FEM Product Group
Cranes and Lifting Equipment

International Tower Crane Conference 2015

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London, 28th May 2015

INTERNATIONAL TOWER CRANES
www.khl.com/itc London, 27 and 28 May
CONFERENCE & RECEPTION 2015

Created and organised by
INTERNATIONAL cranes AND SPECIALIZED TRANSPORT
AMERICAN CRANES & TRANSPORT ACT
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FÉDÉRATION EUROPÉENNE DE LA MANUTENTION
Product Group
Krane und Hebezeuge
Cranes and Lifting Equipment
Grues et ponts roulants et Appareils de levage

Position Paper of
FEM Product Group Cranes and Lifting Equipment
Sub-Group Tower and harbor Cranes

"Guidelines for considering tower crane loads on supporting structures"

February, 2014

http://www.fem-eur.com/data/File/2014_02_Tower_cranes_loads_on_supporting_structures.pdf

TOWER CRANE FOUNDATIONS
WHY A FEM GUIDELINES PAPER ?

- ALIGN PRACTICES … results of a short survey with crane users

Which safety factor should you apply on crane loads for designing foundation ?

Status : no consistent practice resulting in various level of safety in foundation design !

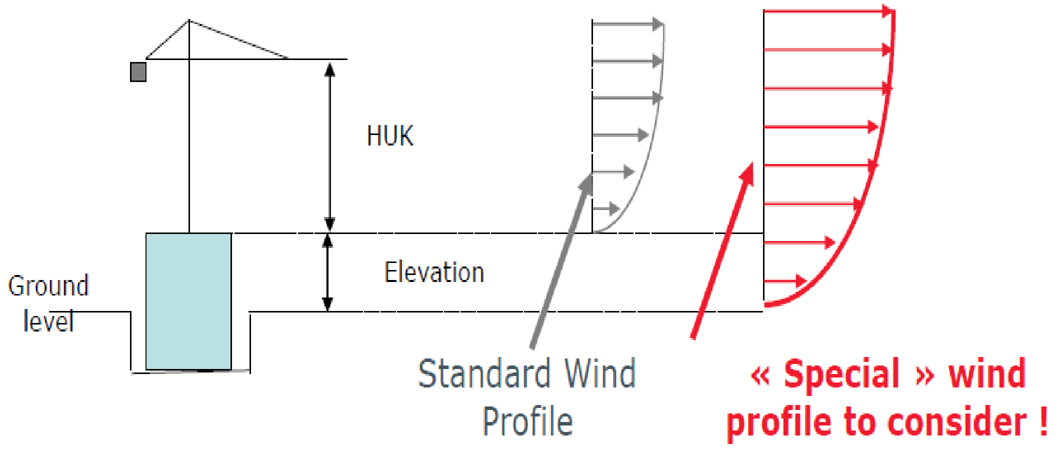
TOWER CRANE FOUNDATIONS
WHY A FEM GUIDELINES PAPER ?

