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Building construction machinery and equipment — Concrete pumps —

Part 2:
Procedure for examination of technical parameters

Machines et matériels pour la construction des bâtiments — Pompes à béton —

Partie 2: Procédure pour la détermination des paramètres techniques

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 195, *Building construction machinery and equipment*, Subcommittee SC 1, *Machinery and equipment for concrete work*.

This second edition cancels and replaces the first edition (ISO 21573-2:2008), which has been technically revised.

The main changes compared to the previous edition are as follows:

— added the actual pumping output and efficiency measurement under defined working conditions (e.g. concrete grade and pumping speed) in order to describe the actual pumping performance;

— added the following characteristic parameters measuring methods:

  — operating mass;

  — overall dimensions including length (L), width (W) and height (H);

  — delivery pressure of pump for driving the distributing and outriggers;

  — maximum load on each outrigger;

  — outrigger speed;

— complemented performance measuring methods and indicated conditions in the following clauses/subclauses:

  — concrete delivery pressure;

  — feeding height of hopper;

  — length, height and angle of the boom;

  — speed of the concrete-placing boom;

— slewing speed;

— slewing angle;

— span of outrigger.

A list of all parts in the ISO 21573 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Building construction machinery and equipment — Concrete pumps —

Part 2: Procedure for examination of technical parameters

1 Scope

This document specifies the procedure and requirements for examining the technical commercial specifications of factory new piston-type concrete pump and rotary-type concrete pump as defined in ISO 21573-1.

It applies to mobile concrete pumps (with or without concrete-placing boom) and stationary concrete pumps.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 21573-1, *Building construction machinery and equipment — Concrete pumps — Part 1: Terminology and commercial specifications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 21573-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
single-roller rotary pump
rotary-type concrete pump that discharges fresh concrete by squeezing an elastic tube by one rotating roller

3.2
double-roller rotary pump
rotary-type concrete pump that discharges fresh concrete by squeezing an elastic tube between double rotating rollers

3.3
concrete storage, mixing and feeding device
device for agitating and discharging concrete or mortar

3.4
outrigger span
actual distance between adjacent centrelines of vertical cylinders with outriggers fully extended or projection distance of the actual distance on the reference plane

4 Test items of performances

The following performances are measured or tested in this examination:

a) overall parameters;

b) pumping performance;

c) feeding height of hopper;

d) performance of the water pump;

e) performance of the concrete-placing boom;

f) performance of the outrigger.

5 Overall parameters

5.1 Operating mass

5.1.1 Measuring conditions

Measure the mass of the concrete pump under the following conditions:

— with the pump fully operational and all systems functional;

— including all standard equipment following the manufacturer's specifications;

— with a driver of mass 75 kg;

— with the fuel tank full;

— with cleaning water, cooling, lubrication and hydraulic systems full;

— with the vehicle parked steadily, the engine switched off, the gearbox shifted to neutral gear, and the brake released.

— with the weighing of the machine which should be done with the brakes of the truck released, for safety reasons, apply wheel stoppers on 2 wheels at least.

5.1.2 Measuring apparatus and accuracy requirement

Truck scale should be used as the measuring apparatus with an accuracy of 0,5 %.

5.1.3 Measuring procedure

5.1.3.1 Measuring method

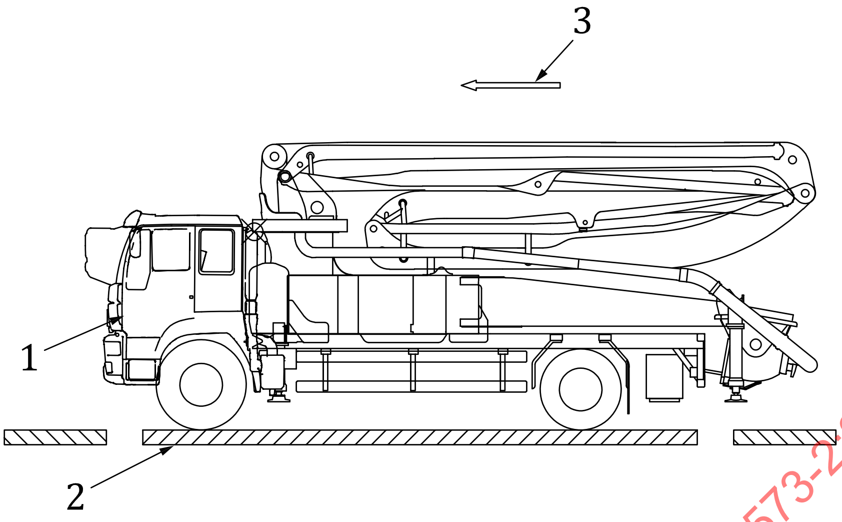
The weighing platform of the scale shall be big enough to accommodate all points of support of the machinery at one time.

The entry ground of the weighing platform shall be kept at the same level with the weighing platform.

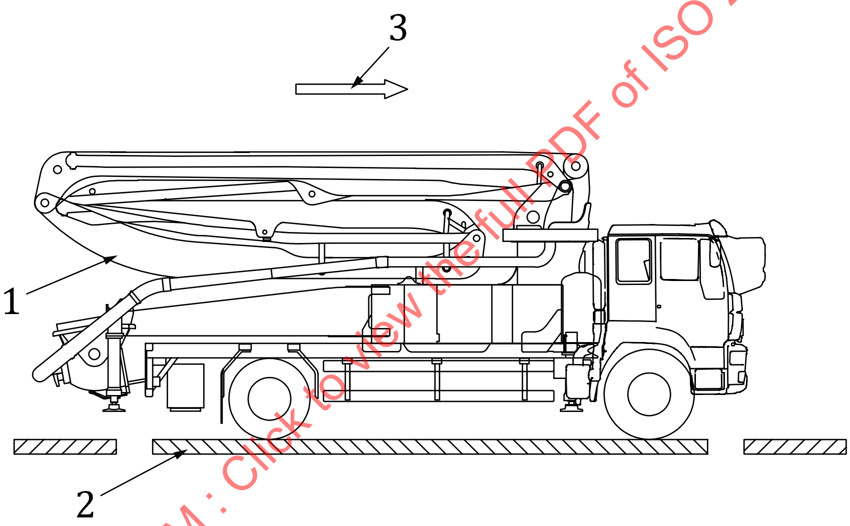
Measure the operating mass as shown in Figure 1.

a) Drive the concrete pump at low speed from one direction into the weighing platform, stop it steadily, and measure the mass $G_0^{'}$ of the concrete pump.

b) Make a turnaround, drive it onto the weighing platform from the opposite direction, stop it steadily, and measure the mass $G_0^{''}$ of the concrete pump again.



a) The first mass measurement



b) The second mass measurement

Key

1 concrete pump

2 weighing platform

3 driving direction

Figure 1 — Diagram for mass measuring of concrete pump

5.1.3.2 Calculation method

Calculate the mass of the concrete pump using Formula (1):

$$G_0 = \frac{G'_0 + G''_0}{2} - (G_1 - 75) \quad (1)$$

where

G_0 is the mass of the concrete pump (kg);

$G_0^{'}$, $G_0^{''}$ is the mass of the concrete pump measured by driving it onto the weighing platform from two directions respectively (kg);

G_1 is the actual driver weight (kg).

Record the measurement results in Table 1.

Table 1 — Measurement record — Mass of the concrete pump

Date of measuring			Place		
Model of concrete pump			Serial number		
Apparatus	Truck scale				Remarks
Characteristics	Parameter	Measured data	Parameter	Calculated value	
Operating mass	$G_0^{'}$		G_0		
	$G_0^{''}$				
	G_1				

5.2 Overall dimensions

5.2.1 Conditions for taking measurements

Measure the overall dimensions of the concrete pump under the following conditions:

- on the rigid and horizontal ground;
- under non-working state (with the concrete-placing boom folded and the outriggers retracted);
- with the wheels straight forward;
- with the tire pressure required;
- with the doors of the driver cab and hood, base-frame panels and hopper cover closed;
- with the radio antenna retracted;
- not including the license plate, but including the bracket of the license plate.

5.2.2 Measuring apparatus and accuracy requirement

Use a tape measure or comparable apparatus with an accuracy of ±1 mm.

5.2.3 Measuring procedure

5.2.3.1 General

The measurement shall be taken between impenetrable, horizontal or vertical, theoretical planes. Measure the overall length, overall width, overall height and wheelbase of several typical types of the concrete pump as shown in Figure 3, Figure 4 and Figure 5. Record the measured values in Table 2, Table 3 and Table 4.

a) Place the machine on a horizontal area. The machine shall be put into the transport or travel mode as specified by the manufacturer.

b) The machine shall be placed between two virtual impenetrable planes. Move the virtual planes as close together as possible without penetrating them. No elements of the machine other than the specified exemptions are allowed to penetrate the virtual plane. The planes are defined in Figure 2.

c) The measurement taken is the distance between the two parallel planes.

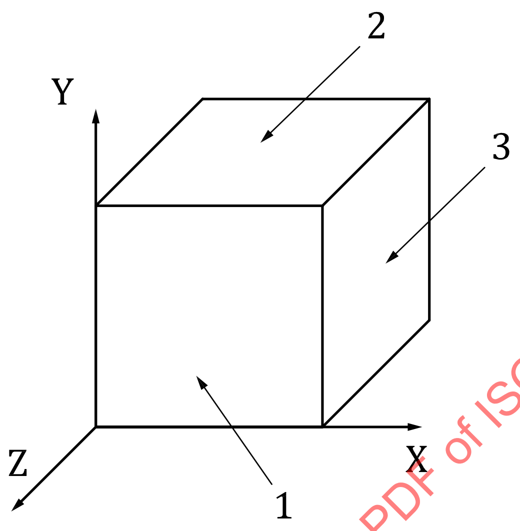


Figure 2 — Planes definition

Key

X X-axi
Z Z-axis
Y Y-axis
1 XY plane
2 parallel to XZ plane
3 parallel to YZ plane

5.2.3.2 Overall length

a) Determine the closest XY plane to the front and rear of the machine.

b) The measurement taken is the distance between the two parallel planes.

c) Record the value as the overall length *L* (mm) of the machine.

