sciendo
Studia Geotechnica et Mechanica, 2019; 41(4); 177–183

Research Article
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Effect of using insert on the flow pressure in cylindrical silo

https://doi.org/10.2478/sgem-2019-0022
received November 12, 2018; accepted July 21, 2019.

Abstract: This paper presents an experimental investigation of the discharge flow pressure in the vertical silo and the hopper due to the use of insert (top cone with trunk cone bottom). Using the Insert inside the silos is one of the proposed solutions to avoid the problems of having funnel flow pattern, which has a significant effect on the distribution of flow pressure exerted on the silo wall and the hopper. The experiments were performed on a metal cylinder prototype; corn was used as a granular material, and the wall and hopper pressure distribution was measured by a special pressure transducer. The experiments revealed an important result in the flow pressure due to the change in the location of the insert. The experiments were conducted in Damascus University laboratories.

Keywords: Silo model; flow pressure; insert; wall pressure.

1 Introduction

The use of cylindrical silo with discharge hopper is widespread in many industries, in which materials are stored and processed until they are used in industry. Finding the dynamic flow pressure produced on the wall and the hopper of a silo during filling and discharging is one of the most important stages when designing silo and operating it safely.[3] In addition to that, the type of flow patterns produced in the silo has a significant effect on the distribution of flow pressure exerted on the silo wall and hopper. It has been agreed that there are two principle patterns of flow in a silo: funnel flow and mass flow.[1,2,9] In mass flow, all the stored material is in motion and is directed downward, and there are no stagnant zones. While these stagnant zones appear in funnel flow beside the wall, which reduces the efficiency of the silo.

One of the proposed solutions to avoid the problems of funnel flow is by using an Insert (an input element) inside the silo,[4,5,6,11,14] where choosing the appropriate position of the Insert inside the silo contributes significantly to reducing the stagnant zone, thus improving the silo Performance.[7]. Although there are studies on this subject,[7,10,12] there is still a need for further research in order to find better positioning of the input element (the Insert).

2 Purpose of Study

The main goals of this study are to investigate the effect of using the Insert (an input element) on the dynamic flow pressure produced on the silo wall as well as the discharge hopper, and to find the best position of the Insert that gives the lowest values for the measured pressure. Moreover, for this purpose, a cylindrical prototype silo was designed (Fig. 1), where the shape of the Insert was designed in the previous study[8] to be used in these experiments. The parameters in this study (hopper angle, silo dimension, the storage material, internal angle of friction, the storage material height) were considered constant. While several levels of placement of the Insert within the silo were determined in order to study the effect of each position of the Insert on the resultant dynamic pressure on the silo wall and hopper.

3 Description of the Model

Experiments were conducted using a silo model similar to the real silo. A physical model of the silo was build, and the dimension of the model was defined in proportion to

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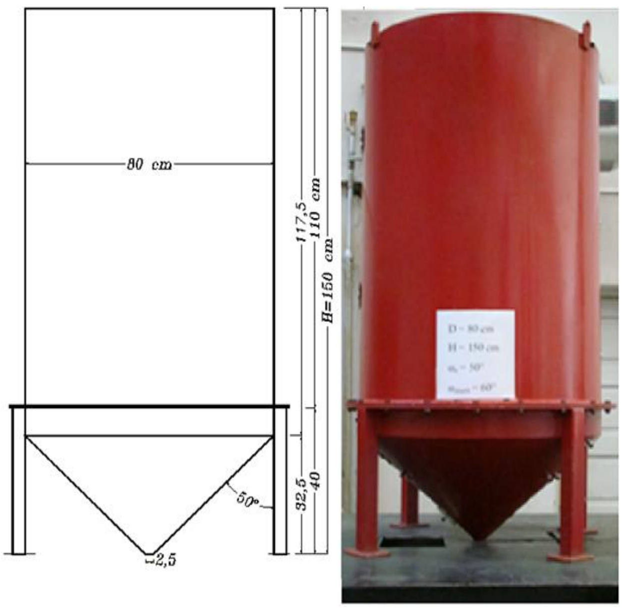

Figure 1: Silo dimension.

Figure 2: The insert.

