Development of Earthquake- and Landslide-Proof Residential Houses in KIT-System

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Abstract

Due to the occurrences of the Niigata-Chuetsu earthquake 2004, last October the Vienna University of Technology already delivered proposals concerning the reconstruction and future disaster mitigation for the protection of the people in the Niigata prefecture.

From the very beginning immediate help should be offered directly to each family. Instead of prefabricated barracks, which cannot be owned by the victims and which must be abandoned after some years, the Vienna University of Technology presented last year projects for individual use. They were developed as one-family-houses (as the smallest unit of dwelling) with a "building kit system".

The idea was that people can initially begin with the erection of a "minimal housing unit" by means of a very simple do-it-yourself construction kit with governmental support on allocated sites, which are seismically more resistant even for settlements. The prerequisite, however is, that people agree to move their new homes to a more safe land and form rather a community instead of living in separated houses, which cannot be built strong enough in order to resist natural forces.

In the course of further research activity, this year investigations will be concentrated on the aspects of heavy snow occurrence regarding the design and construction of the roof, thermal insulation, heating and light in interior spaces as well as the problem of accessibility of road systems and the development of the infrastructure in new settlements.

Keywords: building KIT, minimal housing unit, earthquake- and landslide-proof, Disaster Mitigation

Introduction

The Vienna University of Technology has been conducting research on the topic of "Disaster Mitigation" since the year 2000 in cooperation with the University of Tokyo and other related institutes and universities. As most of the damages caused by natural hazards concern buildings and consequently the people within them, the main focus is placed on the development of hazard-proof construction techniques for public as well as residential buildings. In order to be able to work efficiently and in a practice-oriented way, the "VUT (Vienna University of Technology) Cooperation Center for Disaster Mitigation and Security in Buildings" was founded. It is a platform and network to foster meetings of several institutes, in order to exchange and coordinate their research activities and form groups to continue their research topics in interdisciplinary cooperation.

The most important event is the yearly arranged exhibition at the end of the academic year, which explicitly shows the result of the research projects. In order to inform also the public about the activities, already several times press conferences and TV-reports have been taken place in Austria as well as in Japan. Basically the Cooperation Center consists of two sections — the "Section for Fundamental Research" and the "Section for Object-oriented Research". Whereas the "Section of Fundamental Research" elaborates the basic theories by means of the data and facts about natural hazards (case studies), the "Section for Object-oriented Research" aims at the practical application of this knowledge to buildings in order to mitigate or even prevent damages to structures and the loss of human life. The proposals are developed by means of "Research Driven Education Programs", involving interested and talented students in the design procedure of buildings for concretely defined hazard-prone areas, under the constant surveillance of consulting engineers and experts.

In this function, due to the occurrence of the Niigata-Chuetsu earthquake on October 23, 2004, the Vienna University of Technology initiated a design program in cooperation with Prof. Marui from the Niigata University, developing proposals concerning the reconstruction and future disaster mitigation for the people in the Niigata prefecture. Regarding the aims, the "Niigata Project" was divided into three main parts: the "Super Protecting Structure" and the "Flexible Building Transformation" — both dealing with the design of earthquake- and landslide-proof public buildings, providing shelter and medical treatment for up to 2000 victims in case of emergency — and the "Flexible Building KIT".

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Landslide-proof Settlements

Before starting to rebuild the destroyed dwellings, the main goal must be providing safe land for future settlements. Whereas modern technology already allows the erection of houses withstanding the forces of earthquakes, this is not true for landslides. Especially small scale dwellings were strongly affected by landslides which occurred in succession to the earthquake vibrations in the Chuetsu district. In order to find safer lands proper for smaller settlements or villages, it is necessary to investigate the geological quality of those areas, which were not severely damaged by the earthquake. Those places should be regarded as preferable for the erection of new settlements. Moreover, in order to provide a maximum of security for the future dwellings, it would be recommendable to increase the housing density, so that several buildings together could be reinforced considering landslide-hazards by a solid foundation, anchored in firm soil.