5.2.3.3 Overall width

a) Determine the closest YZ plane to the left and right of the machine, excluding the following protrusion parts: the rear-view mirrors, side indicator light and flexible mudguards.

b) The measurement taken is the distance between the two parallel planes.

c) Record the value as the overall width *W* (mm) of the machine.

5.2.3.4 Overall height

a) Determine the closest XZ plane to the top of the machine and ground.

b) The measurement taken is the distance between the two parallel planes.

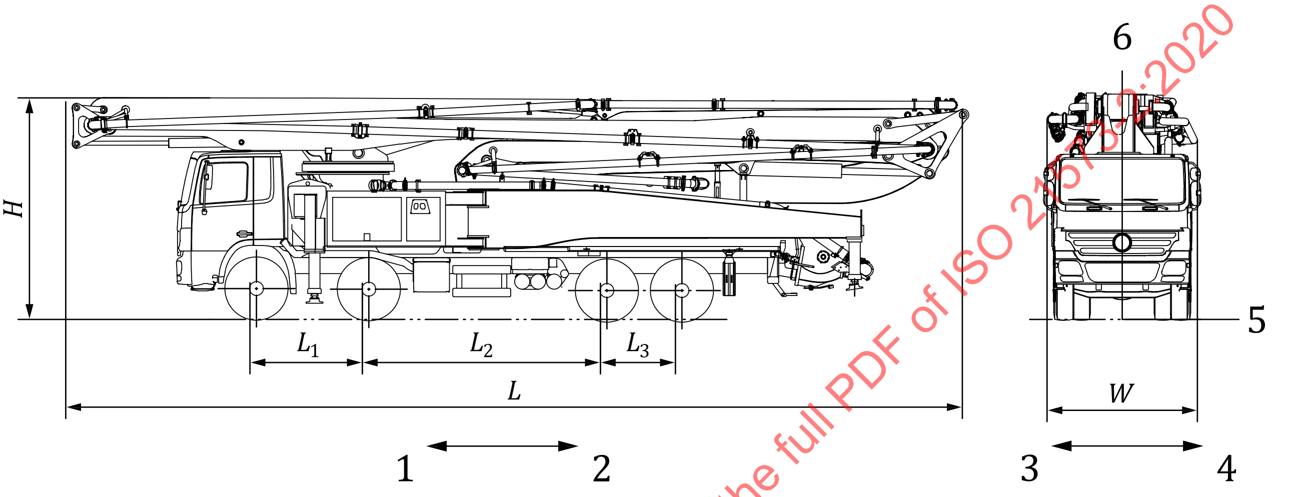
c) Record the value as the overall height *H* (mm) of the machine.

5.2.3.5 Wheelbase

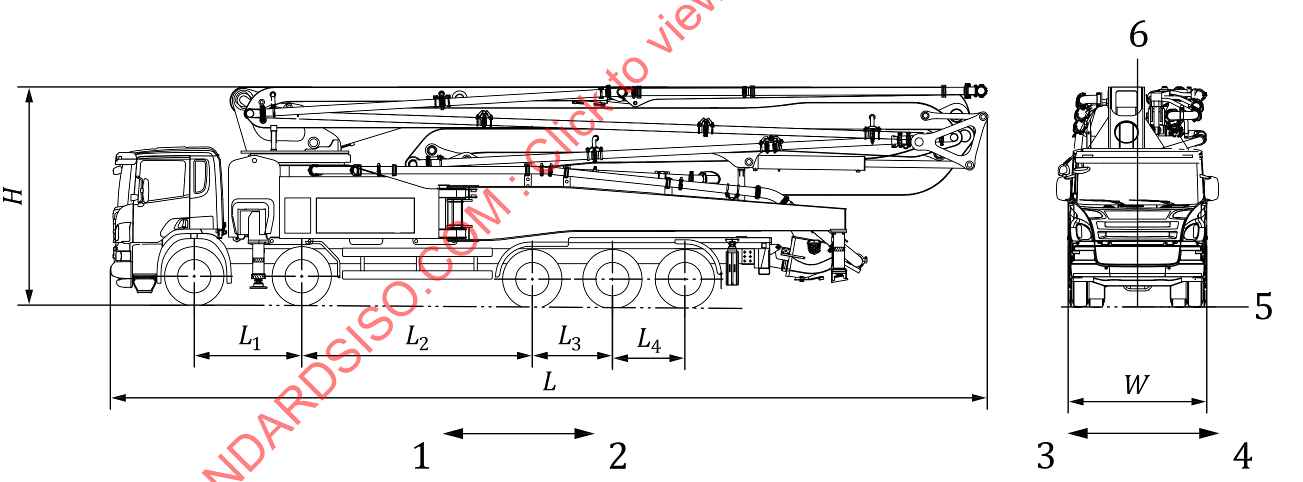
a) Determine the XY plane passing through the centrelines of two adjacent axles. Measure the distance between two planes.

For XY plane passing through the centrelines, place marks on the ground for convenience of measuring.

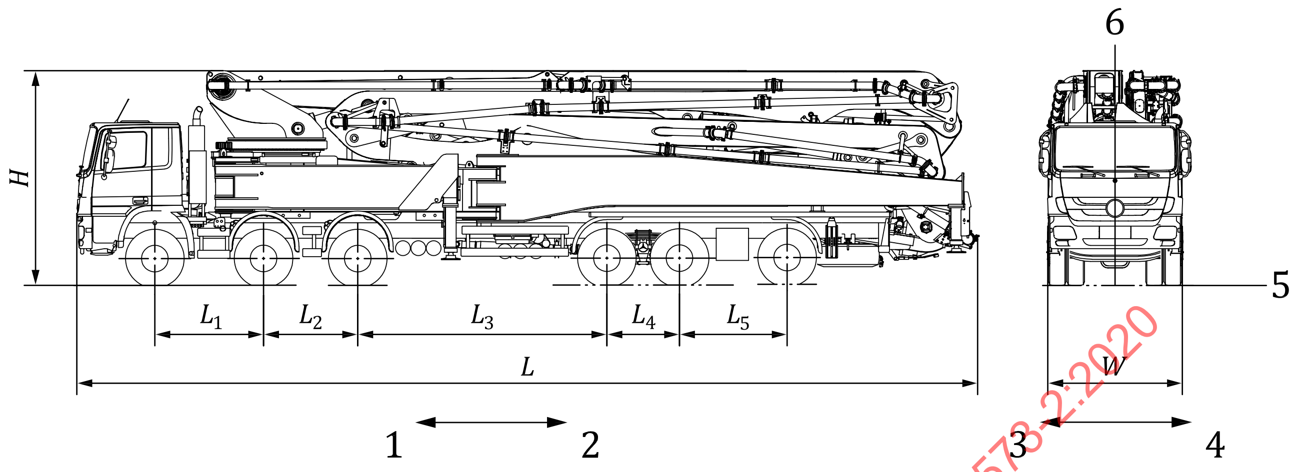
b) Record the values as individual wheelbase L_1, L_2, L_3, L_4, L_5 (mm) of the machine.



a) 4-axis chassis



b) 5-axis chassis

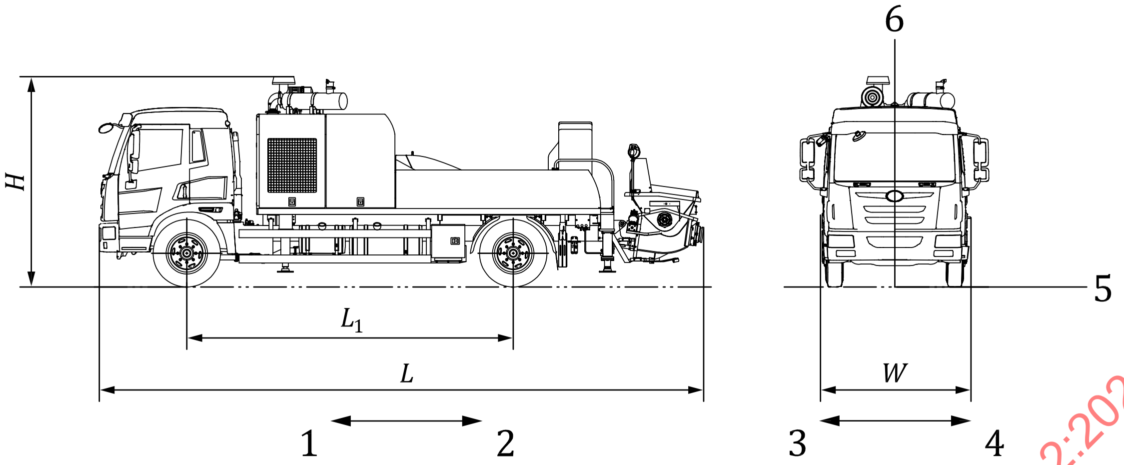


c) 6-axis chassis

Key

L	overall length of machine	1	front
W	overall width of machine	2	rear
H	overall height of machine	3	right
L_1	wheelbase between 1st and 2nd axles	4	left
L_2	wheelbase between 2nd and 3rd axle	5	plane XZ
L_3	wheelbase between 3rd and 4th axles	6	plane YZ
L_4	wheelbase between 4th and 5th axles		
L_5	wheelbase between 5th and 6th axles		

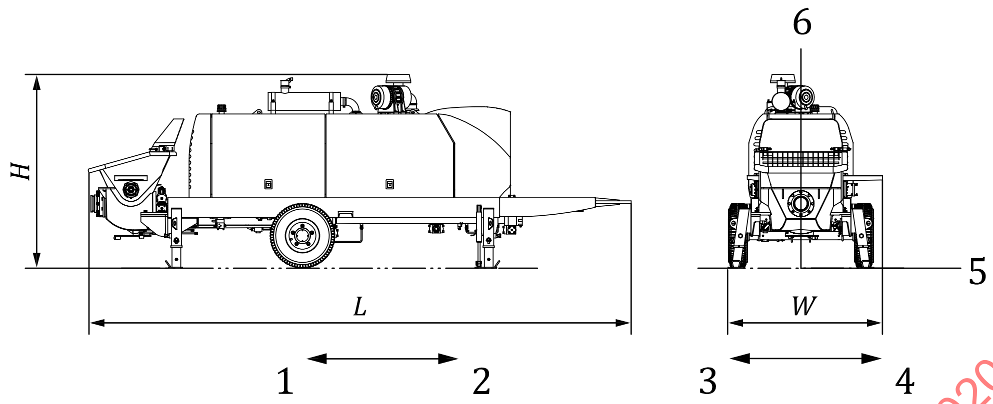
Figure 3 — Overall dimensions of the truck mounted concrete pump with concrete-placing boom



