Via Della Fornace, 16
41043 Formigine (MO) - ITALY

A1	**2024-02-21**	**ISSUE**	**EdiLAB**
REVISION	**DATE**	**DESCRIPTION**	**BY**

PROJECT: SLEWING JIB CRANE 50t CAPACITY – STRUCTURAL ANALYSIS

– ASCOM – Formigine (MO)

DOCUMENT CONTENT

Proof of static strength of structure according to European standards.

TOTAL PAGES 17

PREPARED BY SB-LS	**CHECKED BY** LS	**APPROVED BY** GB

Società di ingegneria
V.le Vittorio Bottego, 8
43121 Parma - ITALY

TABLE OF CONTENTS

1. DESCRIPTION

Slewing jib crane capacity is 50t by 1 lifting point with 4 falls sheave block and a single hook.

Design data:

overall dimensions	
height	H = 18.1 m
length	L = 13.2 m
width	W = 4.1 m
min. clearance under boom	Hb = 15.4 m
outreach	9.15 m
hook stroke	19.0 m
hoisting cap	500 kN
number of falls	4
rope grade	FZ COMPLAST 9PKE (FAS) d.26mm ultimate force Fu =631kN
hoisting velocity (unloaded)	60 fpm = 18.30 m/min
hoisting velocity (loaded at maximum rate)	20 fpm = 6.10 m/min
rotation angle	360° continuous
slewing velocity (unloaded)	1.0 rpm
slewing velocity (loaded at maximum rate)	0.5 rpm
electric motor power:	*125 kW*
hydraulic tank capacity:	*480 l (TBC)*

Design conditions (according to EN13001-1):

Total number of working cycles	$C \leq 1.25\ 10^5$
Class U of total number of working cycles	U4
Load spectrum factor	$kQ \leq 0.25$
Class Q of load spectrum factor	Q2
Relative total number of working cycles	$v = n/ND = 1.25\ 10^5/2.0\ 10^6 = 0.0625$
Stress history parameter	s = v km = 0.016
Jib crane class ($0.008 < s \leq 0.016$)	S1 (fatigue proofs required)
Hoist drive class	HD4
Crane stiffness class	HC4

Load test: static = 1.41 of rated load

Environmental conditions:

temperature range:	-20 ÷ +40 °C
relative humidity:	90%
in service wind speed:	class 9 (Beaufort scale)
out of service wind speed:	class 12 (Beaufort scale – hoisting not allowed)
SWH significant wave height $H_{1/3}$	2.0 m

2. CALCULATION APPROACH.

Structural design conforms the *"ultimate limit states"* method.

EN 13001-2, EN 14985 and EN 13852-1 apply for load analysis, partial and dynamic factors calculations and load combinations (according to appliance specifics).

Adopted finite element program is "MIDAS GEN 2024 V.1.1".

Model generals:
- linear elastic behaviour materials;
- linear static analysis for all the load conditions;
- combinations of load conditions by partial safety factors and dynamic factors as required by codes;
- stress values on structural members are program detected;
- local buckling of sections, panels and stiffeners were proven by external procedure;
- proof of static strength of joints; lifting accessories and mechanics (hook and sheave block, drum and motors); local effects at pin holes insertion; ladders and platforms are investigated separately;

3. DESIGN CODES

For the design of the Straddle Carrier, reference is made to the following Codes:

- EN 1993-1-1: Eurocode 3 – "*Design of steel structures – Part 1-1: General rules and rules for buildings"*;
- EN 1993-1-8: Eurocode 3 – "*Design of steel structures – Part 1-8: Design of joints"*
- EN 1993-1-9: Eurocode 3 – "*Design of steel structures – Part 1-9: Fatigue"*;
- EN 13135 2013: "*Cranes-safety design requirements for equipment"*
- EN 13155: "*Cranes - Safety - Non-fixed load lifting attachments*"
- EN 13000: "*Cranes – Mobile cranes";*
- EN 13001-1: "*Crane safety – General design – Part 1: General principles and requirements";*
- EN 13001-2: "*Crane safety – General design – Part 2: Load actions";*
- EN 14985: "*Cranes – Slewing jib cranes";*
- EN 13852-1: *"Offshore cranes – Part 1: General purpose offshore cranes";*
- EN 13001-3.1: "*Cranes - General design – Part 3.1: Limit states and proof of competence of steel structures";*
- EN 13001-3-2: "*Cranes – General design – Limit states and proof of competence of wire ropes in reeving systems"*

Limit states calculation method according to previous codes adopted.

