Experimental Determination of Stresses on a Model Silo

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SYNOPSIS In this paper we present some results obtained from a cylindrical model silo designed by using the well known Janssen asymptotic expression of bin pressure. Two kinds of tests have been conducted.

- one by varying the outlet diameter, (d)
- the other by varying the hopper slope, θ

All these variation are done to obtain man-flow in the model. The electric responses of the sbain gages give some informations on the deformations of the transition zone. Close to the hopper and reveal the existence of a peak stress responsable of the destruction of many industrial silos cited in the specialized litterature.

INTRODUCTION

May researchers Jenike, A.w. 1971. Rembert (1971) and Bransby (1974) have worked on the dynamical behaviour of a bulk solid stored in different experimental model silos. The originality of this paper lies in the fact that :

- we can record the deformation both during filling and emptying
- the dimensional analysis has enabled, us to design a model whose general kinematical behaviour is well known as stated in the work done by KAMGUEU and al (1979).

EXPERIMENTAL DEVICE

The Experimental device (fig. 1) comprises

- an Archimedean screw to fill the model regularly
- a model silo made of two elements whose diameter is 0,40m thikness 0.3mm and herght 0.90m. At the any extremity of each of these elements there is a flange which permit us to hang the model on a portal frame. Eight 350Ω strain gages have been sticked on the element close to the hopper.
- Two hopsers whose stopes θ are respectively 20° and 40° possibility of varying the outlet diameter.
- The electronic device consists of an extensometer, two tracer-tables and an electromagnet to close the hopper outlet.

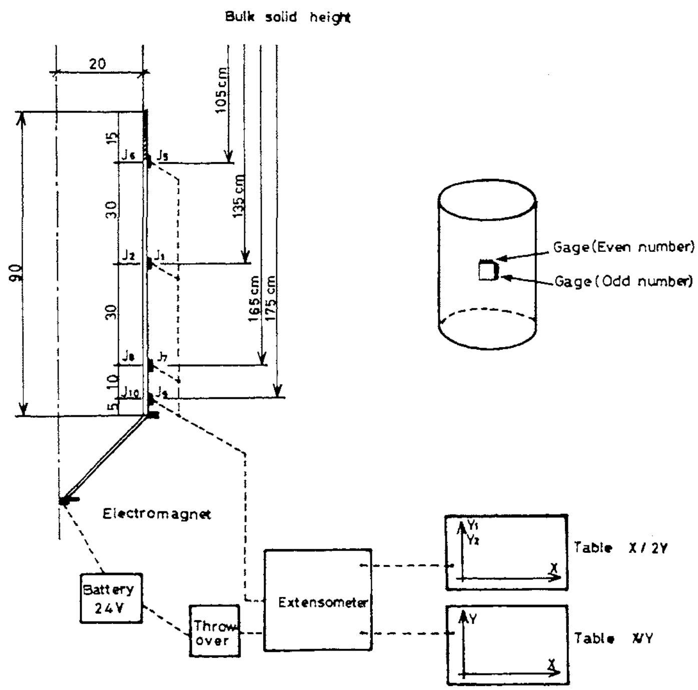

FIG 1 Measuring Device

TESTS AND RESULTS

The bulk material tested is a corn whose properties have been obtained by using the DIN 1977 standards for bins design :

- angle of internal friction $\phi = 30°$

friction angle between corn and steel $\delta = 24°$

- maximum unit weight $\gamma_{max} = 9300 N/m^3$
- minimum unit weight $\gamma_{min} = 7959 N/m^3$

compression index 15%

mobility index 0,42

uniformity index $\frac{d_{60}}{d_{10}} = 1,5$

The formula used to design the silo thickness is the following.

$$P_h = \frac{\gamma_{max} R_h}{K \, tg \, \delta} \quad (K = \frac{1-\sin\phi}{1+\sin\phi})$$

Where

P_h is the horizontal maximum static pressure

R_h the hydraulic radius of the section.

