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Composite Floors of the Buildings

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Asko Sarja, born 1941, received his civil engineering degree at Oulu University in 1967 and his doctor of technology degree in 1979 at Helsinki UT. After working some years in a design office and the Waterways Administration he has worked since 1970 at the Technical Research Centre of Finland with the emphasis on structural engineering and concrete technology.

Summary

Modular product systematics can be applied in modern prefabrication technology. A module is defined to be a partly independent assembly of components. One module is the floor, which is designed to fulfill the mechanical and physical requirements, but also to allow an easy assembly and rapid changes of the partition walls and installations. Different types of floors are classified and examples of composite structures are presented. The main specialities in the design are listed.

1. The principles of modular building system

The building system is an organised whole consisting of its parts, in which the relations between the parts are defined by rules [1], [2]. Modulation involves division of the whole into sub-entities, which to a significant extent are compatible and independent. The compatibility makes it possible to use interchangeable products and designs that can be joined together according to connection rules to form a functional whole of the building.The floor is a typical module owing a character.

2. Performance requirements of floors

The common main requirements of floors can be classified in the following ways:

1. Mechanical requirements, including
   - static load bearing capacity,
   - serviceability behaviour: deflection limits, cracking limits and damping of dynamic vibrations.
2. Physical requirements, including
   - air tightness
   - airborne sound insulation
   - impact sound insulation
   - moisture tightness (in wet parts of the floor)
   - thermal insulation between cold and warm spaces
   - fire resistance and fire insulation.
3. Flexible compatibility with connecting structures and installations
   - partitions
   - piping,
   - wiring,
   - heating and ventilating installations.

In addition to the performance requirements during service life, the entire life cycle requirements include the buildability, changeability of spaces during the use and easy demolition, reuse and wasting.

3. Advantages of prefabricated composite floors

The multiple requirements can be preferably fulfilled with composite structures, because for alternative designs they own more performance parameters than monolithic structures. Usually the composite structures have the meaning of mechanical composite performance under static and dynamic loadings. Taking into account the multiple requirements listed above, the composite performance has to be widened to include all types of these requirements. The weighting of different types of requirements varies for building types. In apartment buildings the static and dynamic requirements are quite easy to fulfil and physical requirements together with the flexibility towards changes during use of spaces and installations is important. In office, commercial and industrial buildings high loading capacity and easy changes of spaces and installations during the use are dominating properties. In special cases like under seismic conditions, the vertical and horizontal loading capacity and large deformation capacity are important.

The main advantages of composite structures for mechanic properties of floors are:

- the increase of load bearing capacity globally or locally, e. g. around openings, either in new structures or in renovation
- reduced structural depth
- reduced material expenditure
- increased rigidity and thus the decrease of deflections and vibrations.
- improvement of the diaphragm action of the slab field
- the mechanic advantages can be reached through increased loading capacity of the structural members, through continuity or through combination of them.

The main advantages for physical properties are:

- improved water tightness
- improved sound insulation
- improved fire resistance.

The main advantages for flexible compatibility with connecting structures and installations are:

- Possibility of installation spaces for pipes, wires, cables and fastenings.
- Possibility for tight connections with connecting structures.

It must be noticed that the composite structures often have also disadvantages associated with the demountability of the floors at the end of the service life. This is because of the difficulty in separation of the components from each others. This is especially the case when using composites of prefabricated components and in-situ concreting. However, the improved flexibility for changes of installations and connecting partitions is much more important than the demolition phase, because the experience shows that the building will typically be changed several times for different uses before demolition. The entire service life of the buildings in Europe is often several hundreds of years. In the opposite, in Japan the service life of office buildings has been reported to have a mean as low as 25 years.

4. Examples of different types of prefabricated composite floors

4.1 Composites for the improvement of mechanical and physical behaviour

The alternative composite floor slab structures can be classified as follows [3], [4]:

1. Composite concrete floors (Fig. 1.)
    - 1.1 Reinforced or prestressed hollow core slabs
    - 1.2 Reinforced or prestressed solid planks
    - 1.3 Reinforced or prestressed double-T units
    - 1.4 Reinforced Filigran solid planks
    - 1.5 Composite beam-block floors
2. Composite steel-concrete floors [6] (Fig. 2.)
    - 2.1 Composite steel sheet-concrete slabs
    - 2.2 Composite prestressed steel sheet-concrete slabs
    - 2.3 Composite steel truss-concrete slabs
3. Steel profile-board floors [6], [7], [8] (Fig. 2).