For the fabrication of the structures and mechanisms, reference is made to the following Codes:

- EN 1090-2 – "E*xecution of steel structures and aluminum structures - Part 2: Technical requirements for the execution of steel structures";*
- EN ISO 13920 – "*General tolerances for welded constructions dimensions for lengths, angles, shape and position*";
- EN ISO 2768 – "*General tolerances -Tolerances for linear and angular dimensions without individual tolerance indications*"

4. DESIGN, EXECUTION CLASSES AND TOLERANCES

According to EN 1090-2: Consequence class **CC = 2**;
Service category **SC = 2**;
Production category **PC = 2**;

Execution class: **EXC = 3**.

Production and manufacturing classes of tolerance are:

According to EN ISO 13920: **class AE**;
According to EN 22768: **class mk**.

5. MATERIALS

If not otherwise noted, materials shall generally refer to the following Codes:

- EN 10025 – “*Hot rolled products of structural steels*”, sections 1 and 2
- EN 10083 – “*Quenched and tempered steels*”, section 1 to 3
- EN 10164 – “*Steel products with improved deformation properties perpendicular to the surface of the product”*
- EN 10210 – “*Hot finished structural hollow sections of non-alloy and fine grain steels*”
- EN 10297 – “*Seamless circular steel tubes for mechanical and general engineering purposes*”

5.1. Base materials.

Elastic modulus	E	200 000 MPa
Poisson module	ν	0,30
shear modulus	G	0,5 E/(1 + υ) = 80 770 MPa
thermal elongation factor	α	12×10^{-6} °C^{-1}
weight per unit volume	ρ	7 850 kg/m^3

Structural steel S355 J2

Grade	ultimate stress [MPa]	Yielding stress [MPa], thk **s** [mm]		
		≤ 16	16 < s ≤ 40	40 < s ≤ 43
S355 J2 - 1.0577	520-720	355	345	335

Quenched and tempered steels

C45 +QT- 1.0503

thickness [mm]	t ≤ 8		8 < t ≤ 20		20 < t ≤ 60	
	Rm	Re	Rm	Re	Rm	Re
	700 to 850	490	650 to 800	430	630 to 780	370

39NiCrMo3- 1.6510

diameter [mm]	16 < d ≤ 40		40 < d ≤ 100		100 < d ≤ 160	
	Rm	Re	Rm	Re	Rm	Re
	930 to 1130	735	880 to 1080	685	830 to 980	635

Safety factors for strength and buckling at ULS	$\gamma_{M0} = \gamma_{M1} =$	1.10

5.2. Welded joints.

The welding processes must be certified by an appropriate WPAR in order to guarantee the required quality of the joints; the execution of the joints must be related to an appropriate WPS. Acceptable processes, required quality level and suggested consumables can comply with the following table:

Process	Execution class	Filler material
GMAW	ISO 4063 CLASS B	G 46 4 M21 2Ni2
SMAW	ISO 4063 CLASS B	E 38 0 RC 11
SAW	ISO 4063 CLASS B	S2

Unless specified, the minimum side of the fillet weld must be 0.7 times the minimum thickness of the welded plates.

5.3. Bolted Joints.

Bolting according to EN 14399-4 HV – HDG, HSFB class 10.9:

- bolts 10.9 (EN 14399-4) tensile ultimate f_{ub} = 1 000 MPa
- nuts 10 (EN 14399-4)
- washers (EN 14399-5) C50 EN10083 (HRC 32-40)

TIGHTENING TABLE					
Design torque $T = k \cdot F_{p,c} \cdot d$, with k = 0.2 E $F_{p,c} = 0.7 \cdot A_{res} \cdot f_u$					
d [mm]	hole [mm]	area [mm^2]	f_u [MPa]	$F_{p,c}$ [kN]	T [kNm]
16	18	157	1000	110	0.352
18	20	192	1000	134	0.484
20	22	245	1000	172	0.686
22	24	303	1000	212	0.933
24	26	353	1000	247	1.186
27	30	459	1000	321	1.735
30	33	561	1000	393	2.356
36	39	817	1000	572	4.118