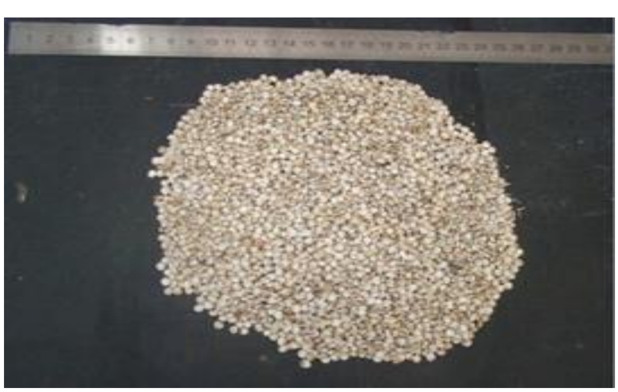

Figure 3: The used granular material.

the real silo. In addition to that, the material flow was also modeled in order to have an accurate result that can be applied on the real silo. The dimensional analysis theory has been considered. Through a number of steps including determining the variable affecting the studied case, the dimension of the model was determined, and 1/10 was adopted as the chosen model scale, and it is appropriate to obtain realistic results.

4 Experimental Procedure

Experiments were performed on cylindrical metal silo with conical hopper (Fig. 1). And a metal Insert, which consists of a cone with truncated cone (CTC) (Fig. 2), was used to be located inside the silo. The dimension and the shape for this Insert has been chosen depending on the previous study,[8] since these dimensions of the Insert gave the best flow pattern. Thus, the Insert location within the silo was changed to determine its effect on the dynamic pressure after testing the effect of its location on the flow pattern.[8]. The stored granular material used was corn (Fig. 3).

The resultant dynamic pressure on the silo wall and hopper was measured during the discharge of silo by means of special pressure transducer (Fig. 5). These measurements were conducted for two cases, discharging the granular material without using the Insert inside the silo, and the other case was discharging the silo by using the Insert.

For this study, four different positions for the Insert were considered according to the following ratio h_1/h_2 = 0.71, 0.82, 1.00, 1.12.

Where h_1 is the height of the Insert base from the discharge outlet (see Fig. 4), and h_2 is the hopper height. In order to measure the pressure during silo discharging, pressure cells were distributed at different levels along the height of the silo wall and hopper (Fig. 4). However, the total numbers of the conducted experiments were 135.

5 Pressure Measurements

The chart in Fig. 6 shows the measured horizontal pressure on the silo wall and hopper during discharge without using an Insert, at the selected nine levels for the pressure transducer. The pressure data showed that a maximum pressure was recorded at the transition section (the section between the cylindrical part and the hopper), then a gradual decrease of pressure occurs until access

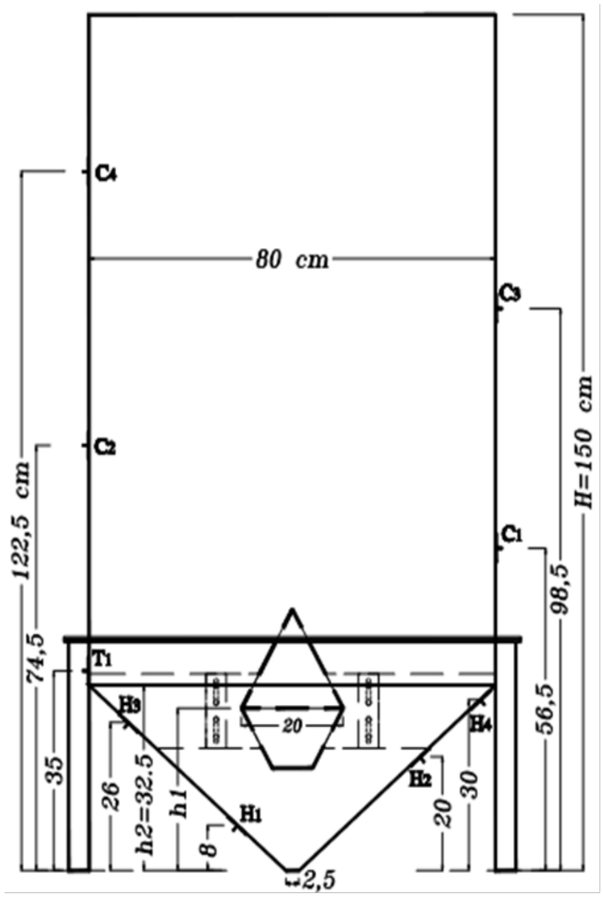

Figure 4: The Insert positions and the levels of the pressure transducers.

Figure 5: The used pressure transducer.

to the discharge outlet, and this is compatible with most studies.

