

IBAU HAMBURG



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Information



Multi-Compartment Silos with Central Cone

**Compact Terminals
for the Cement Industry**

Multi-Compartment Silos with Central Cone

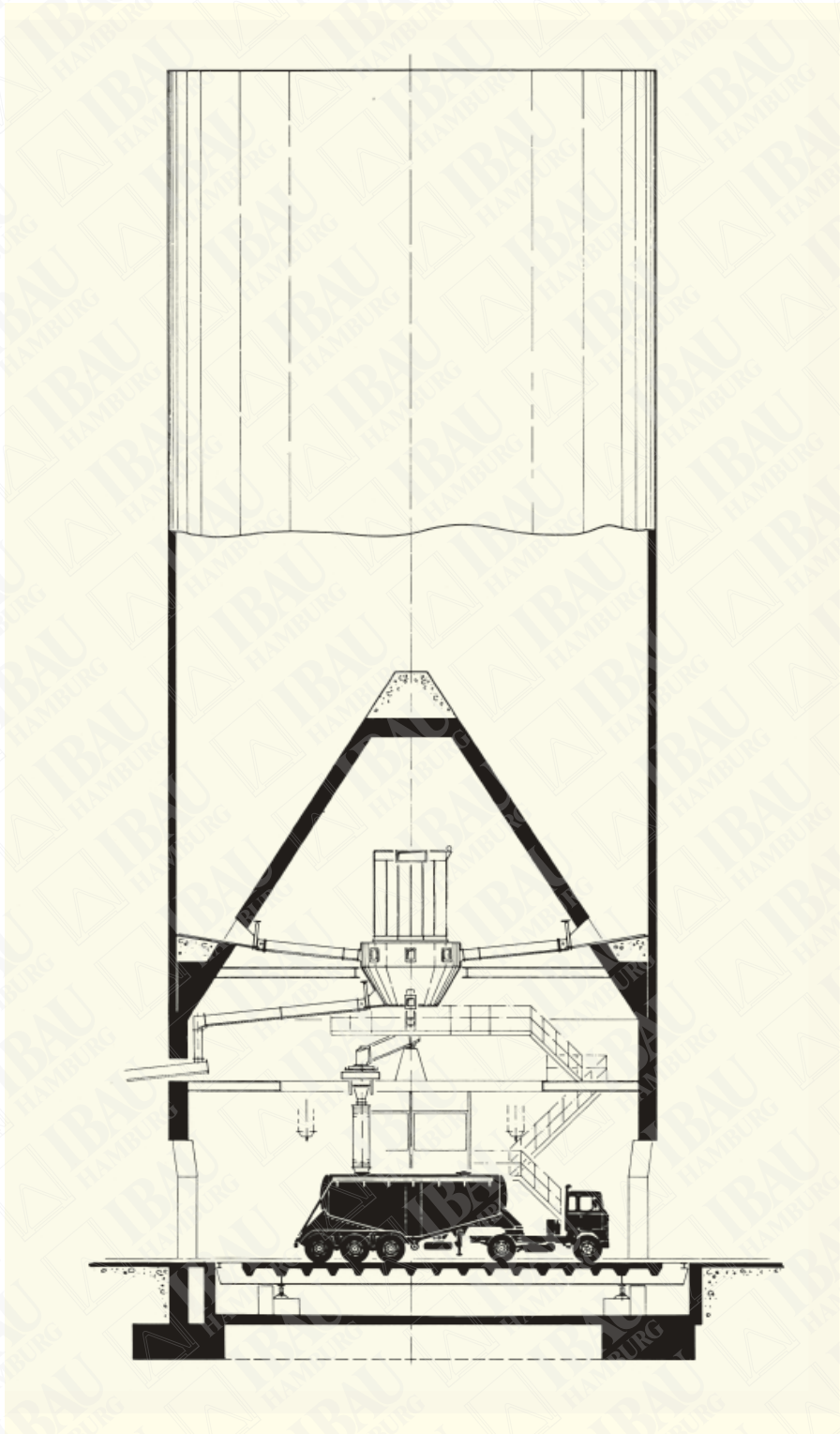


Fig. 1: Central cone silo

1. Introduction

Intensive development during the last few decades in the field of silo technology has produced pneumatic emptying and blending systems which provide reliable storage and good homogenization of the powdered bulk materials.

Changes in the production of binders and fillers, for example by grinding the mixing components separately or utilizing waste materials, fly ash, etc., have had an effect on silo technology, the preparation of the bulk materials and ultimately the dispatch technology. The concentration of storage, blending and dispatch for a greatly increased number of bulk materials, interground additives and mixed products has eventually led to the concept of a multi-compartment, high capacity silo system with integral positive mixer and dispatch station.

2. Design and process technology of multi-compartment silos

The internal compartment divisions result in clear external diameters of 14 to 27 metres, recognizable outwardly as cylindrical silo units. The base of the entire silo floor is formed by the central cone which has proved its worth over many years in single-cell, cylindrical silos (Fig. 1) and ring silos (Fig. 2). The cantilevered conical shape, which also has static-structural advan-



SPENNER ZEMENT Multi-compartment silo, Germany

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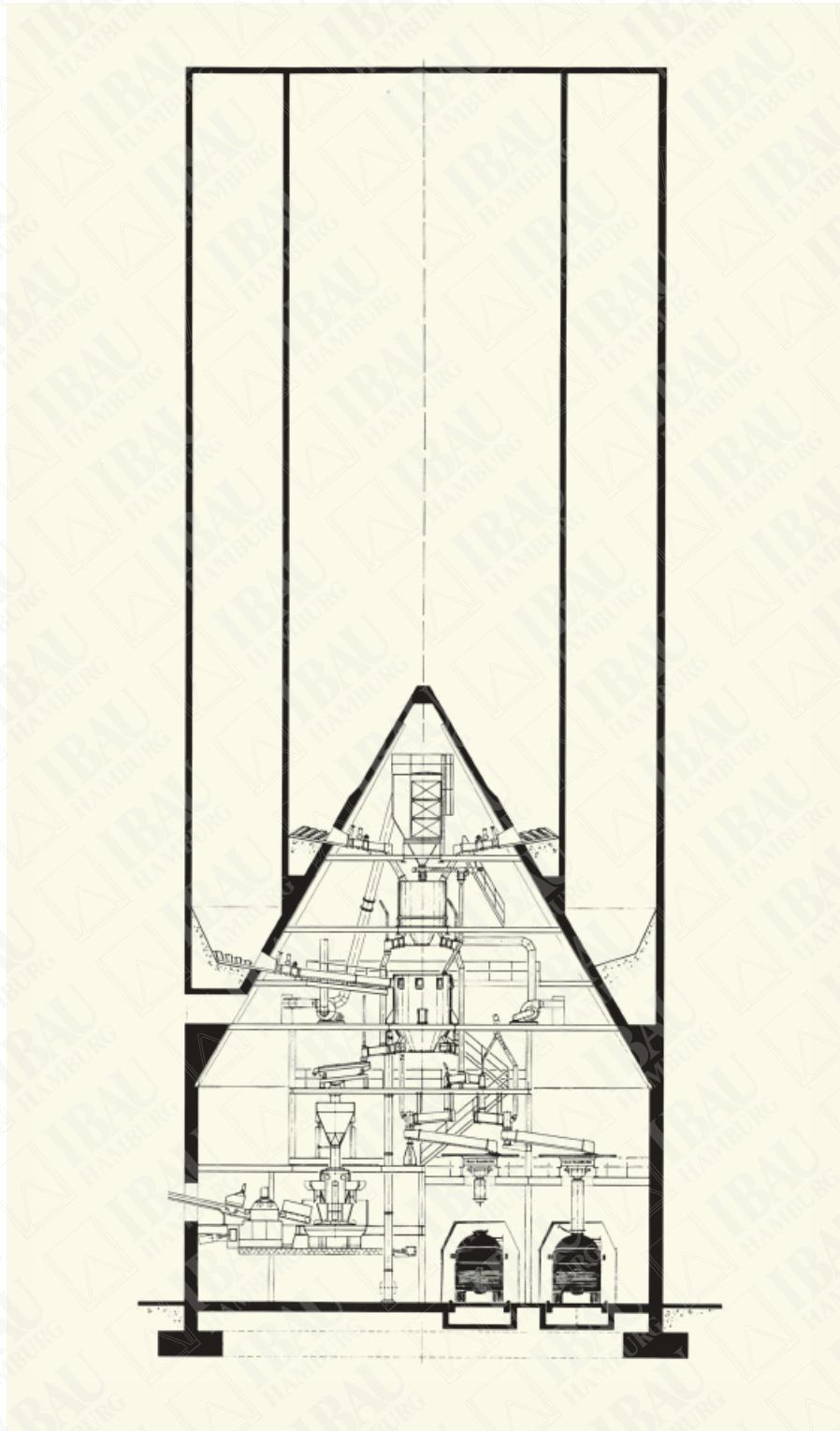


Fig. 2: Ring silo

tages, is used from the process engineering point of view because it forms a slip surface and displaces the bulk material outwards in a gravity-induced flow. The annular fluidizing base at the foot of the cone assisted by the optimum span widths fulfils the conditions for fluidization of the bulk material over the full area; bulk flows of 3 to 500 t/h can be extracted absolutely continuously from these zones and controlled over a wide range.

