks or chips on the teeth.
- Those which have deformation or cracks around the opening.
- Those which have bends, hole deformation and cracks on the ring.
- When there are wear, bends and cracks on the pins in each part.
- Those which have bends, hole deformation and cracks on the link.
- The locking device is not working properly, or the spring is weakening.
- Those which have an arc strike (arc welding mark during arc welding).

Maintenance and Storage

The clamp has many moving parts, and daily maintenance is required.

- Remove a paint residue and sludge from the moving parts, and lubricate the sliding parts.
- Remove a paint residue and sludge from the cams and jaws.
- Wipe off oil adhering to the teeth of the cams and jaws.
- Store in a designated place with good environment.
- Dispose of discarded parts so that they are not reused.

Hacker

Inspection Points

- Elongation
- Wear
- Deformation
- Cracks
- Damage
- Arc strike

Standards for Determining Unacceptable Hackers

- Those which have elongation, wear, or deformation exceeding the specified value of the manufacturer.
- Those which have any crack
- Those which have scratches, drooping, or damage exceeding the specified value of the manufacturer.

Chapter 4

Slinging and Signaling Methods

1 Basic Slinging Procedures (p.119)

Slinging involves many forms of danger because of the great weight of goods handled. It is essential that satisfactory arrangements be provided to ensure safety in the performance of this work by setting operation guidelines, paying careful attention to the safety of the working environment, accurately following the proper slinging procedure and giving clear, correct signals or signs. Table 4-1 shows the basic slinging procedures.

Table 4-1 Basic Slinging Procedures

- Preparation

Item		Key points	Notes
1	Confirm the rated load of the crane	Select the crane sufficient in performance.	When using the crane with jib, check the rated load curve and rated total load table.
2	Find the shape, size, material, and weight of the load as accurately as possible	Check the descriptions on the invoice or such.	If it is not clear, check, find or calculate it.
3	Determine the location of the COG	Take note that COG locates as a point.	Determine the location of the COG correctly. (See p.151)
4	Select the slinging method	Decide the number of ropes, slinging method, slinging positions.	
5	Select the sling gears	Determine the required number, diametrical size and length of sling gears according to the shape, weigh, and slinging method of the load.	(See p.123)
6	Check the sling gears	Check for any damage, deformation, twist or wear.	Taking care to avoid getting your hand or fingers hurt.
7	Check the unloading area	● Check that unloading area is large and hard enough and not slanted. ● Check that the bearer blocks are ready.	Secure the area where workers can evacuate.

- Lifting

Item		Key points	Notes
1	Call for the crane	● Call the operator and indicate the loading place. ● Take your position at a place within full view of the crane operator.	● Use a whistle as well. ● When using wireless devices, check that it works properly.
2	Guide the hook	● Indicate the load to be lifted. ● Move the hook above the load.	Be sure to keep the hook at proper height.
3	Signal for lowering	Signal to lower the hook after it stops right above the load.	Make sure that the hook will not hit slingers on the head.
4	Signal for stopping	Hold the hook right above the COG of load where slinging can be done easily.	If the load is large, stop the hook at the position where the slinging can be done easily.
5	Sling the load	● Take the COG location into account. ● Avoid the collapse of the load. ● Pad the edges of an angular load. ● Ensure to preclude the sling wire ropes from slipping.	● Taking care to avoid getting your fingers caught. ● Watch your footing.
6	Secure the sling wire ropes to the hook	● Take care to avoid twisting the sling wire ropes. ● Make sure the eyes of the wire ropes will not cross each other. ● Put the wire ropes parallel to one another at the center of the hook.	Secure the wire ropes on the hook in the proper order. See Chapter 5: Practical Slinging Methods.

Item		Key points	Notes
7	Signal for inching up	● Check the worker’s position carefully. ● Take your position at a place within full view of the crane operator. ● Inching up the load to prevent the wire ropes from slipping. ● Make sure that the COG of the load, hook and sling wire ropes are in vertical.	Taking care to avoid getting your hand or foot caught.
8	Signal to stop the crane	● Check the hoisting wire rope is taut, and the sling wire ropes are taut evenly before lifting off the bearer blocks. ● Check the sling angle. ● Check the eye is attached at the center of the hook. ● Check the crane hoisting wire rope is in vertical. ● If it is not in vertical, signal to move the crane, and adjust the sling positions or lower it on the ground to sling again.	Check from all the directions.
9	Signal for inching up	● Check the load condition. ● Check the load is lifted vertically ● If the load may swing, stop once to lower the load to sling again. ● Lift the load slightly from the bearer blocks.	
10	Signal to stop the crane after lifted off	● Check the load is slung horizontally. ● Check the load is stable. ● Check the tensions of the sling wire rope. ● If any trouble, lower it to sling again.	Judge whether lifting can be performed or not.
11	Signaling for lifting	Take care not to let the load hit the objects around.	
12	Signal for stopping	Lift the load until the height where the workers can move safety.	
13	Guide the load to the unloading place	● Indicate the unloading place. ● Walk ahead of the crane.	

- Lowering

Item		Key points	Notes
1	Indicate the unloading place and signal to stop	Take your position at a place within full view of the crane operator.	-
2	Signal for lowering	● Make sure the workers are evacuated. ● Make sure that the load does not hit objects around.	Never stay under the load.
3	Signal to stop the crane	● Set the load to the applicable height (around the waist). ● Set the load in correct position.	Stop the crane.
4	Adjust unloading position	Check the area around.	Take care not to get yourself being caught.
5	Signal for lowering	● Stay at the safe area. ● Check all the workers are in safe area. ● Signal to the crane while taking care that the load does not hit objects around.	Do not put your hand on the load.
6	Signal to stop the crane	Check the positions of the load and bearer blocks immediately before the load is landed.	
7	Signal for inching down	Check the load condition and put it on the bearer blocks.	
8	Signal for stopping	● Ensure that the sling wire ropes are taut. ● Check that the bearer blocks support the load properly. ● Check that the sling wire ropes are not caught under the load.	

9	Inching down the load and stop	• Ensure that the sling wire ropes are loosened. • Check that the load is stable. • Avoid lowering too much.	Avoid the collapse of the load.
10	Signal for lowering	Stop the sling wire rope at the position where eyes can be removed.	
11	Signal for stopping	• Check that the load is placed correctly. • Check the unloading area.	
12	Remove the sling wire rope	• Wait until the hook stops completely. • Remove the ropes while avoiding the collapse of the load. • Never pull out the sling wire ropes with the crane hook.	Watch your footing.
13	Signal for lifting	• Lift the load to the proper height. • Signal to the crane while taking care that the load does not hit objects around.	Lift the hook to at least 2 m above the ground as a general guideline.

2 Selection Flow of Sling Gear (p.123)

For selection of the sling gears, check the items in the list. (Table 4-2: p.123)

3 General Precautions for Slinging (p.124)

3.1 Slinging Outfits

Slinging involves danger and is often performed in high places. Accordingly, working outfit is required to be easy to move, however, it is also required to be suitable to protect workers from falling or other accidents.

- Wear a hard hat and secure the chin straps properly. To prevent the risk of falling when working in high places, wear fall protection equipment.
- When using sling wire ropes, be sure to wear leather gloves to prevent injury.
- Wear safety shoes that are suitable for the type of work that is performed. Wear the working boots or leggings to protect your foot depending on the type of the operation.
- Wear the long sleeves and long pants for protection.

3.2 Worker Placement, etc.

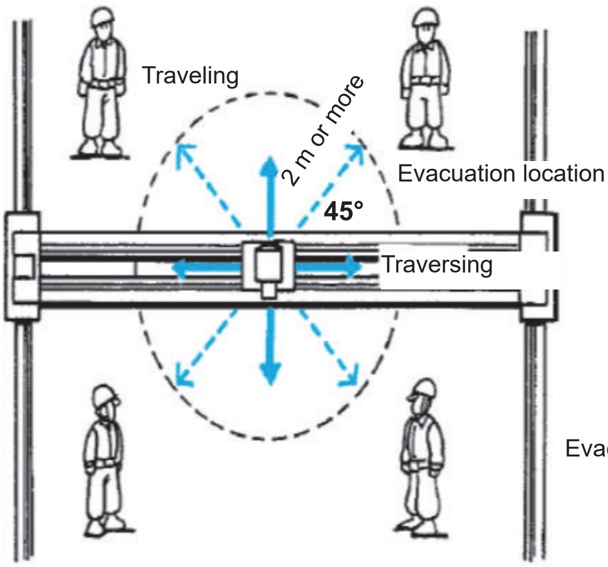
The employer should implement worker placement and other items as described below.

- The employer should designate a person to conduct overall supervision of the work, from the workers who perform slinging (crane operator, signaler, slinger, slinging assistant, etc.). Designate the person responsible for the slinging work, assign duties to each person, decide the arrangement of work areas, specify the areas where entry is prohibited, establish the chain of command structure, and communicate this information to the workers before starting the work.
- Communicate information about the load, such as the type, weight, shape, quantity, and path of conveyance, to the person responsible for the slinging work.
- Decide on fixed signals for crane operation that are appropriate for the work location, and designate a signaler to give the signals.