Repeating the measurements for silo with the use of Insert, at different positions using the following ratio: $\mathbf{h_1/h_2}$ **= 0.71, 0.82, 1.00, 1.12,** respectively. The following figures (Fig. 7, 8, 9 and 10) represent the horizontal pressure data collected on silo wall and hopper, at the selected nine levels for pressure transducer, during discharge.

The measurements showed that the resultant horizontal pressure increases by increasing the depth of the pressure transduced on the silo wall until it accesses a peak pressure at the transition section, and then, a gradual decrease of horizontal pressure on the hopper until reaching the discharge outlet. However, comparing the pressure measured in the silo without using an Insert with the case of using an Insert , a significant decrease can be noticed in the measured pressure, especially at the transition section for Insert positions h_1/h_2 = 0.71, 0.82, 1.00 (Fig. 7, 8 and 9). This applies to the measured pressure on the cylindrical part of the silo as well as on the hopper.

While for the Insert position, h_1/h_2 = 1.12, which is higher than the previous positions, closer to the cylindrical part, an increase in the measured pressure was recorded. Especially at the transition section (Fig. 10). Although the value recorded on the cylindrical part are somewhat low.

6 Results Analysis

By comparing the pressure measurement on the model of silo without using the Insert, with pressure calculated according to the German Code,[15] Theimer equation[13] and Janssen equation[13] (Fig. 11) a good agreement can be noticed especially at the transition section, while the experimental pressure values produced in the cylindrical part are lower than those calculated according to the German Code, however close to the resulting values according to Janssen's relationship.

Moreover the pressure measurements have revealed that the use of the Insert gave important changes in the dynamic pressure, this is because the use of the Insert element according to the ratio **(h1/h2 ≤ 1)** caused a decrease in the pressure on both the silo wall and hopper as well as at the transition section (Fig. 7, 8 and 9); this is due to the beneficial effect of the Insert in directing and facilitation of the flow of granular materials.

While using the insert with position of $\mathbf{(h_1/h_2 > 1)}$ caused an increase in the dynamic pressure at the transition section and the cylindrical part, but less value was recorded on the discharging hopper, and this is agreed with the previous study.[8] So, it can be noticed that

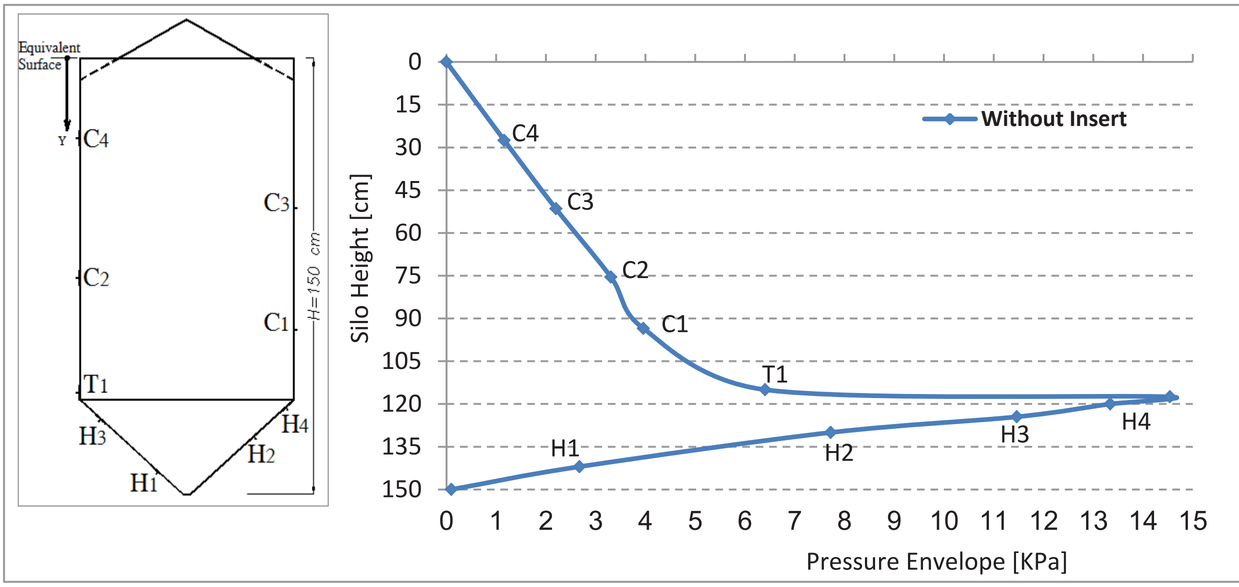

Figure 6: The pressure distribution on the silo wall and hopper without using Insert.