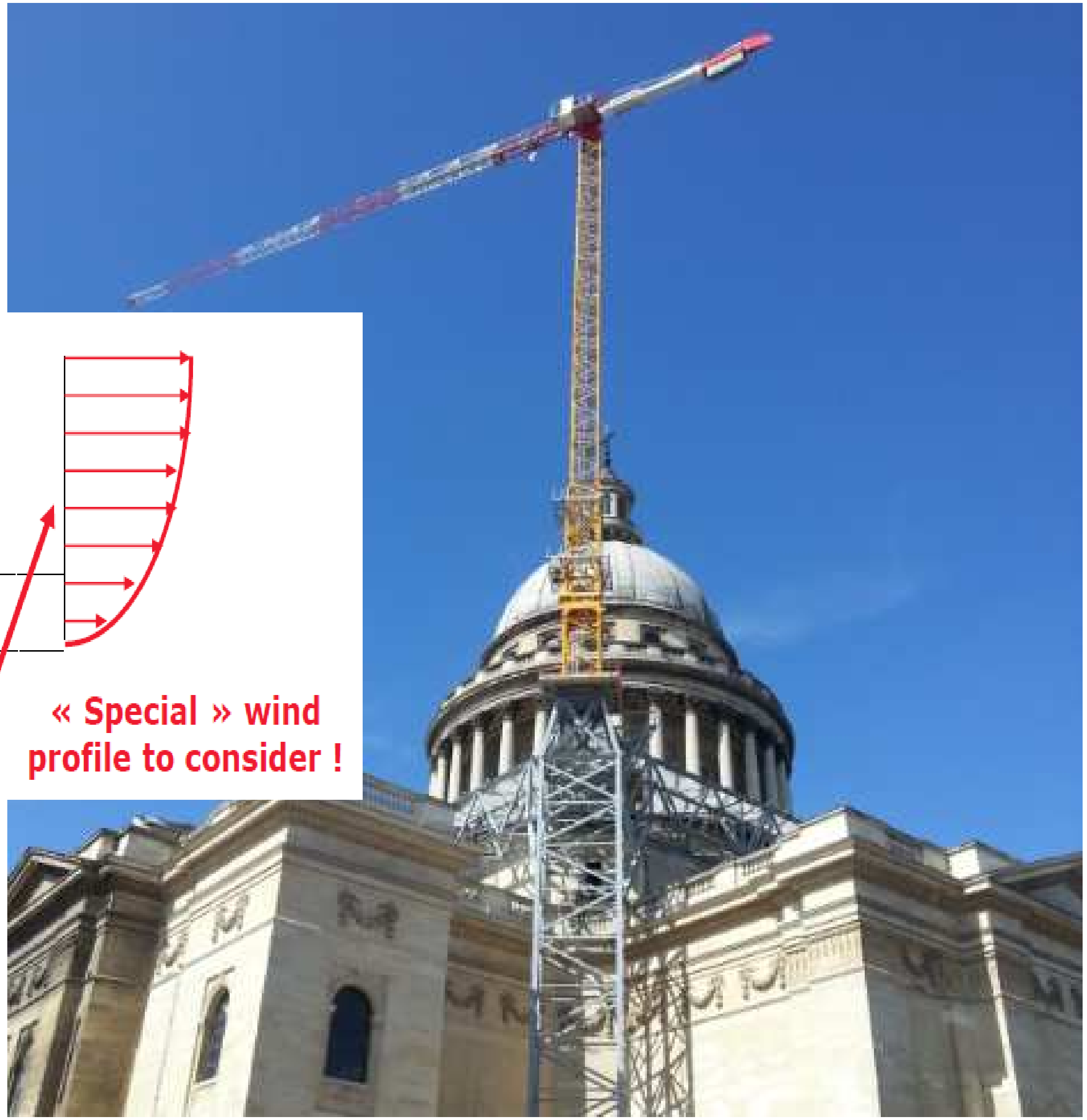
- EVOLUTION of STANDARDS & REGULATION (European references)

Tower crane : Machinery directive 2006/42/EC
EN14439 (+ EN13001)
Crane mechanical engineering

Buildings & foundations :
Eurocodes – EN1990 to EN1999
Civil construction engineering

- **Critical to establish an understandable and consistent common language**


HUK
Ground
level
Elevation
Standard Wind
Profile
« Special » wind
profile to consider !



Goal of the FEM document

Inform and provide relevant basics and guidelines for :