The electric response of the gages are in the tables 1 and 2.

d = 6cm	θ = 20°		d = 3	θ = 200
gages	filling	Emptying	filling	Emptying
1	+8	125	+31	+120
2	-14	+76	185	+89
5	-25	-94	+19	-100
6	-22	+49	+165	+815
7	+61	+113	104	136
8	-30	+92	-245	+92
9	+189	-152	+83	-150
10	-50	+61	-22	+31

Table 1 Electrical responses of the strain gages θ=20°

d = 3	θ = 40°		d = 6	θ = 40°
gages	filling	Emptying	filling	Emptying
1	+12	+145	+27	+365
2	+35	+51	+2	+60
3	+37	-79	+21	-61
6	+2	+51	+2	+29
7	+71	+104	+70	+94
8	+10	+26	+8	+19
9	+125	-14	+10	-7
10	+16	+34	+18	+29

Table 2 Electrical responses of srtain gages θ = 40°

The differents graphs stained for horizontal gages are on figures 2 to 5 indicating the variation of the horizontal normal pressure on the bin.

Figure 6 to 9 show the variation of the vertical pressures induced by the friction between the corn and the silo only, as the silo weight is supported by the frame.

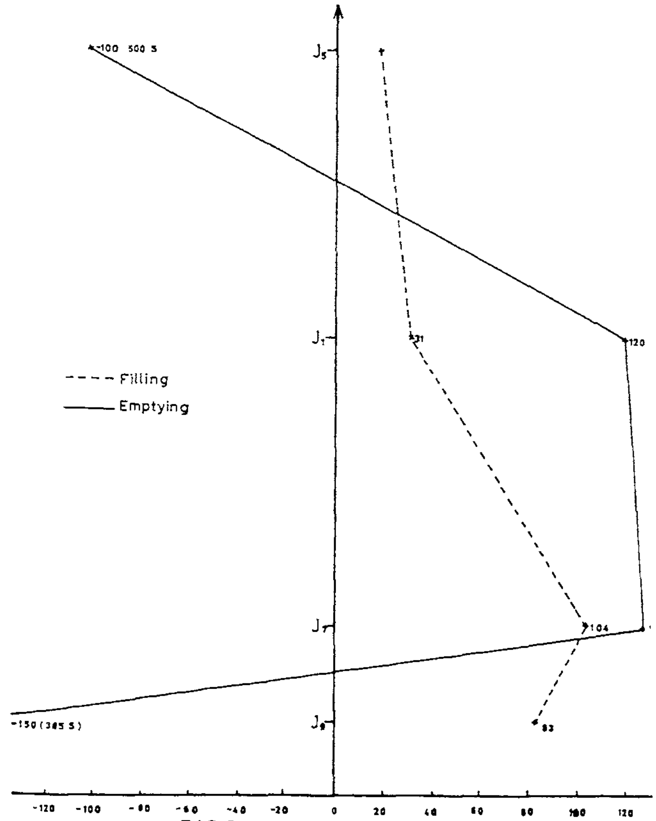

FIG 2 Horizontal Strain Gages (Odd No)
d=3cm θ=20°

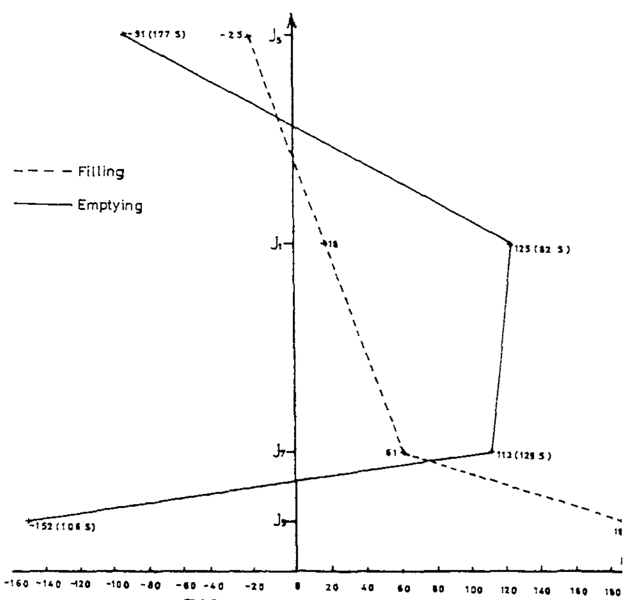

FIG 3 Horizontal Strain Gages (Odd No)
d=6cm θ=20°

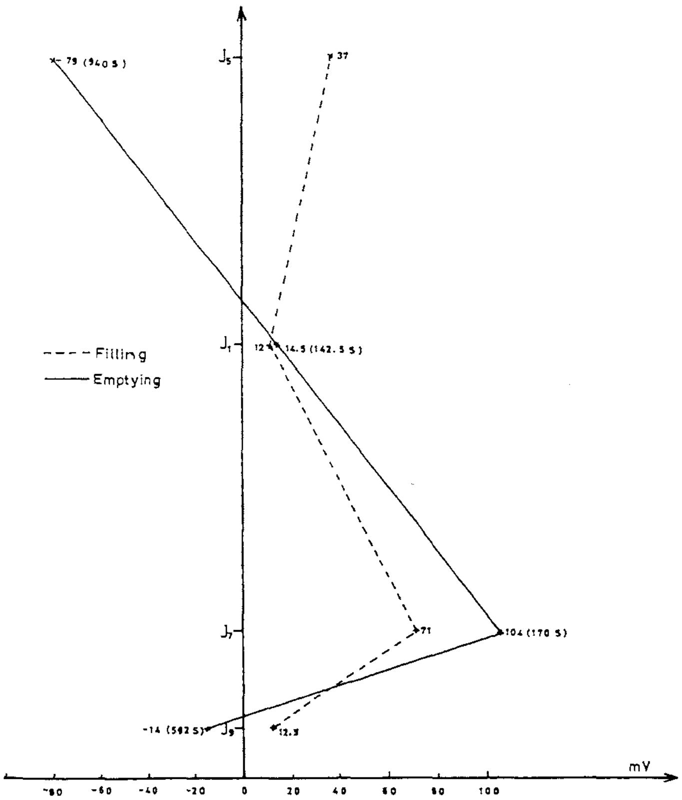

FIG 4 Horizontal Strain Gages (Odd No)
d=3cm θ=40°

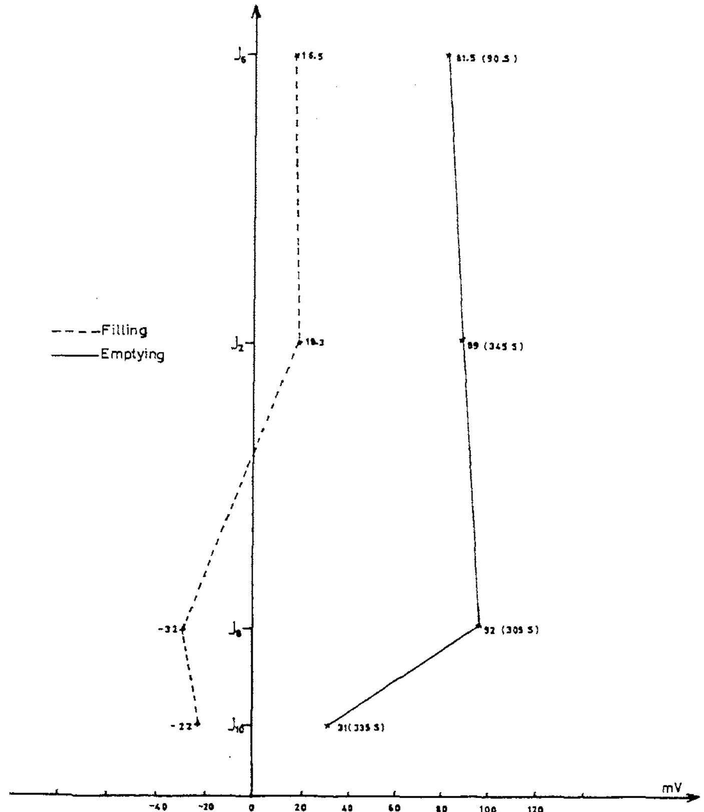

FIG 6 Vertical Strain Gages (Even No)
d=3cm θ=20°

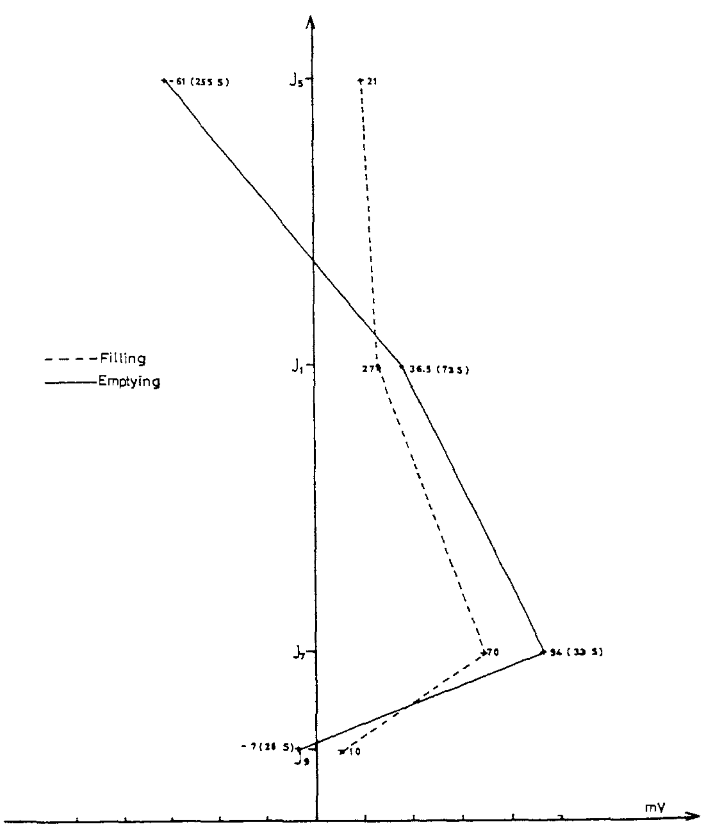

FIG 5 Horizontal Strain Gages (Odd No)
d=6cm θ=40°

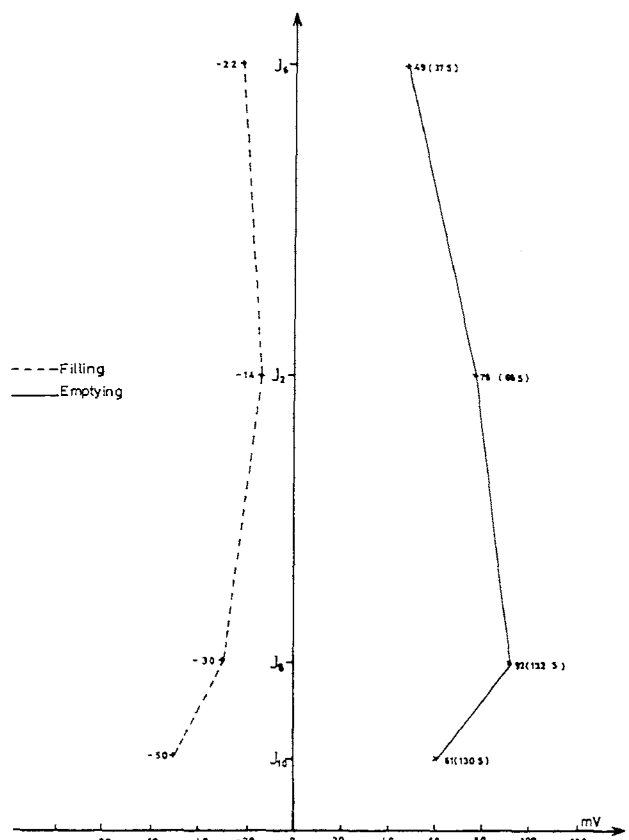

