DEVELOPMENT IN CODES FOR NEW AND EXISTING CONCRETE STRUCTURES
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MEMBER STATES OF MERCOSUR

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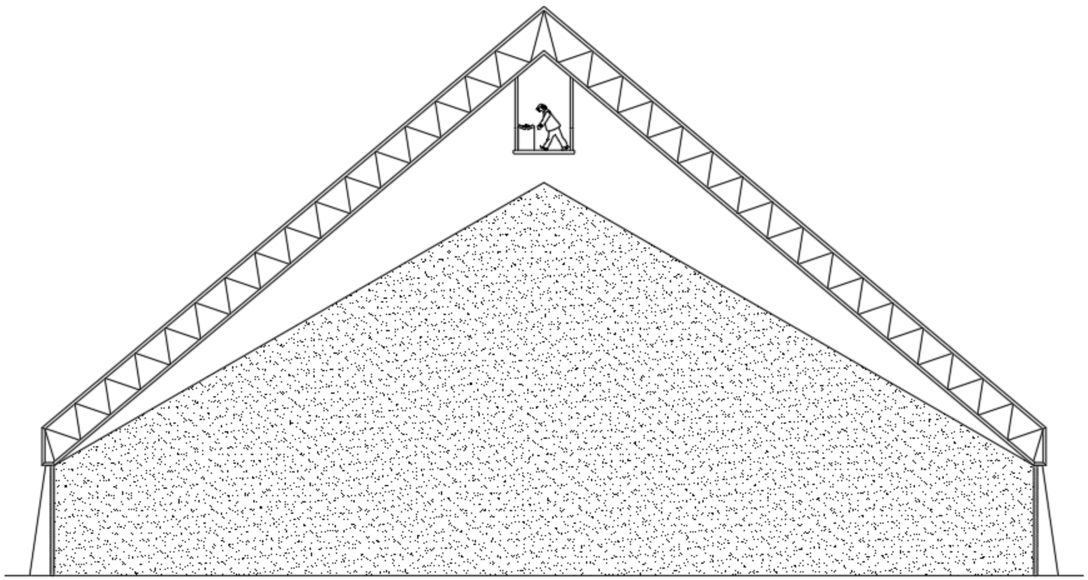
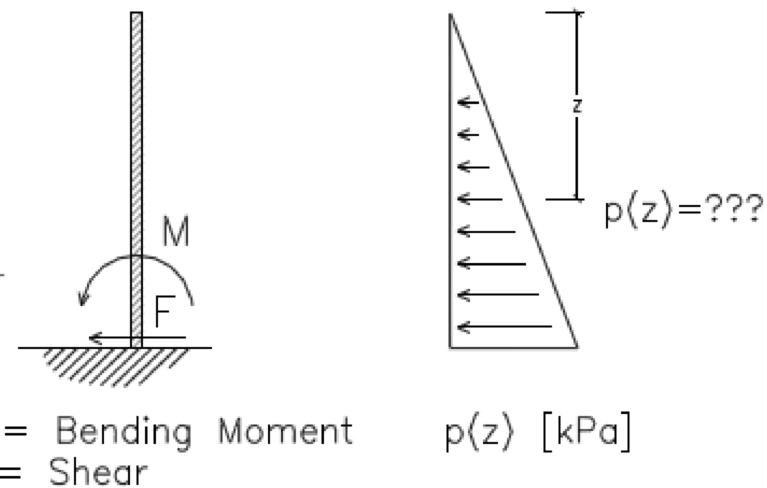
RETAINING SILOS
(silo warehouses)

FILLING PRESSURES IN A RETAINING SILO:





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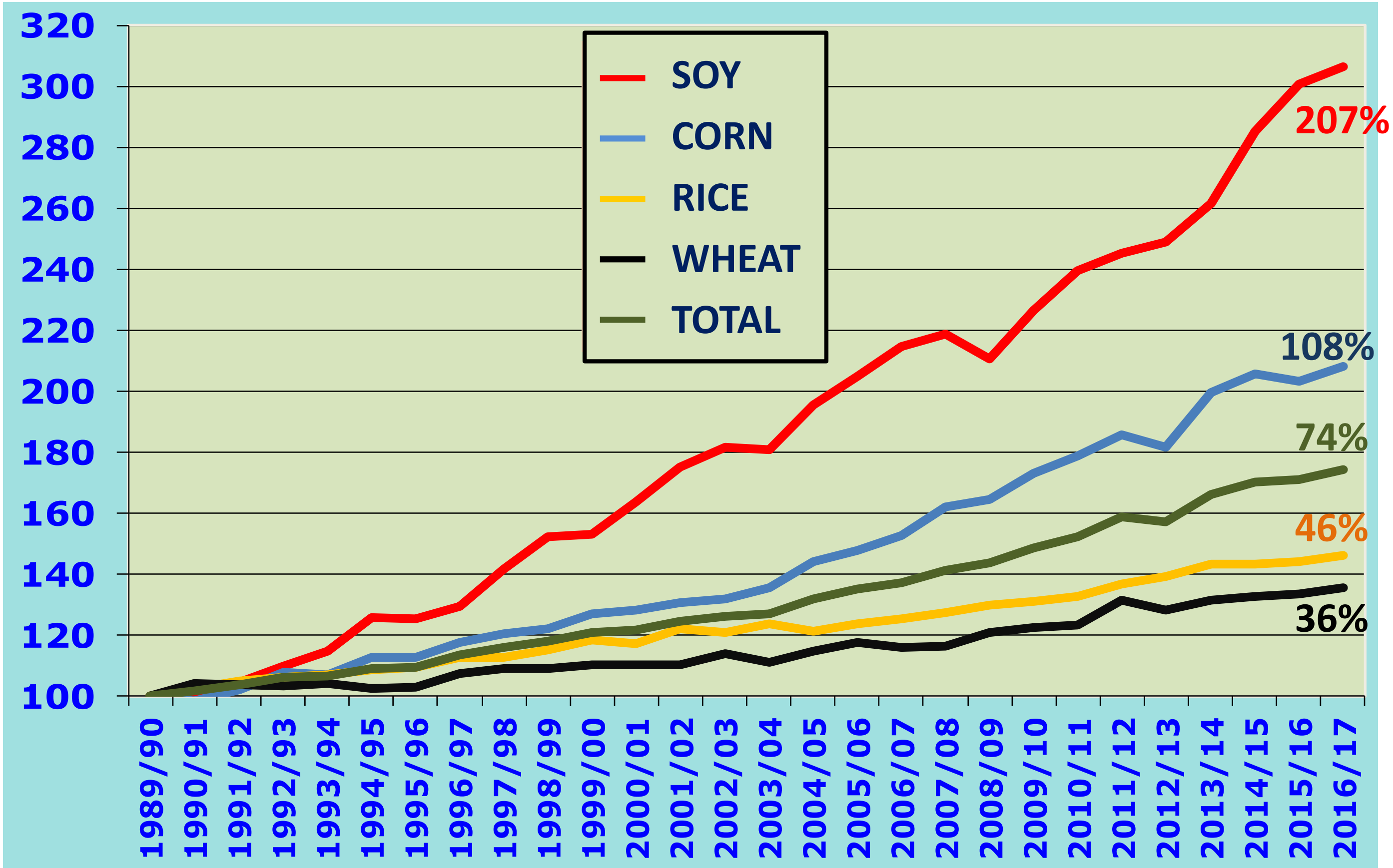
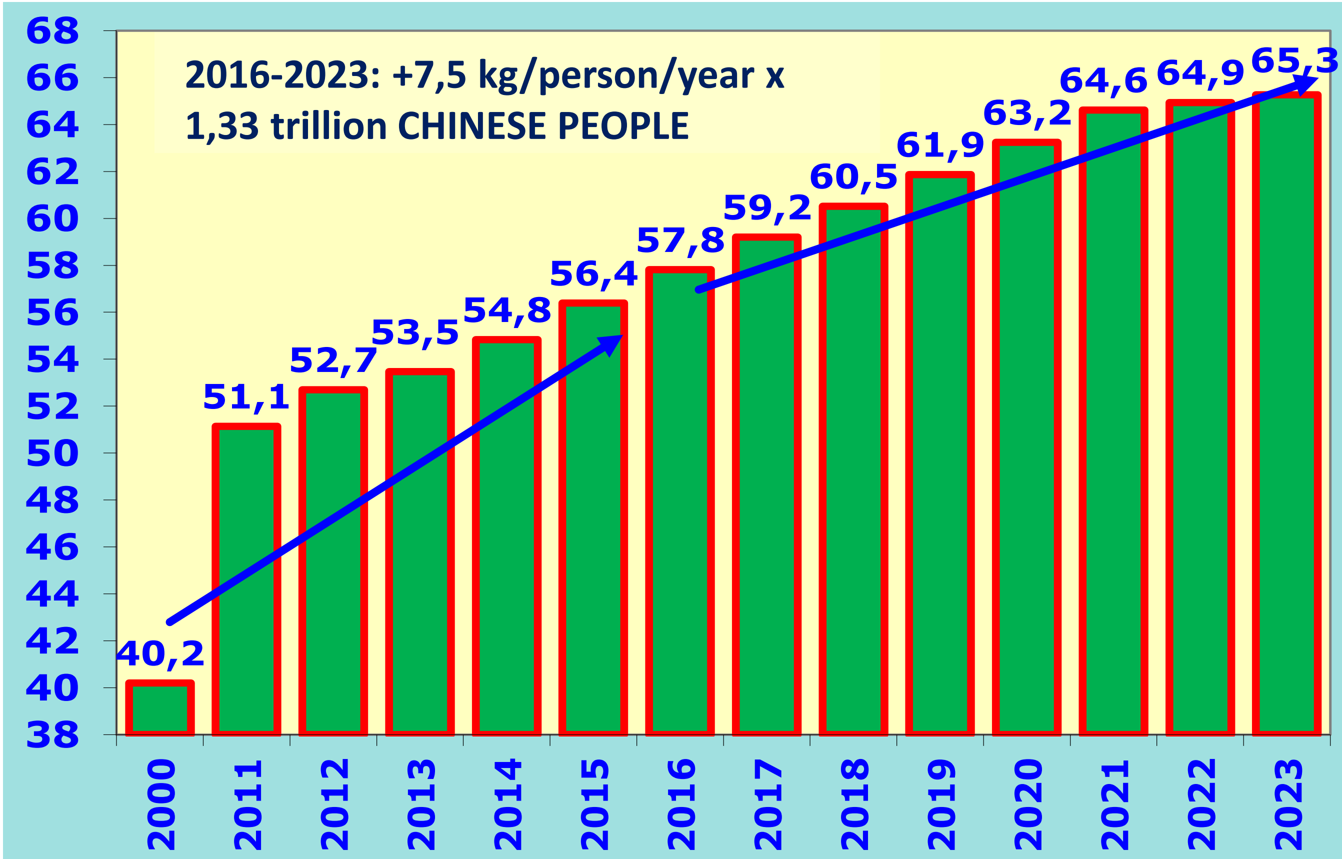