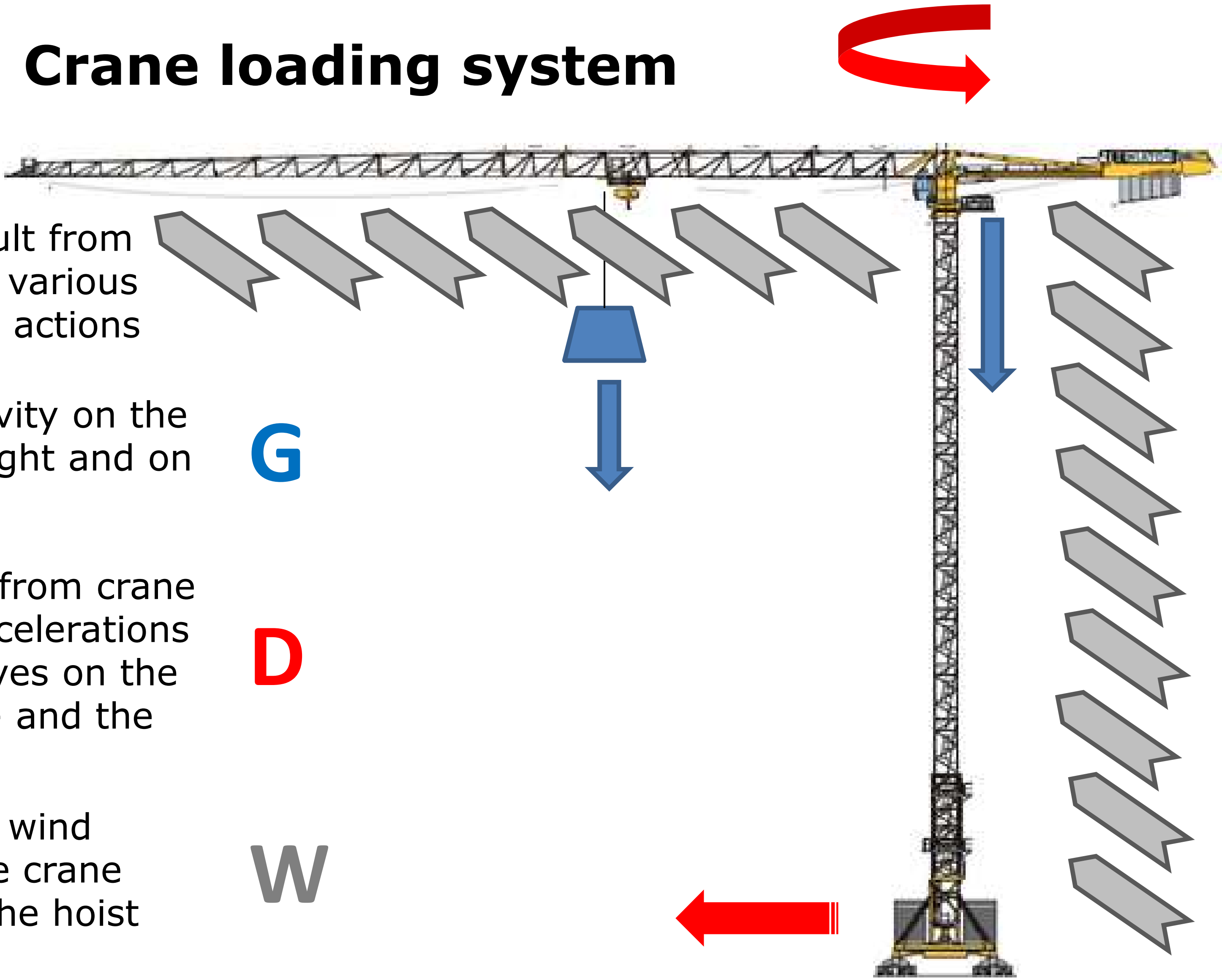
- SAFE
- COMPREHENSIVE
- COMPETITIVE

tower crane foundation design

Crane loading system

Crane loads result from combinations of various elementary load actions

- Effects of gravity on the crane dead weight and on the hoist load **G**
- Inertia loads from crane movements/accelerations of all crane drives on the crane structure and the hoist load **D**
- Effects of the wind pressure on the crane structure and the hoist load **W**



Crane loads combinations

Usually the maximum loads are given for each of the following situations:

- In-service loads, including maximum in-service-wind
- Out-of-service loads, with storm from rear and storm from front or alternatively storm from all sides
- Erection loads, mainly provided as foundation loads for cranes erected on concrete foundation

Loads on crane supports commonly provided by crane manufacturers

- Corner loads of cranes using undercarriage or foundation cross

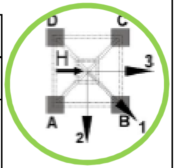
Corner reactions (characteristic load values, numerical example)

Crane type: Jib:

Tower system: tower selection length:

Base tower:

Crane base: Track: 6 m Wheel gauge: 6 m

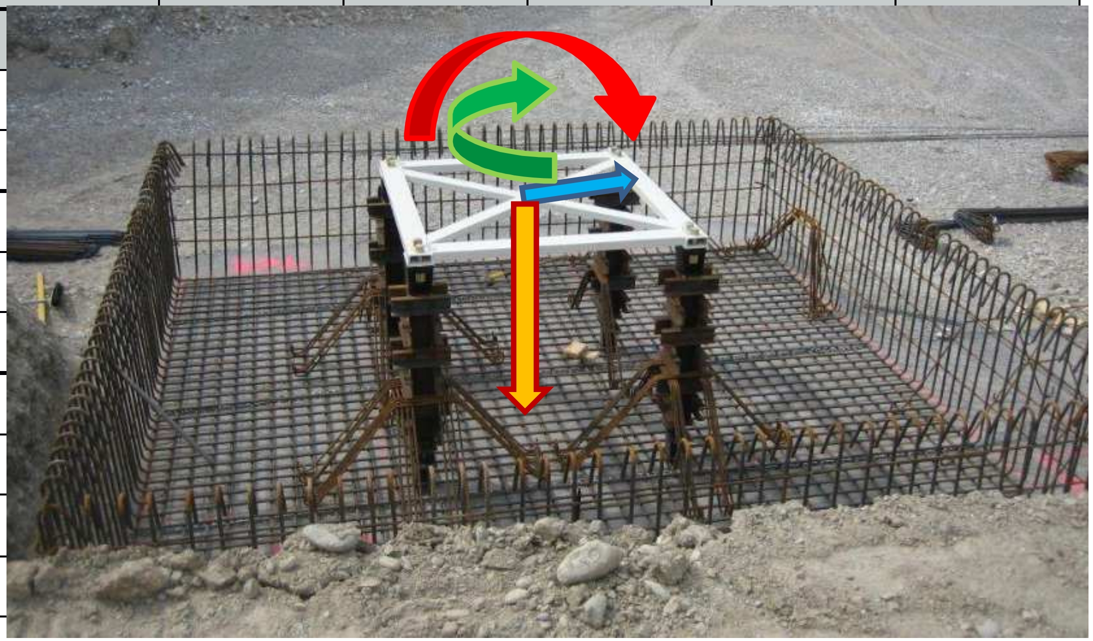


No. of tower sections	Hook height [m]	Central ballast [to]	Corner pressure in operation [kN], M_D = 325 kNm					Corner pressure out of operation [kN], M_D = 0 kNm				
			Corner	Position of jib 1	2	3	Hor. force [kN]	Corner	Position of jib 1	2	3	Hor. force [kN]
5	40,30	86,110	A	442	607	242	56	A	331	737	89	196
			B	**730**	676	641		B	**991**	737	737	
			C	442	277	641		C	331	89	737	
			D	154	208	242		D	0	89	89	

Loads on crane supports commonly provided by crane manufacturers

- Foundation loads of cranes erected on concrete foundation

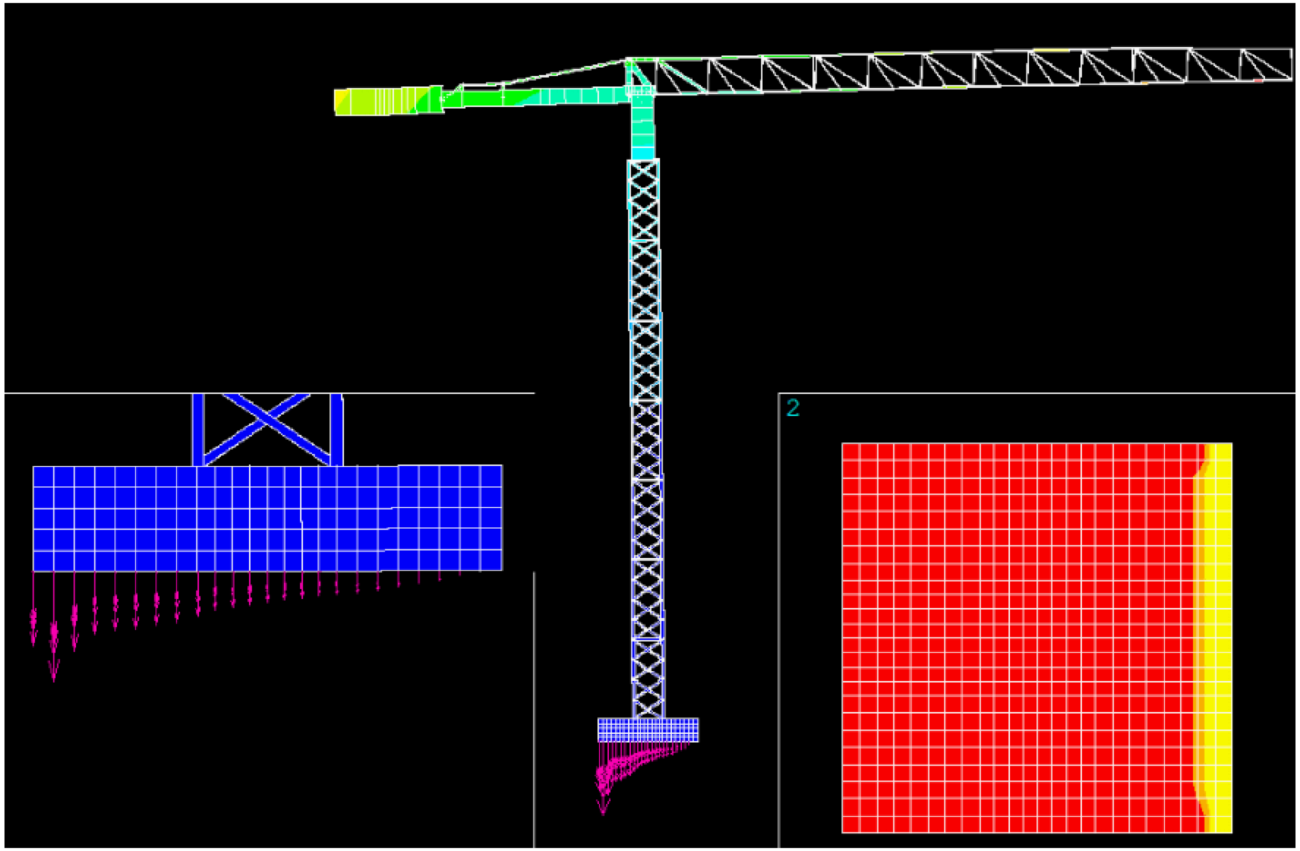
IH	Crane in service			Crane out of service			Assembly		
2	Slewing torque: 390 kNm			Wind category C25					
STR	M	V	H	M	V	H	M	V	H
[m]	[kNm]	[kN]	[kN]						
6.0	2810	642	25						
10.5	2930	661	26						
15.0	3070	679	28						
19.5	3220	697	29						
24.0	3400	715	31						
28.5	3590	733	32						
33.0	3800	752	34						
37.5	3970	800	36						
42.0	4200	828	38						