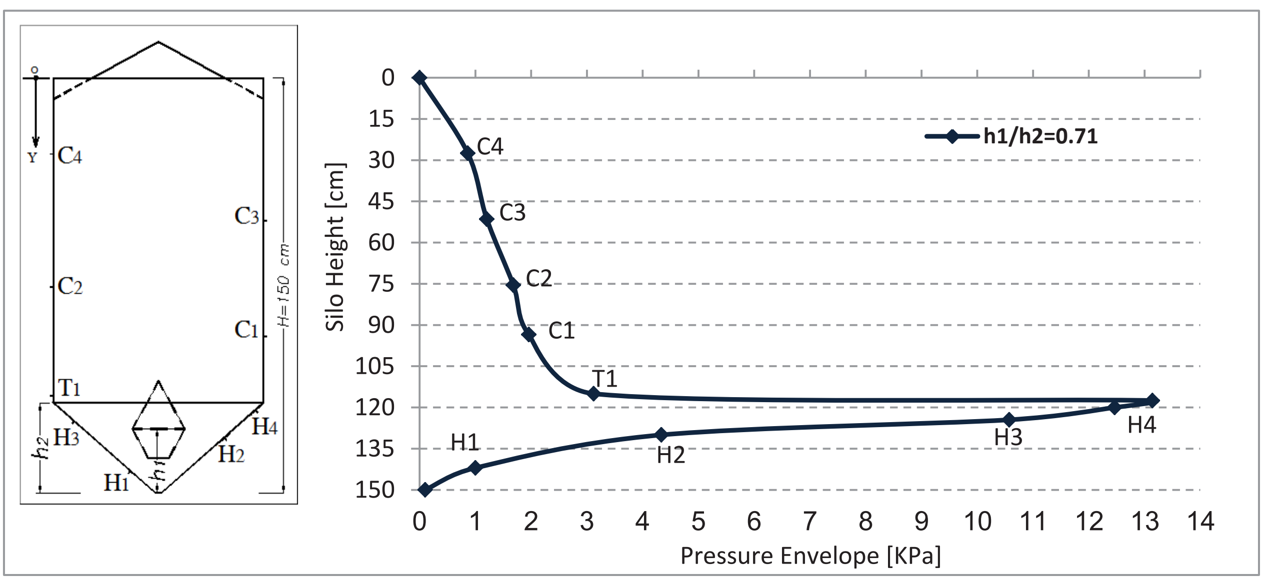

Figure 7: The pressure distribution on the silo wall and hopper with Insert at position **h_1/h_2 = 0.71.**

the closer the Insert is to the discharge hopper, the better it will be in directing the flow, and thus, an important role in reducing the resulting pressure, but to a certain extent, because then it may lead to obstruction of the materials flow. While the presence of the Insert closer to the cylindrical part may adversely affect the flow and can lead to an increase in the value of the measured pressure.

However, the pressure measurement recorded the lowest values for dynamic pressure for the position of the Insert (h_1/h_2 = 1), compared to the rest of the Insert positions. Moreover, this case gave the best form of flow as found in the previous study.[8]

