

Specification for

Cylindrical forage tower silos and recommendations for their use

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- British Constructional Steelwork Association*
- British Steel Industry*
- British Wood Preserving Association
- Cement and Concrete Association*
- Country Landowners' Association
- Department of Agriculture and Fisheries for Scotland
- Farm Buildings Centre
- Ministry of Agriculture (Government of Northern Ireland)
- Ministry of Agriculture, Fisheries and Food*
- National Farmers' Union*
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- Timber Research and Development Association*
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- Agricultural Engineers' Association
- Farm Building Association
- Home Office
- Institution of Civil Engineers
- Institution of Structural Engineers
- National Institute of Agricultural Engineering

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Foreword

This British Standard has been prepared under the authority of the Farm and Horticultural Buildings Industry Standards Committee, to meet the requirements for the large outdoor silos which are currently being developed. It relates to cylindrical silos used for the conservation of crops as silage, and data is specified from which they may be designed. In preparing the standard, consideration has been given to research into silo pressures and investigation into the required properties of the silo components carried out recently, notably in the Civil Engineering Department of the University of Newcastle upon Tyne, to which acknowledgment is given.

The silo structure should be designed not only to resist the pressures and loads to which it is subjected, but also to act as an integrated part of a farming system and as a means of controlling the fermentation of the silage and minimizing the loss of nutrients. For the purpose of structural design, it is important to define the limits of use; these determine the pressures to be used in calculations. Two conditions of loading are dealt with in this standard; firstly, to cover the storage of high dry matter silage which enables a more efficient and economical design to be adopted, provided the farmer can generally fill and maintain the silo in accordance with Appendix D, and, secondly, to cover the storage of all types of forage of high moisture content.

Included in the appendices are recommendations for the determination of the silo capacity, rate of filling, preferred moisture contents and other points to be observed in the use of the silo.

This specification is confirmed with the primary intention of providing information for the maintenance of existing forage tower silos.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 14, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 General

1.1 Scope

This British Standard sets out the basic data for the design of tower silos used for the conservation of grasses as silage under UK farming conditions. From this data silos may be designed, provided the design is carried out in accordance with accepted structural engineering practice.

Additional considerations need to be applied to the data when grasses contain additives, admixtures or other herbage.

The standard applies to cylindrical tower silos of all sizes with over 3 m effective depth of storage.

NOTE The titles of British Standards referred to in this standard are listed on page 14.

1.2 Definitions

For the purpose of this standard, the following definitions apply:

1.2.1

effective height (h_e)

height in metres from floor level to top of the cylinder

1.2.2

utilized height (h_u)

maximum depth in metres of material, before settlement, that will be placed in the silo using intended filling machinery. This is used for the calculation of silo capacity

1.2.3

cylinder height (h_c)

height in metres from top of foundations to top of silo cylinder

1.2.4

settled surface of silage

the level 0.90 h_e above silo floor, the reference level for calculation of pressures; or the level 0.90 h_u above silo floor, the reference level for calculation of silo capacity

1.2.5

depth of silage (h_s)

the distance in metres below settled surface of silage of the point under consideration

1.2.6

1.2.6.1

silo diameter (d)

average internal diameter of silo in metres

1.2.6.2

silo diameter

(d_e) Average external diameter of silo in metres

1.2.7

tower silo

cylindrical structure for conserving silage

1.2.8

general purpose forage silo

a tower silo used for storing any forage of high moisture content

1.2.9

silage

fibrous crops preserved by natural and/or artificial acidification in anaerobic conditions

1.2.10

high dry matter silage

silage made from crops wilted in accordance with certain recommendations; abbreviated to H.D.M. silage

NOTE The recommendations are given in D.1.

1.2.11

dry matter (D.M.)

dry fraction of the crop, i.e. that which would remain after the moisture had been driven off at 105 °C for 16 h

1.2.12

percentage moisture content

weight of moisture driven off, at 105 °C for 16 h, divided by initial sample weight multiplied by 100

1.2.13

standard capacity (C)

dry matter capacity of silo in tonnes under average conditions calculated in accordance with a standard method

NOTE The standard method of calculation is set out in Appendix C.