Key

L	overall length of machine
W	overall width of machine
H	overall height of machine
L_1	wheelbase between 1st and 2nd axles
1	front
2	rear
3	right
4	left
5	plane XZ
6	plane YZ

Figure 4 — Overall dimensions of the truck-mounted concrete pump for connection of a conveying pipeline



Key

L overall length of machine
W overall width of machine
H overall height of machine
1 front
2 rear
3 right
4 left
5 plane XZ
6 plane YZ

Figure 5 — Overall dimensions of the trailer-type concrete pump

Table 2 — Measurement record — Overall dimensions of the truck mounted concrete pump

Date of measuring			Place		
Model of concrete pump			Serial number		
Characteristics		Measured data		Unit	Remarks
Overall dimensions	Overall length, *L*			mm	
	Overall width, *W*			mm	
	Overall height, *H*			mm	
	L_1 - Wheelbase between 1st and 2nd axles			mm	
	L_2 – Wheelbase between 2nd and 3rd axles			mm	
	L_3 – Wheelbase between 3rd and 4th axles			mm	
	L_4 – Wheelbase between 4th and 5th axles			mm	
	L_5 – Wheelbase between 5th and 6th axles			mm	

Table 3 — Measurement record — Overall dimensions of the truck-mounted concrete pump for connection of a conveying pipeline

Date of measuring		Place	
Model of concrete pump		Serial number	

Table 3 *(continued)*

Characteristics		Measured data	Unit	Remarks
Overall dimensions	Overall length, L		mm	
	Overall width, W		mm	
	Overall height, H		mm	
	Wheelbase, L_1		mm	

Table 4 — Measurement record — Overall dimensions of the trailer-type concrete pump

Date of measuring			Place	
Model of concrete pump			Serial number	
Characteristics		**Measured data**	**Unit**	**Remarks**
Overall dimensions	Overall length, L		mm	
	Overall width, W		mm	
	Overall height, H		mm	

6 Pumping performance

6.1 Piston pump

6.1.1 Pumping output

6.1.1.1 General

The volumetric output of the concrete pump is indicated by the theoretical pumping output.

Calculate the theoretical pumping output using Formula (2).

$$Q_{th} = \pi \times D^2 / 4 \times S_t \times n \times 6 \times 10^{-8} \quad (2)$$

where

Q_{th} is the theoretical output volume (m^3/h);

D is the diameter of concrete cylinder (mm);

S_t is the stroke length of concrete piston (mm);

n is the number of strokes per minute (min^{-1}), accounting for acceleration and deceleration phases and the time of shifting of the valve system.

The actual pumping output is related to the volumetric efficiency η_v and the measuring method is defined in 6.1.1.2 to 6.1.1.5.

6.1.1.2 Measuring conditions

Measure the actual pumping output of the concrete pump under the following conditions:

— on the solid and level ground which meets the requirements for pumping and vehicle trafficability;

— with no rain or snow;

— with a temperature at 0 °C to 40 °C.

6.1.1.3 Measuring apparatus and accuracy requirement

The apparatus shall be as follows:

a) stopwatch with an accuracy of 0,1 %;

b) electronic scale with an accuracy of ±0,5 g with the range of 5 kg to 20 kg;

c) weighing sensor with an accuracy of 1 % with the range of ≥1 500 kg;

d) concrete weighing device which shall be able to accommodate at least 10 pump cycles;

e) concrete storage, mixing and feeding device;

f) concrete delivery pipeline;

g) equipment for recycling of concrete.

6.1.1.4 Measuring preparations

a) Adopt the concrete with slump at 18 cm to 21 cm. An example of recommended ratio is listed in Table 5.

Table 5 — Measurement report — Example of concrete ratio

Material name	Material requirement	Material quantity per m^3 concrete (kg/m^3)
Cement	General Portland cement 42.5R	330
Water	Tap water	166
Sand	Natural sand (not less than 80 % mass percentage of fine aggregates <2,5 mm)	900
Aggregate	Fine aggregate(sand): 5 mm to 20 mm Coarse aggregate(gravel): 20 mm to 40 mm	1 080
Admixture	Coal ash	80
Additive	Water reducer	6

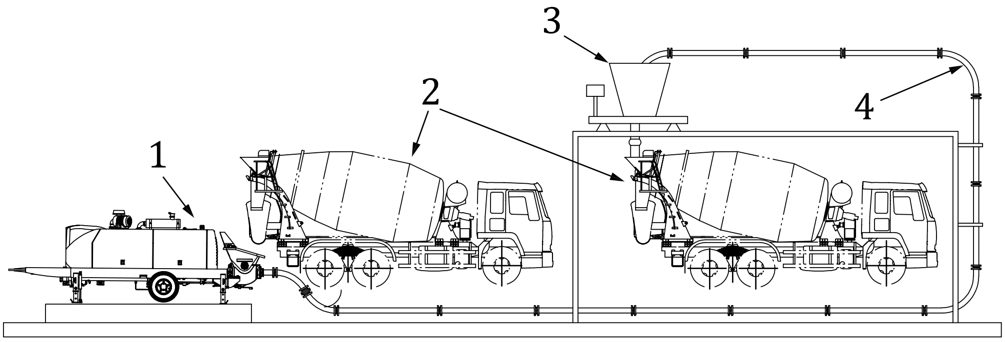
b) Set up the measuring system as shown in Figure 6.

— Extend the outriggers of the concrete pump till reaching the working state; the hopper of concrete pump is located under the discharge hopper of the concrete storage, mixing and feeding device.

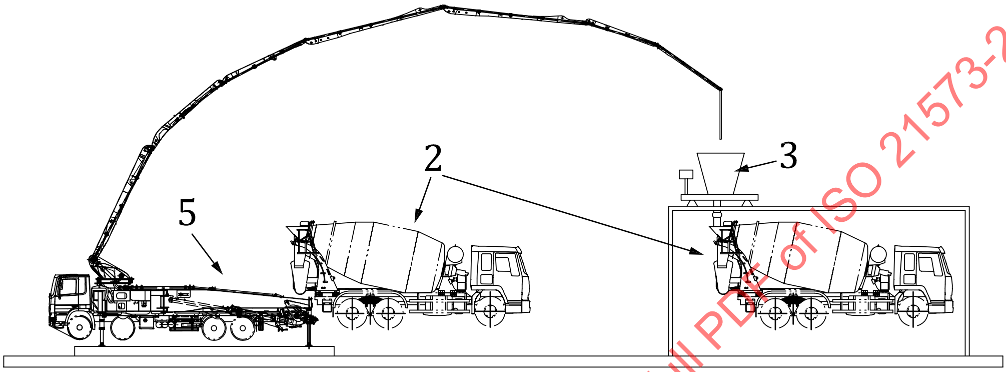
— For the concrete pump without concrete-placing boom, connect its outlet port with the concrete pipeline and place the other end of the pipeline delivery system above the weighing hopper of the weighing device, as shown in Figure 6 a). The pipeline delivery system shall be 52,5 m in horizontal distance, 7 m in vertical height, and 125 mm in inside diameter. The pipeline dimensions are listed in Table 6.

— For the concrete pump with concrete-placing boom, fully unfold the concrete-placing boom to arched configuration and place the end hose above the weighing hopper of the weighing device, 7 m in vertical height, as shown in Figure 6 b).

NOTE 1 Concrete storage, mixing and feeding device shown in the Figure 6 is demonstrated by a truck mixer and a similar agitating equipment can also be used.



a) Concrete pump without concrete-placing boom



b) Concrete pump with concrete-placing boom

Key

1 concrete pump without concrete-placing boom
2 concrete storage, mixing and feeding device
3 weighing device
4 pipeline delivery system
5 concrete pump with concrete-placing boom

Figure 6 — Actual pumping output measuring system

Table 6 — Measurement report — Delivery pipeline dimensions

Type	Nominal inner diameter (mm)	Parameter (mm)	Quantity	Remarks
Straight pipe	125	3 000 (Length)	10	
Straight pipe	125	2 000 (Length)	8	
Straight pipe	125	1 000 (Length)	6	
90° elbow pipe	125	R500 (Radius)	10	
Reducer	125	1 000	1	The connection type depends on the type of outlet port of concrete pump

NOTE 2 The type, diameter, parameter and quantity listed in Table 6 are only examples, which can be adjusted according to the measuring environment.

c) Start with the pumping mortar in order to wet the concrete pipeline fully. Then continue pumping until the mortar is discharged completely.

d) Feed the material for delivery into the concrete storage, mixing and feeding device equipment and agitate the equipment uniformly.

e) Take one concrete specimen used for the measuring concrete pump, measure the density of concrete for 3 times, take the mean value, and record the value in Table 7.

f) Check and calibrate the measuring equipment to ensure that the performance and deviation meet the accuracy requirements defined in 6.1.1.3.