Permanent / Variable loads

Only the dead weight force is a permanent effect !

Even the variable dead weight load moment effect is considered as a live load for the supporting structure



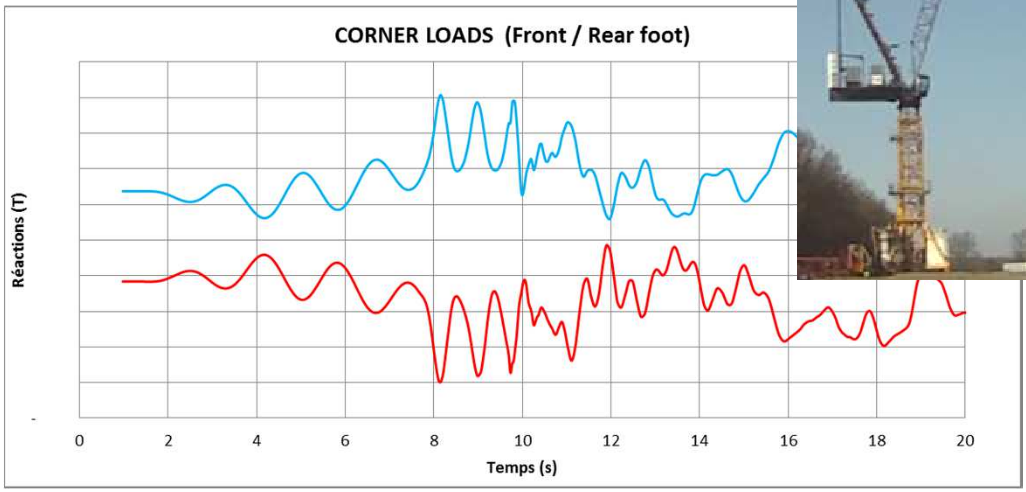
Pressure under concrete block (illustration)

Pressure under concrete block
Red = compression area
Yellow = gap

Characteristic loads

Illustration : emergency stop on luffing

Crane loads provided by crane manufacturers are generally characteristic loads without any partial safety factors included and usually nor dynamic factors.



Ultimate limit states verification
Load combinations

EN 1990:2002 + A1:2005 + A1:2005/AC:2010

The Ultimate limit states proof is considered for :

- Stability of the crane + foundation (EQU)
- Structural strength : internal failure or excessive deformation of the foundation / crane support (STR)
- Failure or excessive deformation of the ground (ground pressure) (GEO)

General :

$$\Sigma\gamma_{G,j} G_{k,j} \text{ "+" } \gamma_{Q,1} Q_{k,1} \text{ "+" } \Sigma\gamma_{Q,i} \psi_0 Q_{k,i}$$