Concrete slabs can be connected with supporting beams to also work as composite slab-beam structures. The beams can be made of concrete or steel. Wooden beams are sometimes also used as composite structures with concrete slabs. In order to achieve a good flexibility for future changes to connecting structures and installations, slim beams have reached increasing use.

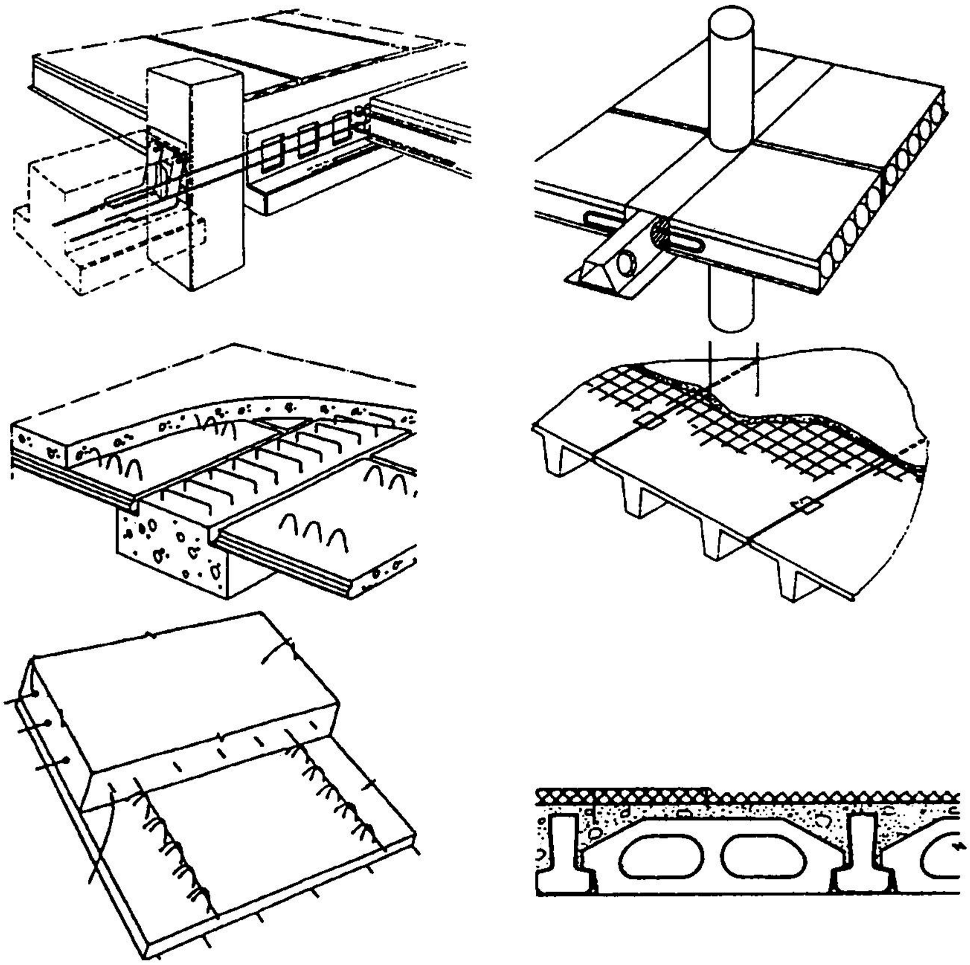

Fig. 1. Composite concrete floors.