GRAINS: GLOBAL DEMAND EXPANSION INDEX SINCE 1990

Base = 100



CHINA: MEAT DEMAND PROJECTION UNTIL 2023 – kg/person/year

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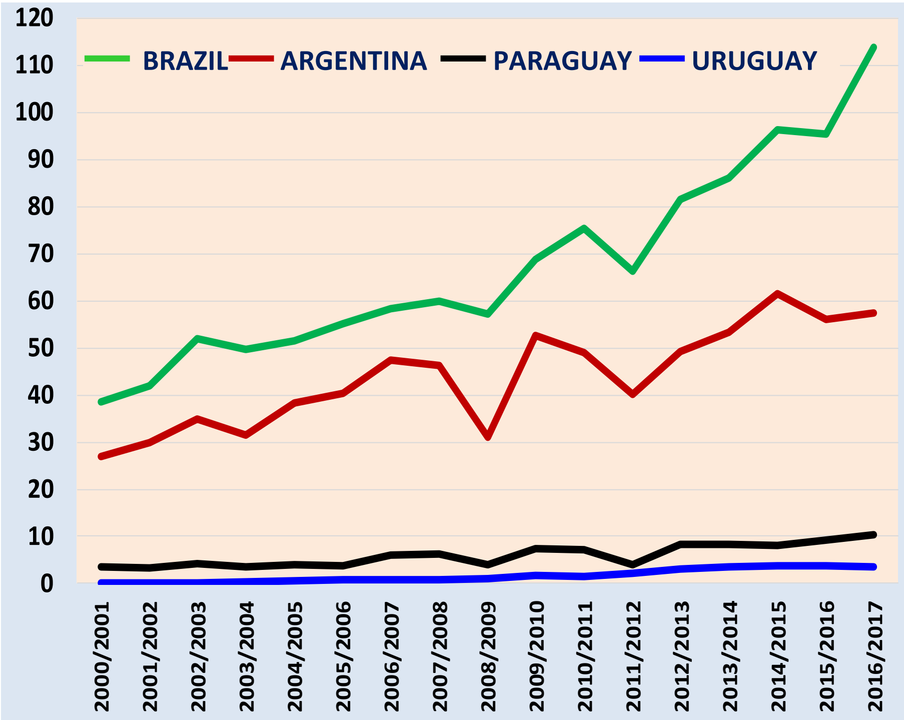
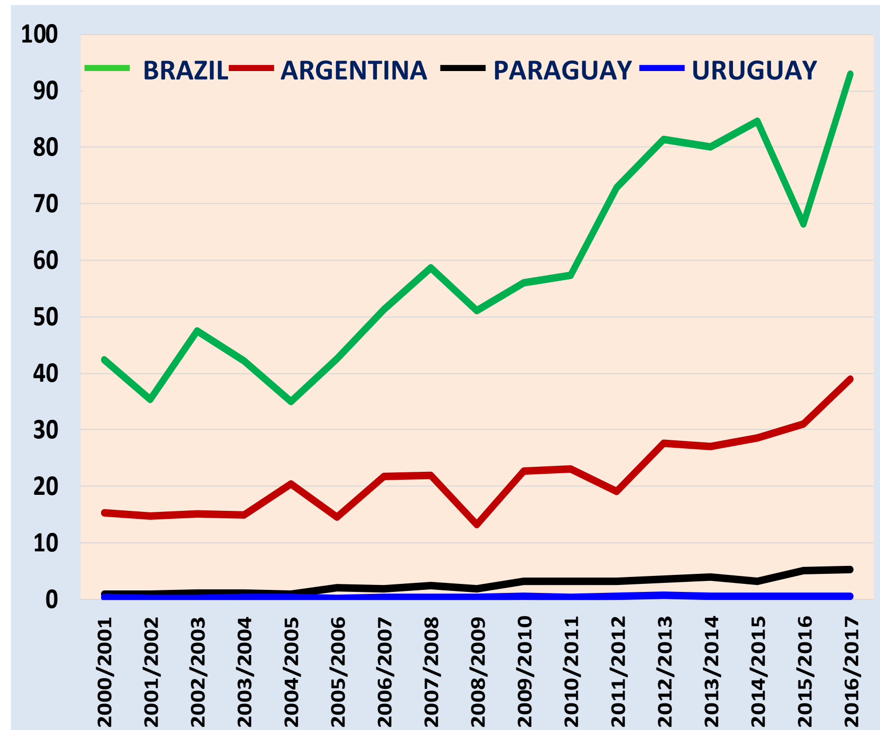