If the outer ring silo is not divided into compartments, the flow-control gates positioned along a circular base line are opened individually in turn or simultaneously to suit the level of the bulk flow. The geometry of the silo floor, the arrangement of the extraction openings at the foot of the inclined conical slip surface and a variable level of fluidization of the bulk material causes mass flow of the bulk material.

In many ways the undivided silo with a central cone already fulfils these conditions, so additional pressure-relieving internal chambers with connected venting systems are not needed in multi-compartment silos of this basic design. It is possible to derive very different compartment cross-sections from the circular shape of the silo to suit the flow characteristic of fluidizable bulk materials. Fig. 3, for

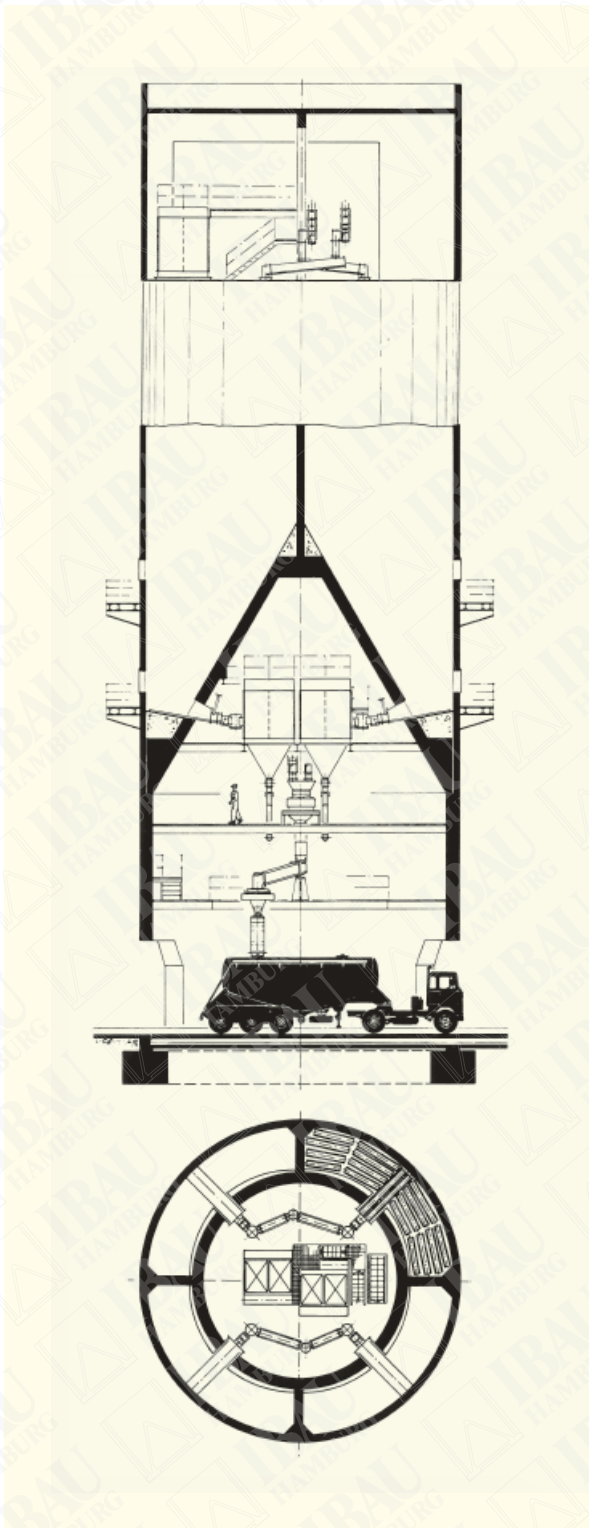


Fig. 3: 4-chamber Central cone silo

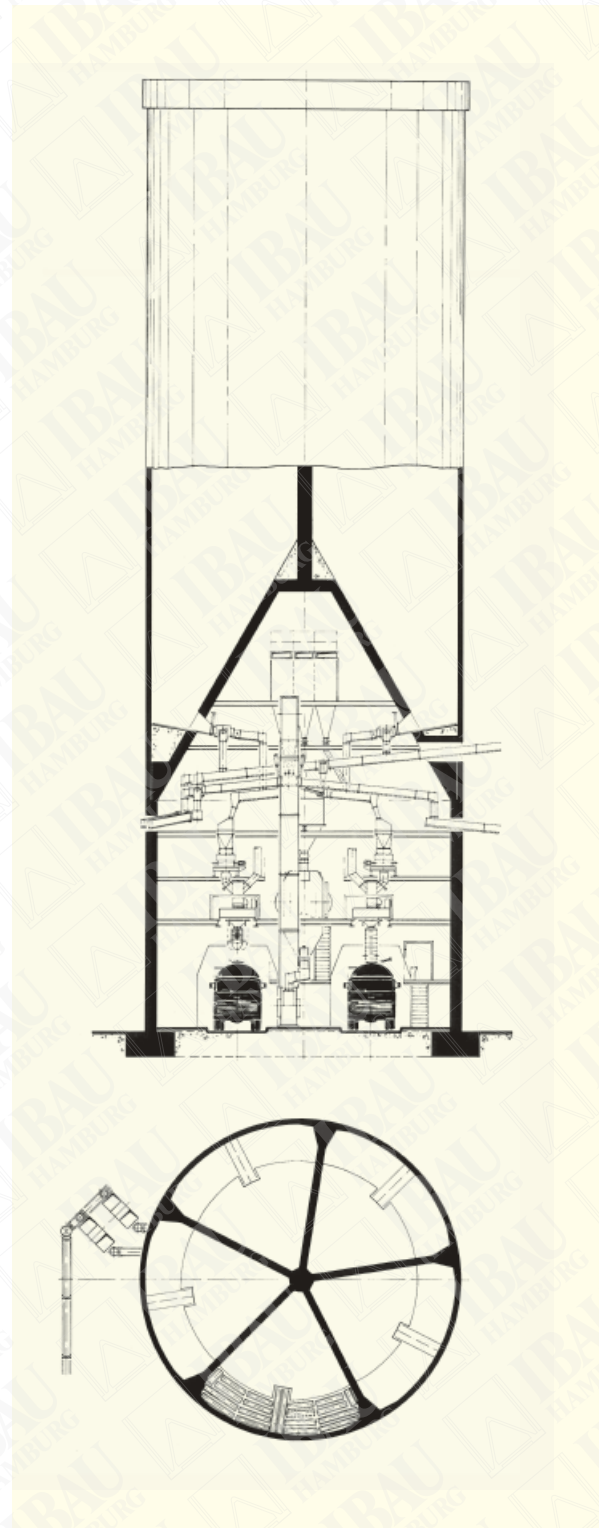


Fig. 4: 5-chamber Central cone silo

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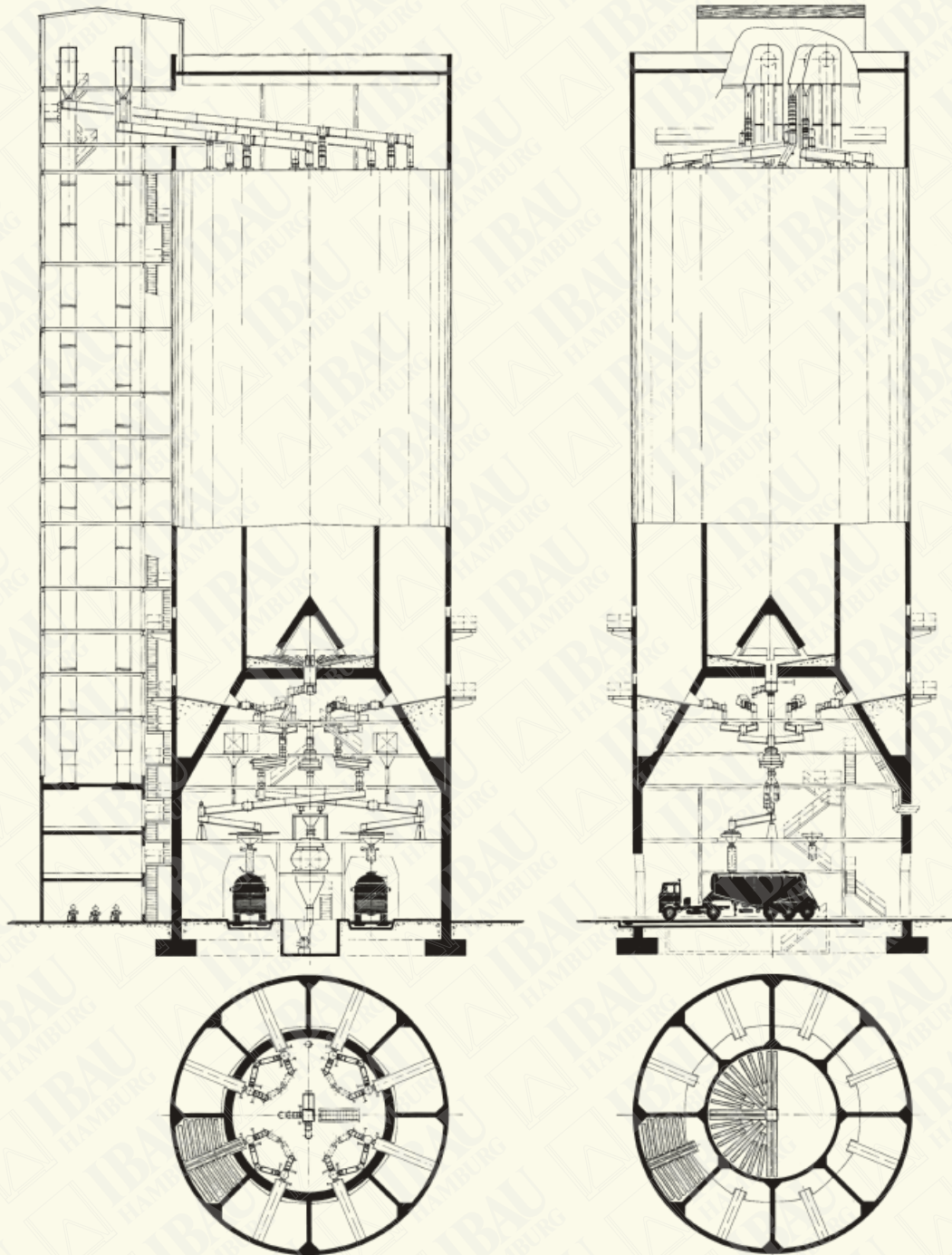