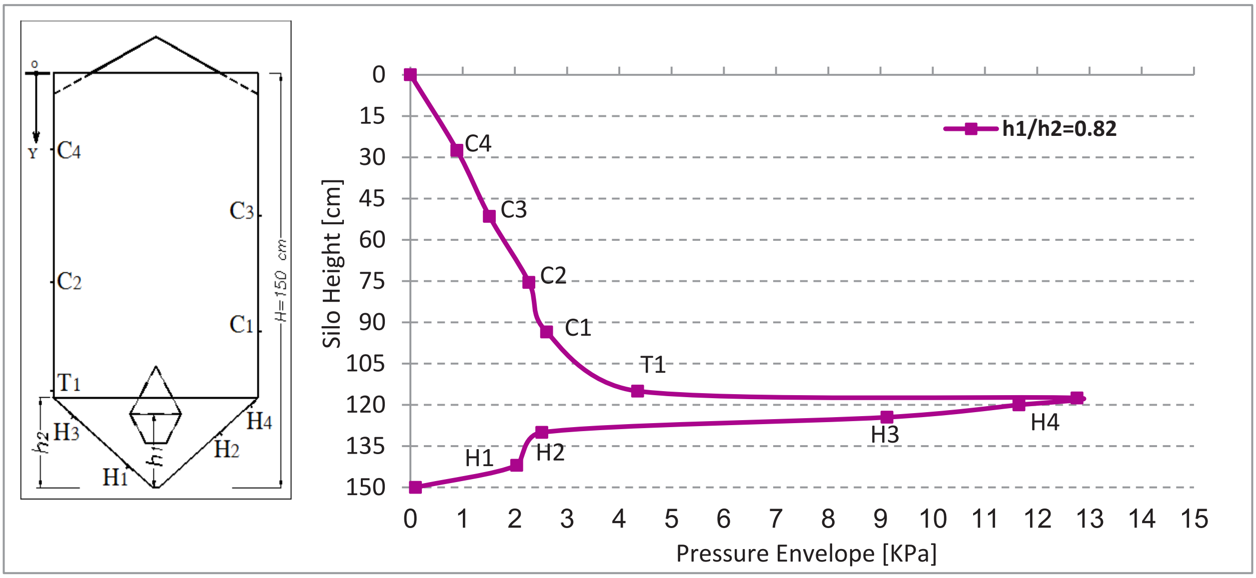

Figure 8: The pressure distribution on the silo wall and hopper with Insert at position $\mathbf{h_1/h_2 = 0.82}$.

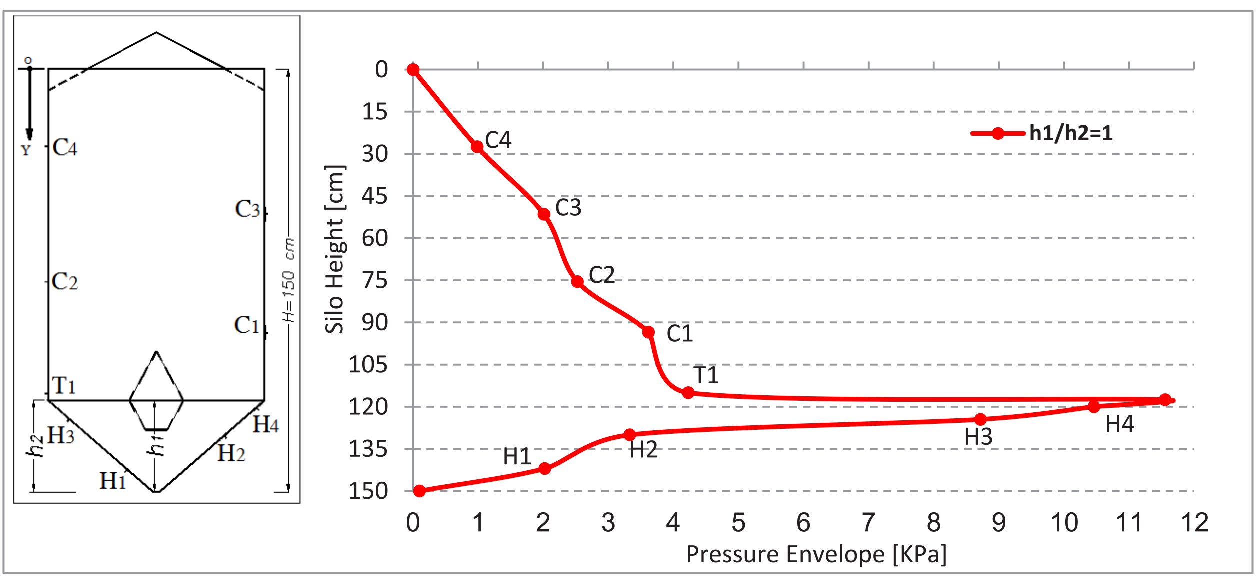

Figure 9: The pressure distribution on the silo wall and hopper with Insert at position $\mathbf{h_1/h_2 = 1}$.

7 Summary Of Finding

- The use of the Insert within the discharge hopper does not cause an increase in dynamic pressure, but on the contrary, reduce the resulting pressure value on both the silo wall and hopper.
- The use of the Insert contributes greatly to the reduction of the large pressure values normally produced at the transition section.
- The best position for the Insert within the silo is when the ratio is **(h_1/h_2 = 1),** because it causes pressure on both the silo wall and hopper less than the pressure resulting from the non-use of the Insert, in addition to being given the best form of flow pattern as found in the previous study.[8]
- The location of the Insert for the ratio **(h_1/h_2 = 1)** corresponds to the location of the transition section.