Partial safety factors for joints design	
Bolts capacity Fillet and partial penetration welds capacity Bearing in contact	γ_{M2} = 1.25
ULS slip resistance	γ_{M3} = 1.25
SLS slip resistance	γ_{M3} = 1.10

6. LOAD ANALYSIS

Following paragraphs contain information about adopted partial safety factors and calculations of dynamic amplification factors with reference to EN 13001-2, EN 14985 and EN 13852-1.
As a matter of fact, the jib crane is a fixed installation that works hoisting offboard loads.
Load combination table adopted is table B.6 of EN 13852-1, with partial and dynamic amplification factors set therein.
Test load values considered and procedures refer to EN 14985.
Exceptional combination containing crane base excitation refers to table 12 a of EN 13001-2.

6.1. Self weight: SW.

Program calculates automatically the self weight of structure, and a gravitational vertical amplification factor equal to **1.44** accounts for:

- slewing ring with reducers and motors, bolts and welds;
- ladders and platforms.

Partial safety factors γ_p adopted for the mass of the crane:

	load comb. type A	load comb. type B	load comb. type C
mass determination	unfavorable load	unfavorable load	unfavorable load
by calculation	1.22	1.16	1.10

When lifting the load off the ground, or when releasing it,
dynamic load factor applied on self weight is: $\phi = 1.0$

6.2. Dead loads: DL

Point loads in model account for the dead loads of:

- slewing ring steering motors;
- power unit, packing engine, diesel and hydraulic tanks;
- drum with partial winded ropes.

Dead loads are affected by the same partial safety factors γ_p and dynamic factor ϕ as the Self Weight.

6.3. Live loads: LL

The live load is the hoisted load, together with sheave block, hook and ballast.

I.e.:

rated cap. for SWH	Rn	500	kN
sheave block and hook weight	DL	20	kN
total live load	**LL**	**520**	kN

Partial safety factors on live load are:

	load comb. type A	load comb. type B	load comb. type C
γ_p	1.34	1.22	1.10

6.3.1. Dynamic amplification factor DAF.

Annex B of EN 13852-1, contains requirements for DAF calculation; following table summarizes input data and calculated DAF value of the appliance, with the same terms and definitions of the euro-norm.

Design data

rated cap. for SWH	Rn	500	kN
sheave block and hook weight	DL	20	kN
total live load	LL	520	kN
sea state		4	
wave height SWH	$H_{1/3}$	2.00	m
Beaufort number		9	
OUT OF SERVICE wind speed		100	mph
		161	km/h
IN SERVICE wind speed		50	mph
		80	km/h
hoisting speed (loaded)		20	fpm
	vS	0.102	m/s
hoisting speed (unloaded)		60	fpm
		0.305	m/s
falls from tip to hook block		4	
falls from drum to tip		2	
slewing velocity		0.5	rpm
ang. velocity	ω	0.0524	rad/s
slewing radius (column axis to tip dist.)	r	9 250	mm

DAF calculation

	ϕn min	1.30	EN13852-1 - Table B.1
vert. vel. of boom tip due to movement of crane base	VD	0	
vert. vel. of load's supporting deck	VC	0.99	m/s
vel. factor without load KH	unloaded KH	0.4	for multiple reeving
min hoisting speed without load	unloaded VH	0.396	m/s
vel. factor with load KH	loaded KH	0.28	for multiple reeving
min hoisting speed loaded	loaded VH	0.277	m/s
lateral vel. factor with load KL	loaded KL	0.6	EN13852-1 - Table B.5
min lateral hook speed (slewing)	loaded VL	0.594	EN13852-1 - Par. B.4.2
relative velocity between load and hook	VR	1.268	m/s

rope type		FZCOMPLASTP26	
material grade		2160	MPa
rope diam	d	26	mm
breaking force	Fu	631	kN
unit weight	SW rope	3.28	kg/m
metallic section	Ar	418	mm2
Modulus at 20% of breaking force	Er	100	kN/mm2
initial permanent extension	Δl	0.1	%
rope length from tip to hook block	l_1	18	m
rope length from drum to tip	l_2	9	m
rope stiffness for l1	$ErAr/l_1$	9 285 209	N/m
rope stiffness for l2	$ErAr/l_2$	9 285 209	N/m
total rope stiffness l1+l2	$Er\ Ar(1/l_1+1/l_2)$	6 190 139	N/m