6.1.1.5 Measuring procedure

6.1.1.5.1 Measuring method

a) The concrete storage, mixing and feeding device starts rotating forward and feeds concrete into the hopper of measuring concrete pump.

b) After the hopper is nearly full of concrete, the measuring concrete pump starts pumping and delivers concrete of pipeline into the weighing device.

c) After the weighing device is nearly full of concrete, the concrete storage, mixing and feeding device stops discharging concrete and at the same time the concrete pump stops pumping, but the hopper and delivery pipeline of the measuring concrete pump are still full of concrete.

d) The concrete storage, mixing and feeding device equipment starts rotating reversely; open the discharging gate of weighing device, discharge all concrete in the weighing device to the concrete storage, mixing and feeding device, close the discharging gate of the weighing device; the concrete storage, mixing and feeding device rotates reversely for 3 min in order to keep measuring the concrete uniformity;

e) Before starting pumping again, record the initial weight data of the weighing device in Table 7.

f) Set displacement and start pumping (for a variable displacement pump measure the 20 %, 40 %, 60 %, 80 % and 100% pumping outputs respectively; for a constant displacement pump measure the 100 % pumping output). At the same time, the concrete storage, mixing and feeding device starts rotating forward; start the stopwatch.

g) After a minimum of 10 pump cycles or revolutions, stop pumping. At the same time, the concrete storage, mixing and feeding device stops rotating forward; stop the stopwatch, record the pumping time this time, and record the value in Table 7.

h) After weighing, record the measuring weight this time, and record the value in Table 7.

i) The concrete storage, mixing and feeding device starts rotating reversely; open the discharging gate of weighing device, discharge all concrete in the weighing device to the concrete storage, mixing and feeding device, close the discharging gate of weighing device; the concrete storage, mixing and feeding device rotates reversely for 3 min in order to keep measuring the concrete uniformity,

j) Repeat step e) to i) and under each pumping condition measure for 3 times continuously.

6.1.1.5.2 Calculation method

a) Calculate actual pumping output using Formula (3):

$$Q_a = \frac{G}{\rho \times t} \times 60 \qquad (3)$$

where

Q_a is actual pumping output (m^3/h);

G is concrete weight (kg);

ρ is concrete density (kg/m^3);

t is pumping time (min).

b) Record the actual pumping output measuring results in Table 7 and calculate the mean value of measuring results for three times under each pumping condition as the actual pumping output of the concrete pump under this pumping condition.

c) Calculate the volumetric efficiency using Formula (4):

$$\eta_v = \frac{Q_a}{Q_{th}} \times 100\% \quad (4)$$

where

η_v is volumetric efficiency;

Q_a is actual pumping output under each pumping condition (m^3/h);

Q_{th} is theoretic output volume (m^3/h).

Table 7 — Measurement report — Actual pumping output

Date of measure					Place			
Model of concrete pump					Serial number			
Pumping displacement		Measure time, t (min)	Weight of weighing device (kg)		Concrete weight, G (kg)	Concrete density, ρ (kg/m^3)	Actual pumping volume, Q_a (m^3/h)	
			Before pumping	After pumping			Each measured data	Mean value
20 %	1							
	2							
	3							
40 %	1							
	2							
	3							
60 %	1							
	2							
	3							
80 %	1							
	2							
	3							
100 %	1							
	2							
	3							

6.1.2 Concrete delivery pressure

6.1.2.1 Measuring conditions

Measure the delivery pressure under the following conditions:

— the commissioning is finished; the pumping unit can run normally;

— with a temperature at 0 °C to 40 °C.

6.1.2.2 Measurement equipment and accuracy requirement

The measurement equipment shall be as follows:

a) pressure gauges with an accuracy of ±0,2 MPa;

b) plug with a small relief cock to block the delivery line; the plug shall be rated to withstand the maximum delivery pressure of the pump.

6.1.2.3 Measuring preparations

a) Set up the measuring system as shown in Figure 7.

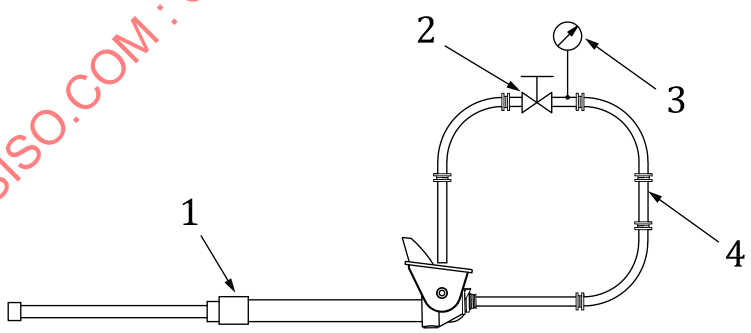
  — Block the delivery line of the concrete pump. Make sure the plug in the delivery line is located at the highest point of the delivery line. Air pockets shall be avoided.

  — Connect the pipeline from the relief cock back to the receiving hopper.

b) Make sure the energy source of the concrete pump is set to provide maximum power.

c) Start pumping and fill the receiving hopper and remaining delivery system with water.

d) Bleed all air out of the delivery system by cycling water through the concrete delivery line.



Key

1 concrete pump

2 plug with a small relief cock

3 pressure gauge

4 pipeline delivery system

Figure 7 — Delivery pressure measuring system

6.1.2.4 Measuring procedure

a) Open the relief cock, start pumping with water.

b) Adjust the relief cock to the closing direction until the hydraulic system is going into relief. The water pressure cannot be raised anymore by the concrete pump pumping water through the relief cock.

c) Vary energy source revolution per minute or output setting of the concrete pump to raise the water pressure.

d) Record the maximum generated water pressure p_D in Table 8.

e) Repeat 3 times, obtain the average value, and record the value in Table 8 and Table 9.

Table 8 — Measurement report — Concrete delivery pressure

Date of measuring			Place		
Model of concrete pump			Serial number		
Characteristics		Measured data	Average value	Unit	Remarks
Concrete delivery pressure p_D	1st time			MPa	
	2nd time			MPa	
	3rd time			MPa	

Table 9 — Measurement report — Pumping performance of the concrete pump

Date of measuring			Place	
Model of concrete pump			Serial number	
Characteristics		Measured data	Unit	Remarks
Concrete pump	Maximum revolution speed of hydraulic pump		min^{-1}	
	Concrete delivery pressure		MPa	p_D
	Maximum number of strokes per minute of concrete piston		min^{-1}	n
	Diameter of concrete cylinder		mm	D
	piston stroke of concrete cylinder		mm	S_t
	Diameter of pumping hydraulic cylinder		mm	d_1
	Rod diameter of pumping hydraulic cylinder		mm	d_2
	Stroke volume		m^3	$q = \pi D^2 / 4 \times S_t / 10^9$
	Maximum theoretical pumping output		m^3/h	$Q_{th,max}$
	Volumetric efficiency (100 % displacement)			$\eta_v = \frac{Q_a}{Q_{th}} \times 100\ \%$
	Hydraulic system power setting		kW	

6.2 Rotary pump

6.2.1 Single-roller rotary pump (see A.1)

6.2.1.1 Pumping output

a) Calculate the output volume per one hour using Formula (5):

$$V_1 = r_5 \times 2 \times \alpha \times \pi \times \frac{\phi^2}{4}$$

$$r_5 = r_2 + \frac{\phi}{2}$$

$$\alpha = \cos^{-1}\left[\frac{\left(r_1{}^2 + r_5{}^2 - r_3{}^2\right)}{\left(2 \times r_1 \times r_5\right)}\right] \times \frac{\pi}{180}$$

$$q = \frac{\left(2 \times \pi \times r_5 \times \pi \times \varphi^2\right)}{4} - \left(2 \times V_1\right)$$

$$Q_{\text{th,max}} = N \times 60 \times q \times 10^{-9} \qquad (5)$$

b) Record the pumping output measuring results in Table 10.

6.2.1.2 Delivery pressure

a) Calculate the delivery pressure of the single-roller rotary pump using Formula (6):

$$p_1 = \frac{T}{\sin \beta_1 \times \frac{r_1}{10^3}}$$

$$\beta_1 = \frac{\left(2\pi \times X_{\text{G}}\right)}{\left(2\pi \times r_3\right)}$$

$$X_{\text{G}} = \frac{(4 \times a)}{3\pi}$$

$$a = \left[r_4{}^2 + \left(r_3 \times \cos\theta\right)^2\right]^{\frac{1}{2}}$$

$$r_4 = r_3 \times (1 - \sin\theta)$$

$$\theta = \cos^{-1}\left[\frac{\left(r_1{}^2 + r_3{}^2 - r_2{}^2\right)}{\left(2 \times r_1 \times r_3\right)}\right] \times \frac{\pi}{180} - \frac{\pi}{2}$$

$$r_2 = r_{\text{p}} - \phi - t$$

$$r_3 = r_0 + t$$

$$S = \left(\frac{\pi}{2}\right) \times a \times b$$

$$a = \left[r_4{}^2 + \left(r_3 \times \cos\theta\right)^2\right]^{\frac{1}{2}}$$

$$b = \frac{1}{4} \times (\pi \times \phi)$$

$$p_{th,max} = \frac{p_1}{S} \quad (6)$$

where

a is the long radius of semi-ellipse contact zone (mm);

b is the short radius of semi-ellipse contact zone (mm);

N is the rotating speed of rotor (min^{-1});

p_1 is the load by inside pressure (N);

$p_{th,max}$ is the output pressure (MPa);

$Q_{th,max}$ is the output volume per one hour (m^3/h);

q is the output volume by one rotation of rotor (mm^3/r);

r_0 is the radius of roller (mm);

r_1 is the distance between pump centre to roller centre (mm);

r_2 is the distance between pump centre and inside contact point between rotor and tube (mm);

r_3 is the distance between inside contact point of roller and tube and roller centre (mm);

r_4 is the perpendicular distance from inside contact point of roller and tube to pump centreline (mm);

r_5 is the distance between pump centre and tube centreline (mm);

r_p is the radius of pump centre to surface of pad (mm);

S is the projected area of contact zone of tube and roller (mm^2);

T is the rotor drive torque (N·m);

t is the thickness of pumping tube (mm);

V_1 is the inside volume of tube depressed by roller (mm^3);

X_G is the centre of gravity of semi-square contact zone of tube and roller (mm);

α is the centre angle occupied by roller used for calculation of V_1 (rad);

β_1 is the angle between p_1 and p_0 (rad);

ϕ is the inside diameter of pumping tube (mm);

θ is the angle between r_3 and r_4 (rad).

See Figure A.1.

b) Record the delivery pressure measuring results in Table 10.

