Prefabricated installation*) units for residential and multi-story buildings
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1. PROJECT

Prefabricated houses offer very good conditions for construction efficiency due to their high degree of prefabrication. The margin for decreasing costs, however, is not yet fully utilized. Considerable potentials for cost savings is in the field of installations. The project ‘Installationskern’ marked the first step to explore installation savings in prefabricated construction of residential homes (one-family houses). Due to the higher requirements in terms of fire resistance and noise reduction a second project was established to adapt installation units for the use in multi-story buildings.

Both projects included the intensive co-operation between the Fachhochschule Rosenheim (University of applied science), house manufacturers and the installation supplying industries. Main subject of the second project for example were three apartment buildings in wood construction in Flensburg, in the north of Germany. They were built by ‘Regnauer Fertigbau GmbH & CO KG’, a manufacturer for prefabricated buildings.

The aim of the projects was to develop concepts and systems for prefabricated installation units in prefabricated houses to decrease costs and help avoid mistakes in the co-ordination of the trades. Next to the documentation about planning and installation, the practicability for the concepts was examined.

project 1: building-high installation units for one-family-houses (fig. 1) [1]
project 2: story-high installation units for an apartment building in Flensburg, Germany (fig. 2) [2]

2. REQUIREMENTS

The integration of installations into buildings has to follow the severe German building regulations. There are strict demands in terms of structural design, fire resistance, noise control, thermal insulation and sanitary aspects.

Structural design
Structural design is very important to ensure stability of the installation units during use. A major difference between Germany and North America is in the kind of toilets being used. While toilets in North America usually are standing on the floor, toilets in Germany are more often hung on the wall which requires a stronger construction for the wall to prevent ceramic tiles from cracking. The established value for the load on a toilet is 400 kg with a lever arm of 35 cm!

Fire resistance
There are severe regulations about fire classification of building components, their construction and the materials used, especially in buildings with more than one story. They are written down in the ‘Musterbauordnung’ (national building code) [3] and the ‘Landesbauordnungen’ (provincial building codes) [4].

In most cases buildings up to 3 storys high can be built using wood construction. Building components such as walls, ceilings and roof have to have a fire rating of F30-B. That means in case of a fire the component has to stand for at least 30 minutes. Combustible materials are allowed in the construction. Installations going through such components have to have the same fire rating. To comply with this requirements special construction details are essential.

*) utilities (water, heating, gas etc.)

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Sound control
In multi-story houses there are minimum values required for sound insulation in walls and ceilings between apartment units. They are composed in the DIN 4109 [5] and VDI 4100 [6]. It has to be remarked though that the base for the allowed values are walls with a weight of 220 kg/m² which has it’s origin in the traditional massive type of construction in Germany. Building components with a light type of construction show another behaviour in terms of sound control. Installations that show a lot of noise sources such as running water, flushing toilets etc. need extensive sound insulation. As a conclusion installation units used as partition walls in multi-story dwellings have to satisfy the higher demands in terms of sound control.

Thermal insulation
To ensure a supply of clean fresh water, as well as a minimum heat loss of hot water pipes, all pipes have to have sufficient thermal insulation. The pipes themselves have to be made out of non-toxic materials as well as resist incrustation, corrosion and bacteria.

3. INSTALLATION’” UNITS

Prefabrication
The most important pre-condition for prefabricating the house technique is the concentration of all pipes and wires for supply and disposal in one central installation module which is all-storey high (Fig. 3 ). The module can also be made of multiple units stacked on top of each other. When delivered to the building site, the modules should contain all pipes, fittings and distributors etc. for the house (heating, ventilation, solar technique, water and hot water supply, electric current, vacuum cleaner etc.). A comparison of the production of installation units with the traditional way of installation of house technique showed a decline of costs when the level of prefabrication was increased.

Functions
The central module takes over two functions in the building. It is an all-story shaft for installations and, at the same time, a partition wall for rooms. These two functions represent a challenge for the designing engineer as the sound insulating properties of the building shall not be affected by using the all-storey high shaft for installations of a light type of construction, which is prefabricated to a high degree. The construction is shown in Fig. 3.

Structure
Like other building components, the installation units are made of a wooden structure with a sheathing of OSB or gypsum boards. The installation units were developed in a two-layer design. All components holding sanitary appliances were integrated into the frame work, while pipes, tubes and other sanitary engineering were run between the framework of the two layers. Installations were consistently attached just to the layer facing the sanitary room, to reduce noise being emitted to the room on the back side. This technology also allowed to assemble the components without through-threading pipes through the framework. Figure 4 shows the principle of the construction.

Sanitary engineering
A successful attempt to improve sound control was made by using specially designed sanitary engineering. For example, tubes made of weighted plastics instead of cast iron pipes were used for the waste water disposal.

Pure plastic- as well as a composite material pipes were used to accelerate the sanitary installation. The composite pipes were a combination of a plastic inner and outer layer with a thin aluminium layer in between to provide the best characteristics of each layer. The plastic has an inert behaviour to water, while aluminium avoids diffusion of oxygen and unacceptable deformation by temperature variations. The pipes were connected with press fittings and a special tool. The press-technology is faster and less dangerous than the traditional solder technique for copper pipes.

