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Minimum cost design of welded steel silos

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A transit silo constructed from steel plate elements is investigated (Fig.1). This type of silo consists of roof, circular cylindrical bin, transition ringbeam, conical hopper and supporting columns. Our aim is to show the design procedure and fabrication cost calculations of these parts and to give designers aspects for the minimum weight and cost design, since the minimum cost design is not treated till now in the literature.

The main structural dimensions of a silo shown in Fig.1 are the height H and the radius R of the bin welded from horizontal courses of thin plates. For a given stored material, storage capacity of the bin and hopper, for a H/R ratio and H the value of R can be calculated and the structural dimensions of the silo parts can be designed on the basis of stress and buckling strength constraints.

The question of the optimum design is to determine the optimal H/R ratio for which the self weight of the structure or the cost is minimal. To illustrate the behaviour of these objective functions a numerical example is selected and self weight as well as cost calculations are performed for various H/R ratios. In the cost calculation the fabrication cost including welding is determined by using the method described in our recent publications based on the Pahl-Beelich formulae and on COSTCOMP software data. The extreme heights of H = 7.5 and 18.0 are selected and dimensions, self weights and costs are calculated for H = 7.5, 12.0, 15.0 and 18.0 m for storage of cement with a density of 1600 kg/m^3 and storage capacity of 500 m^3.

The following conclusions can be drawn. When the H/R ratio increases the self weight of the bin increases but the self weight of the other parts decreases. The self weight of the whole structure has a minimum at H/R = 4.76. The difference between the self weights of the best and worst solution is about 9%.

The material and fabrication cost of the whole structure decreases when H/R increases and reaches the minimum at the practical upper limit of H/R. Thus, the designers have to choose the maximal practical H/R ratio to achieve minimal costs. The difference between the best and worst solution is about 8%.

The number of columns should be minimal, the practical minimal number is 6. The slope angle of the hopper should be chosen in accordance with the friction angle of the stored material. In the design of bin thickness the effect of a sudden temperature change as well as the dynamic filling and emptying effects are taken into account by multiplying factors.

The optimal dimensions of the welded box ringbeam can be calculated from the stress and local buckling constraints, taking into account the compression and bending. In the design of columns the effect of snow and wind can be neglected, the leading action is the weight of the stored material. Simple closed formulae can be derived for the optimal dimensions of columns of square hollow section.

Fig. 2. shows the cost as a function of H/R for k_f/k_m=1.5, where K ($) is the total cost, k_f ($/min) and k_m ($/kg) are the fabrication and material cost factors, respectively.

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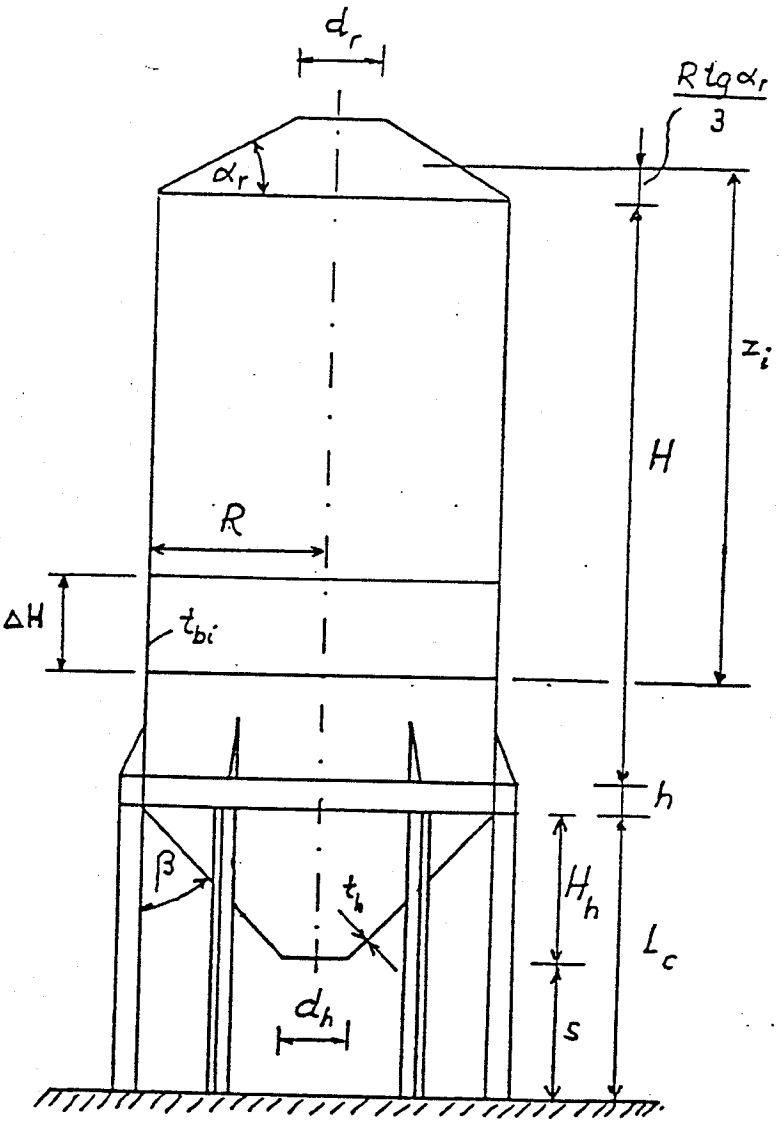

Fig. 1. Main dimensions of a welded steel silo

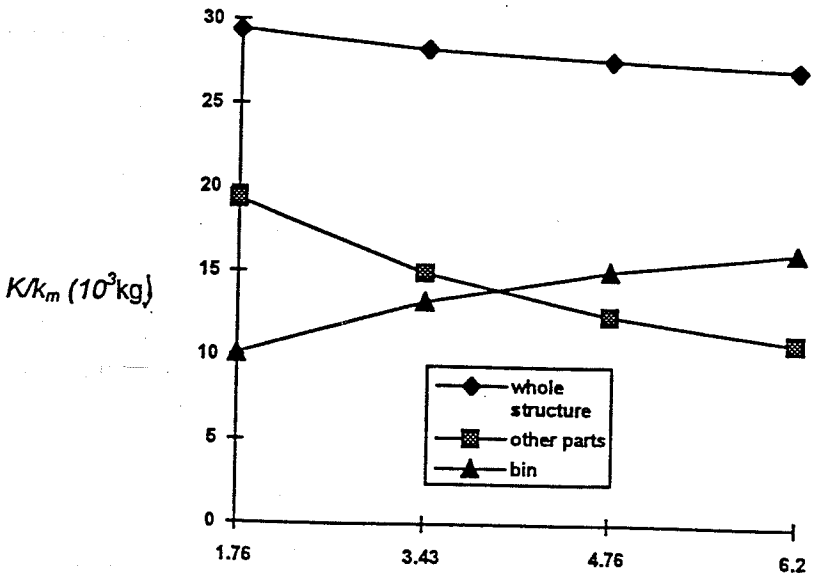

Fig. 2. Cost of silo parts in the function of H/R for k_s/k_m=1.5