Fig. 5: Ring silo with ring compartment subdivided into 8 sections, and one inner silo cell, see Fig. 15 for construction

instance, shows a central cone silo with 5 compartments. Appropriate back-filling and secondary slopes at the base are used to avoid trapping the bulk material at acute-angled wall junctions which can occur in the central silo compartments. A ring silo design with a central silo and 8 outer compartments can be seen in Fig. 5. Fig. 6 shows a different subdivision of the ring silo cross-section with 5 compartments in the central silo. The multi-compartment silo shown in fig. 7 is particularly interesting. In the upper level there are fairly large storage compartments, i.e. 1 central silo and 6 ring compartments, and in the lower level there are 12 multi-purpose compartments for mixed components and finished products.

These conditions for continuity were achieved both for bulk flows greater than 100 t/h and for very small flows of less than 10 t/h. Various recipes for the mixed products which are made up in weighing hoppers above the positive mixer require correspondingly low fine flows which are extracted and metered by the flow-control gates at the discharge boxes. Under these fluidizing conditions bulk materials such as various types of cement, limestone meal, fly ash, etc. are only fluidized to a limited extent on part of the silo base zone so that the restricted outlet cross-sections achieve air saturation of

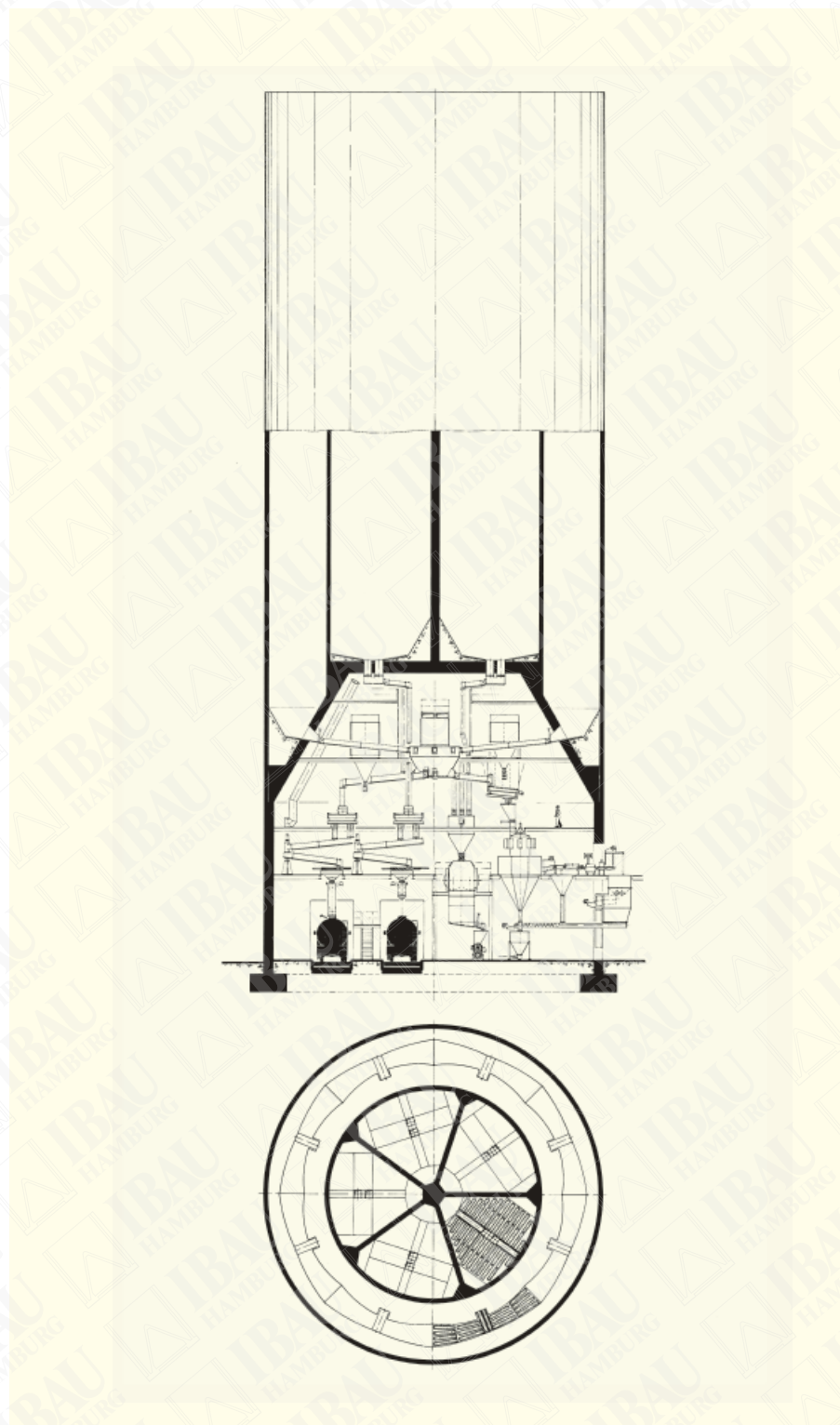


Fig. 6: Ring silo with inner silo subdivided into 5 sections, see Fig. 13

Multi-Compartment Silos with Central Cone

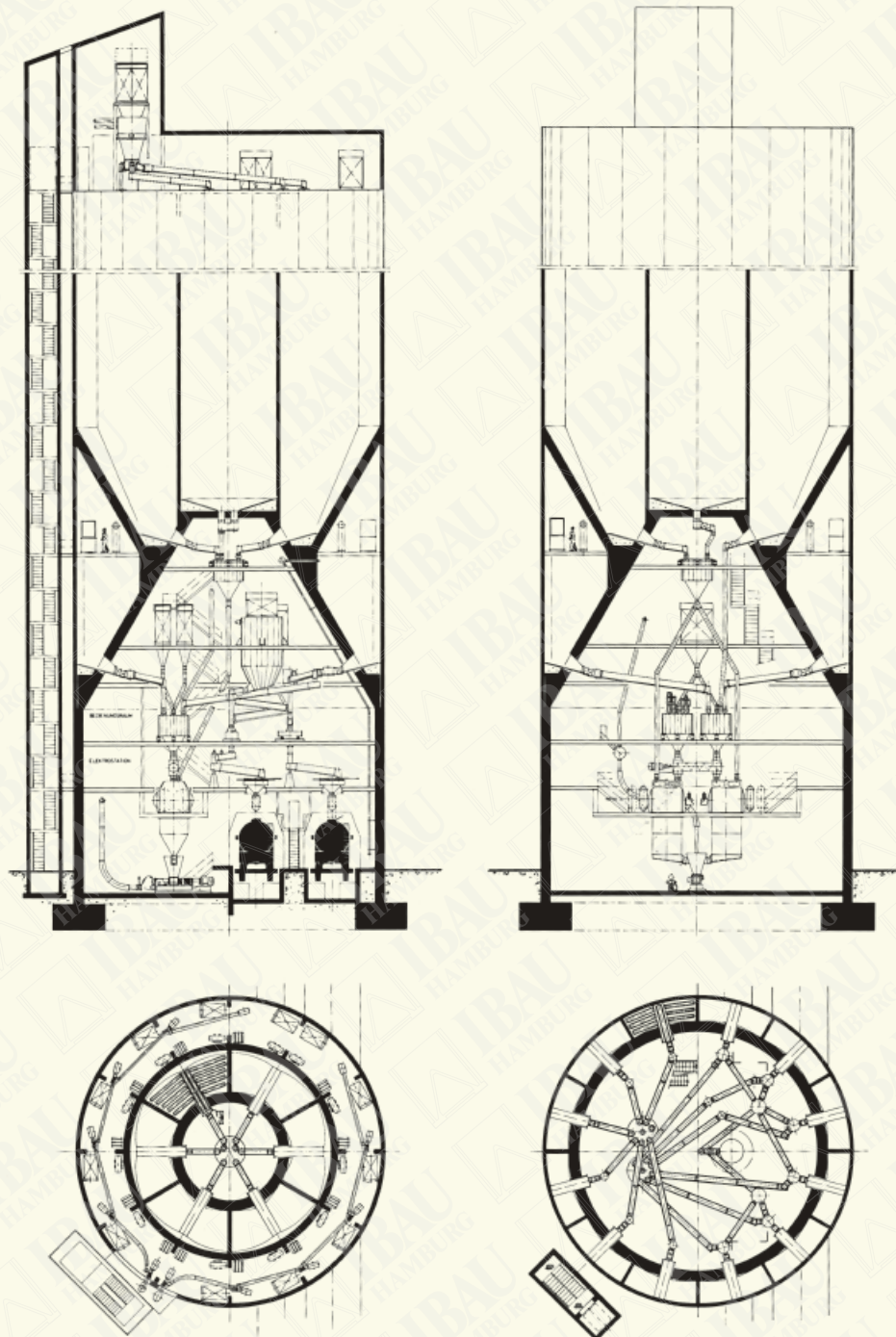


Fig. 7: Ring silo (mixing system) with $7 + 12 = 19$ compartments, see Fig. 16 for construction