LL on model of structure	LL	520	kN
structure tip vert. deflection		95	mm
structure stiffness (according to FE model)		5 473 684	N/m
total stiffness		2 904 954	N/m
gravity acceleration	g	9.81	m/s2
dynamic factor DAF	**Φn**	**1.985**	

6.4. Offlead and sidelead forces: LL

Offlead and sidelead forces are affected by the same partial safety factors γ_p and dynamic factor Φn as the Live Load.

offlead displacement of load relative to boom tip	$2.5+1.5\ H_{1/3}$	5.47	m EN 13852-1 - Par. B3.2.3
offlead angle to vert.	α offlead	16.9	deg
offlead hor. force	**F offlead**	**158**	kN
sidelead displacement of load relative to boom tip	$0.5\ (2.5+1.5\ H_{1/3})$	2.74	m EN 13852-1 - Par. B3.3.3
sidelead angle to vert.	α sidelead	8.6	deg
sidelead hor. force	**F sidelead**	**79**	kN

6.5. Forces caused by slewing movements: Fcf (centrifugal), Fbrk (braking).

Design angular velocity is according to EN 13852-1 - Par. B3.2.2 and B3.3.2.

mass of the hoist load	m	53 007	kg
	ω/2	0.026	rad/s
centrifugal force m ω2 r	**Fcf**	**0.336**	**kN radial**

		occasional condition	exceptional condition	
circumf. velocity	v	0.484	0.484	m/s
time to stop	Δt	3	1.5	s
acceleration	am	0.161	0.323	m/s2
braking force	**Fbrk**	**8.56**	**17.12**	**kN circumferential**

Partial and dynamic safety factors on forces caused by slewing are:

	load comb. type A	load comb. type B	load comb. type C
γ_p	1.22	1.16	1.10
ϕ	1.0	1.0	1.0

6.6. Wind forces.

Partial and dynamic safety factors are:

	load comb. type A	load comb. type B	load comb. type C
γ_p	-	1.16	1.10
ϕ	-	1.0	1.0

Design pressure calculation

	in service	out of service	
reference velocity $v_{ref.}$	22	45	m/s
Beaufort number	9	12	-
gust wind velocity $v_{gust} = 1.5\ v_{ref.}$	34	67	m/s
wind pressure $q(3) = 0.5\ \rho\ v(3)^2$	703	2810	N/m^2

Wind force will be calculated as $F = q(3)\ c\ A$

where: c = aerodynamic coefficient of the member under consideration

6.6.1. Wind on the load: WX LL; WY LL

Hoisting movements are excluded when extreme wind conditions take place.
Wind on the load is calculated according to EN 13001-2 par. 4.2.3.1, using a conventional invested area per unit ton.

air density	ρ	1.25	kg/m^3
EN 13001-2 par. 4.2.3.1			
aerodynamic factor ca	ca	2.4	-
live load	LL	52000	kg
conventional invested area (min = 0.8 m2)	Ag	26	m^2
tot WIND on load		**43.8**	**kN conventional**

6.6.2. Wind on the crane: WX SW; WY SW

Wind on structure is calculated according to EN 13001-2 Annex A.

wind on column

column diam.	Dext column	1820	mm
member length	l0	15400	mm
relative aerodynamic length	αr	1.00	EN 13001-2 - Table A.1
aerodynamic length of member	la	15347	mm
aerodynamic slenderness ratio	la/Dext	8.43	
aerodynamic factor	c0	1.20	EN 13001-2 - Table A.2
solidity ratio	ϕ	1.00	
c0 reduction factor	ψ	0.68	EN 13001-2 - Table A.1
aerodynamic factor c0 ψ	ca	0.816	

		in service	out of service	
	wind pressure q(3)	703	2810	N/m^2
force per unit length of column	**q(3) ca Dext**	1 043	4 174	N/m

transversal wind on boom

boom length	l_0	10900	mm
relative aerodynamic length	αr	2.00	EN 13001-2 - Table A.1
aerodynamic length of member αr l_0	la	21800	mm