1.2.14

density (δ)

total weight (kg) of silage per cubic metre

1.2.15

dry density (δ_d)

weight (kg) of dry matter in silage per cubic metre,

$$\text{i.e., } \delta_d = \delta \frac{100 - \text{moisture content \%}}{100}$$

1.2.16

M.A.D. fibre

percentage by weight of modified acid detergent fibre in dry matter of crop or silage

NOTE The M.A.D. fibre percentage of a crop is increased by between 4 % and 15 % during fermentation into silage in the tower, the exact amount depending on the type of fermentation.

1.2.17**crude protein (*C.P.*)**

percentage by weight of crude protein in dry matter of crop or silage

NOTE The C.P. percentage of a crop is increased by between 4 % and 15 % during fermentation into silage in the tower, the exact amount depending on the type of fermentation.

1.3 Symbols

The symbols used in this British Standard are as follows:

<i>S</i>	Spacing of stiffening rings in metres.
<i>E</i>	Young's modulus in N/m ² .
<i>t</i>	Thickness of the silo wall sheet in metres.
<i>r</i>	External radius of the silo wall or stiffening ring in metres.
<i>u</i>	Poisson's ratio (0.3 for steel).
<i>I</i>	Moment of inertia of the stiffening ring in metres ⁴ .
<i>p</i>	Permissible depression of internal pressure in the silo below atmospheric to be used in calculating buckling under internal suction.
<i>f_b</i>	Axial compressive stress in a cylinder which would produce elastic buckling instability.
<i>p_{crit}</i>	Depression below atmospheric of the internal pressure in a cylinder which will cause elastic buckling instability of the cylinder wall.

See also 1.2 for symbols used for the terms defined in that clause.

2 Silo dimensions

Provided all structural requirements are met, the height is limited by the necessity of having to wilt consistently to moisture contents which avoid undue risk of fluid pressure developing and effluent being exuded (see D.1). The diameter of the silo is limited by the need to ensure that the required rate of consolidation of the grass can be achieved with the planned field machinery system and that the required rate of unloading can be maintained (see D.2).

3 Foundations, anchorage and siting**3.1 Foundations**

The foundations shall be considered as an integral part of the design and shall be constructed in accordance with the relevant recommendations of BS 8004. Due regard shall be given to differences in settlement between silo bases and adjacent structures.

The foundation shall provide uniform contact pressure on the bearing sections of the silo wall.

Fluid pressure release drainage shall be provided in accordance with 6.2.

Whether structural or non-structural, the concrete liable to come in contact with effluent shall be of not less than 150 mm vertical thickness and shall be of dense concrete of at least 30 N/mm² compressive strength with a minimum cement content of 330 kg/m³. The cement used shall comply with BS 12. See Appendix E for composition of silage effluent.

3.2 Anchorage

The silo cylinder shall be securely anchored to the foundation when its dead weight is insufficient to resist the upward forces of wind overturning combined with silage uplift calculated in accordance with 4.1.2 and 4.1.6.2.

3.3 Siting

The wall of the silo shall not be sited within 1.25 *h_e* of domestic dwellings.

4 Loading

The loading to be assumed in the design of the silo shall be calculated in accordance with 4.1 for H.D.M. silage, and with 4.2 for general purpose silos.

For the purpose of calculation of loading, the unit weights of the materials shall be those specified in BS 648.

4.1 Silo for H.D.M. silage

4.1.1 Imposed roof load. Imposed roof load shall be calculated in accordance with BS 6399-1.

4.1.2 Wind load. The structure, supporting framework, foundations, attachments such as chutes, ladders and ducts, together with their appropriate connections and fixings shall be designed to resist the wind pressure and loads calculated in accordance with Part 2 of CP 3:Chapter V. For the purpose of designing against overturning, the design wind speed *V_s* shall be based on a design life of 30 years. The silo shall be stiff enough to resist, without exceeding permissible stresses, the distortion due to the variation in pressure round the silo for a design wind speed of 0.8 × *V_s* based on a design life of 30 years.

NOTE CP 3:Chapter V-2 is currently being revised as BS 6399-2.