the mixture with very low extraction quantities and sharply reduced percentages of air. A self-regulating air overflow system which depends on the set pressure is in operation under these conditions; this reduces the air supply in the fluidizing section concerned without changing the state of fluidization. The utilization of space in the compartments is virtually 100 % because of their comparatively small horizontal dimensions, thus planned changes of the type of material cause no problems. The same geometrical conditions and the intermittent extraction operation which normally occurs result in mass flows with turbulent mixing which further improves the quality of the bulk material.

3. Separation and mixing of types of material and the dispatch system

Measures to keep the types separated apply to the silo and compartment feeding system and to the interconnected conveyors below the silo compartments. Pneumatic conveying systems in pipes are preferred for providing absolutely residue-free silo feeding systems, especially when several, chemically very different bulk materials have to pass through one transport line in turn. High levels of wear make it necessary to pay attention in this technology to wear-resistant

sealing of the conveying diverter. Conveying combinations consisting of airslides and bucket elevators or vertical pneumatic conveyors offer energy-saving and virtually wear-free solutions; here again it is important to seal the diverting elements and the problem was solved by using solid designs.

Airslides are always the most suitable means of transport for the generally short interconnecting conveyors below the silo compartments. Operation of the exhaust air filtration system can only be combined where there are compatible bulk materials. Otherwise decentralized filter installations and dust return systems are needed for the entire plant for the sake of quality assurance.

The production of a diversity of mixed products has also set new trends. Separate grinding or the use of further interground additives as well as the adaptation of the production process have led to the integration of a mixing station into the multi-compartment silo plant. Recipes which have been checked and combined by weighing hoppers are mixed in batches in a "single shaft mixer" (Fig. 8) in the shortest possible time to form a homogenous mass. The mixer is compactly designed, has a trough lined with wearing tiles and a low energy consumption and runs extremely quietly.



Batch type mixer with toggle lever system



Material transport after mixer via IBAU PUMP

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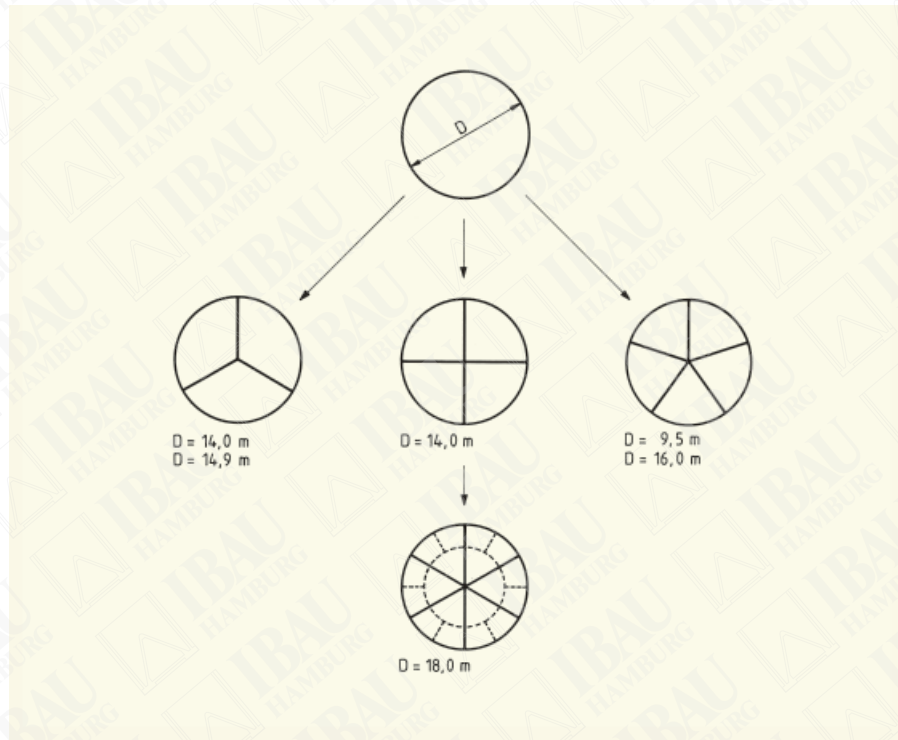


Fig. 10: Multi-compartment silos evolved from the circular-cylindrical single cell silo

Depending on the plant design the mixed products can either be transferred directly to the dispatch system or conveyed to silo compartments provided for the purpose (Fig. 9).

The cantilevered design of the multi-compartment silos ensures a generous housing space and access for all the equipment and machines for operating the system. The silo cells and hence the silo floors are normally elevated for two reasons: Firstly, the extraction devices and the necessary mechanical equipment have to be housed under the cells and, secondly, direct lorry or rail loading is usually an objective to eliminate

additional transport and loading points, thus vehicle access is provided under the silo. The systems are very extensively automated and are fitted with protective circuits and electronic monitoring adapted to the requirements of the operator.

4. Construction engineering aspects

The separate storage of the bulk materials, ground additives and mixed products described above necessitates the construction of multi-compartment silos. From the process engineering point of view the arrangement of the individual silo cells can be

developed advantageously from a free-standing cylindrical silo, because - as described above - this achieves the shortest possible transport distances to centrally positioned collecting and mixing hoppers. The retention of the external circular-cylindrical form also offers advantages from the static-structural point of view: When all cells are filled an approximately uniformly distributed silo pressure acts on the outer silo wall, so that in theory only peripheral tensile forces occur in this load situation.

However, it should be borne in mind that if only individual cells are

filled, bending moments are also produced in the cell walls including the associated section of the outer silo wall and this increases the consumption of concrete (thicker walls) and reinforcing steel.

In order to restrict the bending moments, so that a cost-effective design is still achieved the free wall lengths between two wall intersections should not exceed 14 m and these should be joined to one another by concrete haunches.

As for single-cell circular-cylindrical silos and ring silos, the silo floor is formed as a central cone or truncated cone. Such plane structures have exceptionally favourable load bearing characteristics; they carry the high loads from the silo contents almost entirely by membrane compressive stresses both in the meridian and circumferential directions.

In addition to this the cone or truncated cone shell which spans the entire silo space can result in savings in the silo height as the extraction devices and parts of other necessary mechanical equipment can be housed inside the cone.

This means that the individual cells of a subdivided silo or a subdivided ring cell can be emptied at the side through openings in the surface of the cone or truncated cone shell.

The fact that the lower silo space is spanned without intermediate supports also means that there is complete freedom in the arrangement of the mechanical equipment already mentioned which is usually very extensive; this is also important for possible later extensions or conversions of this equipment.

This again assumes that all required platforms (usually of steelwork) near and below the cone are suspended by using tension bars.

The resulting suspension loads (tensile forces), can be taken without problem by the load bearing, rotationally-symmetrical cone shells. Thus the entire area of the lower silo space can be designed without columns, which is often regarded as an advantage.

In addition to this it is possible to design tension bars more economically than compression columns as the stability does not have to be taken into account.

The free load bearing central cone, whether designed as a cone or truncated cone shell, also has the advantage that without exception all loads are transferred to the outer wall where they are transmitted very simply and therefore very cost-effectively, directly to the foundation and thus to the ground.

