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PREFABRICATION IN THE BRICK INDUSTRY

A. Krechting
Bundesverband der Deutschen Ziegelindustrie e.V. D-53113 Bonn

Abstract

Construction with factory-made prefabricated brick elements has developed into an efficient, individual and economical construction method and is gaining increasingly in importance. The paper is a report on proven and also new innovative construction methods from the areas of prefabricated wall, roof and floor elements, giving concrete examples taken from practical applications (reference objects).
Furthermore, the report deals with special aspects of manufacturing (prefabrication in the factory), transport and assembly as well as the assembly of elements on the site (execution recommendations). The industrial prefabrication of wall units is one possibility for further extending the market position of masonry industry.

Key words

Prefabrication, wall panels, brick floor elements, brick solid roof elements

1 Introduction

This report aims to outline the basic principles of the construction method and is a supplement to the lecture to be held at the International Brick/Block Conference in Amsterdam. Furthermore, it should contribute to a better understanding of the subject.

The revision of the technical basis of the masonry standard DIN 1053-4, issue 1978-09 “Masonry – Buildings made of prefabricated brick units /1/” is finished. The new German masonry standard DIN 1053-4 entitled “Masonry; Section 4: Prefabricated units /2/”, has been published by the *Deutsche Institut für Normung e.V*. (DIN) with the issue of February 2004.

Tight financial budgets in the residential building sector and narrow completion deadlines – coupled at the same time with the need to optimise yields – are factors which represent a challenge to investors and architects in many places. The prefabricated construction method is gaining recognition as an essential solution to the problem. Decisive advantages lie in the rapid building progress, optimum organisation of the construction procedure, reduced time and wage costs as well as a guaranteed schedule.

Production efficiency and a high quality standard are ensured by prefabrication in the plant, which is independent of weather conditions, and by the use of semi-automatic computer-controlled bricklaying machines. For example the length of the individual wall sheets is oriented to the architecture and can be up to approx. 10 m. Extreme dimensional accuracy guarantees that further building parts, such as windows, can already be ordered at the beginning of the building phase in order to save time.

Figure 1 Example of building

2 Advantages of prefabrication – product quality

- Permanent quality control during manufacture
- Maximum brick and mortar quality with masonry conforming to trade regulations and standards
- Binding dimensional accuracy of the wall elements due to computer-aided planning and fabrication
- Accurate observance of the time schedule due to manufacturing independent of weather conditions
- Works combination of masonry and supplementary elements
- Partial completion of the walls (roller blind casings, strap roller cases, etc.)
- Dry and transportable masonry
- Increased working safety

3 Advantages of the system – quick and economical

- Freedom of architectural design, no system-related re-planning compared to the conventional construction method
- Improved coordination at the interface architect – structural engineer
- Environmentally compatible and ecological building materials
- Adoption of the existing load-bearing structure and execution design
- Reduction in construction time
- Storey-high and room-wide elements according to DIN 1053-4 /2/ (German standard)
- Considerable reduction in site installations and supply
- No additional costs for containers
- Stability of value
- Good building-physical properties

4 Characteristic features of the construction method

Prefabricated brick units are wall, floor and roof elements, which are factory produced using bricks and bonding mortar or concrete. A special advantage of brick element construction is that the total structure in its three-dimensional elements, including the intermediate floors and the roof, is mainly produced of one single building material. Deformation differences, owing to a change in material, can be virtually ruled out. The freedom of architectural design is hardly restricted by this construction method. An increase in productivity and quality is achieved by moving the essential working processes into a prefabrication factory, which is therefore largely independent of the weather conditions. Wall, floor and roof elements are produced by means of special semi-automatic and fully automatic processing equipment.

Depending on the intended use and the manufacturing process, different authors /3/ /4/ distinguishes the following segments of element construction.

4.1 Wall panels

Wall panels are prefabricated wall units of masonry bricks and masonry mortar built up in layers. The elements are manufactured in production halls, standing upright, by means of automatic bricklaying systems (semi- or fully automatic), mostly storey-high like conventional masonry (vertical production).