Permanent load

Variable elementary loads

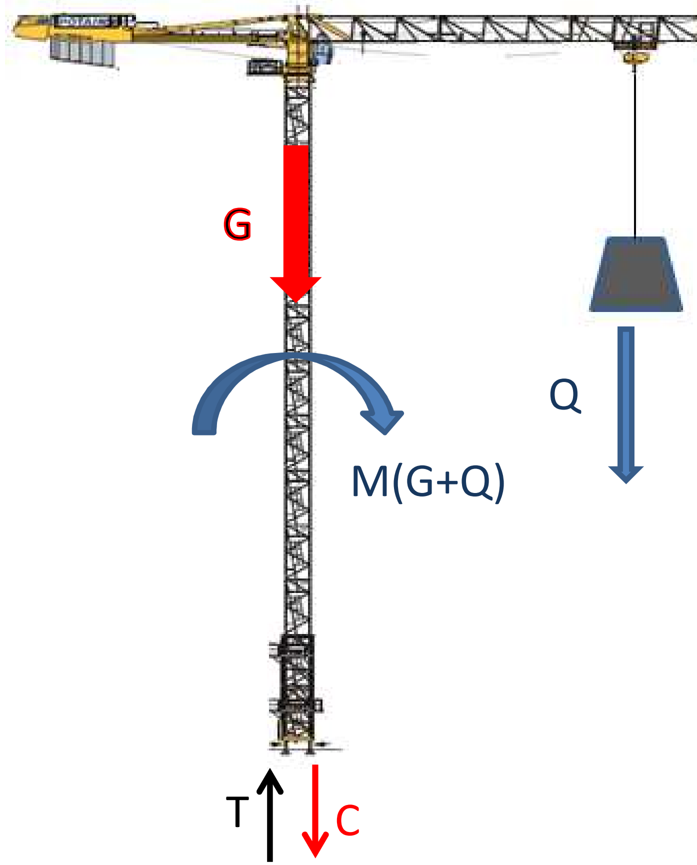
For a tower crane, it is simplified to :

$$\Sigma\gamma_{G,j} G_{k,j} \text{ "+" } \Sigma\gamma_{Q,i} Q_{k,i}$$

Permanent load

Variable resulting load

Partial safety factors
Favorable / Unfavorable load



	Max compressive load (C)	Max tensile load (T)
Permanent load from the crane (dead weight vertical action G)		
- Favourable	-	γ_{Ginf}
- Unfavourable	γ_{Gsup}	-
Variable load from the crane (including weight moment action M(G+Q))		
- Favourable	-	-
- Unfavourable	γ_{Qsup}	γ_{Qsup}

Cranes on Chassis

Load case	Partial safety factors if second order and dynamic effects are <u>included</u> by the crane manufacturer			Partial safety factors if second order and dynamic effects are <u>not included</u> by the crane manufacturer (f = 1,10)		
	γ_{Gsup}	γ_{Ginf}	γ_{Qsup}	γ_{Gsup}	γ_{Ginf}	γ_{Qsup}
In service (in operation)	Not applicable		1,35	Not applicable		1,5
Out of service (storm from rear)	for tower cranes on undercarriage or cruciform base		1,22	for tower cranes on undercarriage or cruciform base		1,35
Out of service (storm from front/side)			1,1			1,22
In erection (assembly)			1,22			1,35

Combined effect of dead weight force & moment
No tension load !

Note : For cranes on chassis, a proof of stability is not required as the crane stability checked by the crane manufacturer already defines the ballast required on the chassis according to crane standard.

Cranes on shallow foundations
(concrete block)

	Partial safety factors if second order and dynamic effects are included by the crane manufacturer [1)]			Partial safety factors if second order and dynamic effects are not included by the crane manufacturer (f = 1,10)		
Load case	γ_{Gsup}	γ_{Ginf}	γ_{Qsup}	γ_{Gsup}	γ_{Ginf}	γ_{Qsup}
In service (in operation)	1,35	1	1,35	1,35	1	1,5
Out of service (storm from rear)	1,22	1	1,22	1,22	1	1,35
Out of service (storm from front/side)	1,1	1	1,1	1,1	1	1,22
In erection (assembly)	1,22	1	1,22	1,22	1	1,35

For max compression (γ_{Gsup} column, right-hand group)