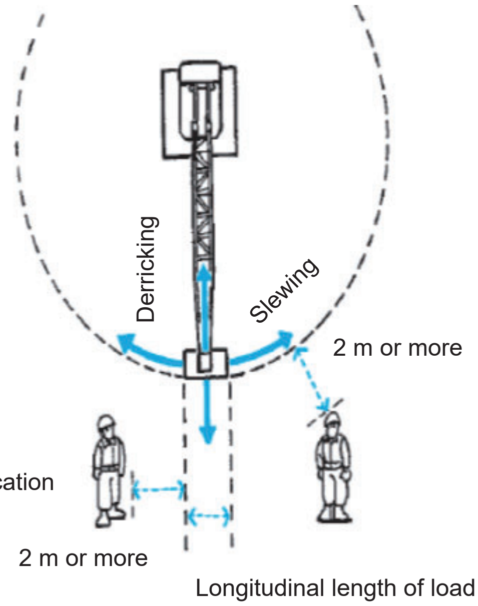
3.3 Prestart Meeting (Fig 4-3: p.126)

The person responsible for the slinging work checks the details of operation and working plan with other members.

- Notify the details (type, mass, shape, quantity) of the load.
- Check the working conditions, and select the applicable path of conveyance not to pass over the other workers. If it is necessary to set the path of conveyance in the job site, set the evacuation location by considering the load height, and notify the evacuation procedure to all the workers.
  - (a) When working with the overhead traveling crane or bridge crane with traveling and traversing functions, evacuate in 45° from the moving directions and keep the distance of 2 m or more from the load.
  - (b) When working with the mobile crane or jib crane with slewing function, keep the distance of 2 m or more from the slewing load.



Overhead traveling crane, Bridge crane



Mobile crane, Jib crane

Fig. 4-1 Evacuation location

- Communicate the work methods, work procedures, and work assignments to the workers.
- When the slinger, signaler, and slinging assistant have a work position, an evacuation location when conveying, and tasks to prevent the load from swinging, communicate the work positions and swing prevention methods to each worker.
- Specify the appropriate protective equipment to wear, and check that it is worn.
- Check that the signaling methods are used consistently at each work location.
- Have the signalers wear items such as arm bands and marked helmets so that the crane operator can identify them easily.
- If wireless devices are used to give signals, check the conditions of wireless communication, such as the transmission range, before starting the work.

3.4 Basic Precautions for Slinging

- If there is any concern during the work, perform the slinging again to ensure the safety.
- Never stay on the load.
- Do not leave the tools on the load.
- Do not enter or let anyone enter under the load.

4 Methods of Slinging with Wire Ropes (p.126)

When lifting by crane, select wire ropes, chains, and belt slings according to the type of the load. In this section, the slinging method by using a wire rope will be described.

4.1 Methods of Securing Wire Ropes to Hook (p.126)

Fastening Wire Ropes by the Eye

The method of slinging with the eyes of wire ropes on the crane hook includes two-rope, three-rope, four-rope slinging and so on, depending on the number of wire ropes used. (Fig. 4-4: p.126.)

Single-turn Slinging

This is a method of hanging sling wire rope on the middle part on the hook. (See Fig. 4-5: p.127.)

One-Round-Turn Slinging

This is a method of securing a wire rope on the crane hook by winding its bight around the hook once in a single round turn. (See Fig. 4-6: p.128.)

Blackwall Hitch

The blackwall hitch means winding a wire rope around the crane hook shoulder in one round turn. It is seldom that 2 or more wire ropes are used at the same time.

This method uses the same single loop as the one-round-turn slinging but the location of the loop is moved up to the shoulder of the hook. (See Fig. 4-7: p.128.)

Looping (generally prohibited)

This refers to the method of shortening the length of one sling wire rope when two sling wire ropes are used, by passing it through an eye and back over the hook. A safe alternative to this method is to use a lever block to adjust the length. (See Fig. 4-8: p.129, p.159.)

4.2 Methods of Securing Wire Ropes to Load (p.130)

Fastening Wire Ropes by the Eye

This is a method of securing sling wire ropes to the load by putting their eyes on the hangers of the load. (See Fig. 4-9: p.130.)

Single-turn Slinging

This method supports the load from the bottom by passing the bight of the sling wire ropes under it. (See Fig. 4-10: p.130.)

Noosing by the Eye

This method secures the load by putting the eye of the wire rope. Use eye or shackle at one end through that at the other end so as to form a noose around the load. (See Fig. 4-11: p.131, Fig. 4-12: p.131, Fig. 4-13: p.131, Fig. 4-14: p.131.)

One-Round-Turn Slinging

This is a method of securing the load by winding a sling wire rope around it in a single round turn. (See Fig. 4-15: p.133, Fig. 4-16: p.133.)

Bale Sling Hitch

This method secures the load with a sling wire rope passing through eyes, passing eyes through a sling wire rope doubled over, or endless wire rope. (See Fig. 4-17: p.134.)

Slinging with Single Hitch on Bottom

This method, used for slinging cylinder or cone-shaped loads with a round bottom, ensures the load by crossing two wire ropes in a single hitch on its underside. (See Fig. 4-18: p.134.)

Single-Rope Slinging (Avoid wherever possible)

Single-rope slinging with the rope fastened tightly to the load is generally prohibited due to the following reasons. (See Fig. 4-19: p.135.)

5 Methods of Slinging with Chain Slings (p.136)

5.1 Example of Slinging with Chain Sling (p.136)

Use the proper diameter of the chain with upper and lower fittings for slinging. It can be used with clamps or hackers as necessary. Use the chain properly according to the operating manual from the manufacturer. (See Fig. 4-20: p.134, Fig. 4-21: p.134, Fig. 4-22: p.134, Fig. 4-23: p.134.)

6 Signaling Method (p.137)

It is stipulated in the regulations that “The employer must, when carrying out the work using a crane, set fixed signals for operation of the crane, designate a person who gives the said signals and have the said person give the said signals. Workers engaging in the work must follow the signals”. As the method of signaling may differ depending on the job site, the slingers and crane operators must confirm the method specified in each job site.

In general, signaling by hand is used widely. (See p.139-141.) A primary consideration in signaling by hand is to give distinct signals by the specified motions of hand in a clear manner.

The voice signaling by using the wireless devices is also used at the job sites such as high-rise building. It is important that the crane operator repeats voice messages given by the signaler.

The following is the points for the signaler of the crane operation to take note.

- Only a designated person must perform signaling to the crane operator.
- The signaler should understand the slinging work, rated load, operating range, and operating performance of the crane fully.
- Have the signaler work in a safe location that is visible to the crane operator, and which has a clear view of the work.
- Use the fixed signals to indicate the operation to the crane operator clearly.
- Always lift the load in a straight line. Make sure that the load will not be lifted obliquely, and then give the signal.
- Make sure that the slinging has been completed, and then give a signal for lifting.
- Stop the load when the sling wire ropes are taut, make sure ropes are fixed securely, and then give a signal to lift it further.
- Indicate the transporting direction and unloading position clearly and give a signal as early as possible.
- Stop the load slightly above the bearer blocks, make sure that the load can be landed safely, and then give a signal for lowering.
- After slinging is completed, lift the hook to a height of at least 2 meters, and all the workers confirm that work is done correctly.

6.1 Voice Signaling (Ex.) (p.142)

- Usually, signals for the part to be operated, the degrees of operation, and the form of action to be taken should be given in this order.
- Crane operator should repeat voice messages given by the signaler.
- As the method of signaling, all the workers should fully understand the method specified in each job site.

Chapter 5

Practical Slinging Methods

1 Slinging Procedure (p.149)

1.1 Check the Rated Loads and Rated Total Loads of the Crane and Other Equipment (p.149)

The rated load indicated on the overhead traveling crane is the maximum load (weight) that can be lifted by the overhead traveling crane. The weight of the load must not exceed this amount. Since overhead traveling cranes and bridge cranes are usually not equipped with an overload preventive device or overload limit device, careful attention is required.

For jib cranes and mobile cranes, the rated load and rated total load varies depending on the jib angle and operating radius, so the slingers need to coordinate closely with the crane operator.

Fig. 5-1 Display example of rated load on overhead traveling crane

1.2 Find the Weight of the Load (p.150)

The first thing slingers have to do is to find the weight of the load to be lifted as accurately as possible. You can easily find the weight of those products which you handle daily or which have their weight labeled. However, when handling a load of unknown weight, you have to ask its weight of an experienced colleague or the group leader or check it on the drawings, tags, invoice or some other papers. Or, estimate the weight by calculation.

There are many instances where you have to estimate the weight of the load by the eye. Estimation of the weight requires work experience and it is difficult to estimate it visually. Wrong estimation causes overload of the crane and unexpected accidents. Furthermore, it will decrease the work efficiency largely. Care should be taken for the following points.

- Survey the shape of the load carefully and find its dimensions by the eye.
- Check the material of which the load is made. Loads of equal volume may differ in weight if they are made of different materials
- Calculate its weight. (See p.44)
- It is dangerous to estimate the weight lighter than the actual weight. Add 20% to the weight of loads estimated by the eye.
- If you know by heart the weight of various materials, you can readily calculate the weight of loads from their size, quantity or volume.
- If you know by heart the weight of various materials per meter, square meter or cubic meter, you can readily calculate the weight of loads from their size, quantity or volume.