Table 10 — Measurement report — Concrete pump (single-roller rotary pump)

Date of measuring		Place	
Model of concrete pump		Serial number	

Table 10 *(continued)*

Characteristics		Measured data	Unit	Remarks
Concrete pump	Revolution speed of hydraulic pump		min^{-1}	
	No load operation hydraulic pressure		MPa	p_n
	Maximum hydraulic pressure (relief valve)		MPa	p_r
	Rotating speed of rotor		min^{-1}	N
	Distance between pump centre and tube centreline		mm	r_5
	Inside diameter of pumping tube		mm	φ
	Inside volume of tube depressed by roller		mm	V_1
	Output volume per rotation of rotor		m^3	$q=\left[\frac{\left(2\times\pi\times r_5\times\pi\times\phi^2\right)}{4}\right]-\left(2\times V_1\right)$
	Load by inside pressure		N	p_1
	Projected area of contact zone of tube and roller		mm^2	S
	Maximum theoretical delivery pressure		MPa	$p_{th,max}=\frac{p_1}{S}$
	Maximum theoretical pumping output		m^3/h	$Q_{th,max}=N\times60\times q\times10^{-9}$

6.2.2 Double-roller rotary pump (see A.2)

6.2.2.1 Pumping output

a) Calculate the output volume per one hour using Formula (7):

$$V_1=r_3\times2\times\theta\times\pi\times\frac{\phi^2}{4}$$

$$r_3=r_0+t$$

$$\theta=\cos^{-1}\left[\frac{\left(r_3-\phi\right)}{r_3}\right]\times\frac{\pi}{180}$$

$$q=\frac{\left(2\times\pi\times r_5\times\pi\times\phi^2\right)}{4}-\left(2\times V_1\right)$$

$$Q_{th,max}=N\times60\times q\times10^{-9} \quad (7)$$

b) Record the pumping output measuring results in Table 11.

6.2.2.2 Delivery pressure

a) Calculate the delivery pressure of the single-roller rotary pump using Formula (8):

$$p_1 = \frac{T}{2 \times \sin \beta_1 \times \frac{r_1}{10^3}}$$

$$\beta_1 = \frac{(2\pi \times X_G)}{(2\pi \times r_3)}$$

$$X_G = \frac{(4 \times a)}{3\pi}$$

$$a = \left[2 \times r_3{}^2 \times (1 - \cos \theta)\right]^{\frac{1}{2}}$$

$$\theta = \cos^{-1}\left[\frac{(r_3 - \phi)}{r_3}\right] \times \frac{\pi}{180}$$

$$r_3 = r_0 + t$$

$$S = \left(\frac{\pi}{2}\right) \times a \times b$$

$$b = \left(\frac{1}{4}\right) \times (\pi \times \phi)$$

$$p_{th,max} = \frac{p_1}{S} \quad (8)$$

where

a	is the long radius of semi-ellipse contact zone (mm);
b	is the short radius of semi-ellipse contact zone (mm);
N	is the rotating speed of rotor (min^{-1});
p_1	is the load by inside pressure (N);
$p_{th,max}$	is the maximum theoretical delivery pressure (MPa);
$Q_{th,max}$	is the maximum theoretical pumping output (m^3/h);
q	is the output volume per rotation of rotor (mm^3/r);
r_0	is the radius of roller (mm);
r_1	is the distance between pump casing centre and tube centre circle (mm);
r_3	is the distance between inside contact point of roller and roller centre (mm);
r_5	is the distance between pump centre and tube centreline (mm);
S	is the projected area of contact zone of tube and roller (mm^2);
T	is the rotor drive torque (N·m);
t	is the thickness of pumping tube (mm);

V_1 is the inside volume of tube depressed by roller (mm³);

X_G is the centre of gravity of semi-ellipse contact zone of tube and roller (mm);

β_1 is the angle between p_1 and p_0 (rad);

ϕ is the inside diameter of pumping tube (mm);

θ is the angle between r_3 and p_0 (rad).

b) Record the delivery pressure measuring results in Table 11.

See Figure A.2.

Table 11 — Measurement report — Concrete pump (double-roller rotary pump)

Date of measuring			Place	
Model of concrete pump			Serial number	
Characteristics		Measured data	Unit	Remarks
Concrete pump	Revolution speed of hydraulic pump		min^{-1}	
	No load operation hydraulic pressure		MPa	p_n
	Maximum hydraulic pressure (relief valve)		MPa	p_r
	Rotating speed of rotor		min^{-1}	N
	Distance between casing centre and tube centreline		mm	r_5
	Inside diameter of pumping tube		mm	φ
	Inside volume of tube depressed by roller		mm	V_1
	Output volume per rotation of rotor		m³	$q=\left[\frac{\left(2\times\pi\times r_5\times\pi\times\phi^2\right)}{4}\right]-\left(2\times V_1\right)$
	Load by inside pressure		N	p_1
	Projected area of contact zone of tube and roller		mm²	S
	Maximum theoretical delivery pressure		MPa	$p_{th,max}=\frac{p_1}{S}$
	Maximum theoretical pumping output		m³/h	$Q_{th,max}=N\times60\times q\times10^{-9}$

7 Feeding height of hopper

7.1 Measuring conditions

Measure the feeding height of hopper under the following conditions:

— on the rigid and horizontal ground;

— with all outriggers fully extended and then raised vertically to the status as specified by the manufacturer for full operation;

— on a straight line vertical to the support plane (Plane XZ) and parallel with the longitudinal symmetric plane (Plane YZ) of the machine;

— the rigid parts at the rear-most edge of feeding hopper shall not include the deformable and movable parts under external force, such as rubber board.

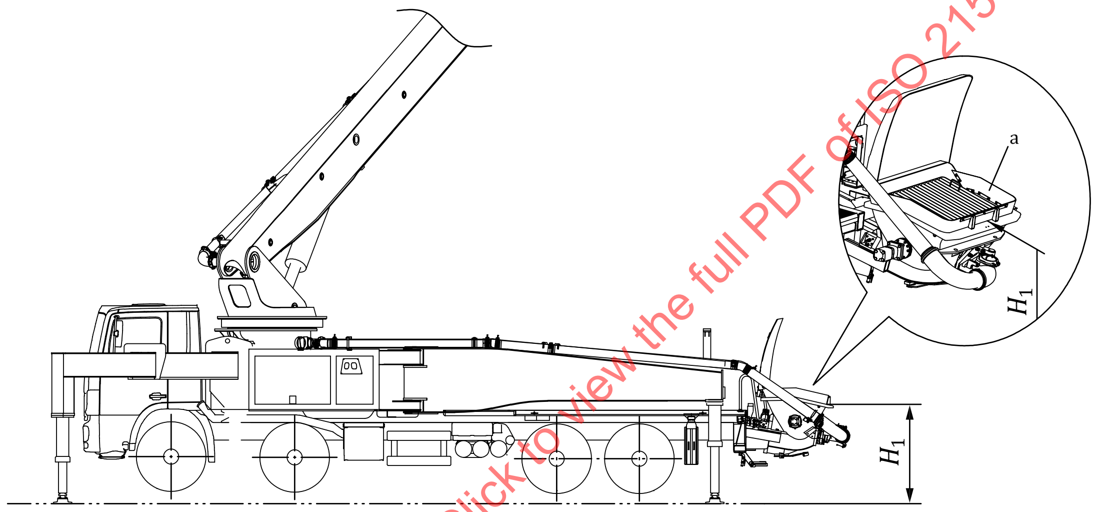
7.2 Measurement equipment and accuracy requirement

Use a tape measure or comparable equipment with an accuracy of ±1 mm.

7.3 Measuring procedure

a) Measure the vertical distance between the surface of rigid part of hopper rear-most edge and the ground as shown in Figure 8.

b) Record the measured data hopper height H_1 (mm) in the Table 12.



a Rubber board (non-rigid and movable).

Figure 8 — Feeding height of hopper

Table 12 — Measurement report — Hopper height of the concrete pump

Date of measuring		Place	
Model of concrete pump		Serial number	
Characteristics	Measured data	Unit	Remarks
Feeding height of hopper, H_1		mm	

8 Performance of water pump

8.1 Measuring conditions

Measure the performance of the water pump under the following condition:

— the equipment is as supplied by the manufacturer.

8.2 Measurement equipment and accuracy requirement

The measurement equipment shall be as follows:

a) water pressure gauge with an accuracy of ±0,2 MPa;

b) water flow meter with an accuracy of 0,1 %.

8.3 Measuring procedure

8.3.1 Relief pressure of water system

Start up the water pump and let it run normally, shut off the delivery pipeline of the water pump by closing the throttle valve completely provided on the delivery line. Measure the water pressure, record the value in Table 13.

8.3.2 Water output without load

Open the throttle valve fully, measure the water pressure and the water output at water pump outlet, record the values in Table 13.

Table 13 — Measurement report — Water pump of the concrete pump

Date of measuring				Place	
Model of concrete pump				Serial number	
Characteristics			Measured data	Unit	Remarks
Water pump	Shut off	Water pressure		MPa	
	No-load	Water output		dm^3(l)/min	
		Water pressure		MPa	

9 Performance of concrete-placing boom

9.1 Measuring conditions

Measure the performance of the concrete-placing boom under the following conditions:

— operate the outriggers and concrete-placing booms in order to check whether the related structures and functions are normal;

— on a solid and horizontal support ground;

— with the temperature of the hydraulic system at 40 °C to 60 °C;

— only operations allowed by the manufacturer's instruction handbook shall be done to perform the performance measuring.

9.2 Measurement equipment and accuracy requirement

The measurement equipment shall be as follows:

a) tape measure or comparable equipment with an accuracy of ±1 mm;

b) angle gauge with an accuracy of ±1°;

c) hour meter or stopwatch with an accuracy of ±1 s;

d) pressure gauge with an accuracy of ±0,2 MPa.