Figure 2 Wall panels with vertical pouring channels and anchor bars

The length of the individual elements is oriented according to the architecture and can amount to up to approx. 7 m. According to DIN 1053-4 /2/ bricks may be used for wall panels, which in a certain grid have vertical channels, in order to be able to take up the anchorages (anchor bars) necessary for transport and erection. Under certain circumstances it may be possible to dispense with pouring channels, provided that equivalent transport procedures are applied.

The shear-resistant connection of the wall panels to each other is made by butt joint. On average, the widths of the vertical joints are approx. 30 mm. After assembly, depending on the load acting on them, they are closed with normal or lightweight mortar. Loop reinforcements in the area of the horizontal joints are statically not necessary and normally only serve to provide additional construction security. Owing to their static and building-physical properties, wall panel bricks do not differ from other masonry bricks according to the German product standard.

4.2 Cast panels

Cast panels are wall construction units, which are manufactured in horizontal position on production tables, production lines or in circulating production systems (horizontal production). The individual elements are room-high and up to 10 m long. Here, especially shaped (vertical coring) bricks in lengths of 25 – 50 cm are placed on formwork in perforation direction according to the load acting on them. The bonding of the bricks to each other is ensured by concrete according to DIN 1045 /5/ or lightweight concrete. The field of application, the dimensioning and the construction design of cast panels are regulated by DIN 1053-4 /2/.

The assembly of the individual elements is carried out by slinging with chains, ropes or belts on concrete-embedded rope shaft, flat steel or ball-head anchor bars – similar to the assembly method of pre-cast reinforced concrete units.

4.3 Composite panels

Composite panels are a special form of the cast panel construction method. Here, special hollow bricks (25 to 50 cm), strongly profiled at the outside, are used, which act statically and structurally as displacers and have widths of approx. 33 to 62.5 cm. During manufacture the bricks are laid in perforation direction without a mortared butt joint into a fresh concrete layer of at least 35 cm. The distance between the brick rows is at least 30 mm.
Single-leaf composite panels are produced after laying the bricks by wet-on-wet pouring of the interspaces between the brick rows and simultaneous application of at least 35 mm concrete topping – concrete or lightweight concrete. As a result 2 sheets with vertical concrete ribs are formed. For two-leaf composite panels an additional layer of bricks is laid into the second fresh layer of concrete and then poured up to the front plate of the brick.

In principle composite panels can be compared to pre-cast reinforced concrete elements with displacers.
Further important segments of brick element construction are the brick floor elements and the brick solid roof elements.

4.4 Brick floor elements

Brick floor elements are versatile. Due to their capillary structure they improve the interior climate, they are an excellent plaster base, show excellent breathability, good heat insulation properties, low building moisture and they contribute through low creep and shrinkage to crack-free building.

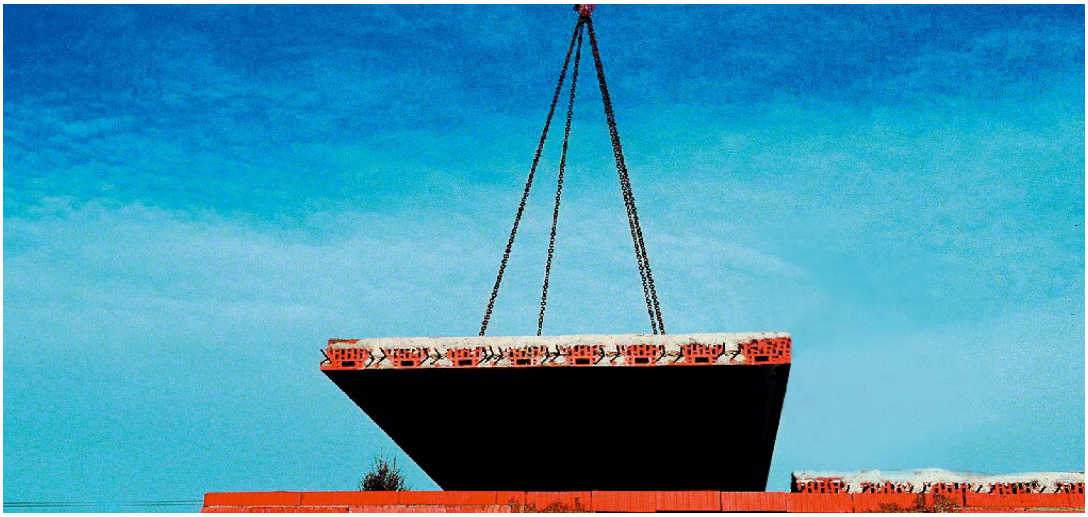

Figure 3 Brick floor elements

4.5 Brick solid roof elements

The special advantages of the brick solid roof are found in fire resistance, wind tightness, high sound insulation and in the very good summer heat insulation and consequently in the improved quality of living under the roof in attic flats.
An overview of prefabricated brick construction elements made from backing and facing bricks is contained in Table 1.
Not all of the examples mentioned are covered by the technical fundamental principles in DIN 1053-4.