Estimation + 20%

Fig. 5-2 Estimate the Weight of the Load

1.3 Determine the Location of the COG (p.151)

Another important factor in slinging is to determine the location of the COG of the load to be lifted as accurately as possible in order to select the proper sling gears and slinging method.

Determine the Location of the COG

Since estimation of COG is performed based on eye measurement in actual job, it is difficult find it correctly. Care should be taken to adjust the slinging positions and methods depending on the conditions of the load. Do not rely on the positions for the provided rings.

Be aware that the COG of load locates as a point (not a line), and it must be checked from all the directions to perform slinging safely. Especially when turning the load, check the COG from each direction carefully to prevent an accident from occurring.

When the load is lifted balanced, its COG locates directly under the hook. Once the load is lifted safely, indicate its COG for reference to ensure the safety and improve the work efficiency.

How to Determine the Location of the COG during the Work

However, there is a wide variety of products to be handled and it is very difficult to locate the COG of those which have a complex shape. When actually lifting any of these loads, you have to lift it slightly from the floor or the ground for trial by the following procedure:

(1) Determine the COG of the load as above and sling it.

(2) Lift it a little very slowly. (Without lifting off the ground)

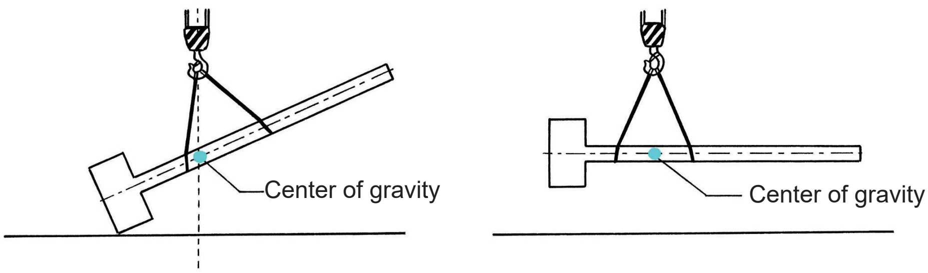


Fig. 5-3 How to Determine the Location of the COG during the Work

(3) If it does not remain horizontal on the sling, return it to the ground and move the position of the sling toward the side of the load which stayed on the ground during lifting.

(4) Slightly lift the load again and examine its behavior.

(5) Repeat this process until the load comes to stay horizontal on the sling.

Even for the load provided with rings or COG display, the procedure is the same except for step 1 (estimation of COG).

How to Select Sling Gear and Hoisting Accessory (p.152)

Taking the weight, COG, shape, slinging positions of the load and crane performance into account, select the most applicable sling gears and hoisting accessories. (See p.123.)

It is necessary to find which of sling wire rope, chain, belt sling and other sling gear to use, depending on the COG, number of ropes to be used and the sling angle, and then select the one that has sufficient strength and length to support the load properly.

In slinging regularly-handled or some specific loads, it is advisable that the safest and most efficient sling gear available be selected specially for each of these loads. There are some special accessories equipped with magnet or vacuum lifter to handle steel, glass products or such.

Check the sling gears before the work, and make sure that there is no abnormality.

Guiding the Hook (p.153)

Call for the crane

When signaling by hand, take your position at a place within full view of the crane operator, and indicate the load position.

When performing the voice signaling by using the wireless devices, check the conditions of wireless communication in advance, and take your position at a place within full view of the load and area around it. It is important to check the crane operator repeats voice messages given by the signaler.

Guiding the Hook

As a general rule, guide the hook directly above the load. If the load is too large and slinging work cannot be done safely, guide the hook at the position where the slinging can be done easily. Then move the hook directly above the load before lifting off.

If sling wire ropes are too thick to handle, place the sling wire ropes on the hook first, perform slinging, and then move the hook directly above the COG of load before lifting off, if necessary.

To lift off the load in a stable condition, COG of the load must be within the line of the lifting points.

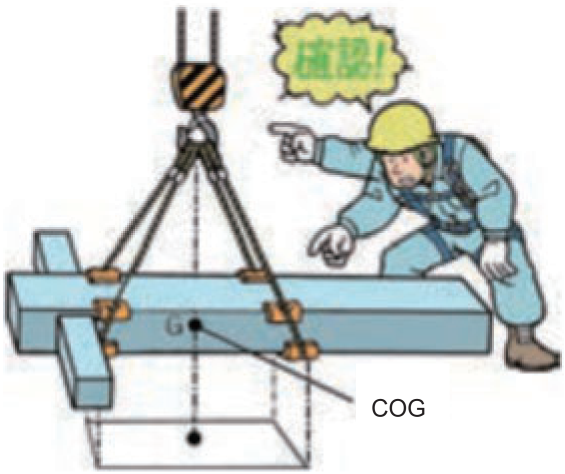


Fig. 5-4 COG of Load

If COG of the load is out of this line, the load may slant or sling wore ropes may come off. Even if it is within that line, when the COG of the hook is not directly above the load, the load may rotate or shift after lifting off. Accordingly, it is important to guide the hook directly above the load before lifting off.

Slinging (p.154)

To lift the different shapes of the load with sling wire ropes, it is necessary to select the most applicable method depending on the shape to prevent the load from rotating or shifting. If the load may collapse, shift or fall over due to swinging during conveyance, tighten or fix it with lever hoist as preventive measure. For the angular or slippery load, put pads on the edges to sling it safely.

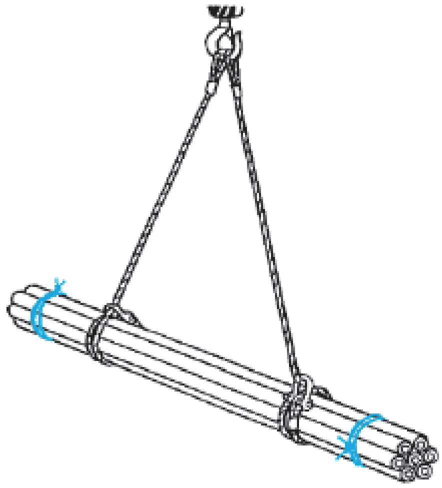
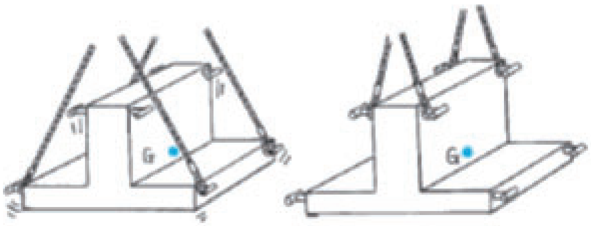


Fig. 5-5 Fixing of Load

When Securing on the Load

- If the load is too large and slinging is difficult to be performed directly above its COG, you can select the alternative method. Sling the load at the place where the job can be done easily, and move the hook directly above the load when lifting off. However, when moving the hook with the sling wire ropes attached, take care not to hit the load or equipment around.
- To lift the load in stable condition, sling at the higher positions than the COG.



Sling from the bottom (unstable)　　Sling at the top (stable)

Fig. 5-6 Slinging Positions

- When the lopsided load is lifted with single-turn slinging, the load may rotate. Extra attentions should be taken for such cases.

G: Center of gravity

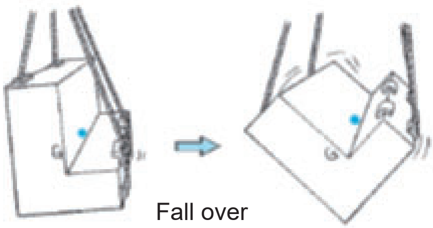


Fig. 5-7 Lopsided load

- If the long objects are lifted with larger sling angle, the sling gears may slip inward, and it can cause the falling of the load. Attach pads between the load and sling gears, and lift the load by fastening with eyes, one-round-turn noosing, or bale sling hitch to prevent the sling points from shifting.

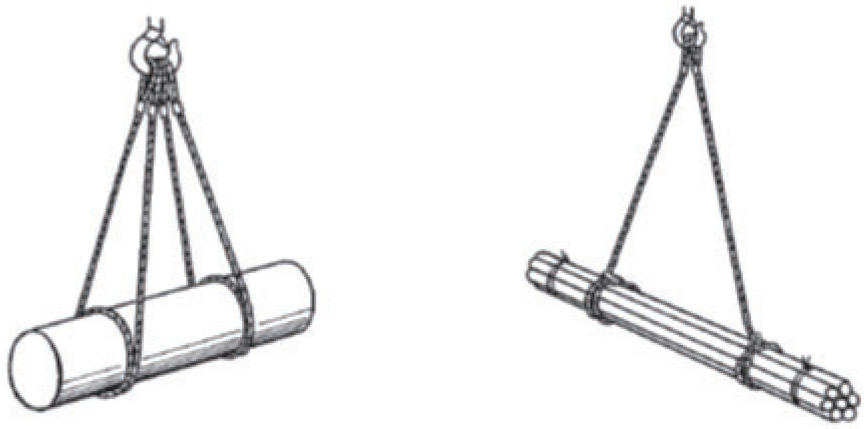


Fig. 5-8 One-round-turn noosing for long objects

- If there is a risk that the load can be broken by the component force caused due to large sling angle, check the lift capability of the crane, and use the longer sling wire rope to decrease the sling angle. It the sling angle is difficult to be decreased, consider the alternative method such as using the lifting beam.