9.3 Measuring procedure

9.3.1 Maximum length of the concrete-placing boom

9.3.1.1 Measuring method

a) Fully unfold the concrete-placing boom to the horizontal position.

b) Measure the maximum horizontal distance R_{B1} from the hinge centre of 1st boom section to the centre of end hose, as shown in Figure 9.

c) Measure the horizontal distance R_{B2} from the hinge centre of 1st boom section to the centre of turret, as shown in Figure 9.

9.3.1.2 Calculation method

a) If the turret is under negative or zero offset state (Shown in Figure 9 a)), calculate the maximum placing radius R_B using Formula (9):

$$R_B = R_{B1} - R_{B2} \tag{9}$$

b) If the turret is under positive offset state (Shown in Figure 9 b)), calculate the maximum placing radius R_B using Formula (10):

$$R_B = R_{B1} + R_{B2} \tag{10}$$

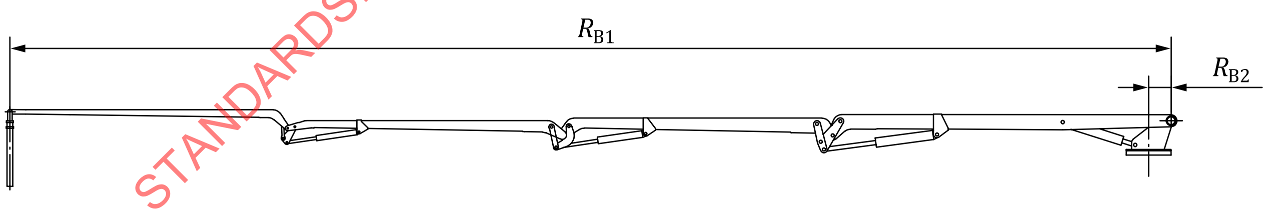
where

R_{B1} is the distance between the hinge centre of 1st boom section and the centre of end hose (mm);

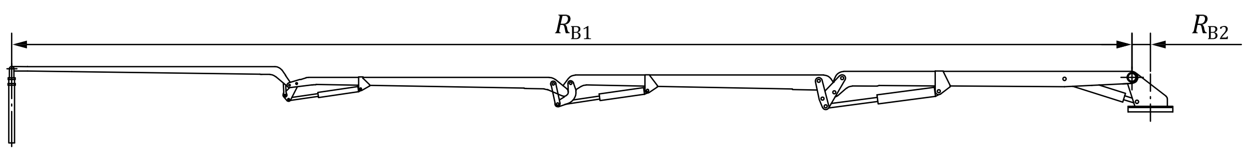
R_{B2} is the distance between the hinge centre of 1st boom section and the centre of turret (mm);

R_B is the maximum placing radius (mm).

c) Record the measurement data in Table 14.



a) Negative offset of slewing platform



b) Positive offset of slewing platform

Figure 9 — Placing radius

9.3.2 Maximum height of the concrete-placing boom

9.3.2.1 Measuring method

a) Fully extend the horizontal outriggers and then fully raise the vertical outriggers.

b) Fully unfold the concrete-placing boom to the horizontal position.

c) Measure the vertical distance H_{B1} from the hinge centre between the 1st boom section and turret to the ground, as shown in Figure 10.

d) Measure the maximum horizontal distance R_{B1} from the hinge centre of 1st boom section to the centre of end hose, as shown in Figure 10.

9.3.2.2 Calculation method

a) Calculate the maximum placing height H_B using Formula (11):

$$H_B = H_{B1} + R_{B1} \qquad (11)$$

where

H_{B1} is the vertical distance from the hinge centre of 1st boom section to the ground (mm);

H_B is the maximum placing height (mm).

b) Record the measured data in Table 14.

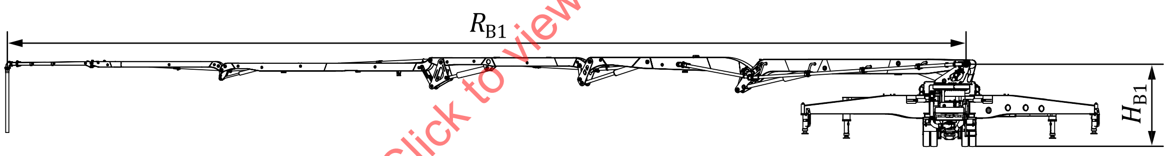


Figure 10 — Placing height

9.3.3 Concrete-placing boom section folding angle

a) Fully extend the horizontal outriggers and then fully raise the vertical outriggers.

b) Operate every concrete-placing boom section from folding status to unfolding status.

c) Measure the maximum movement angles α, β, γ, δ, ε and η of every concrete-placing boom section, as shown in Figure 12;

d) Record the data in Table 14.

9.3.4 Length of concrete-placing boom section

a) Fully extend the horizontal outriggers and then fully raise the vertical outriggers.

b) Fully unfold the concrete-placing boom to the horizontal position.

c) For the last boom section length, measure the distance from the hinge centre of the last boom section to the centre of the end hose.

d) For the other concrete-placing boom section length, measure the distance between two hinge centres of this specific concrete-placing boom section as shown in Figure 11.

e) Record the measurements data in Table 14.

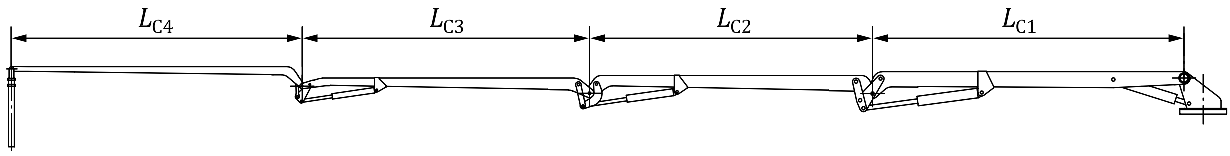
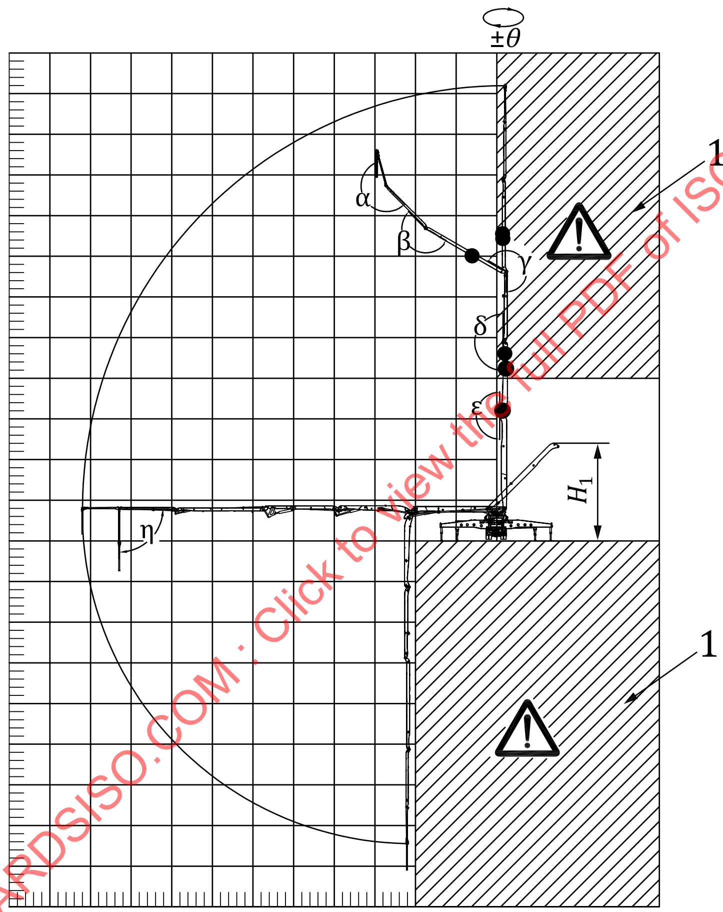


Figure 11 — Concrete-placing boom section length

9.3.5 Concrete-placing boom operation zone

Draw the chart of the concrete-placing boom operation zone by measuring the length of each stage concrete-placing boom, folding angle of each concrete-placing boom, as shown in Figure 12.



Key

1 prohibited operating area

Figure 12 — Example for operation zone of concrete-placing boom

9.3.6 Minimum unfolding/folding time and average speed of concrete-placing boom section

a) The machine shall be set up according to the manufacturer's instructions.

b) Operate every concrete-placing boom section at an average speed.

c) Switch the concrete-placing boom section from the folded status to the fully unfolded status.

d) Switch the concrete-placing boom section from fully the unfolded status to the folded status;

e) Record the unfolding and folding time T_{Bn} in Table 14;

f) Calculate the average speed v_{Bn} of concrete-placing boom end using Formula (12):

$$v_{Bn} = \frac{\pi \cdot L_{Bn} \cdot \alpha_{Bn}}{180 \times T_{Bn}} \tag{12}$$

where

v_{Bn} is the average speed at the ending of concrete-placing boom when operates the No. n boom section (m/s);

L_{Bn} is the distance from end of concrete-placing boom to hinge centre of this boom section when operates the No. n boom section (m), as shown in Figure 13;

α_{Bn} is the maximum movement angles of the No. n boom section as shown in 9.3.3 (°);

T_{Bn} is the unfolding and folding time of the No. n boom section (s).

g) Record the average speed v_{Bn} in Table 14.