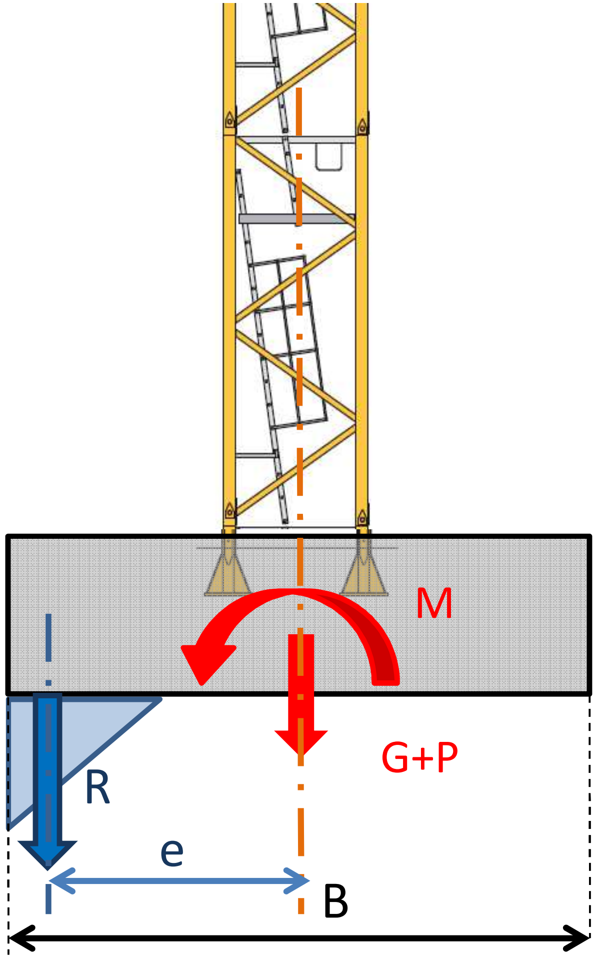
For max tension and min stability (γ_{Ginf} column, right-hand group)

Cranes on shallow foundations (concrete block) – Ultimate limit state

Proof of stability of concrete block foundation

As a general guideline for shallow foundation, the resulting load (R) eccentricity (e) shall not be greater than 1/2 of the concrete block outside dimension (B) in any direction.

$$e \approx \frac{\gamma_Q . M}{\gamma_G . (G + P)} < \frac{1}{2} \times \mathrm{B}$$



Note : This guideline is defined considering the temporary installation of the tower crane on the construction site. In case of special application (e.g. permanent installation on a stock yard) a maximum eccentricity of 1/3rd may be necessary.

Serviceability limit states verification
Load combinations

EN 1990:2002 + A1:2005 + A1:2005/AC:2010

Serviceability limit states proof for :

- Limitation of ground deformation (then resulting crane stability)

$$\Sigma\, G_{k,j} \text{ "+" } Q_{k,1} \text{ "+" } \Sigma\, \psi_0 Q_{k,i}$$

Permanent load

Variable elementary loads

For a tower crane, it is simplified to :

$$\Sigma G_{k,j} \text{ "+" } \Sigma\, Q_{k,i}$$

Permanent load

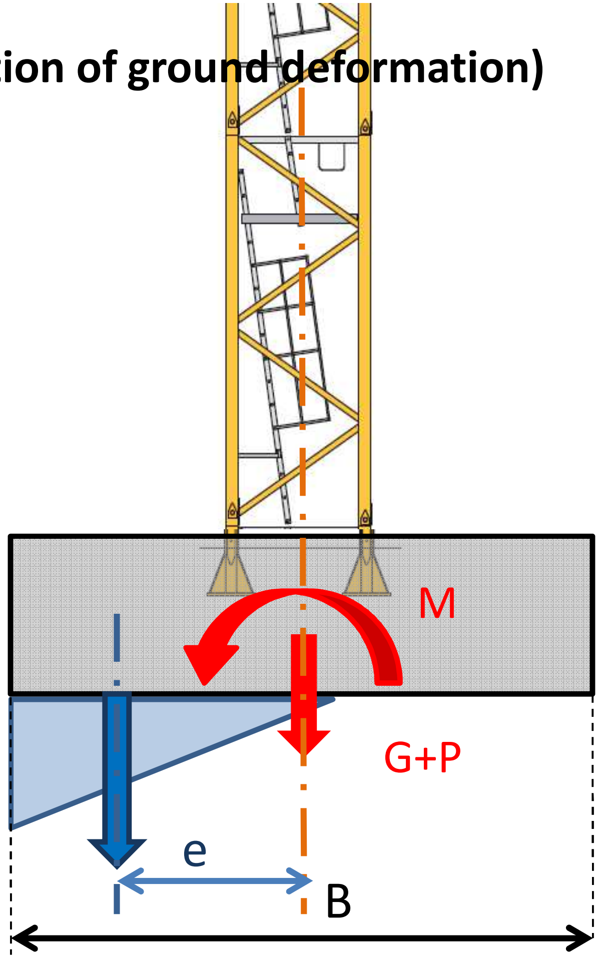
Variable resulting load

Cranes on shallow foundations (concrete block) – Serviceability limit state

Proof of stability of concrete block foundation (limitation of ground deformation)

As a general guideline for shallow foundation, the resulting load eccentricity (e) shall not be greater than 1/3rd of the concrete block outside dimension (B) in any direction.