FIG 7 Vertical Strain Gages (Even No)
d=6cm θ=20

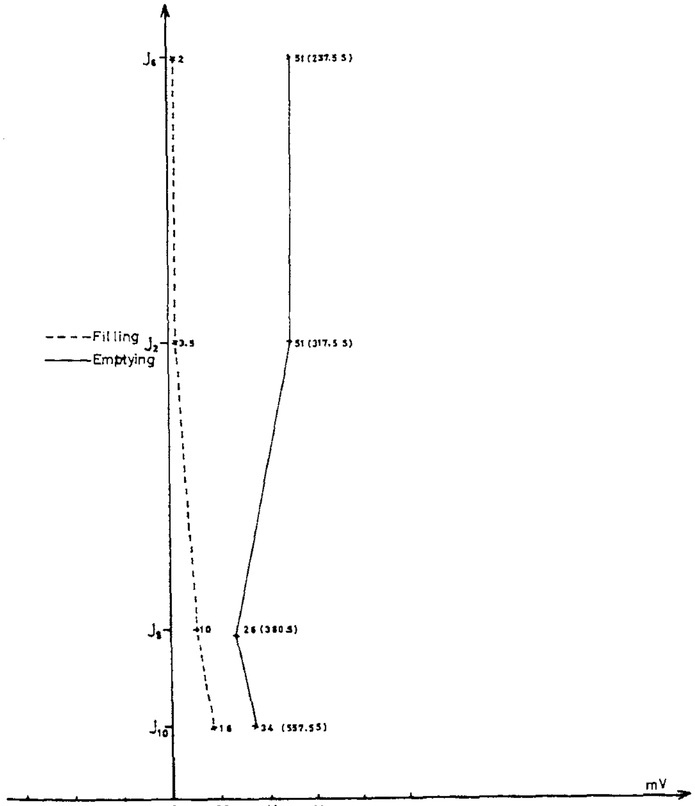

FIG 8 Vertical Strain Gages (Even No)
d=3cm θ=40°

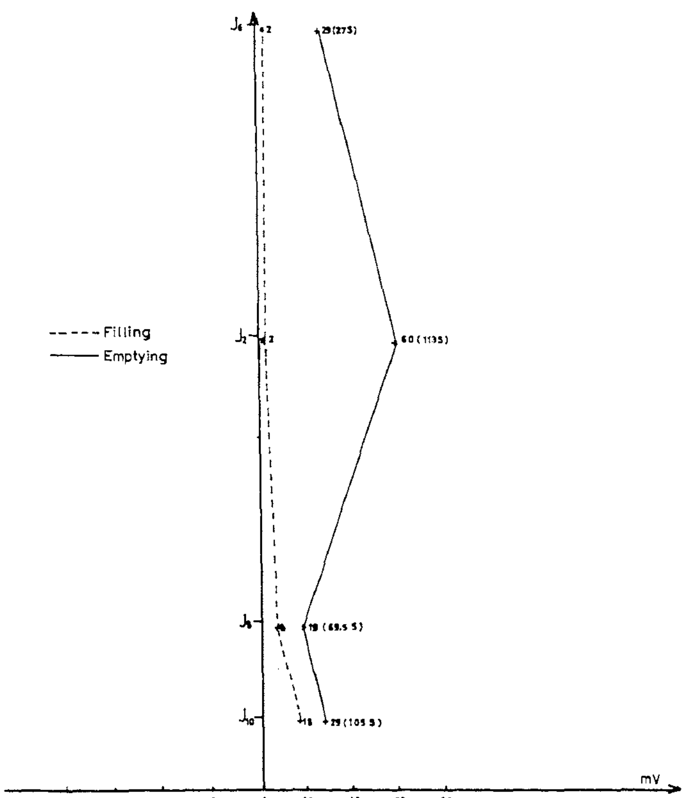

FIG 9 Vertical Strain Gages (Even No)
d=6cm θ=40°

In any case the maximum strain obtained during the em tying in greater than the maximum obtain during the fi ling and the ratio is approximately 4. Certains gage (N° 5 and 9) give compression strains instead of trac tion strains.This may be due to the general instabili of the model which is very thin and hight.

The maximum horizontal pressure generally appears at · beginning of the flow and as the flow continues the pressure decreases.

The presence of this peak stress at the beginning of t emptying may be linked to the fact that the bulk soli in the model changes his volume (dilatancy) and by trying to enter a new equilibrum position, developps a very hight stress.

CONCLUSION

The measurement of stresses in a flowing granular med is a very complicated problem of soil mechanics (Hand and Perry 1975).

Netherless the improvement of our model may go throught the use of a very hight response electronic device.

- Attention must be focussed on the transition zone close to the hopper.
- The discharge rate of a mass flow bin has no seriou influence on the stresses exerted on the silo durin the flow.

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