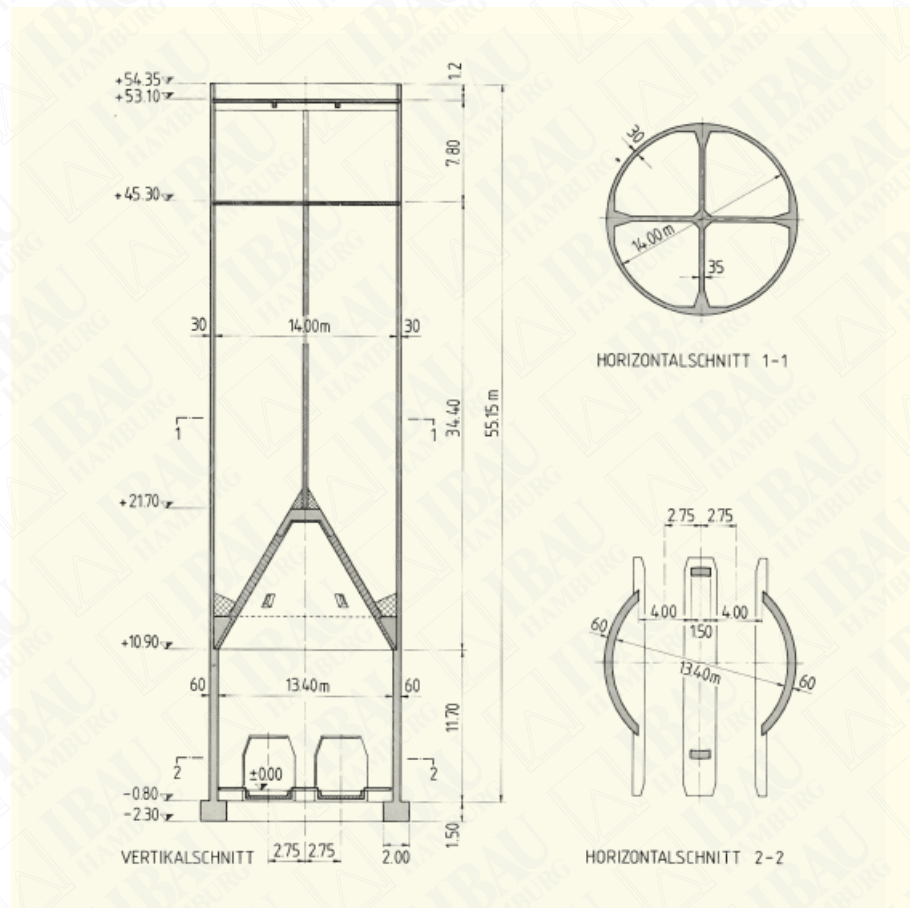


Fig. 11: 4-compartment silo

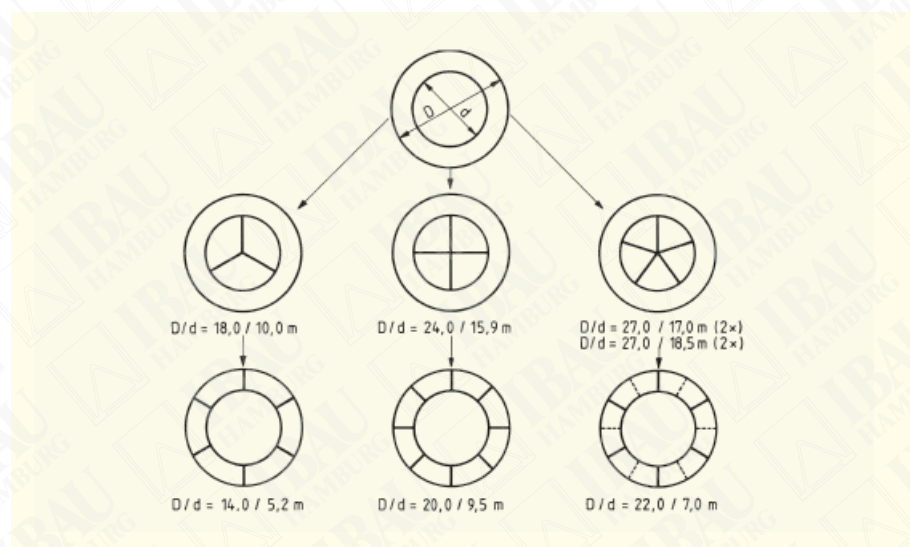


Fig. 12: Multi-compartment silos evolved from the ring silo

Multi-Compartment Silos with Central Cone

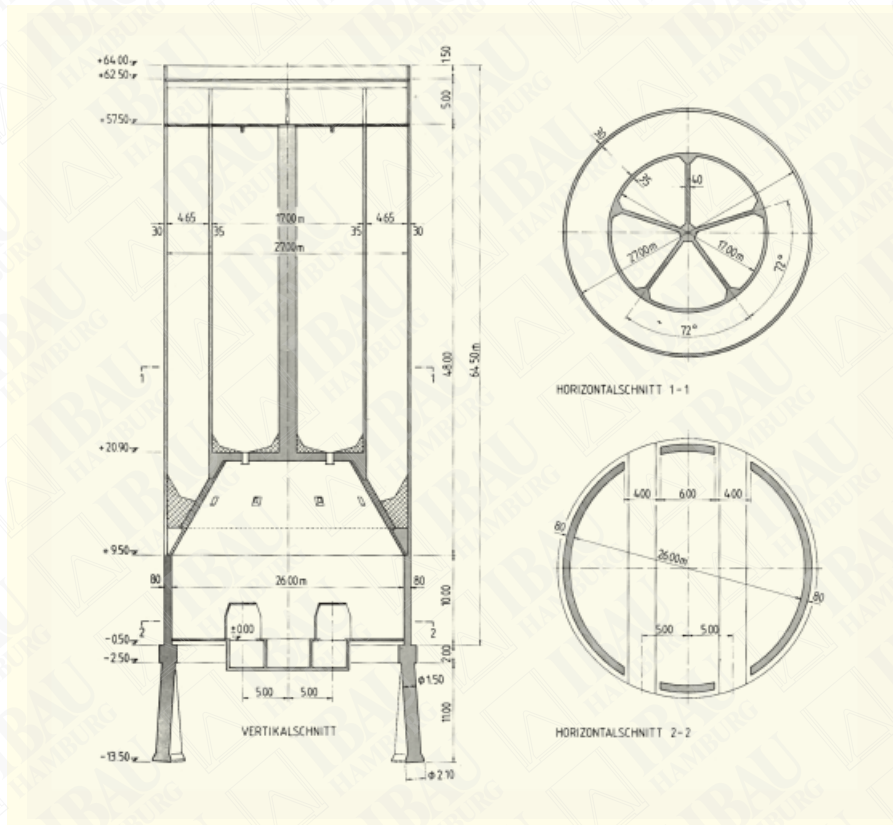


Fig. 13: Ring silo with inner silo subdivided into 5 sections



Fig. 14: Silo walls of the silo shown in Fig. 13 after completion of slipforming

Circular cylindrical silos have already been constructed with 3 to 6 subdivisions, depending on the diameter (Fig. 10).

An example of a 4-compartment silo of this type for cement is shown in Fig. 11. The silo floor consists of the usual central cone which, for the reasons given before, is elevated. The cell walls have flexural rigid connections to the cone wall. Various subdivisions are possible with ring silos (2 concentric cylindrical shells) depending on the requirements, e.g. silos have been built, in which the outer ring chamber is not subdivided as it is used for storing the major component, while the inner silo for storing the components needed in smaller quantities has 3, 4 or 5 cells. However, the reverse type of subdivision has also been constructed, in which the inner silo is undivided but the outer ring chamber is subdivided into 6 or 8 compartments (Fig. 12).

Fig. 13, for example, shows a silo with an outer ring compartment and an inner silo divided into 5 compartments. The internal diameter of the outer silo wall is 27.0 m. The silo floor is formed by a truncated cone shell which spans the entire silo space without intermediate support in spite of the large diameter. The floor of the inner silo is suspended at the 5 intersecting cell walls which act as shear walls. During construction, i.e.

after completion of the slip forming process, all the silo walls are clearly visible (Fig. 14).

In contrast, Fig. 15 shows an existing silo which has a ring chamber divided into 8 compartments. Here again the silo floor is an elevated truncated cone. The flat silo floor of the inner silo has also been provided with a small additional cone to relieve the pressure at the outlet.

A further design of this type of silo is shown in Fig. 16. Located in the upper part of the silo is a ring compartment divided into 6 compartments and an inner silo cell. The floor of the outer compartments is formed by a truncated cone shell in the form of a funnel.

As the previous example, the actual load bearing body, which here again spans the entire silo space without intermediate support, consists of the central cone in the form of a truncated cone on which are seated all the other components such as cell walls and funnel shell.

Between the cone and the funnel there is an annular space which is divided into 12 more compartments which are used for storing various bulk materials and inter-ground additives which have to be stored in small quantities. Altogether this silo, also known as a mixing station, has 19 compartments.