$$e \approx \frac{M}{G+P} < \frac{1}{3} \times \mathrm{B}$$

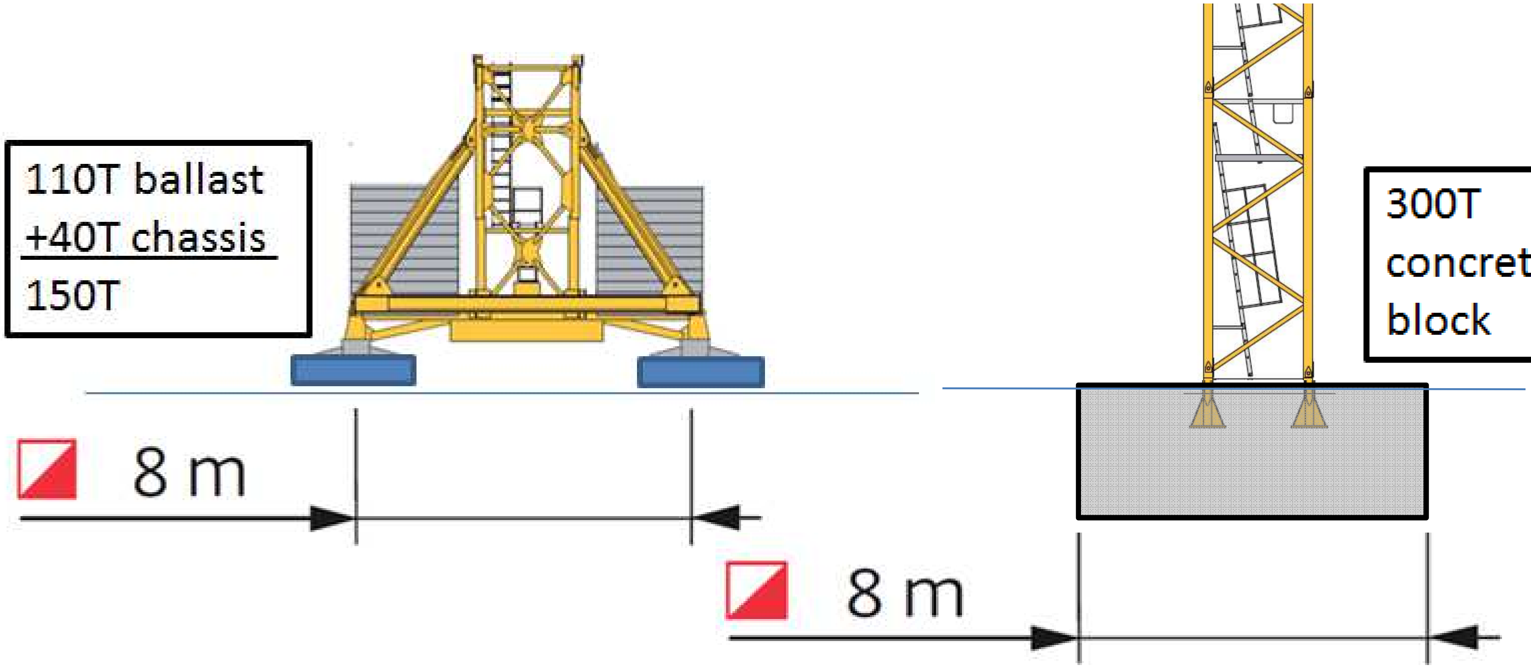


Note : This guideline is defined considering the temporary installation of the tower crane on the construction site.
In case of special application (e.g. permanent installation on a stock yard), a maximum eccentricity of 1/6th for the load combination "crane in service", assumed as quasi-permanent ELS combination, may be necessary.

Crane on shallow foundations vs crane on chassis

Comparison of the base ballast (for same crane configuration)

Typically, the stability of a crane on shallow foundation will be increased approx. +50% to +100% compared to a crane installed on chassis.



Crane loads on supporting structures
Foundation design conclusion

– **Maximum crane load on supporting structure is the result of multiple loads combinations** (dead and live weights loads, inertia loads from the different movements, different wind conditions loads).

– **It is the responsibility of the crane manufacturer to analyze all governing load combinations and to provide the maximum resulting crane loads.** It is not indented that the crane user will re-combined all the single crane loads for each crane situation.

– **It is the responsibility of the crane user to ensure the tower crane support is properly designed considering the resulting crane loads provided.**

– FEM is then promoting a **consistent guidance** and recommendation to users in **Europe and elsewhere *for a safe and competitive practice***

THANK YOU !

Senate House construction site, London University, c1935