SOY PRODUCTION IN MERCOSUR COUNTRIES, IN MILLION TONS



CORN PRODUCTION IN MERCOSUR COUNTRIES, IN MILLION TONS

COUNTRY	GRAIN PRODUCTION *	STORAGE CAPACITY	DEFICIT / SURPLUS	FARM CAPACITY	FARM CAPACITY
	MILLION TONS	MILLION TONS	MILLION TONS	MILLION TONS	%
USA	574.9	636.7	61.8	353.8	56%
BRAZIL	234.4	162	-72.4	25	15%
ARGENTINA	125.5	75.1	-50.4	16	21%
URUGUAY	6.8	6.8	0	0.3	4%

* Includes soy, corn, wheat and rice production.

OBS: It does not include the capacity in bag silos

Made by Carlos Cogo Consultoria Agroeconomica

STORAGE: COMPARISON BETWEEN HARVEST AND STATIC CAPACITY IN 2016

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In Brazil, only a small part of grain production (approximately 8,5%) is stored in silo-bags. The rest of the deficit is resolved storing in the open air, with losses above 10%.

(La Nación, Buenos Aires)

CORN STORED IN THE OPEN AIR – MATO GROSSO (AUGUST/2015)

VERTICAL SILO CLUSTERS
TGM - Montevideo

HORIZONTAL SILO WAREHOUSES
Corporación Navíos - Nueva Palmira

Prof. Adam Sadowski - Imperial College London, UK

Breve reseña :

El Dr Adam Jan Sadowski es profesor en la Sección de Estructuras en Imperial College London (UK). Sus líneas de investigación incluyen la modelación teórica y computacional de la resistencia y estabilidad de cáscaras estructurales complejas, aplicando teoría de cáscaras, elementos finitos, matemática aplicada y mecánica de sólidos. Destaca su actividad en el estudio de fenómenos de descarga excéntrica de granos en silos, junto al Prof. J. M. Rotter. Integra varios comités europeos para la revisión de normas relativas a cascaras metálicas, silos, tanques, conducciones tubulares, pandeo de cascaras entre otras. Es autor de más de 40 publicaciones en revisitas internacionales científicas, con más de 300 citas colectivamente.

1er Seminario : Lunes 2 de Octubre : 11:00 a 12:30 : Anfiteatro del Aulario - Facultad de Ingeniería

"Modelling of eccentric discharge in thin-walled metal silos"

(Modelado de procesos de descarga excéntrica en silos metálicos de pared delgada)

2do Seminario : Miércoles 4 de Octubre : 12:00 a 13:30 : Salón de Posgrado del IMFIA - Facultad de Ingeniería

"Nonlinear behaviour of cylindrical shells under bending "