5 Technical fundamental principles and standardization

Brick element construction is a building method proved and tested in practice for more than 40 years. The directive for buildings of large-format prefabricated brick units was already published in 1967. DIN 1053-4, 1978-09, “Masonry; Buildings of prefabricated units /1/” is the uniform technical fundamental principle for this construction method. Since the publication of DIN 1053-4 in 1978 numerous building-physical and static marginal conditions have changed. As a consequence the revision of DIN 1053-4 was concluded. In particular the monolithic exterior wall using high thermal insulation bricks and lightweight mortar was to be included in the standard. Apart from that the standard, which until then had applied to bricks only, was also opened up for other masonry block industries.

After long negotiations, especially with the highest construction supervision authority (DIBt), the white paper of the standard is now available, published by the DIN in February 2004 /2/. The initiation by the construction supervision authority is expected in September 2004. This applies both to the initiation as a product standard and to the initiation as a technical building regulation (dimensioning standard).

6 Transport and assembly

In particular the proof of safety during transport and assembly of prefabricated brick elements is a complex subject. Different transport systems are applied. In addition to the proven system of pouring anchors, suspensions with load-bearing bolts, suspensions with flat lifting slings and the transport on base elements are used.

Prefabricated brick units can be used in principle in all areas of residential, commercial and industrial building. Due to works production control and foreign supervision, consistent quality is guaranteed. Material management as well as the installation and supply of building sites are reduced to their fundamentally important matters. Through a works combination of prefabricated brick units with integrated load-bearing elements, such as window lintels, circular beams and ring anchors as well as safety holders and bracing reinforcements, this construction method becomes a full system.

Figure 4 Assembly of brick panel

7 Example in practice

7.1 Nursing home for dementia patient

With the growing percentage of elderly people in our society the number of people with geriatric illnesses is also increasing. As the treatment and care of dementia patients is not possible in an optimal way in the existing classical old people's homes.

A new and in this form unique nursing home has been developed, which in its lay-out of the ground plan reminds us of an 8 /6/. Each of the two circles of the 8 consists of a central circulation walk with care, functional and day rooms, a wide circular corridor and residents' rooms outside leading off the corridor. Further functional rooms as well as administration and personnel areas are accommodated in the basement and in the upper floor. Starting point for the planning process were round corridor areas, offering the residents, who owing to their illness are often aimless and disoriented, the opportunity to take a "never-ending walk".

For the construction of the ground floor and upper floor walls, planners, construction service companies and the building owner decided in favour of prefabricated wall units of bricks. The most important factor for this choice was the expected reduction in the construction period. According to calculations up to 4 weeks construction time can be saved by using prefabricated brick wall elements in the execution of the ground-floor walls. When planning the project, the repetitive uniform ground-plan types of the residents' rooms proved to be an advantage for the use of prefabricated brick units. In this case, wall sheets of the same kind are repeated up to 20 times.

7.2 Building project sponsored by public founds

Prefabricated elements: A concept, from which the investor of a residential building project sponsored by public funds in Düsseldorf also benefits: The project must be calculated optimally from an economic point of view. This can succeed with

prefabricated elements. They ensure a reduction in building time, technically perfect completion and lower wage costs. For the investor this means: lower intermediate financing, earlier beginning of capital reflux from rent earnings and early repayment of mortgages.
Architectural plans already oriented to prefabricated element construction form the basis for completion of the building carcass. In accordance with this layout the element plans are compiled, in which the wall units are broken down into elements floor by floor. Each individual element is compared with the architect's plan, checked for correctness and cleared by the architect for production. Possible discrepancies between the architectural plan and static engineering plan are ruled out. In this way, building site management is already practised during the work preparation phase and relieves the control on the building site.
The storey-high and maximally room-wide brick wall panels planned individually for the building project are manufactured at the works in the order of their installation on site. Depending on the plan specifications, they are fitted with recesses for windows and doors, with roller blind casings and belt roller casings, ring anchors, U-shells for retrofitted ring anchors and concrete parts. The results are completely "fitted" carcass walls in brick masonry according to DIN 1053, Part 4, under constant supervision of quality and workmanship through own and foreign control.