Iron mounting elements for the sanitary ceramics were fixed to the wooden structure with sound reducing fasteners.

Planning and execution
The planning of the installation modules for both projects was carried out by the Fachhochschule Rosenheim in close co-operation with the partner companies. Then production and erection were supervised and documented. Fig 5 to 7 e.g. show the course of the project of an 3-story high apartment building in Flensburg, Germany (Fig. 2).
4. SOUND CONTROL MEASUREMENTS

Extensive measurements were conducted to examine the sound behaviour of different kinds of installation units in different houses as well as the efficiency of different sound reduction methods. They were done by the ‘IFT Rosenheim’ (Institute for window technology, Rosenheim) in order of the Fachhochschule Rosenheim.

In the Flensburg project three different types of installation modules (two with a wooden structure, one with a steel structure) have been compared to each other to find out which concept would be best for the use in prefabricated houses of a light type of construction. The results showed excellent values for the airborne sound insulation of Installation units (Fig. 8). Sound control in terms of installation sound showed good values for the units with wood structure and acceptable values for the steel structures. Fig. 9 shows the improvement of the new concepts in comparison to conventional installations of 1995.

The measurement results underlined the fact of a different sound insulation behaviour of installation units in light type of construction in comparison to ones in massive type of construction.

5. CONCLUSIONS

As a conclusion it may be stated that the developed installation module may be already used today for one-family houses, as well as for multi-story dwellings, especially for prefabricated houses in wood construction.

Examples are shown in Fig. 1 and Fig. 2.

The German requirements for fire ratings can be met in wood buildings up to three stories high by an applicable bulkheading of pipes, ducts and tubes in the ceiling. The bulkheading shall have the same fire rating as the building component, the installation runs through. The classification is F30-B.

The problems previously experienced in the field of sound insulation have been solved in most points by the consistent two-layer type of construction of the module (Fig. 4) and by taking sound insulating measures in the area of installation. Nevertheless the research showed also that not every sound reducing measures for installations, integrated in walls of massive type of construction can be taken over for the light type of construction. For individual questions there is still a need for development.

The installation module separated into one-story high parts lead to a considerable improvement in sound reduction from one story to the next. However, the additional connecting points of pipes which were necessary then resulted in a higher expenditure in mounting at the building site which can be expected since a lower level of prefabrication was achieved thereby.

The research showed that with an improvement in planning and a better control of the production in the plant many eventual origins of mistakes in the co-ordination of the trades can be avoided. This leads to:

- better quality of installations in buildings
- improvement of sound control
- higher living comfort
- increased efficiencies in overall construction and installation costs

Examinations of the efficiency show that the present construction can lead to a decrease of materials used for the installation by about 25 % and a decrease of share in wages by about 20 %. Prefabrication of house installation will rise from 25 % now to about 50 % by the use of a central installation unit shown in Fig 1.

The efficiency of the new installation technique, like press technology for pipes, is still capable of being improved. For example, by usage of mounting elements which are especially made for prefabricated houses or by using prefabricated bundles of pipes and modular building parts.

6. REFERENCES

7. FIGURES

Figure 1
Prefabricated building–high installation unit for one-family houses. Next to walls, roof etc. the ‘Installationskern’ arrives as another building component on the construction site. All installations are pre-assembled in the plant.
Prefabricated installation units in an apartment building in Flensburg, Germany. The units were produced as story-high, pre-installed components in the plant and transported to construction site. After the walls of each story were built up, the units were hoisted into place by a crane and connected to each other forming a building-high shaft.

Examples of prefabricated installation modules for the use in residential buildings. The left side shows the wooden structure as well as the installed components for the house technique such as heating, ventilation, solar technique, water and hot water supply, electric current etc. On the right picture a complete installation unit is hoisted into the already erected ground floor of a prefabricated house.
Figure 4
Principle of the design and construction for installation modules. The technology allowed to assemble the components layer-wise (bottom) without through-threading pipes through the framework. The established vertical zones (right) reduce possible collision spots of different pipes and installed aggregates.

Figure 5
Story-high installation unit for a multi-story building. The 3D-planning (left) helps to recognize collision spots of framework, pipes, ducts etc. View at a completely installed unit in the plant (right).
Figure 6
Three different installation units on shipping pallets (left).
Installation module hooked up on a crane during erection of the building (right).

Figure 7
After the units were adjusted, fastened and connected to the main supply (left), they got planked and the ceramic tile finish work was done. Finally the sanitary ceramics were mounted to the wall (right).
Figure 8
Comparison of airborne sound insulation data regarding partition walls, installation units used as partition wall and installation units in combination with partition walls.
The broken lines show minimum values for partition walls according to DIN 4109 [5] and VDI 4100 [6].
Figure 9
Comparison of own measurements (left) with measurements of the Fraunhofer Institute for building physics [7] (right). The measurements were made to examine installation sound levels of installation modules in light type of construction buildings. The incitation was a flushing toilet. It was measured horizontal, within a section.

The broken lines show maximum allowed sound levels according to different sound control levels established in DIN 4109 [5] and VDI 4100 [6].