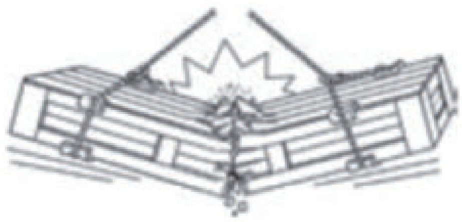


Fig. 5-9 Damaged load

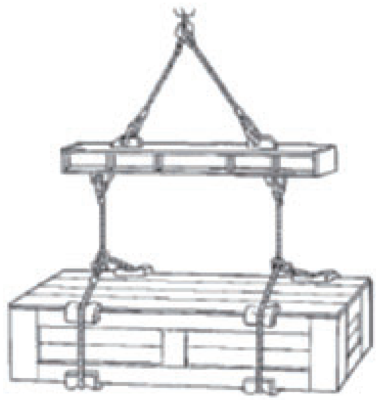


Fig. 5-10 Slinging with lifting beam

- Check that the sling wire ropes under the load are not kinked.

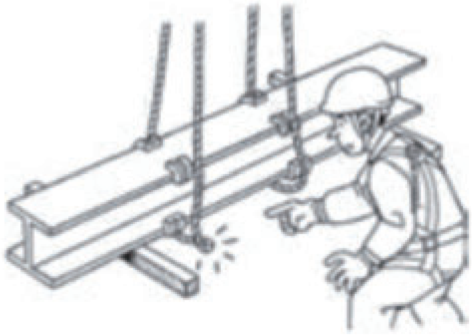


Fig. 5-11 Kink

- Pad the edges of an angular load to protect the sling wire ropes and load.

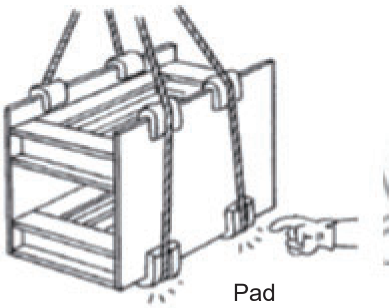


Fig. 5-12 Angular load

When hanging on the Hook

- Check the function of the hook latch. Depending on the conditions, the sling wire ropes may come out from the hook as shown in Fig. 5-13. In some job sites, two latch devices are used for prevention.

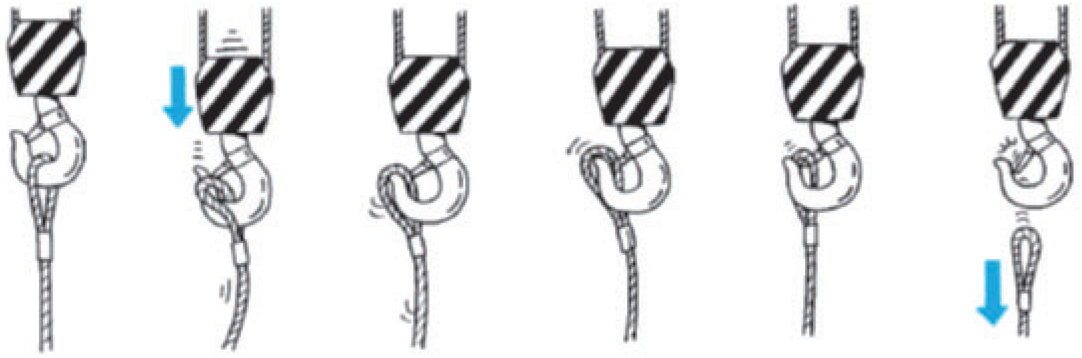


Fig. 5-13 How an eye comes out from a hook

- Attach the sling wire ropes to the hook one by one in order, starting from the back of the hook, so that the eyes of the sling wire ropes do not overlap each other on the hook, and so that the wire ropes do not cross each other under the hook. When the sling angle is large, the last sling wire rope that is attached to the hook is more likely to become detached, or if the sling wire ropes for a load such as the one shown in Fig. 5-14 are attached in the order of 2-1-4-3, the sling wire ropes cross each other under the hook. In cases such as these, orient the load so that the lengthwise direction is perpendicular to the direction of the hook, as shown in Fig. 5-15 and Fig. 5-17, and attach the hooks in an order that makes the last wire rope attached to the hook less likely to become detached, and which prevents the sling wire ropes from crossing each other.

  (a) Attaching order of eyes in four-rope slinging with four-point

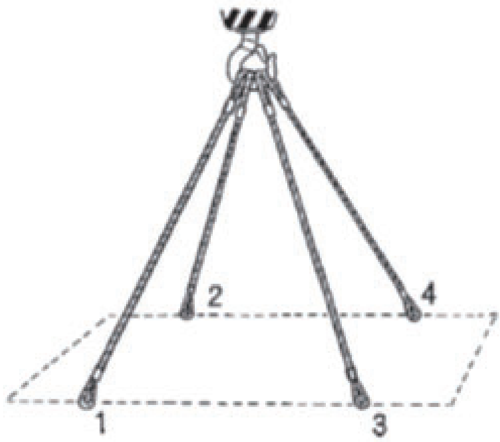


Fig. 5-14 Lengthwise direction is parallel to the direction of the hook (1-2-3-4 or 2-1-4-3 from hook end)

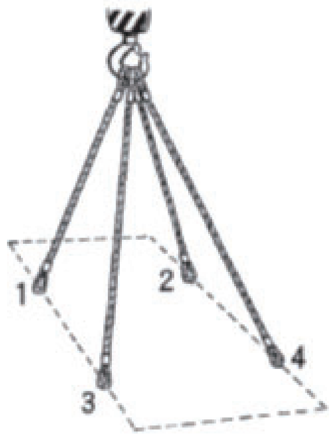


Fig. 5-15 Lengthwise direction is perpendicular to the direction of the hook (1-3-2-4 or 3-1-4-2 from hook end)

(b) Attaching order of eyes in two-rope slinging with four-point

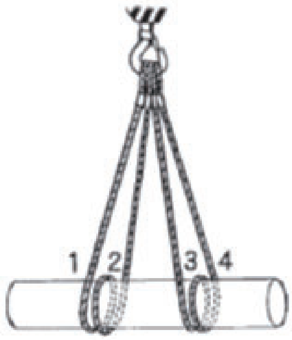


Fig. 5-16 Lengthwise direction is parallel to the direction of the hook (1-2-3-4 from hook end)

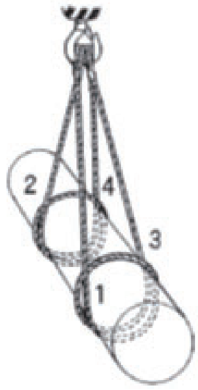


Fig. 5-17 Lengthwise direction is perpendicular to the direction of the hook (1-2-3-4 or 2-1-4-3 from hook end)

- Guide the hook to the place where the sling gears can be attached easily and slingers can be worked in stable posture with the secured ground condition.
- According to the “Guideline related to Safety of Slinging Operation”, the sling angle should be within 90 ° as a general rule, however, for single-turn slinging with two-rope and four-point, it should be within 60 °, and for slinging adjusted with another hoisting accessory, slinging with clamp or hacker, it must be within 60 °. For other methods, be sure to set the proper sling angle taking the shape and size of the load and lift capability of the crane into account.

Slinging a lopsided load

There is a case you have to work on the load that has irregular shapes with the COG off the center. The following are slinging methods used to keep these lopsided loads horizontal.

- Symmetrical slinging

Find the location of the COG accurately, bring the hook directly above the COG and set the slinging positions symmetrically.

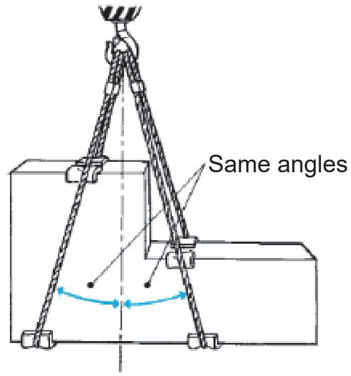


Fig. 5-18 Symmetrical slinging

An error in locating the COG would result in a dangerous behavior of the load, as described in Fig. 5-19, which lets great tension work on the left sling wire rope and may cause the slings to slip off the toad. Even if the sling wire ropes stay in their positions, the lifted load would be significantly inclined. If it is inclined at lifting off, lower the load and set the hook or slinging positions at the COG as shown in Fig. 5-20, and lift it again.