Brick wall elements are structures which are resistant to shear and tensile loads and ensure the usual three-dimensional stability for masonry in connection with circular beams or floor sheets. They are produced in different constructional designs – as monolithic external walls, load-bearing masonry for two-leaf wall structures or for the application of heat insulating composite systems, as load-bearing or non-bearing internal walls, as sound insulating walls for separating walls between two different apartments. For transport by crane on the building site, the elements - depending on the weight – are fitted in a certain grid with cast anchors and loops, on average with at least 4 anchors. In order to guarantee the building site logistics overall, exact construction times are scheduled and assembly sequence plans are compiled for the investor, taking into account the externally produced concrete parts – from the start of the building project to the final handover.
After expert technical preparation of the building site, the prefabricated elements are loaded "just in time" onto heavy-duty pallets in accordance with the assembly sequence, transported to the building site and where possible processed floor by floor directly from the low-loader. In accordance with the assembly plan, the wall sheets are set down by crane in the mortar bed in exact elevation and alignment. Each element is squared vertically by adjustable assembly supports. The walls remain secured until the mortar is hardened. Reinforcement loops in the horizontal joints serve to connect the wall panels to each other. Connections resistant to shear and tensile forces are provided by overlapping loops, through which a vertical reinforcement is passed. After assembly the vertical joints – depending on the load – are filled storey-high and flush-jointed with lightweight mortar or normal mortar.

A team comprising 3 skilled workers can assemble up to 40 wall elements per day.

For the project in Düsseldorf, altogether 960 wall elements have been processed by two assembly teams at times since the start of construction at the beginning of February 2004. The complete carcass will be finished by the beginning of May 2004, whereby the individual houses are phased. The complex should be ready for occupation at the end of the year.

Further information on brick element construction is available on the Internet website of the *Arbeitsgemeinschaft Ziegelelementbau [association of brick element construction trades]* www.ziegelelementbau.de.

Figure 5 Brick panels delivered on pallets

8 Conclusion

For more than 40 years brick system buildings has proved to be a reliable construction method in practice. Rationalisation and quality management will become more and more important on the building site. The development of larger thermal insulating clay units has made clay unit masonry already one of the fastest possibilities in masonry construction. The speed on site can nevertheless be increased by the use of prefabricated wall elements. With the help of automated manufacturing equipment, building components are produced in the factory as wall and floor elements, so that the entire structure can be assembled in its three dimensional elements on the building site within a very short space of time.

Decisive for the market however will be that it is successful in further improving the degree of familiarity of brick unit construction and in making users and end consumers fully aware of the most important arguments for the use of prefabricated brick units, namely

- high quality
- cost effectiveness
- short building time and
- high reliability in the price calculation and date planning.

The signs are favourable.

Table 1: Possible prefabricated brick construction elements in backing bricks and facing bricks /7/

Construction units of backing bricks	Construction elements of facing bricks, facing units and clinkers
- Brick wall units - Wall panels - Precast panels - Composite panels (rectangular units, door and window units, angle units, gable units, circular units, column units) - Brick floor / ceiling units - Brick support and clay boards for ribbed floor / ceilings - Brick solid roofs - Flat brick lintels - Brick roller blind housings - Brick roller blind aprons - Brick screens - Brick prefabricated arched cellar components	- Fair-faced brick facades, complete with finished pointing - Terracotta facades (as prefabricated component facade, wall or floor / ceiling cladding) - Prefabricated lintels with brick facing - Prefabricated window sills with facing clinkers or window sill tiles - Half-timbered filler units of clinkers or facing bricks - Clinker facing skins for old building renovation - Masonry copings - Clinker chimney stacks - Stairs - Special building components, e.g. round window jambs (“bull’s-eye/oeil de boeuf”), cornice profiling - Noise protection walls of acoustic bricks

9 References

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