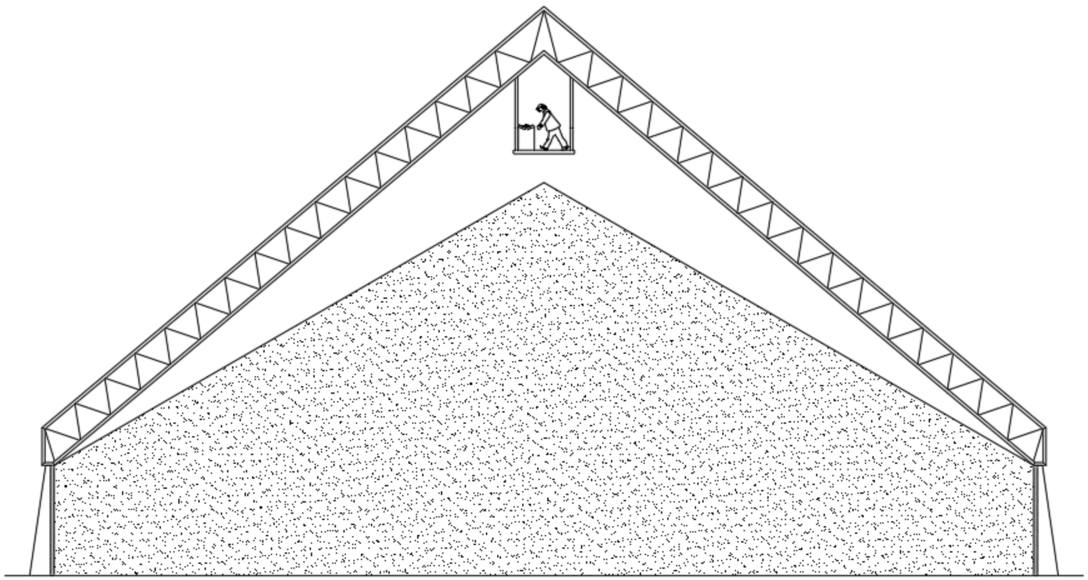
(Comportamiento no lineal de cáscaras cilíndricas sometidas a flexión)

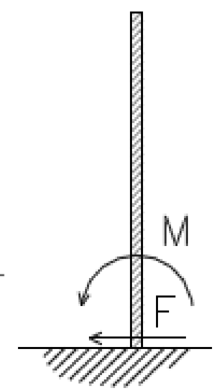
3er Seminario : Viernes 6 de Octubre : 12:00 a 13:30 : Salón de Posgrado del IMFIA - Facultad de Ingeniería

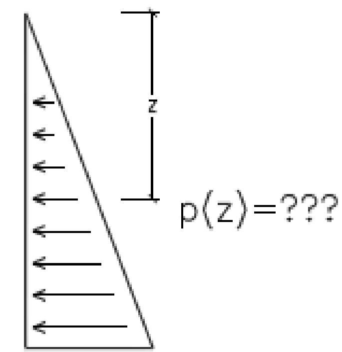
"Characterisation of strain hardening in mild steels"

(Caracterización del endurecimiento por deformación en aceros dúctiles)

FILLING PRESSURES IN A RETAINING SILO:



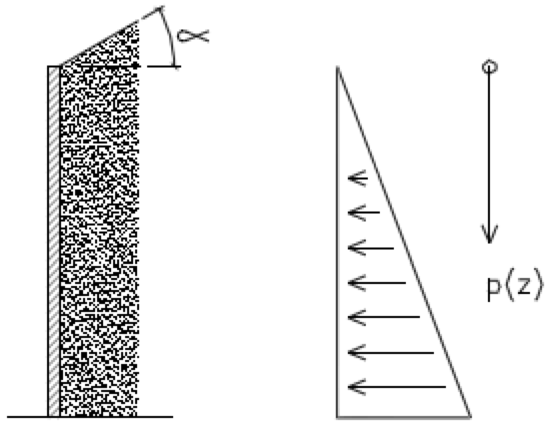




M = Bending Moment
F = Shear

p(z) [kPa]

ANDRÉ & MARCEL REIMBERT:



VERTICAL WALLS

ACTIVE PRESSURE: $p(z) = \gamma \cdot z \left(\frac{\pi/2-\varnothing}{\pi/2+\varnothing}\right)^2\left(1+\frac{2\alpha}{\pi}\right)$

PASSIVE PRESSURE: $p(z) = \gamma \cdot z \left(\frac{\pi/2-\varnothing}{\pi/2+\varnothing}\right)\left(1+\frac{2\alpha}{\pi}\right)$

Assuming that the internal friction angle is equal to the natural slope angle:

ACTIVE PRESSURE: $p(z) = \gamma \cdot z \left(\frac{\pi/2-\varnothing}{\pi/2+\varnothing}\right)^2\left(1+\frac{2\varnothing}{\pi}\right)$