		tip	root	
height	d	415	1490	mm
width	b	1000	1900	mm
dim. ratio	b/d	2.41	1.28	
aerodynamic factor	c_0	1.4	1.8	EN 13001-2 - Table A.4
aerodynamic slenderness ratio	la/d	52.53	14.63	
c0 reduction factor	ψ	0.875	0.725	EN 13001-2 - Table A.1
aerodynamic factor c0 ψ	ca	1.225	1.305	
in service pressure = 703 N/m^2				
force per unit length q(3) ca d		357	1 366	N/m
out of service pressure = 2810 N/m^2				
force per unit length q(3) ca d		1 429	5 464	N/m

wind on winch and cabinet room

room length	b	2800		mm
room height	d	2800		mm
room width	t	1500		mm
drag factor	ca	1.2		
		in service	out of service	
total transv. force on room		6.61	26.44	kN
total long. force on room		3.54	14.16	kN

6.7. Temperature variations.

Temperature variations is almost uniform along crane members, thus resulting in not relevant effects; temperature variations shall be omitted in calculations.

6.8. Snow and ice.

Structure shape is not susceptible to relevant snow or ice accumulation and the load condition will be neglected.

6.9. Test load: test LL.

The static test shall be performed with the following resultant load:

test factor $\psi = 1.56 - 0.003\, m_{RC}$ [t] = 1.41 for a rated capacity of 20 t < $m_{RC} \leq 120$ t

test LL = $\psi\, m_{RC} + m_{LA}$ = 725 kN

Partial and dynamic safety factors are:

	load comb. type C
γ_p	1.10
ϕ	1.0

Reduced wind and centrifugal forces shall be added according to EN 13852-1, table B6

6.10. Excitation of crane foundation: EQ.

7. LOAD COMBINATIONS

Comprehensive load combinations, partial safety factors and dynamic factors refer to **EN 13852-1, table B.6;** partial safety factors γ_p and dynamic factors ϕ_i can be found there, if not previously exposed.
Hoisting and slewing movements are never concomitant.

Loads description.

loads	description
SW	structure self weight
DL	electrical and hydraulic cabinet
LL	sheave block and hoisted load
Fcf	centrifugal force
Fbrk	braking force in slewing
LL+Fol	sheave block, hoisted load and offlead
Fsl	sidelead
WX LL	in service wind on load: dir. X
WY LL	in service wind on load: dir. Y
WX SW	in service wind on structure: dir X
WY SW	in service wind on structure: dir Y
WX out SW	out of service wind on structure: dir X
WY out SW	out of service wind on structure: dir Y
test LL	Test load
E-stop	exceptional braking force in slewing
EQ	earthquake induced actions

7.1. Ultimate limit state combinations type A and B.

Load combinations **type A** deal with regular loads, under normal operation.
Load combinations **type B** deal with regular and occasional loads, under normal operation.

Relevant load combinations refer to columns **A1**, **A2**, **B1** and **B2**.

- **group A1** complies with hoisting and depositing loads conditions;
- **group A2** complies with crane slewing movement;
- **group B1** complies with hoisting and depositing loads with wind;
- **group B2** complies with crane slewing movement with wind.

	combinations type A		**combinations type B**			
	HOISTING	**SLEWING**	**HOISTING with WIND**		**SLEWING with WIND**	
loads	A1	A2	B1-1	B1-2	B2-1	B2-2
SW	1.220	1.220	1.160	1.160	1.160	1.160
DL	1.220	1.220	1.160	1.160	1.160	1.160
LL						
Fcf		1.220			1.160	1.160
Fbrk		1.220			1.160	1.160
LL+Fol	2.660	1.340	2.422	2.422	1.220	1.220
Fsl	2.660	1.340	2.422	2.422	1.220	1.220
WX LL			1.160		1.160	
WY LL				1.160		1.160
WX SW			1.160		1.160	
WY SW				1.160		1.160
WX out SW						
WY out SW						
test LL						
E-stop						
EQ						

7.2. Ultimate limit state combinations type C.

Load combinations **type C** deal with exceptional events or load test phase.

combinations type C					
loads	Out of service WIND		Test load		slewing E-stop
SW	C1-1	C1-2	C2-1	C2-2	C3
DL	1.1	1.1	1.1	1.1	1.1
LL	1.1	1.1	1.1	1.1	1.1
Fcf					1.1
Fbrk			0.11	0.11	1.1
LL+Fol			0.11	0.11	
Fsl					
WX LL					
WY LL			0.22		
WX SW				0.22	
WY SW			0.22		
WX out SW				0.22	
WY out SW	1.1				
test LL		1.1			
E-stop			1.1	1.1	
EQ					1.1

7.3. Relevant relative displacements (SLS combinations).

Relevant deformations of jib crane are those that can interfere with its normal operations: global displacements or excessive deformation of the boom rule the proof of global buckling.