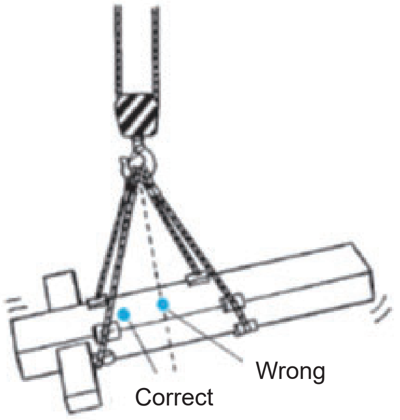


Fig. 5-19 Slinging with COG locating error

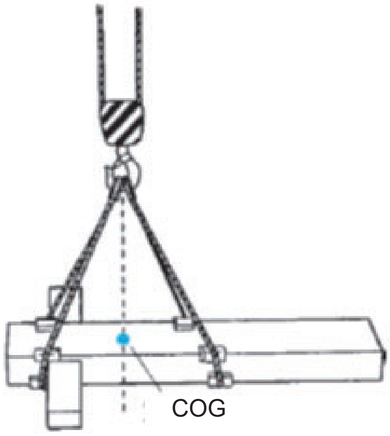


Fig. 5-20 Slinging with correct COG location

- Asymmetrical slinging

Another method uses two sling wire ropes of different lengths to bring the hook directly above the COG of the load so that the load can be lifted safely. In this method, two sling wire ropes of different lengths to be used for right and left sides. Care should be taken to use a thicker, stronger wire rope that can lift the whole weight of the load on the side with a smaller sling angle because a greater force works on the sling wire rope (effective rope) on this side.

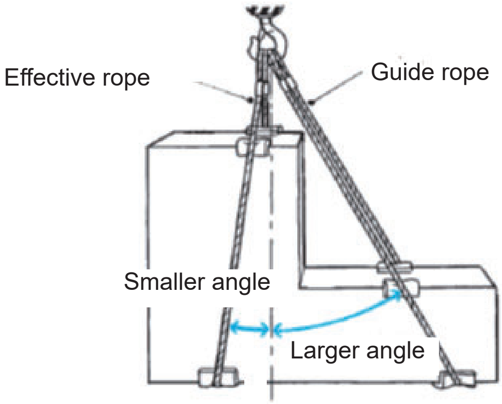


Fig. 5-21 Asymmetrical slinging

- Slinging adjusted with another hoisting accessory

To sling asymmetrical load, sling wire ropes can be adjusted with another hoisting accessory. Balance the asymmetrical load by adjusting the right and left wire rope length. Chain blocks or lever hoists are used for adjustment.

This method is an alternative to looping and asymmetrical slinging can be performed more safely, however, the load with higher COG position becomes unstable. When using two sling wire ropes fastened by eyes at the effective side, adjust the fastening direction and angle not to apply excessive bending force on wire ropes.

Fasten the eyes of the sling wire ropes on the upper and lower hooks, and adjust the supporting side not to apply the tension too much. When using lever hoists for adjustment, set the selector to the lifting side and wind the excessive chain to the body.

Set the sling angle as small as possible. (60 degrees in maximum)

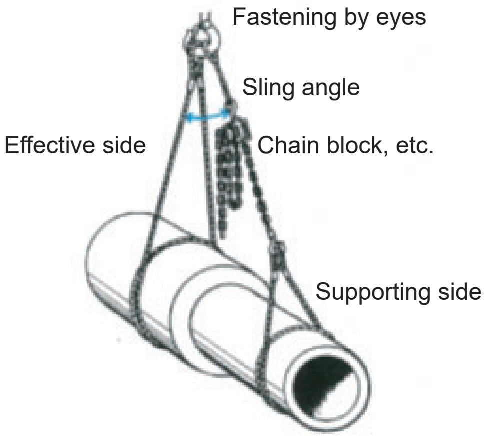


Fig. 5-22 Slinging adjusted with another hoisting accessory: Effective side: One-round-turn slinging

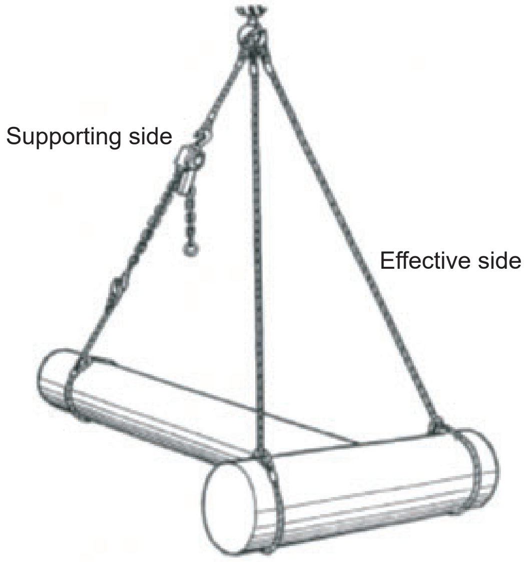


Fig. 5-23 Slinging adjusted with another hoisting accessory: Effective side: Fastening by eyes

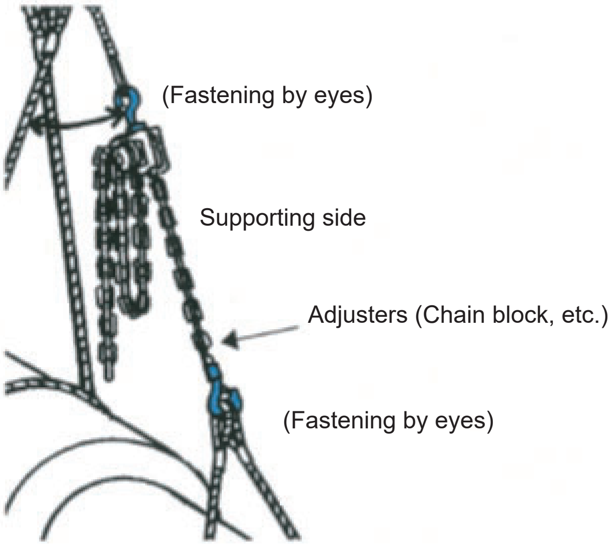


Fig. 5-24 How to Attach the Adjusters

Stop before lifting off the ground (p.161)

This is the most hazardous step in the conveyance work using the crane. Extra care should be taken for locations, postures and actions of workers and slinging conditions.

Inching up the load slowly until the sling wire ropes are taut. Your hands may be caught between the sling wire rope/pad and load. Do not hold the wire rope, but push it with your palm. When sling wire ropes are taut, stop lifting and check the following points. (See Fig. 5-31: p.101, Fig. 5-32: p.101.)

Location of Worker

- Have the signaling by hand in a safe location that is visible to the crane operator. (See Fig. 5-33: p.162.) Have the voice signaling by using the wireless devices in a safe location which has a clear view of the work.
- Signalers and slingers must communicate closely, do not make a decision for signaling on oneself. (See Fig. 5-34: p.162.)
- When performing sling work with 2 or more workers, be sure to communicate each other.
- The load may swing at the moment of lifting off. Singers and other workers must not enter the area such as narrow space between the structures where no place to evacuate is secured. (See Fig. 5-35: p.162.)
- If the load may swing at lifting off, give a signal to the operator.

Confirm Slinging Conditions

When sling wire ropes are taut, stop the crane and check the following points. If the slinging condition is not stable or the load cannot be lifted horizontally, lower it back to the ground and adjust the sling position. (See Fig. 5-36: p.162.)

- COG of the load, center of the hook, and hoisting wire rope of the crane are in a straight line.
- Sling wire ropes are taut evenly.
- No collapse of the load is observed.
- Sling wire ropes do not slip and sling accessories such as pads are installed securely.
- Sling gears are applied correctly at the center of the hook (positions and orders).
- Sling wire ropes do not move.
- Sling wire ropes are applied to the correct positions.
- Pads are applied securely.
- Eyebolts and shackles are installed correctly.

Stop after lifted off the ground (p.163)

Inching up the load slowly, stop once the load has been lifted off, and confirm its stability and the safety of the sling gear. (See Fig. 5-37: p.163.) (See Fig. 5-38: p.163.)

Confirm Slinging Conditions

- If the load is unstable, lower it back to the floor and adjust the sling position.
- The load is in stable condition.
- Nothing will fall while the load is being transported.
- Sling gears are installed correctly and the load and accessories are protected properly.
- Pads or other sling gears are not lifted together.

If no problem is found, the load is ready for lifting.

Lifting (p.164)

Check for obstacles before lifting. Slingers should evacuate to the safe area.

Set the applicable height of the load taking the slinging method and unloading area into account.

- Lift the load until a height where the workers can move safely (higher than the worker) and normally.
- When using a floor-operated crane, lifting magnet, or vacuum lifter, move the load to close area without obstacles, stop lifting as low position as possible.

Guiding the load to the unloading place (p.164)

When slingers or signalers are guiding along the load, have them in a safe location that is visible to the crane operator, and let other workers evacuate as necessary. (See Fig. 5-39: p.164.)

Location of Slingers

Slingers should evacuate to safe area where free from the danger of being jammed or hit by the load in case an unexpected accident occurs.

- Evacuate to the evacuation area that was decided in the prestart meeting.
- When walking along with the load while it is being conveyed, stay at least 2 meters away from the edge of the lifted load.

Guiding the load

- Use the fixed signals to indicate the direction to the crane operator, and give guidance while remaining ahead of the load until it reaches the unloading place.
- Indicate the unloading place to the crane operator.
  Check the following points during conveyance.
  - Do not enter under the load.