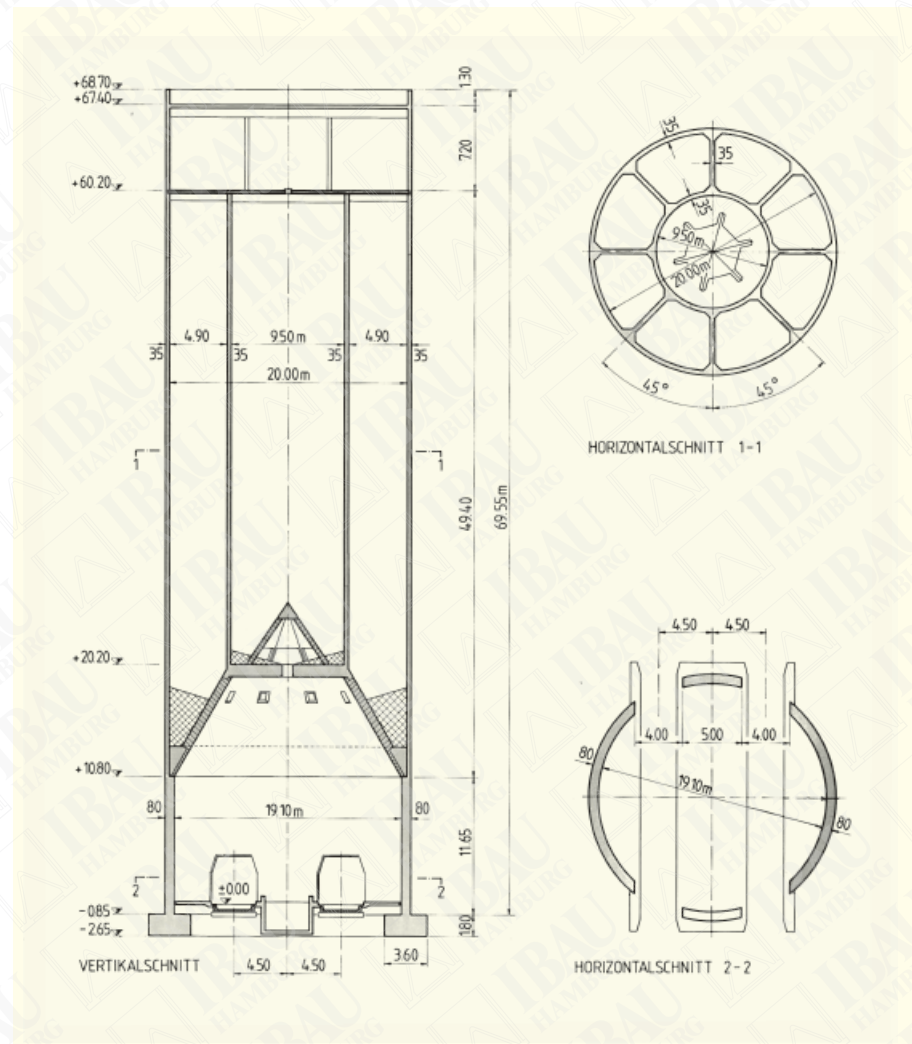


Fig. 15: Ring silo with 8 compartments and one inner-silo

The aerial photograph taken after completion of the slip forming provides a good view of the cell division in the upper part of the silo (Fig. 17). In principle, the execution of the construction work follows the same concept for all the silos described.

As all loads - as already mentioned - are carried entirely by the outer silo wall, simple foundations

in accordance with the ground conditions are recommended, either in the form of ring foundations (Fig. 11, 15, 16) or with large diameter piles.

All the silo walls can be built using sliding formwork, starting directly from the upper edge of the foundation. The sliding formwork can be converted or extended quite simply and without

great time delays at shoulders in the outer silo wall, i.e. the position where the central cone rests, and at the transitions from the free cross-section to the cellular cross-section.

The cone is produced either using in-situ concrete construction on formwork and scaffolding or by using precast reinforced concrete

Multi-Compartment Silos with Central Cone



Alignment and tensioning of the cone segments (under construction)

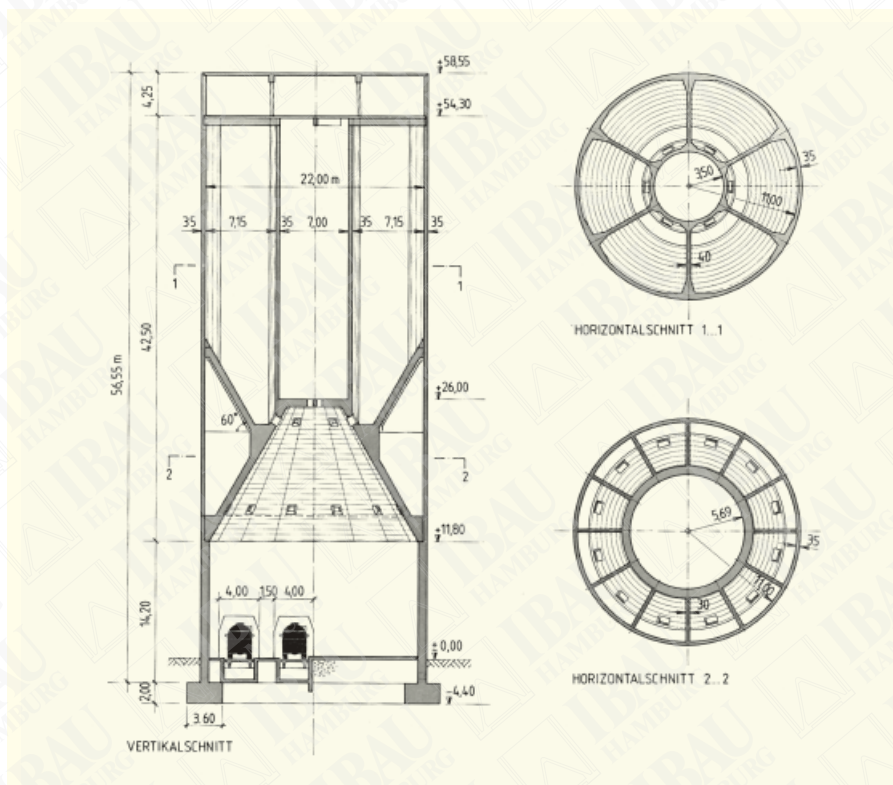


Fig. 16: Ring silo (mixing system) with $7 + 12 = 19$ compartments

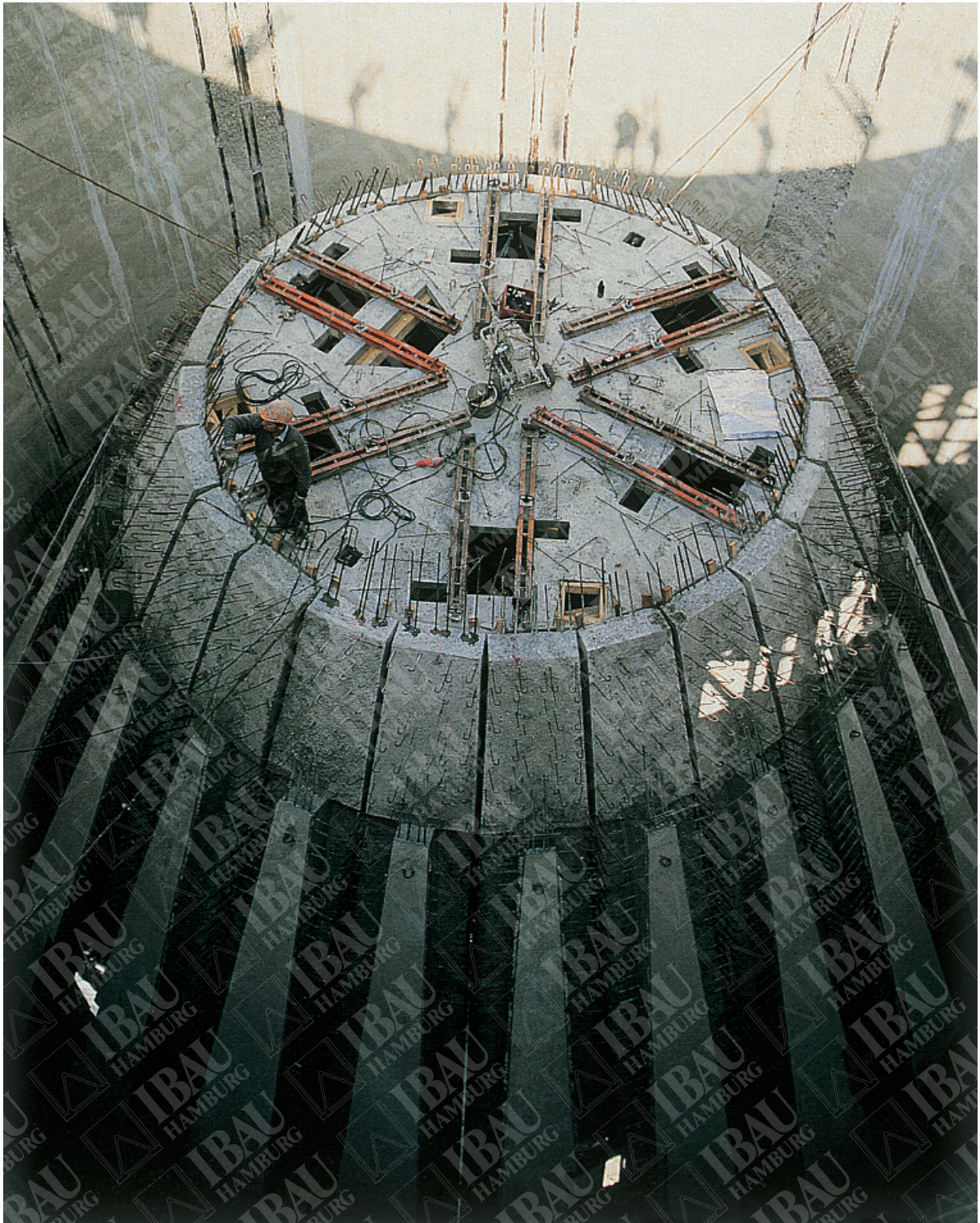
segments. In all the multi-compartment silos constructed so far by the system described here, tenders have shown that the use of precast reinforced concrete members is to be preferred from both the economic and the scheduling points of view.

The system developed for single-cell silos can also be applied directly to multi-compartment silos.

During construction the precast members are either supported on a central scaffolding tower or stay directly against the outer silo wall using suspension rods.