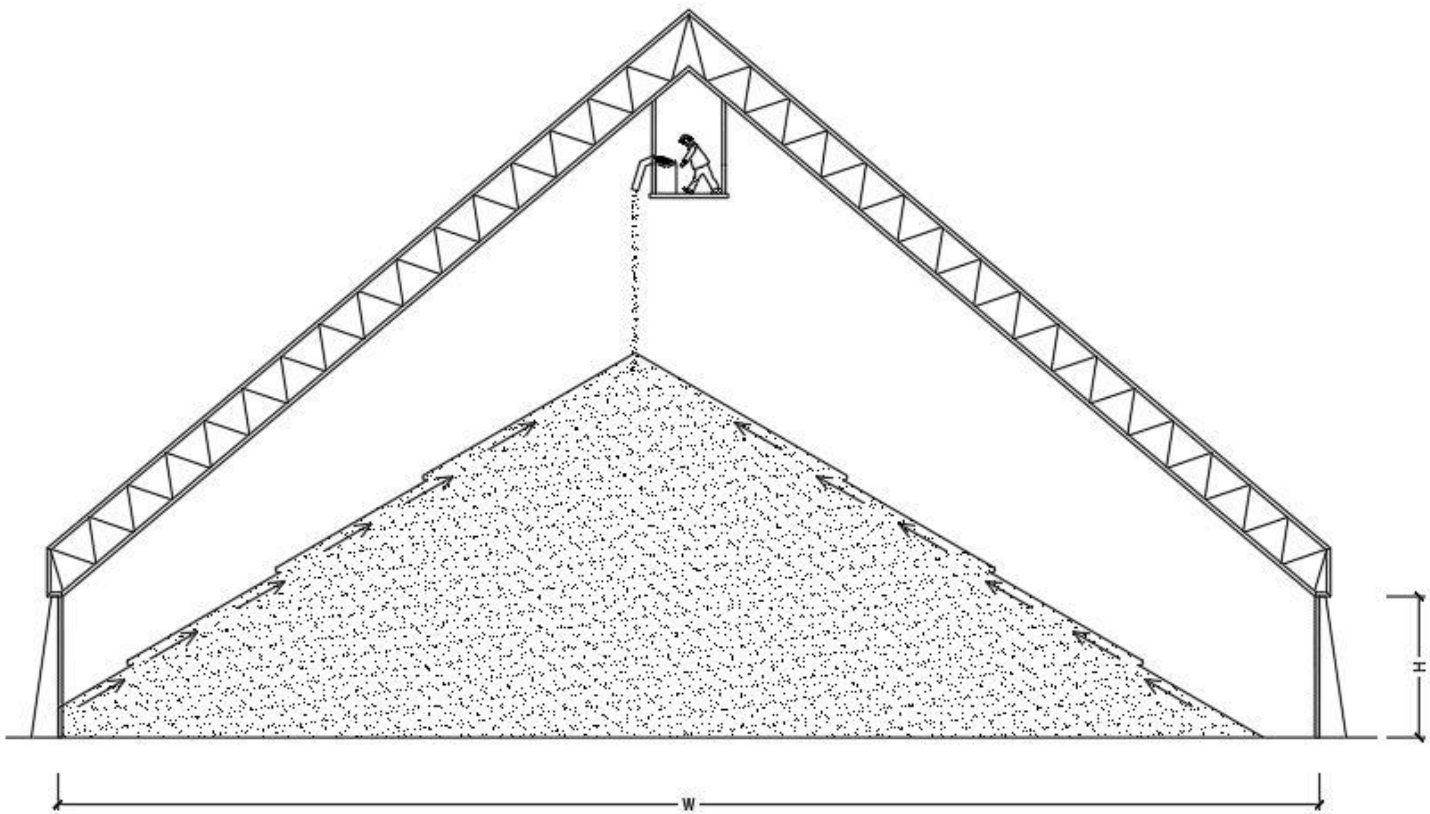
PASSIVE PRESSURE: $p(z) = \gamma \cdot z \left(\frac{\pi/2-\varnothing}{\pi/2+\varnothing}\right)\left(1+\frac{2\varnothing}{\pi}\right)$

UNE 1991: $p(z)=\gamma.K.(1+\text{sen}\,\emptyset).z$

"The evaluation of the lateral pressure ratio K should take account of the restraint provided by the wall against outward movement of the stored solid. Where a structural analysis is used to demonstrate that the wall can displace sufficiently in its elastic range, a lower value of K may be adopted."