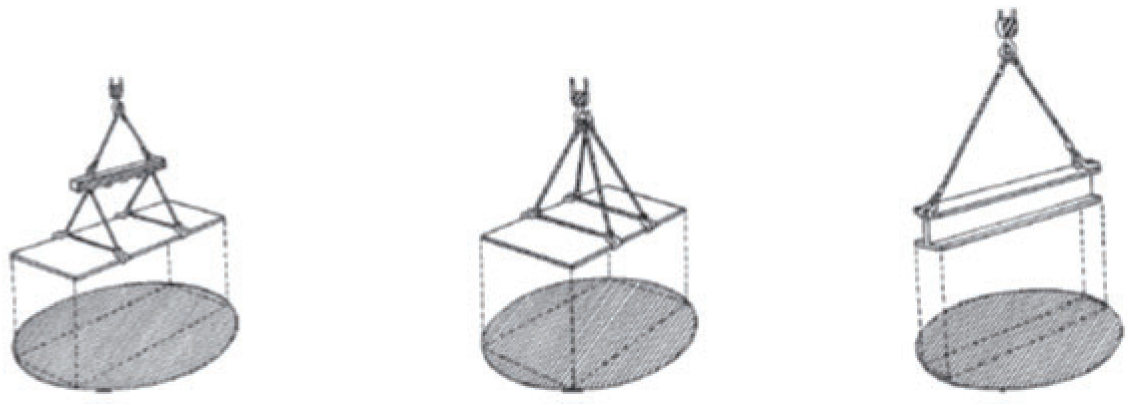


Fig. 5-25 Under the load

- Keep the safe distance from the load.
- Do not select the path of conveyance to pass over the other workers. Select the route as far as possible from workers.
- Never stay on the load.
- During the conveyance of load, do not hold the load with hands while swinging. The signalers should instruct to the crane operator to stop swinging. (In some job sites, touching the load with hands is prohibited from lifting off to grounding.)

Prevent the Load from Rotating

- If long objects swing or rotate during the work, they may hit the structures around. To prevent such accident from occurring, guide the load with guide ropes. Multiple guide ropes are used depending on the job site or the load.
- If the guide ropes are caught to the equipment around, it may cause accidents such as load collapse. Use the guide rope without eyes or notches. (See Fig. 5-44: p.166.)

Stop before lowering and grounding (p.166)

Check the unloading area and conditions of the bearer blocks (strength, levelness, bearing capacity), and prepare the applicable size and quantities of bearer blocks in advance. The bearer blocks are used to make slinging work easier. They are used not only to secure or protect the load, but also to protect the footing of the slingers. Prepare the bearer blocks higher than the safety shoes.

Make sure that there is no worker between the load and equipment or structures, and that the workers can evacuate in an emergency case. Furthermore, careful attention should be paid to the following precautions before lowering. (See Fig. 5-45: p.166.)

- Check for obstacles before lowering.
- Do not lower the load while swinging. Stop swinging according to the signals, and then lower it.
- If it is necessary to adjust the load position at the unloading area, be sure to stop the crane.
- Do not lower the load rapidly. Stop the load slightly above the bearer blocks, and check for the safety.
- Signalers and slingers must stay at the safe area. Do not step under the load to prepare bearer blocks or other work.
- Always place the load on the bearer blocks (not directly on the ground).

Stop after grounding (p.167)

After the load is grounded by inching down, stop the crane while the sling wire ropes are taut, check for the safety and inching down further. And then loosen the sling wire ropes within the range that the load stays in stable. Do not loosen the sling wire ropes too much. The accessories such as pads may fall off.

Check the following points after the load is grounded.

- The load is placed properly.
- The load is in a stable condition on the bearer blocks. (If not, place it again.)
- The sling wire ropes and pads are not caught under the load.
- The round load is fixed with the safeguard fully.
- No collapse of the steel bars or tied materials is observed.

Lifting the Hook, Removing the Sling Gears (p.168)

Check the load conditions, lower the hook to the position where the sling wire ropes can be removed, and then remove the sling wire ropes from the hook. Do not lower it more than necessary. For long objects and some other goods whose COG cannot be located easily, it is advisable that the COG position be marked on them to make the next stage of work easier to perform.

When removing the sling gears, be sure to study the safer and easier side (hook side or load side) to be removed.

- When removing the gears at the hook side, guide the hook to a place where removal can be performed easily.
- Thicker sling wire rope may move suddenly due to twisting. Check the twisting state of the rope and decide the working area. When removing the gears with 2 or more workers, be sure to communicate each other.
- Do not pull out the sling wire ropes with the crane as a general rule. If it is pulled out with the crane, it may hit the load or cause the load to collapse or fall.

End of Work, Store the Tools (p.169)

Never proceed to another work until the tools are stored in place. Store the tools for each operation.

- Remove the sling gear from the hooks and the load.
  Do not leave any sling gear attached to the hooks or the load.
- Lift the hook to a height of at least 2 meters.
- Give the finish signal to the operator.
- Keep the sling wire ropes straight and store them to the specified location.
- Store the sling gears and hoisting accessories to the specified location.

(Reference) How to Stow or Stack Loads

Another important task for stingers is to ensure that loads carried by crane or any other lifting equipment will be stowed or stacked properly. Stacking these goods improperly or stowing them in a disorderly manner may not only cause an accident but also result in significantly lower efficiency of work.

When stowing or stacking the loads, careful attention should be paid to the following precautions.

- Select suitable bearer blocks for each type of load and set them properly to support the toad stably, so the removal of the sling gear and the next stage of work can be done easily. Prepare the bearer blocks higher than the safety shoes not to get the footing caught.
- Be sure to stow or stack unloaded goods stably, so they will not fall or slip off the stack. When stacking goods, put lighter or smaller things on top of heavier or larger ones to keep the COG of the stack at the lowest level possible. Do not stack goods into too high a pile that may, if shaken or vibrated, readily topple down.
- Keep the repository of goods in order. Disorderly stacks of materials or finished products or the protrusion of some of them into passageways would hamper safe passing and make the whole place dangerous, resulting in lower efficiency of operation.
- When taking out a material or product from the lower layer of a stack, be sure to remove all things on it first. Never try to pull it out by force from under other things.
- Store tools, spare parts, attachments and accessories properly divided into those which are needed frequently and those which are used only now and then.

Chapter 6

Relevant Laws and Regulations

1 Industrial Safety and Health Law

Law No. 57 of June 8, 1972

(Issue of Inspection Certificate, etc.) p.180

Article 39

2. The Chief of the Labor Standards Office shall, as provided for by the Ordinance of the Ministry of Health, Labour and Welfare, issue the inspection certificate for the specified machines, etc., which have passed the inspection concerning the installation of the specified machines, etc., in that set forth in paragraph (3) of the preceding article.
3. The Chief of the Labor Standards Office shall, as provided for by the Ordinance of the Ministry of Health, Labour and Welfare, endorse the inspection certificate of the specified machines, etc., which have passed the inspection concerning the partial alteration or the resumption of the use of the specified machines, etc. in the inspection set forth in paragraph (3) of the preceding article.

(Restriction on Engagement) p.184

Article 61

In the case that one's industry comes under one of those defined by Cabinet Order, the employer shall conduct safety and/or health education on the following matters, as provided for by the Ordinance of the Ministry of Health, Labour and Welfare, for those who are newly charged as foremen or others to directly guide or supervise workers in operations (except operations chief):

1. Matters pertaining to the decision of the method of work and the assignment of workers
2. Matters pertaining to the method of guiding or supervising workers
3. In addition to the matters listed in preceding two items, matters necessary for preventing industrial accidents, as provided for by the Ordinance of the Ministry of Health, Labour and Welfare.

2 Enforcement Order of the Industrial Safety and Health Act

Amendment of Cabinet Order No. 13 of 2012

(Specified Machines, etc.) p.180

Article 12

1. Machines, etc. specified by the Cabinet Order set forth in paragraph (1) of Article 37 of the Act (excluding the case that they are clearly not for domestic use) shall be the machines, etc. listed below:
3. Cranes with a lifting capacity of 3 tons or more (for stacker cranes, 1 ton or more)

3 Safety Ordinance for Cranes

(Limitation on Overload) p.188

Article 23

The employer must not use a crane being loaded with the load exceeding its Rated Capacity.

2. Notwithstanding the provisions of the preceding paragraph, the employer may, in the case of having remarkable difficulty to conform to the provisions of the same paragraph due to the unavoidable reason and when taking the following measures, use the crane loaded over its Rated Capacity up to the load on the load test prescribed in paragraph (3) of Article 6:

(i) to submit in advance, a crane special case report (Form No. 10) to the Chief of the Competent Labour Standards Inspection Office,

(ii) to confirm in advance, that there is no abnormality by performing the load test prescribed in paragraph (3) of Article 6;

(iii) to designate a person who supervises the operation, and to operate the crane under the direct supervision by the said person.

(Limitation on Overload) p.188

Article 25

1. The employer must, when carrying out the work using a crane, set fixed signals for operation of the crane, designate a person who gives the said signals and have the said person give the said signals. However, this does not apply to when having only a crane operator carry out the work single-handedly.
2. The person designated pursuant to the preceding paragraph, when engaging in the work set forth in the same paragraph, must give the signals set forth in the same paragraph.
3. Workers engaging in the work set forth in paragraph (1) must follow the signals set forth in the same paragraph.

(Restriction on Riding) p. 188

Article 26

The employer must not carry workers by a crane, nor have workers work being hanged from the crane.