Figs. 18 - 21 shows the lifting and positioning of heavy segments weighing 22.4 t for the 22.0 m diameter silo shown in Fig. 16 using the method just referred to above, i.e. by staying against the outer silo wall.

If the cone or truncated cone is produced from in-situ cast concrete, then conventional formwork and scaffolding or commercially-available formwork systems are used (Fig. 22).



Completely mounted silo cone with tensioning wires to the silo wall (under construction)

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View of the compartments in the upper part of the silo shown in Fig. 16 (aerial photograph)

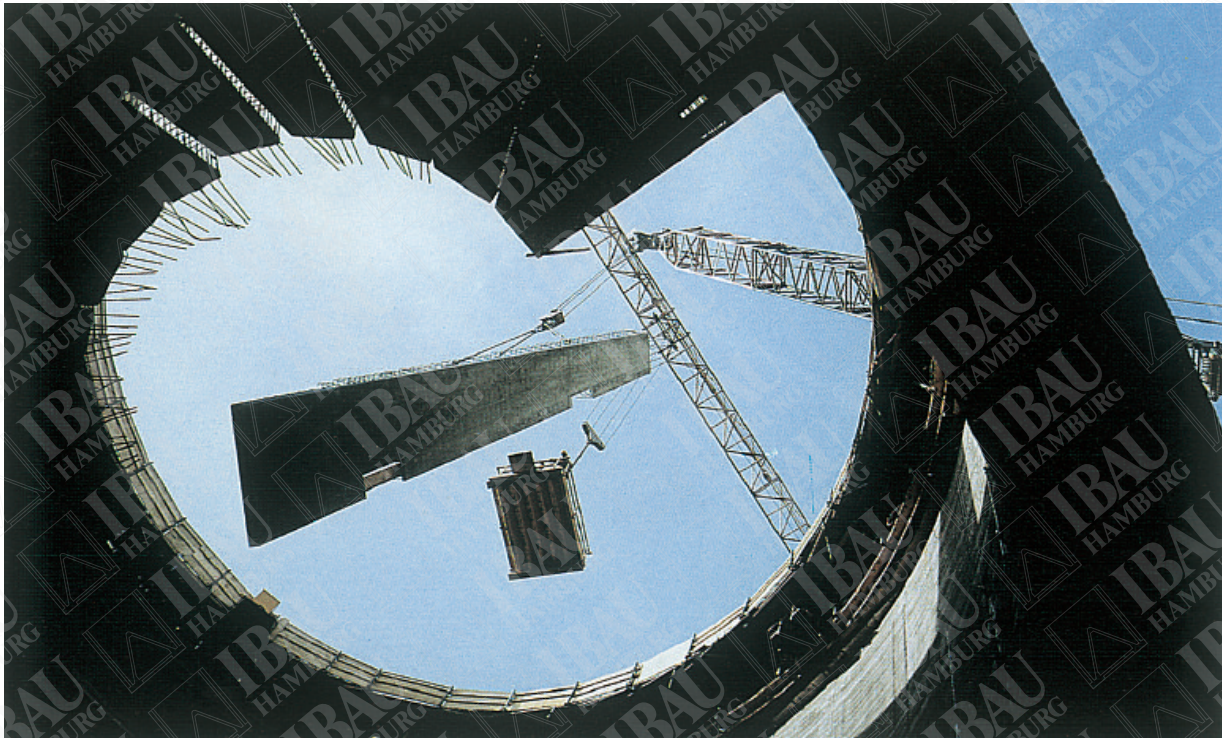


Fig. 18 and 19: Lifting of the reinforced concrete segments weighing 23.4 t for the silo shown in Fig. 16

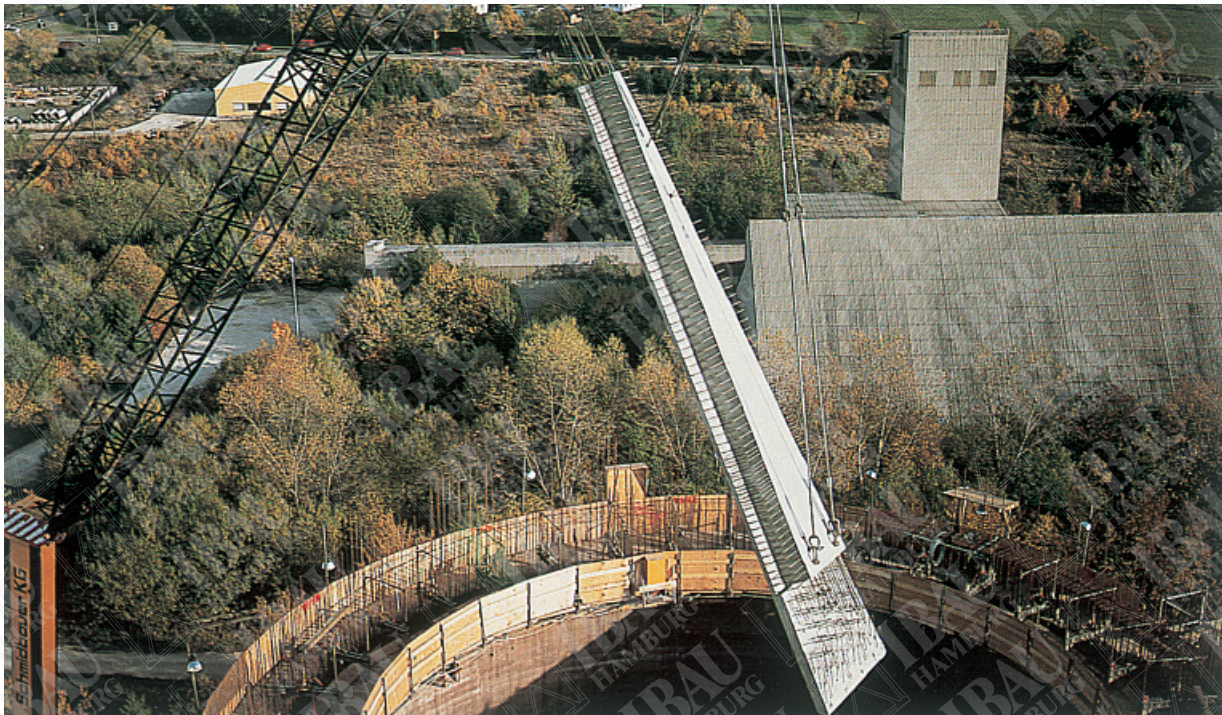


Fig.: 19

Multi-Compartment Silos with Central Cone

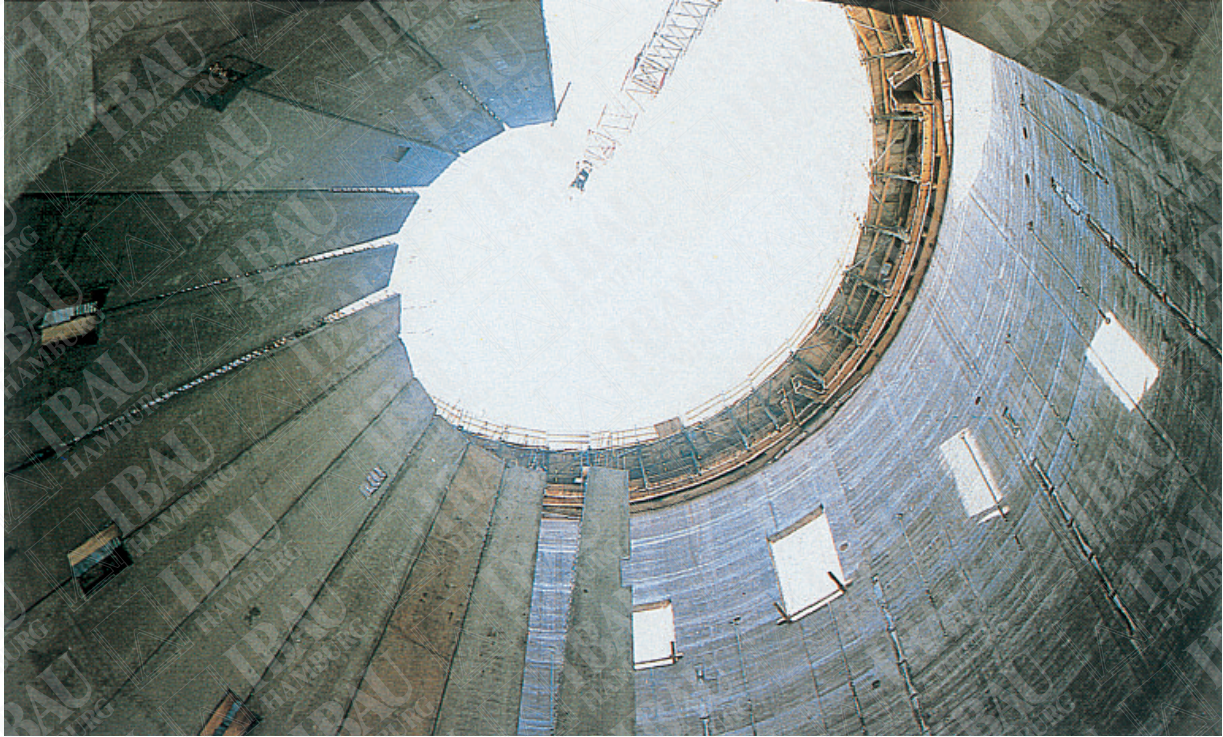


Fig. 20: Segments in position, stayed against the silo wall (during construction)