Table C.2: Typical values of the coefficient of variation of particulate solids properties

Bulk solid	Coefficient of variation δ				
	Lateral pressure ratio (K)	Angle of internal friction (ϕ_i) (degrees)	Wall friction coefficient (μ)		
			Wall friction category		
			Type D1	Type D2	Type D3
Aggregate	0,11	0,11	0,09	0,09	0,09
Alumina	0,14	0,16	0,05	0,05	0,05
Animal feed mixture	0,08	0,06	0,19	0,19	0,19
Animal feed pellets	0,05	0,05	0,14	0,14	0,14
Barley	0,08	0,10	0,11	0,11	0,11
Cement	0,14	0,16	0,05	0,05	0,05
Cement clinker	0,21	0,14	0,05	0,05	0,05
Coal	0,11	0,11	0,09	0,09	0,09
Coal, powdered	0,14	0,18	0,05	0,05	0,05
Coke	0,11	0,11	0,09	0,09	0,09
Flyash	0,14	0,12	0,05	0,05	0,05
Flour	0,08	0,05	0,11	0,11	0,11
Iron ore pellets	0,11	0,11	0,09	0,09	0,09
Lime, hydrated	0,14	0,18	0,05	0,05	0,05
Limestone powder	0,14	0,16	0,05	0,05	0,05
Maize	0,10	0,10	0,17	0,17	0,17
Phosphate	0,11	0,13	0,09	0,09	0,09
Potatoes	0,08	0,09	0,11	0,11	0,11
Sand	0,08	0,07	0,11	0,11	0,11
Slag clinkers	0,08	0,07	0,11	0,11	0,11
Soya beans	0,08	0,12	0,11	0,11	0,11
Sugar	0,14	0,14	0,05	0,05	0,05
Sugarbeet pellets	0,11	0,11	0,09	0,09	0,09
Wheat	0,08	0,09	0,11	0,11	0,11



Given the width/height ratio , the grain always reaches the wall after falling down the grain slope.

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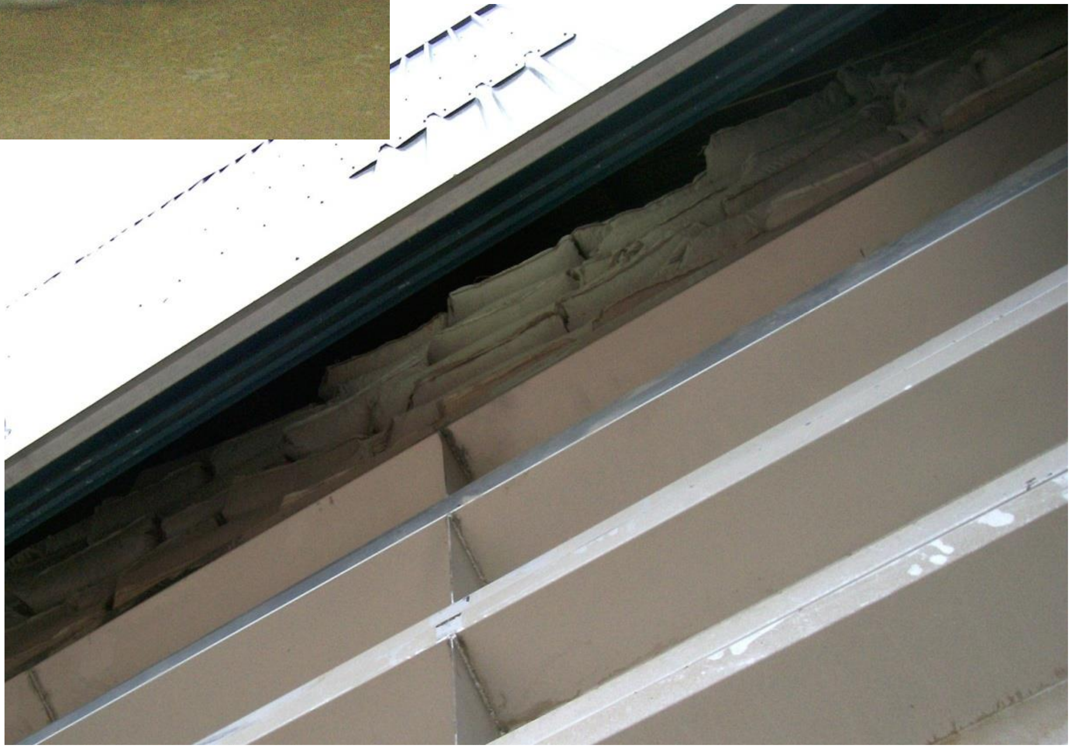
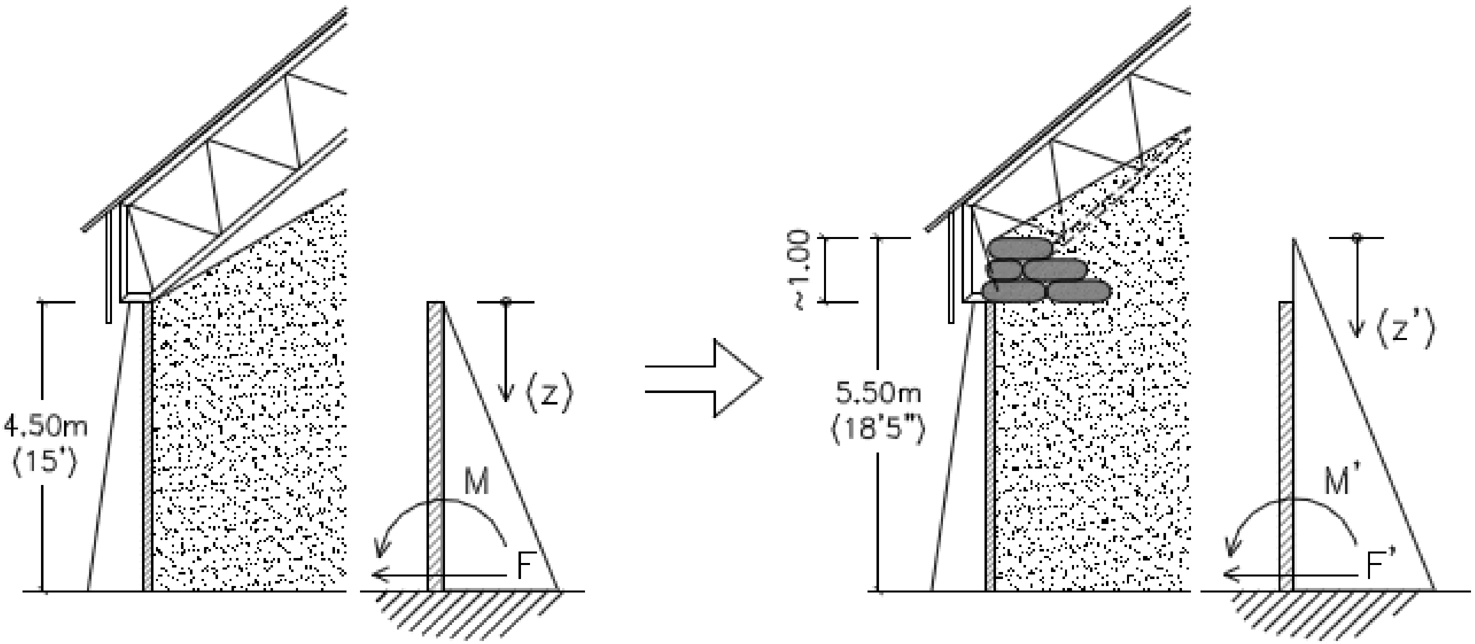
Silo warehouse during a rice harvest season in Uruguay