(Safety Coefficient of Chain Sling) p.194-195
Article 213-2

1. The employer must not use a chain as the slinging equipment for a crane, a Mobile Crane or a derrick, unless its safety coefficient is more than the value listed in the following items, based on the types of chain slings.

(i) a chain falling under all of the followings: 4:

a) in the case of pulling it with the force of the half of its breaking load, the elongation is 0.5 % or less; and

b) the value of the tensile strength is 400 N/mm^2 or more and its elongation is equal to or more than the value listed in the right column of the following table corresponding to the value of tensile strength listed in left column of the same table;

Tensile strength (N/mm^2)	Elongation (%)
400 or more and less than 630	20
630 or more and less than 1000	17
More than 1000	15

(ii) a chain not falling under the preceding item: 5.

2. The safety coefficient set forth in the preceding paragraph is the value obtained from dividing the breaking load of a chain sling by the value of the maximum load applied on the said chain sling.

(Safety Coefficient of Hook, etc.) p.195

Article 214

1. The employer must not use a hook or a shackle as slinging equipment for a crane, a Mobile Crane or a derrick, unless the safety coefficient is 5 or more.
2. The safety coefficient set forth in the preceding paragraph is the value obtained from dividing the breaking load of the hook or the shackle by the value of the maximum load applied on the said hook or the said shackle.

I. Knowledge of cranes

[Question 1] Which of the following is the correct definition of "crane"?

(1) Any mechanical device designed to lift loads by power and carry the lifted loads horizontally, other than mobile cranes and derricks

(2) A mechanical device designed to lift loads by power

(3) A mechanical device designed to lift loads manually by human power and carry the lifted loads horizontally

[Question 2] Which of the following is NOT included in the definition of "crane" in the Safety Ordinance for Cranes?

(1) Overhead traveling crane

(2) Wheel crane

(3) Bridge crane

[Question 3] Which of the following is NOT the correct definition of a technical term related to cranes?

(1) "Span" means the horizontal distance between the centers of the traveling rails.

(2) "Slewing" means motion other than the rotation of the jib or other similar component of the jib crane with its center of rotation as the axis.

(3) "Rated load" means the maximum load that can be hung on the crane's hook.

[Question 4] Which of the following correctly describes the span of an overhead traveling crane?

(1) The interval between the main girder beam and auxiliary girder beam.

(2) The horizontal distance between the centers of the traveling rails

(3) The horizontal distance between the centers of the traversing rails

[Question 5] Which of the following is NOT a correct description of the motions of a crane?

(1) "Slewing" means the rotation of the jib or other similar component of the jib crane horizontally around a particular axis of rotation.

(2) "Jib derricking" means moving the jib up and down with the end at the jib base as the axis of rotation, and "lifting or raising of the jib" refers to the motion of the jib in the direction that decreases the jib angle.

(3) In the case of an overhead traveling crane, "traveling" refers to the movement of the crane on its rail or runway.

[Question 6] Which of the following is NOT a correct description of the "traveling" motion of a crane?

(1) "Traveling" refers to the movement of the trolley on the main rope of a cable crane.

(2) "Traveling" refers to the movement of a wall crane along the wall surface.

(3) "Traveling" refers to the movement of a tower jib crane along the ground surface.

[Question 7] Which of the following is NOT a correct description of the motions of a crane?

(1) "Derricking" means moving the jib of a jib crane up and down with the end at the jib base as the axis of rotation.

(2) In the case of a bridge crane, "traversing" means moving the trolley along the girder.

(3) "Winding" means moving the lifted load along a circular path.

[Question 8] Which of the following types of cranes is mainly used for engineering works such as dam or bridge construction?

(1) Bridge crane

(2) Low-floor crane

(3) Cable crane

[Question 9] Which of the following is a device to prevent runaway of an outdoor crane when there is strong wind?

(1) Anchor
(2) Hydraulic buffer device
(3) Overload preventive device

[Question 10] Which of the following is NOT a correct description of the precautions for operating a crane?

(1) When a power outage occurs during operation, return the controller handle to the stop position, then turn off the main switch and wait.
(2) Do not pull the load sideways or lift it obliquely.
(3) Perform inspection and refueling while operating the crane, in order to improve the effectiveness and efficiency of crane operations.

[Question 11] Which of the following is NOT a correct description of the information related to load swing?

(1) The longer the wire rope, the shorter the period of the swing.
(2) The basic method for preventing swing is to accelerate or decelerate more gradually for heavier loads.
(3) The basic method for preventing swing is to perform operations based on the length of the wire rope (period of swing).

II. Dynamics necessary for performing slinging work with a crane

[Question 1] Which of the following are the three elements of force?

(1) Velocity, direction, and magnitude

(2) Direction, magnitude, and acting point

(3) Stress, direction, and magnitude

[Question 2] Which of the following is a correct description of when two applied forces counterbalance each other?

(1) When the two forces are applied along the same line in the same direction, with equal magnitude

(2) When the two forces are applied along the same line in opposite directions, with equal magnitude

(3) When the two forces are applied along different lines in opposite directions, with equal magnitude

[Question 3] Which of the following is NOT a correct description of the stability of an object that is placed on a level surface?

(1) The stability of an object varies depending on how it is positioned.

(2) When an object placed on a level surface is tilted slightly, the center of gravity moves down to a lower position.

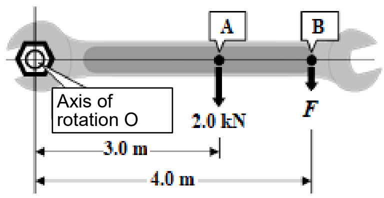
(3) Objects with a larger base area are more stable.

[Question 4] In the illustration below, which of the following is the force *F* of point B when the moment of force for point A is equal to that for point B?

(1) 1.5 kN

(2) 3.0 kN

(3) 4.5 kN



[Question 5] When an object is in circular motion, a force pulls the object outward from the center of the circle. Which of the following is the name of this force?

(1) Friction
(2) Centripetal force
(3) Centrifugal force

[Question 6] An object at rest tends to stay at rest and an object in motion tends to stay in motion, unless acted upon by an external force. What is this property called?

(1) Velocity
(2) Inertia
(3) Acceleration

[Question 7] Which of the following is the load that acts to cut the key that holds a gear shaft in place?

(1) Bending load
(2) Twisting load
(3) Shearing load

[Question 8] Which of the following is the type of load that has an invariable magnitude and direction of force, like the dead weight of the crane structure?

(1) Static load
(2) Dynamic Load
(3) Single-acting load

[Question 9] Which of the following is NOT a correct description of the main types of load that are applied to each part of the crane?

(1) Tensile load is applied to the winding drum.

(2) Compressive load is applied to the traversing rails.

(3) Bending load is applied to the girders.

[Question 10] If cargo is suddenly lifted off the ground, the load that is applied to the sling wire rope is much greater than the weight of the cargo, which can cause the sling wire rope to break. What is this type of load called?

(1) Compressive load

(2) Shearing load

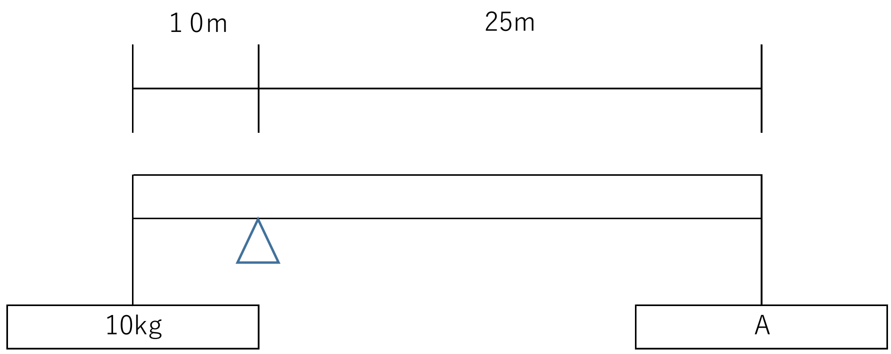
(3) Impact load

[Question 11] Which of the following is the weight A that is necessary to balance both sides of the pole shown in the illustration below? For this question, do not include the weight of the pole.

(1) 2.5 kg

(2) 4.0 kg

(3) 5.0 kg

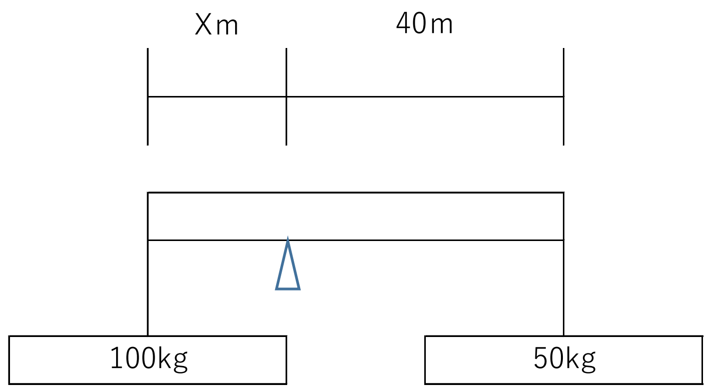


[Question 12] Which of the following is the length X that is necessary to balance both sides of the pole shown in the illustration below? For this question, do not include the weight of the pole.