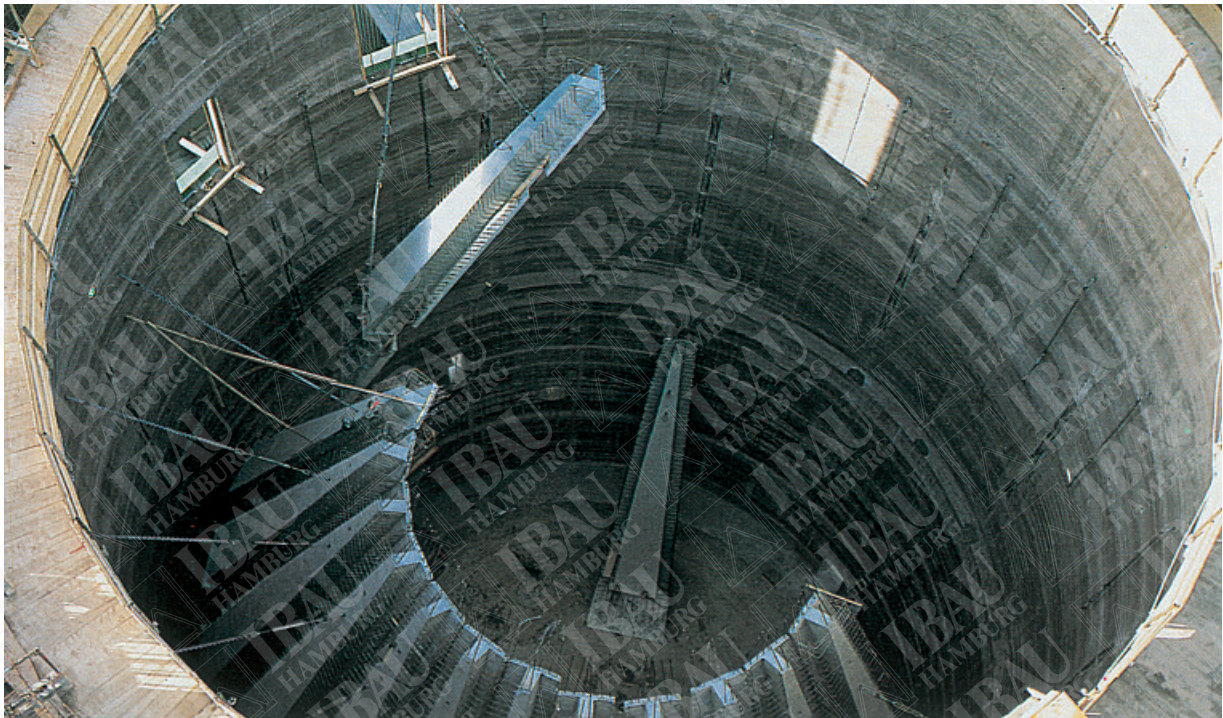


Fig. 21: Segments in position, resting on step in the silo wall (during construction)

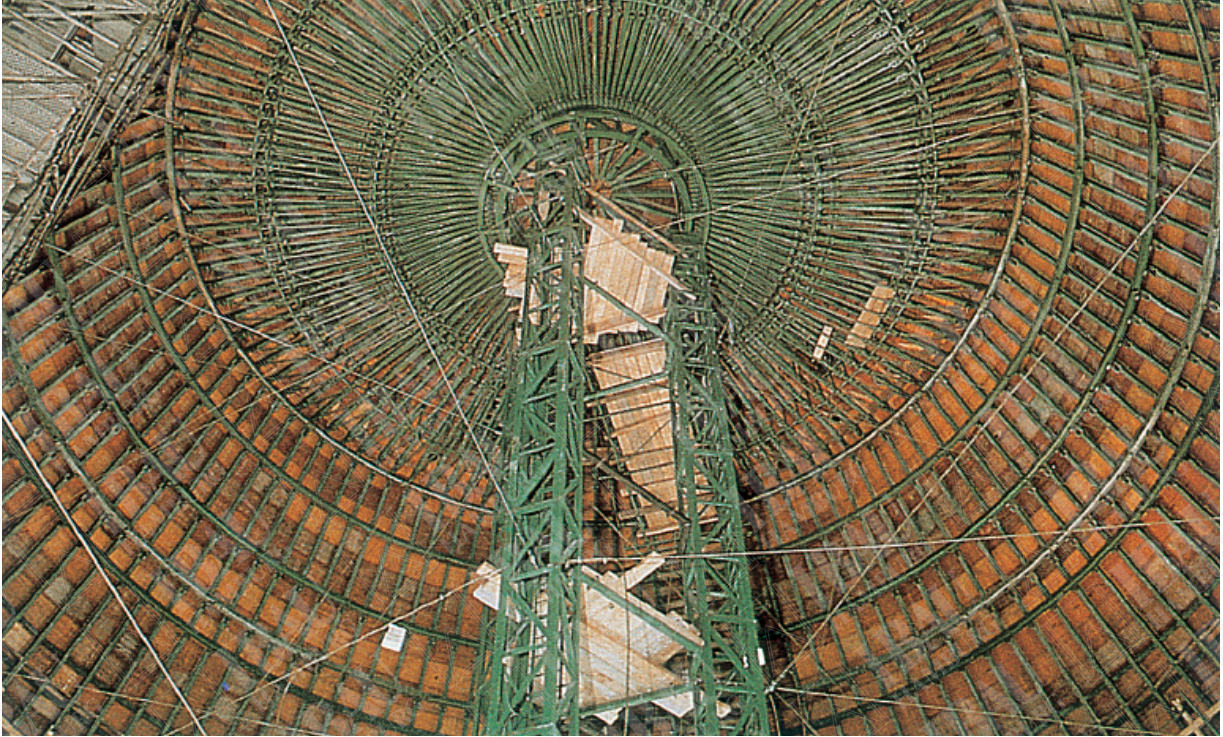
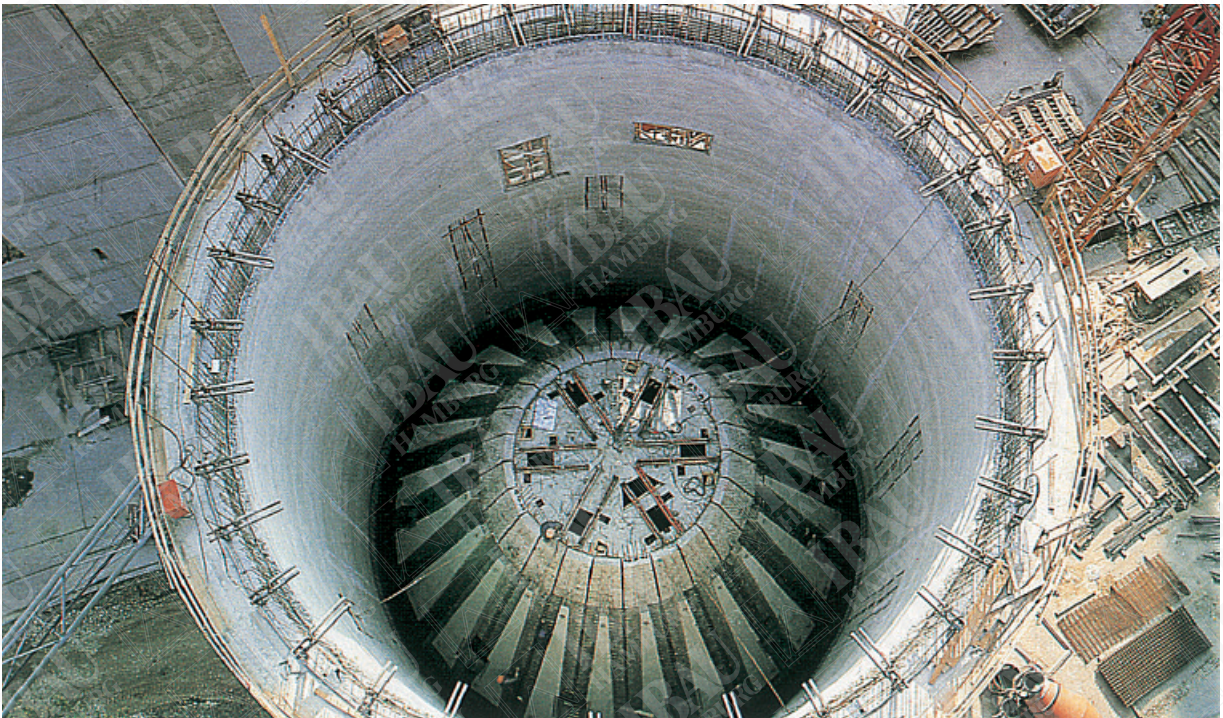


Fig. 22: Formwork system for the insitu concrete construction (system round steel construction, Bregenz)



View into the silo showing the premounted silo cone (under construction)

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Cement silo installation with bulk loading
in Samalayuca / Mexico



Raw meal blending silo,
Dyckerhoff Zement / Germany



High capacity mixing plant
HOLCIM, Antwerp / Belgium



Coal-fired power plant
Mehrums / Germany



Shipunloader on rubber tyres for Continental
rida Materials, Port Canaveral / USA



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