Deformations and displacements by regular loads are calculated setting all partial safety factors γ_p **=1.0**.

Group A1: hoisting Load case	**SLS A1-01**	**SLS A1-04**	**SLS A1-07**	**SLS A1-10**

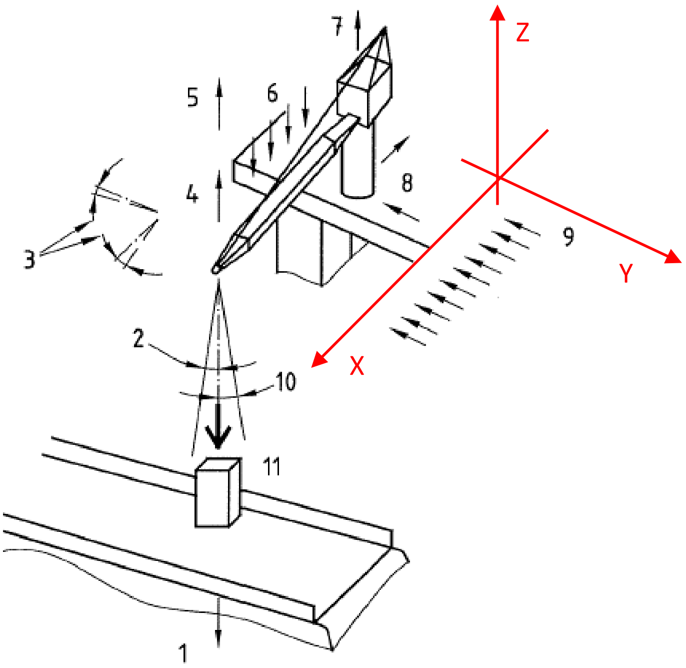
8. FINITE ELEMENT MODEL.

9. APPLIED LOADS: CONDITIONS.

10. OUTPUT

10.1. Unfactored reactions per load condition.

REACTIONS TABLE						
	boom long.	boom transv.	vertical	bending X	bending Y	torque
Load case	**FX (kN)**	**FY (kN)**	**FZ (kN)**	**MX (kN·m)**	**MY (kN·m)**	**MZ (kN·m)**
SW	0	0	438	0	-427	0
DL	0	0	41	0	123	0
LL	0	0	520	0	-4 699	0
Fcf	0	0	0	0	-5	0
Fbrk	0	-9	0	138	0	-76
LL+Fol	-158	0	521	0	-7 267	0
Fsd	0	-79	0	1 278	0	-702
WX LL	-44	0	0	0	-713	0
WY LL	0	-44	0	712	0	-391
WX SW	-27	0	0	0	-222	0
WY SW	0	-33	0	333	0	-25
WXout SW	-107	0	0	0	-889	0
WYout SW	0	-134	0	1 332	0	-100
test LL	0	0	724	0	-6 542	0
E-stop	0	-17	0	277	0	-152
max	**0**	**0**	**724**	**1 332**	**123**	**0**
min	**-158**	**-134**	**0**	**0**	**-7 267**	**-702**



1 deck velocity
2 offlead
3 installation inclination (trim and heel)
4 hoisting velocity
5 boom tip velocity
6 snow and ice
7 vertical installation accelerations
8 horizontal installation accelerations
9 wind
10 sidelead
11 actual hook load

10.2. Internal forces envelopes.

Envelope includes all combinations type A and B:

10.2.1. Envelope of load combinations type A

10.2.2. Envelope of load combinations type B

10.3. Beam stresses diagram: envelope values.

Combined stress in diagrams represents the absolute largest value coming from axial force, bending and shear.

Maximum absolute values of normal and shear stresses refer to following load combinations.