(1) 10 m

(2) 20 m

(3) 30 m



III. Performing slinging work with a crane

[Question 1] Which of the following is a correct description of the information related to pulley blocks?

(1) A movable pulley is fixed at a specified place and is used to change the direction of the rope.

(2) When using a movable pulley to lift a load, the length of rope that is pulled is shorter than the height to which the load is lifted.

(3) A heavy load can be lifted with less force by using a movable pulley.

[Question 2] Which of the following is NOT a correct description of the criteria for prohibiting the use of a belt sling?

(1) Do not use a belt sling if an end loop is cut or damaged.

(2) Do not use a belt sling if a clasp is cracked or bent.

(3) It is OK to use a belt sling if it discolored or melted due to heat or chemicals.

[Question 3] Which of the following is NOT a correct description of the information related to checking the sling state?

(1) It is OK to lift bearer blocks along with the load.

(2) If the load is unstable, lower it back to the floor and adjust the sling position.

(3) Make sure that nothing will fall while the load is being transported.

[Question 4] Which of the following is NOT a correct description of the eye splicing that is applied at the ends of a sling wire rope?

(1) Although "makisashi" (winding insertion) is easier to perform than "kagosashi" (split insertion), extra care is required because the splice may come unwound if the wire rope rotates when the load is lifted.

(2) Eye splicing is performed by hand, so the strength may vary depending on the splicing skill level.

(3) When "kagosashi" (split insertion) is used, the wire rope can be used for slinging, even if it was processed for use as an anchoring wire rope.

[Question 5] Which of the following is NOT a correct description of the information related to guiding the load to the unloading place?

(1) When walking along with the load while it is being conveyed, stay at least 1 meter away from the edge of the lifted load.

(2) Evacuate to the evacuation area that was decided in the prestart meeting.

(3) Use the fixed signals to indicate the direction to the crane operator, and give guidance while remaining ahead of the load until it reaches the unloading place.

[Question 6] Which of the following is NOT a correct description of the information related to tasks performed after the slinging work is complete?

(1) Remove the sling gear from the hooks and the load. Do not leave any sling gear attached to the hooks or the load.

(2) Lift the hook to a height of at least 1 meter.

(3) Give the finish signal to the operator.

[Question 7] Which of the following is NOT a correct description of the clothing for slinging work?

(1) Wear a hard hat and secure the chin straps properly.

(2) To prevent the risk of falling when working in high places, wear fall protection equipment (safety belt).

(3) Wear short sleeves and short pants that are suitable for the type of work that is performed.

[Question 8] Which of the following is NOT a correct description related to the safe use of load chains?

(1) Use a load chain for slinging only if the working load is clearly understood.

(2) Do not drop the chain from a high place.

(3) Use a chain if it is twisted.

[Question 9] Which of the following is NOT a correct description related to the safe use of wire ropes?

(1) Use wire ropes at the proper sling angle, and ensure that the safety factor is at least 6.
(2) Wire ropes can be used with high-temperature loads.
(3) Do not use a wire rope if there are any kinks or other abnormalities.

[Question 10] Which of the following is NOT a correct description of the information related to estimating the weight of a load?

(1) Carefully consider the shape, and estimate the dimensions.
(2) If you do not know the weight of a load, ask the person responsible for the slinging work.
(3) Select sling gear that is suitable for a weight that is less than the actual weight of the load.

[Question 11] Which of the following is NOT a correct description of the information related to lifting clamps?

(1) Use vertical clamps for lifting vertically-oriented loads, and use horizontal clamps for lifting horizontally-oriented loads.
(2) Take care to prevent impact load from being applied to the cargo or clamps.
(3) It is OK to use clamps when lifting stacks of two or more items, or when lifting pads.

[Question 12] Which of the following is NOT a correct description of the information related to belt slings?

(1) The crane operator must not leave the operating position while the load is lifted.
(2) When a choke hitch is used, the belt sling squeezes tightly on the load as it is lifted.
(3) It is OK to use a belt sling that is wet with water or oil.

[Question 13] Which of the following is NOT a correct description of the information related to using hackers for slinging work?

(1) Select hackers that are appropriate for the shape, weight, and thickness of the load.

(2) It is OK to use hackers when lifting stacked items with different dimensions.

(3) When using hackers, ensure that the sling angle is 60 degrees or less, and that the angle between adjacent slings is 30 degrees or less.

[Question 14] Which of the following is NOT a correct description of the information related to the signals for slinging?

(1) Have two people give the signals to ensure that the crane operator can see them well.

(2) Have the signaler work in a safe location that is visible to the crane operator, and which has a clear view of the work.

(3) Always lift the load in a straight line. Make sure that the load will not be lifted obliquely, and then give the signal.

[Question 15] Which of the following describes the basic procedures for slinging work in the correct order?

(1) Decide the slinging method → Check the center of gravity of the load → Check the weight of the load → Check the rated load

(2) Check the rated load → Check the center of gravity of the load → Decide the slinging method → Check the weight of the load

(3) Check the rated load → Check the weight of the load → Check the center of gravity of the load → Decide the slinging method

IV. Relevant laws and regulations

[Question 1] Which of the following people is permitted to perform slinging work when using a floor-operated crane with a lifting load of 5 t or more?

(1) Person who completed the skill training course for floor-operated cranes

(2) Person who completed the special education course related to slinging work

(3) Person who completed the skill training course in slinging work

[Question 2] Which of the following is NOT stipulated in the regulations as a condition for prohibiting workers from entering the space under the lifted load?

(1) When lowering the load or sling gear by using a method other than power lowering

(2) When lifting the load by using a magnetic lifter or vacuum lifter

(3) When lifting a load that has been slung with a wire rope in two places

[Question 3] According to the regulations on prohibiting the use of inadequate wire rope, which of the following is the percentage of nominal diameter decrease that must not be exceeded?

(1) 5%

(2) 6%

(3) 7%

[Question 4] According to the regulations on prohibiting the use of inadequate wire rope, which of the following is a type of sling wire rope that can be used?

(1) A wire rope with 9% or less of its element wires (excluding filler wires) that have been cut within one twist

(2) A kinked wire rope

(3) A wire rope with remarkable deformation or corrosion

[Question 5] Which of the following is the period of time that self-inspection records must be kept, as stipulated in the Safety Ordinance for Cranes?
(1) For 1 year
(2) For 2 years
(3) For 3 years

[Question 6] Which of the following is the validity term of a crane inspection certificate?
(1) 6 months
(2) 1 year
(3) 2 years

[Question 7] Which of the following is NOT a correct description of the laws and regulations for cranes?
(1) Operation signals must be performed by a slinging assistant.
(2) The crane must not be used to transport or lift workers.
(3) The crane operator must not leave the operating position while the load is lifted.

[Question 8] Which of the following is NOT a correct description of the crane operations when there is a storm or strong wind?
(1) It is OK for the employer to perform crane operations when there is a storm.
(2) The employer must take measures such as setting devices that prevent runaway, if the crane is expected to be exposed to wind with an instantaneous wind velocity exceeding 30 m/s.
(3) The employer must suspend work related to cranes when there is a forecast of strong wind that may pose a danger to the work.

[Question 9] Which of the following is the correct period for checking the sling wire rope for problems?
(1) Every day in the prestart inspection
(2) Once a week in the periodical inspections
(3) Once a month in the periodical inspections

[Question 10] Which of the following is the correct safety factor for sling wire ropes, as stipulated in the Safety Ordinance for Cranes?

(1) 4 or more

(2) 5 or more

(3) 6 or more

[Question 11] Which of the following is the correct safety factor for load chains, as stipulated in the Safety Ordinance for Cranes?

(1) 1 or more

(2) 4 or more, or 3 or more when certain conditions are met

(3) 5 or more, or 4 or more when certain conditions are met

[Question 12] Which of the following is the correct safety factor for sling hooks and shackles, as stipulated in the Safety Ordinance for Cranes?

(1) 3 or more

(2) 4 or more

(3) 5 or more

Answers

I. Knowledge of cranes (11 questions)

[Q1] (1), [Q2] (2), [Q3] (2), [Q4] (2), [Q5] (2),
[Q6] (1), [Q7] (3), [Q8] (3), [Q9] (1), [Q10] (3),
[Q11] (1)

II. Dynamics necessary for performing slinging work with a crane (12 questions)

[Q1] (2), [Q2] (2), [Q3] (2), [Q4] (1), [Q5] (3),
[Q6] (2), [Q7] (3), [Q8] (1), [Q9] (1), [Q10] (3),
[Q11] (2), [Q12] (2)

III. Performing slinging work with a crane (15 questions)

[Q1] (3), [Q2] (3), [Q3] (1), [Q4] (3), [Q5] (1),
[Q6] (2), [Q7] (3), [Q8] (3), [Q9] (2), [Q10] (3),
[Q11] (3), [Q12] (3), [Q13] (2), [Q14] (1), [Q15] (3)

IV. Relevant laws and regulations (12 questions)

[Q1] (3), [Q2] (3), [Q3] (3), [Q4] (1), [Q5] (3),
[Q6] (3), [Q7] (1), [Q8] (1), [Q9] (1), [Q10] (3),
[Q11] (3), [Q12] (3)