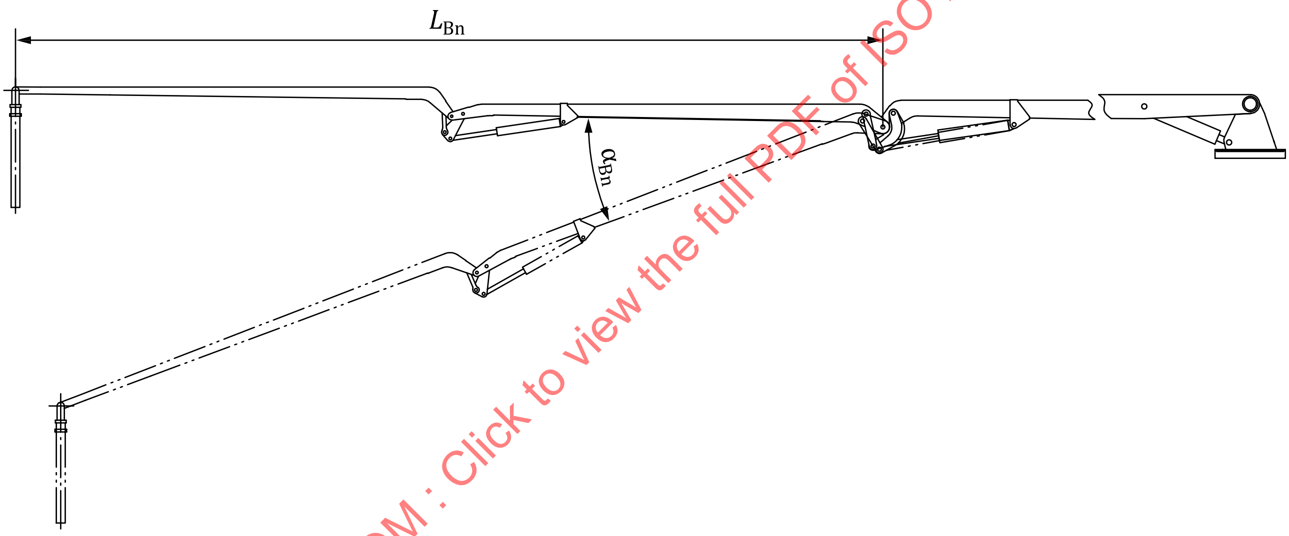


Figure 13 — Unfolding/Folding motion of concrete-placing boom

9.3.7 Maximum slewing speed

9.3.7.1 Measuring method

a) The machine shall be set up according to the manufacturer's instructions.

b) Unfold all concrete-placing boom sections to the horizontal status, slew them at the maximum speed along the measuring path angle as shown in Figure 14.

c) Measure the measuring path angle δ_S and the related time t_S.

d) Measure the distance L_S from the end of concrete-placing boom to the slewing centre of the concrete-placing boom.

9.3.7.2 Calculation method

a) Calculate the maximum slewing speed v_S of concrete-placing boom using Formula (13):

$$v_S = \frac{\pi \cdot L_S \cdot \delta_S}{180 \times t_S} \tag{13}$$

where

v_S is the linear speed of concrete-placing boom ending during slewing (m/s);

δ_S is the measuring path angle of concrete-placing boom during slewing (°);

t_S is the time required during slewing measuring (s);

L_S is the distance from the concrete-placing boom ending to the slewing centre of the concrete-placing boom when unfolding all concrete-placing boom sections to horizontal status (m).

b) Record the measured data in Table 14.

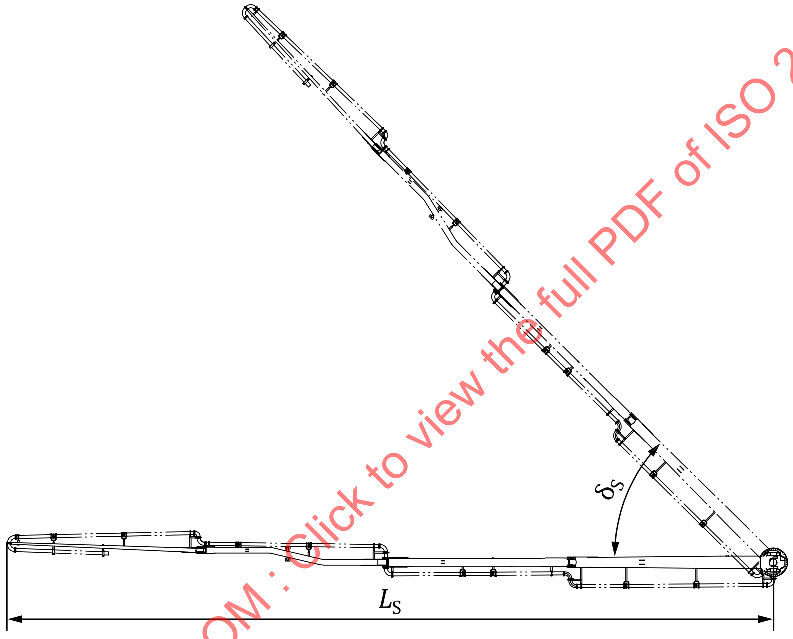


Figure 14 — Slewing motion of concrete-placing boom

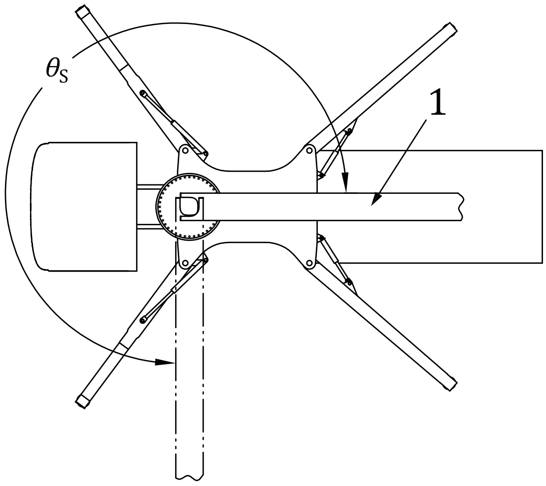
9.3.8 Maximum slewing angle

a) The machine shall be set up according to the manufacturer's instructions.

b) Fold all concrete-placing boom sections, raise the first boom section to an appropriate angle, slew it clockwise (counter-clockwise) to the limit position.

c) Measure the related slewing angle. This angle is the maximum slewing angle θ_S, as shown in Figure 15;

d) Record the data in Table 14.



Key

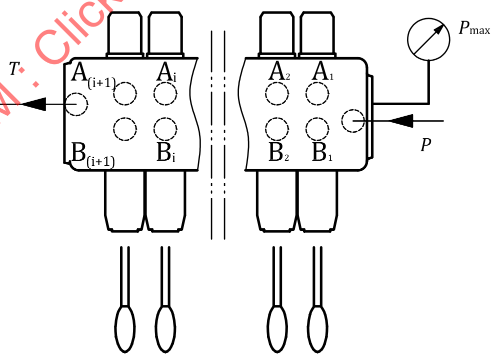
1 concrete-placing boom

Figure 15 — Slewing angle of concrete-placing boom

9.3.9 Concrete-placing boom system pressure

a) Install a pressure gauge at the pressure measurement ports of the concrete-placing boom distributing valve and ensure there are no other hydraulic components or pipeline between the pressure gauge and oil ports, as shown in Figure 16.

b) Operate the concrete-placing boom hydraulic system till the minimum limiting pressure is reached, hold for 2 s to 3 s, read the pressure value P_B under stable working condition, and record the value in Table 14.



Key

T return pressure

P inlet pressure

P_{max} maximum working pressure

A one side working oil port

B the other side working oil port

Figure 16 — Concrete-placing boom system pressure measuring

Table 14 — Measurement report — Performance of the concrete-placing boom

Date of measuring			Place			
Model of concrete pump			Serial number			
Characteristics			Measured data		Unit	Remarks
Concrete-placing boom	Maximum placing radius				mm	R_B
	Maximum placing height				mm	H_B
	Length of concrete-placing boom section	1st boom section			mm	L_{C1}
		2nd boom section			mm	L_{C2}
		3rd boom section			mm	L_{C3}
		4th boom section			mm	L_{C4}
		5th boom section			mm	L_{C5}
		6th boom section			mm	L_{C6}
	Folding angle	1st boom section			(°)	α
		2nd boom section			(°)	β
		3rd boom section			(°)	γ
		4th boom section			(°)	δ
		5th boom section			(°)	ε
		6th boom section			(°)	ζ
	Average speed of concrete-placing boom end		Unfold	Fold		
		1st boom section			m/s	v_{B1}
		2nd boom section			m/s	v_{B2}
		3rd boom section			m/s	v_{B3}
		4th boom section			m/s	v_{B4}
		5th boom section			m/s	v_{B5}
		6th boom section			m/s	v_{B6}
	Minimum unfolding/folding time of concrete-placing boom		Unfold	Fold		
		1st boom section			s	T_{B1}
		2nd boom section			s	T_{B2}
		3rd boom section			s	T_{B3}
		4th boom section			s	T_{B4}
		5th boom section			s	T_{B5}
		6th boom section			s	T_{B6}
	Maximum speed of concrete-placing boom slewing end				m/s	v_S
	Maximum slewing angle	Clockwise			°	θ
		Counter-clockwise			°	
	Concrete-placing boom system pressure				MPa	P_B

10 Performance of outriggers

10.1 Span of outrigger

10.1.1 Measuring conditions

Measure the outrigger span of the concrete pump under the following conditions:

— on the rigid and horizontal ground with bearing capacity no less than the maximum support force of outriggers;

— all outriggers fully extended to the set-up position on the horizontal plane;

— all outriggers fully raised to the operation position in the vertical direction;

— measure the front and rear outrigger spans on a straight-line parallel with the support plane (Plane X) and vertical to the longitudinal symmetric plane (Plane Y) of the machine.

— measure the left and the right outrigger spans on a straight-line parallel with the support plane (Plane X) and the longitudinal symmetric plane (Plane Y) of the machine.

— measure the actual left and right outrigger spans on a straight-line paralleling with the support plane (Plane X) and loading centreline of vertical outrigger.

10.1.2 Measurement equipment and accuracy requirement

Use a tape measure or comparable equipment with an accuracy of ±1 mm.

10.1.3 Measuring procedure

10.1.3.1 General

Measure the front and rear outrigger span and the left and right outrigger span as the procedure defined in 10.1.3.2 and 10.1.3.3 and Figure 17; record the values in Table 15.

10.1.3.2 Front and rear outrigger span

a) Measure the distance between two planes vertical to both plane X and plane Z and passing through the loading centrelines of front outriggers.

b) Measure the distance between two planes vertical to both plane X and plane Z and passing through the loading centrelines of rear outriggers.

c) Record the value as front outrigger span S_1 and rear outrigger span S_2.