The pressure obtained from Reimbert's passive thrust, adopting an internal friction angle of 30° for rice, turns out to be twice the value of the original calculation.



Considering also that the stored grain height is a meter over the design value, we would have a shearing stress 3 times higher and a bending moment 3.6 times higher than the design loads.

$$F' = \left(\frac{5,5}{4,5}\right)^2 x F = 1,5F$$

$$M' = \left(\frac{5,5}{4,5}\right)^3 x M = 1,83M$$

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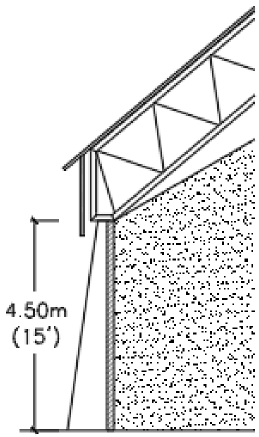
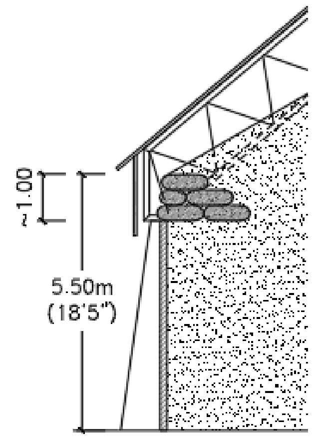
CRACKS IN SILO WAREHOUSE WALL DUE TO OVERLOADING





* WITHOUT OVERLAPING SECONDARY ACTIONS

ACTIVE PRESSURE

SLAB–WALL	BM=1	BM=1.83	ACORDING TO THE OBSERVED
BUTRESS *	BM=1	BM=1.10	

PASIVE PRESSURE

SLAB–WALL	BM=2	BM=3.60	IN DISREPAIR WITH THE OBSERVED
BUTRESS *	BM=2	BM=2.20	

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Thank you for your attention!

Many thanks to agro-business consultant Dr. Carlos Cobos for his contribution to this presentation

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