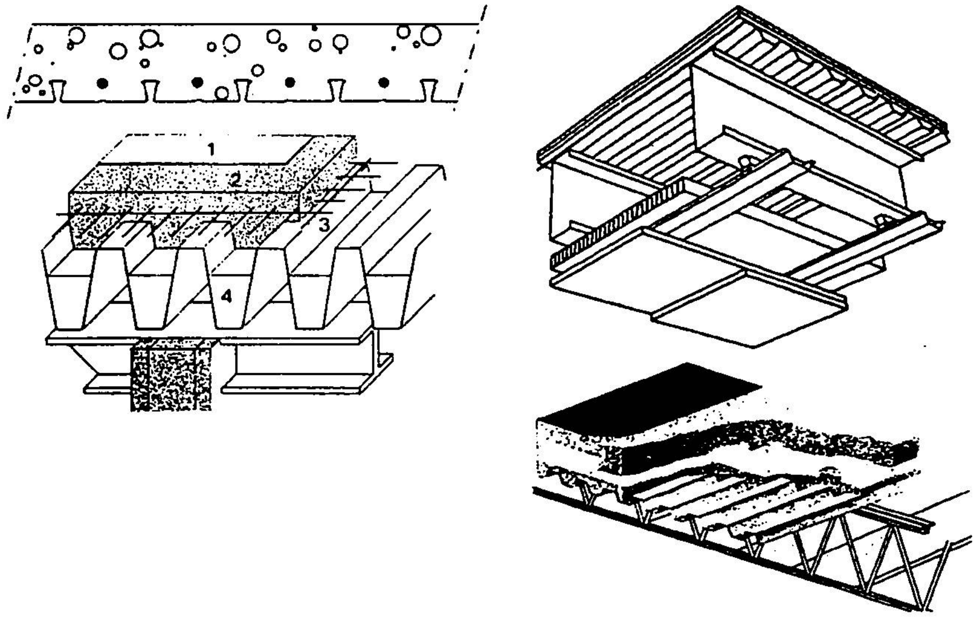

Fig. 2. Composite steel-concrete floors.

4.2 Composites for the improvement of flexible compatibility with connecting structures and installations

The floors are the most important modules for improvement of the installation flexibility for changes during use of the buildings. There are four main principles to solve the compatibility for free distribution of ventilation, electrical wiring, water and sewage piping and information cable networks over the floor area (Fig. 3.) [4]:

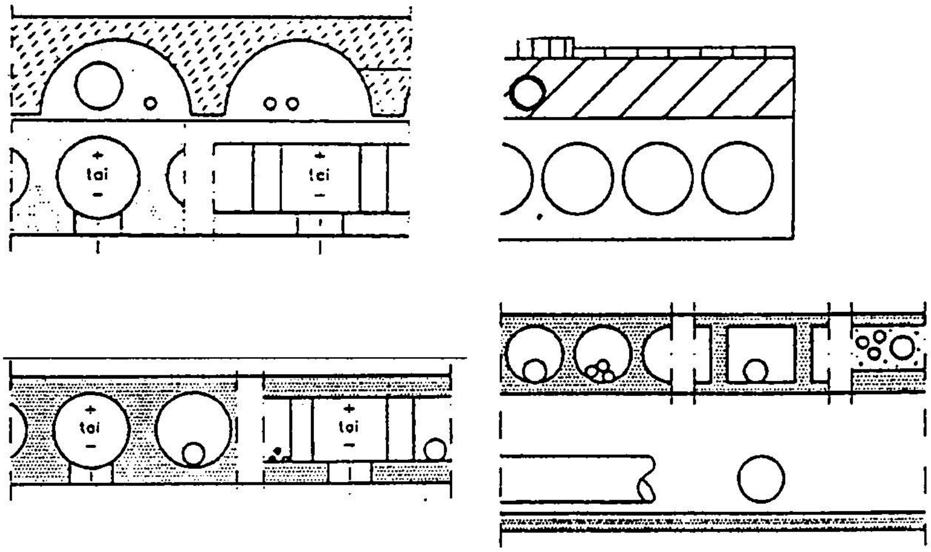

Fig. 3. Installation models in floors.

1. Installations in one- or two-dimensional holes of the bearing slab
2. Installations in the installation floor space above the bearing slab
3. Installations in the soft material above the bearing slab
4. Installations in the ceiling under the slab

The last 3 models listed above can practically serve for the improvement of sound insulation of floors even into very high level. Type 2. is often used in office buildings, where large pipes are needed for ventilation. Type 1. floor can serve the addition purpose of distributing the air for ventilation or combined ventilation and heating without any special pipes. Such kinds of solutions are used for low-energy buildings, where the massive floors can serve for daily storage of heating energy [4].

5. Specialities in designing the composite floors

In order to guarantee the proper behaviour of composite structures, the following phenomenas have to be analysed and solved during the design:

1. Shear stresses at the interfaces of the structural parts.
2. The interface stresses and deformations at different phases of production, as:
    - separated components
    - assemblies of components before possible in-situ concreting
    - final stage without and with external loading.

In addition to the load induced stresses and strains, time dependent visco-plastic stresses and deformations at different times are also important in calculating the interface stresses and deformations.

When using slim beams-slab composites it is important to notice the two-dimensional shear at the interfaces between slab and beam and inside the slab. The last mentioned two-dimensional shear is especially important when using hollow-core slabs with thin webs [5].

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