10.1.3.3 Left and right outrigger span

a) Measure the distance between two planes passing through the loading centrelines of left front and left rear outriggers and vertical to the plane X and centreline respectively.

b) Measure the distance between two planes passing through the loading centrelines of right front and right rear outriggers and vertical to the plane X and centreline respectively.

c) Record the value as actual left outrigger span S_5 and actual right outrigger span S_6.

d) Calculate the left outrigger span S_3 and right outrigger span S_4 using Formulae (14) and (15), record in Table 15:

$$S_3 = \sqrt{(S_5)^2 - (S_2 - S_1)^2 / 4} \qquad (14)$$

$$S_4 = \sqrt{(S_6)^2 - (S_2 - S_1)^2 / 4} \tag{15}$$

where

S_1 is the front outrigger span (mm);

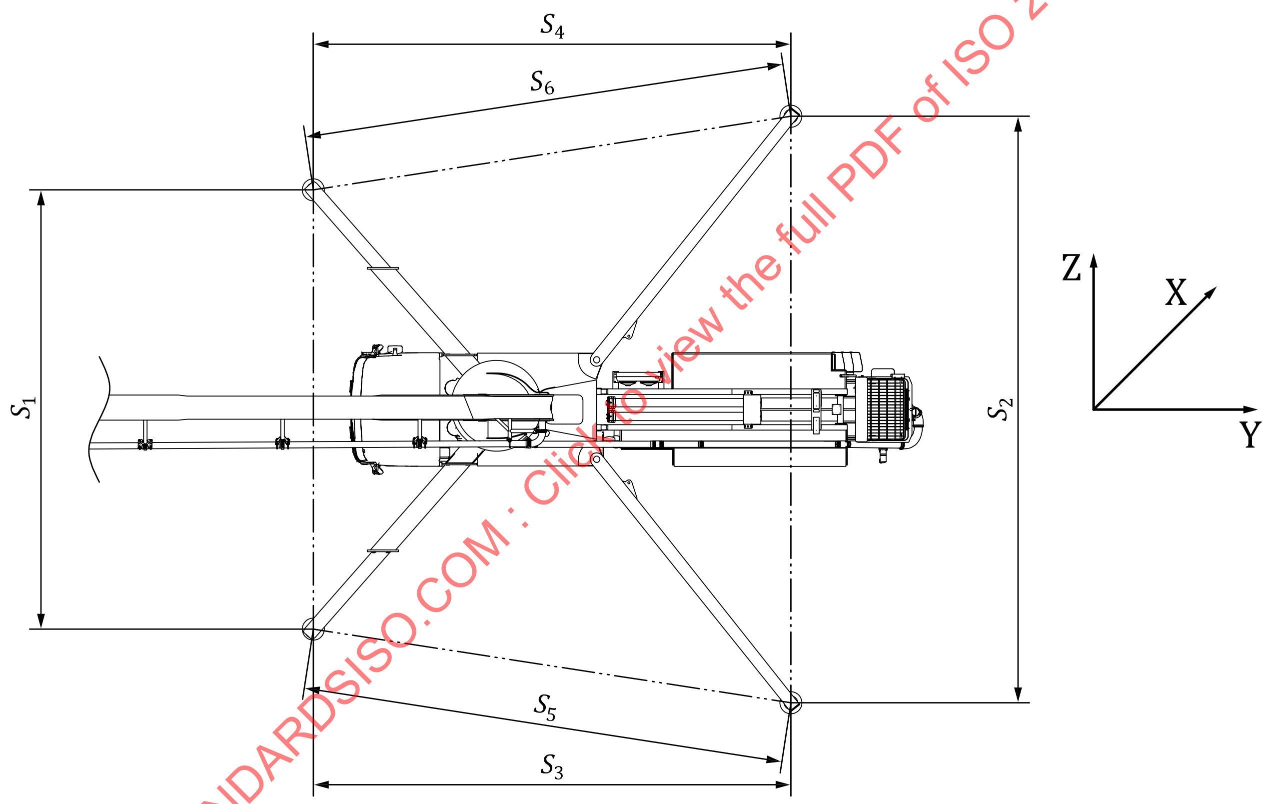
S_2 is the rear outrigger span (mm);

S_3 is the left outrigger span (mm);

S_4 is the right outrigger span (mm);

S_5 is the actual left outrigger span (mm);

S_6 is the actual right outrigger span (mm).



Key

X plane X

Y plane Y

Z plane Z

Figure 17 — Outrigger span

Table 15 — Measurement report —Outrigger span of the concrete pump

Date of measuring			Place	
Model of concrete pump			Serial number	
Characteristics		Measured data	Unit	Remarks
Outrigger span	Front outrigger span, S_1		mm	
	Rear outrigger span, S_2		mm	
	Actual left outrigger span, S_5		mm	
	Actual right outrigger span, S_6		mm	
	Left outrigger span, S_3		mm	
	Right outrigger span, S_4		mm	

10.2 Maximum load on each outrigger

10.2.1 Measuring conditions

Measure the load on each outrigger under the following conditions:

— on the rigid and horizontal ground with bearing capacity no less than the maximum support force of outriggers;

— the inclination of the slewing support plane shall not exceed 1°;

— the environmental temperature is 0 °C to 40 °C;

— the tolerance for vertical load shall be ±1 %.

10.2.2 Measuring apparatus and accuracy requirement

Use a force sensor with an accuracy of 0,5 %.

10.2.3 Measuring procedure

a) The machine shall be set up according to the manufacturer's instructions.

b) The measuring load is 1,25 times of the workload.

c) Distribute the equivalent measuring load uniformly in accordance with the load ratio of concrete-placing boom parts defined by the manufacturer.

d) Apply the measuring load by means of hanging concentrated loads or uniform load substitutes (the uniform load substitutes shall be uniformly fixed on the concrete-placing boom) to the corresponding positions of concrete-placing boom. An example of a method of concentrated loads is shown in Figure 18. In Figure 18, W_1, W_2, W_3, W_4, and W_5 are weights of concentrated loads.

e) Keep the concrete-placing boom stable without any vibration during loading.

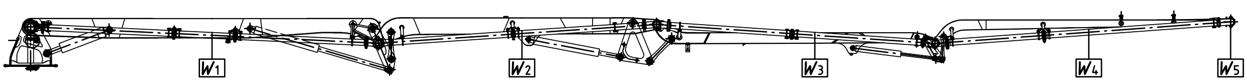


Figure 18 — Example of the loading of concrete-placing boom

f) Slew the concrete-placing boom at the rated slewing speed for 360°; during slewing keep the hanging loads from touching the ground and repeat the measurement for three times. Measure the maximum load of four outriggers each time and calculate the average of three measurements, Record the parameters listed in Table 16.

Table 16 — Measurement report — Maximum load on each outrigger

Date of measuring			Place		
Model of concrete pump			Serial number		
No.	Maximum load on each outrigger (MPa)				comment
	Left front outrigger	Left rear outrigger	Right front outrigger	Right rear outrigger	
1					
2					
3					
Average					

10.3 Speed of outriggers movement

10.3.1 Measuring conditions

Measure all outrigger movements at the maximum speed under the following conditions:

— the machine shall be set up according to the manufacturer's instructions;

— operate the outriggers in order to check whether the related outriggers structures and functions are normal;

— on a solid and horizontal support ground;

— the temperature of the hydraulic system is 40 °C to 60 °C.

10.3.2 Measuring apparatus and accuracy requirement

The measurement apparatus shall be as follows:

a) tape measure or comparable apparatus with an accuracy of ±1 mm;

b) angle gauge with an accuracy of ±1°;

c) hour meter or stopwatch with an accuracy of ±1 s.

10.3.3 Measuring procedure

10.3.3.1 Swing speed of outriggers

10.3.3.1.1 Measuring method

a) The machine shall be set up according to the manufacturer's instructions.

b) Measure the swing time t_0.

c) Measure the length L_0 from the outrigger swing centreline to the end of outrigger after the outriggers are fully extended, as shown in Figure 19.

10.3.3.1.2 Calculation method

a) Calculate the outrigger swing speed v_0 using Formula (16):

$$v_0 = \frac{\pi \cdot L_0 \cdot \beta_0}{180 \times t_0} \qquad (16)$$

where

v_0 is the outrigger ending linear speed (m/s);

L_0 is the length from outrigger swing centreline to the end of outrigger (m);

β_0 is the maximum swing angle of outriggers (°);

t_0 is the swing time of outriggers (s).

b) Record the measured data in Table 17.

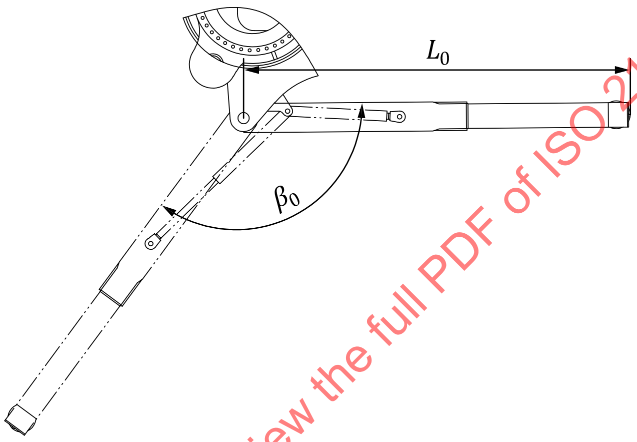


Figure 19 — Outrigger swing

10.3.3.2 Horizontal telescoping speed of outriggers

10.3.3.2.1 Measuring method

a) Extend (retract) the outriggers at the maximum speed.

b) Measure the extending (retracting) length L_E and the time required to move the outriggers along the test path length t_E, as shown in Figure 20.

10.3.3.2.2 Calculation method

a) Calculate the outrigger telescoping speed v_E using Formula (17):

$$v_E = \frac{L_E}{t_E} \qquad (17)$$

where

v_E is the outrigger ending linear speed (m/s);

L_E is the extending (retracting) test path length of outriggers (m);

t_E is the time to move the outriggers along test path angle (s).

b) Record the measured data in Table 17.