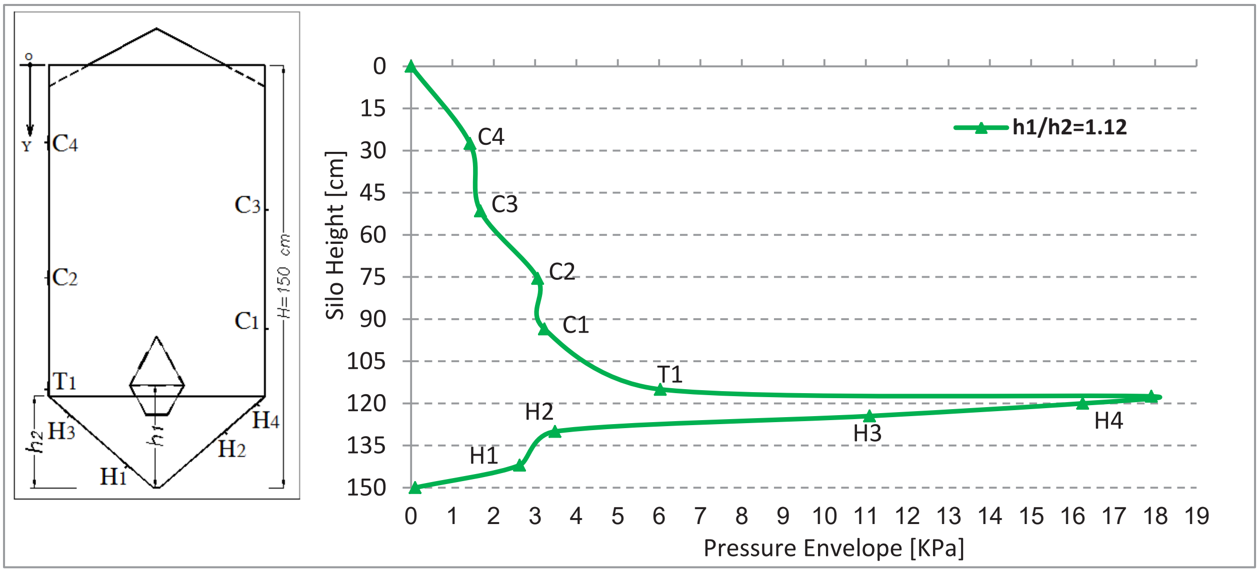

Figure 10: The pressure distribution on the silo wall and hopper with Insert at position h_1/h_2 **=1.12.**

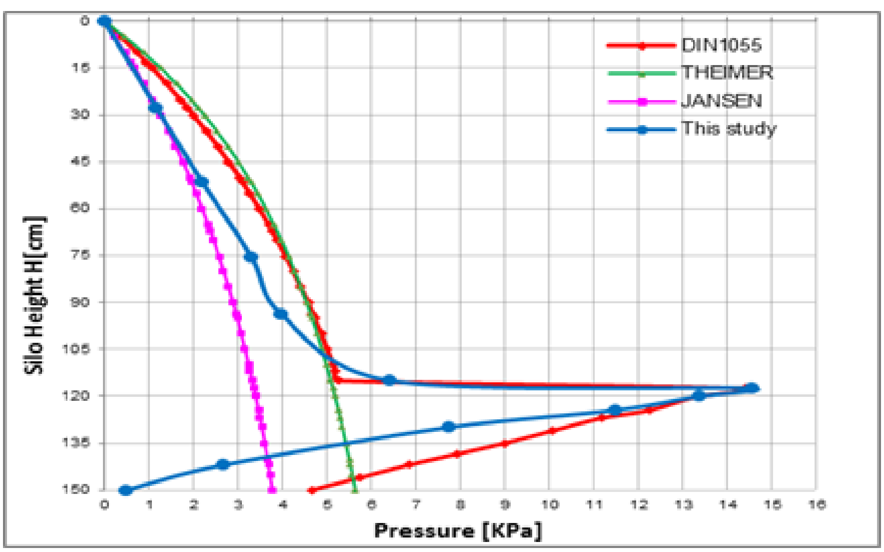

Figure 11 The pressure distribution on the silo wall and hopper without using Insert, by German Code DIN 1055[15], by Thiemer equation [13], and Janssen.

8 Conclusion

It can be concluded that the use of the Insert close to the transition section of the silo will help to improve the flow shape of the material in silos, and thus reduce the resulting dynamic pressure on the silo wall and hopper as well as the transition section. Because there is a close relationship between the flow pattern and the resulting dynamic pressure.

Therefore, it is important to follow up the research and to conduct a numerical study of the effect of the Insert on the resulting pressure.

Acknowledgements: The authors are grateful to the Middle East University, Amman, Jordan for the financial support.

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