Cooperation with local carpenters

In order to quickly start with the reconstruction work after a disaster has occurred, it would be economically advantageous to cooperate with local carpenters rather than depend on external companies for prefabricated houses. The modules for the dwellings could be easily manufactured on the spot — even with the aid of the victims themselves — at the same time providing work and enhancing the local economy. In interdisciplinary cooperation between carpenters and earthquake engineers (of universities), involving the young man power of the population, earthquake resistant wood constructions should be developed and new production halls for private houses erected, with the aim of accelerating the reconstruction procedure in Niigata Prefecture.

Flexible Building KIT

The Flexible Building KIT is a research project of the "Institute for Structural?Design and?Timber? Engineering" (Prof. Wolfgang WINTER) which was carried out in the framework of the "Niigata Project" by the "Cooperation Center for Disaster Mitigation and Security in Buildings". The main idea in this "Building KIT-System" is to offer immediate help directly to those families whose houses have been destroyed either by the earthquake or consequent landslides and who usually would have to live in barracks for several months or even years, before being able to rebuild their homes.

In order to provide the possibility of regaining their own living space and identity as soon as possible, this modular housing system is designed for quick and easy assembly, enabling the affected population to take part in the building process themselves.

Based on a minimal housing unit consisting of a bathroom, a kitchen, a living space and a terrace area, the rectangular modules can be expanded in all directions step by step, according to the needs and financial means of the residents.

Construction KIT Village (Design: T. Rief)

It is assumed that, shortly after a catastrophe, the government would allocate predefined plots of land to support each family. The first step of action is the provision of a basic dwelling consisting of a bathroom, a kitchen, living space and a terrace area (in total approx. $30m^2$).

The construction is based on a rectangular module system which is expandable in all directions. In order to adapt to local culture and needs all modules are prepared for tatami floor mats. The house owners may expand the buildings based on their needs. Because of the uniform grid system and the already prepared CNC-joints, an expansion is possible without major disturbance to the existing buildings. Although the system provides complete freedom of planning, some suggestions for possible extensions are provided (see floor plans Fig.2; phase 1 to 4). To show the numerous design possibilities an elementary school building has been designed using the proposed system.

The reconstructed site plan of an existing village on a plateau in the Niigata prefecture (Fig.1) shows possible arrays of flexible houses for residential, public and commercial use.

The primary system consists of a double symmetric timber frame structure based on a regular grid. Prefabricated columns and crossbeams are connected by CNC countersunk joints which provide easy assembling without the need of steel connections. The shortcut CNC stands for Computer(ized) Numerical(ly) Control(led), and refers specifically to the computer control of machine tools for the purpose of (repeatedly) manufacturing complex parts in wood as well as other materials, using a computer program. The resulting framework will then be braced against shearing forces by OSB-wall units.

To increase the seismic resistance, optional brake dampers and connecting-type visco-elastic dampers will be placed between columns and crossbeams.

Fig. 1. Reconstructed village plan

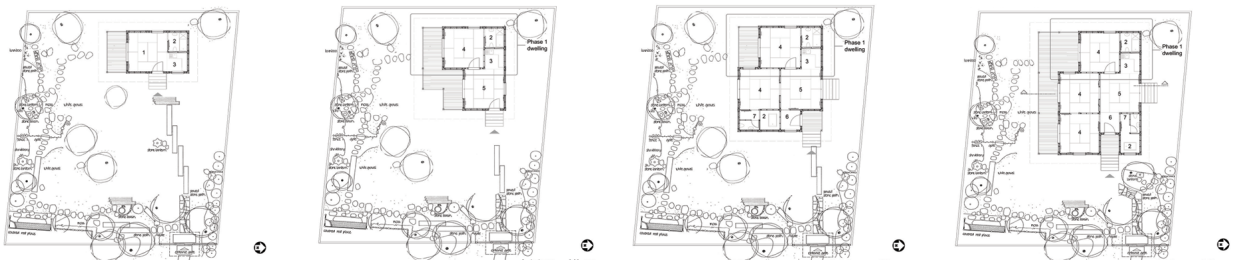

Fig. 2. Scheme of possibilities of extension of the modular housing system, Phase 1 (minimal housing unit) to 4

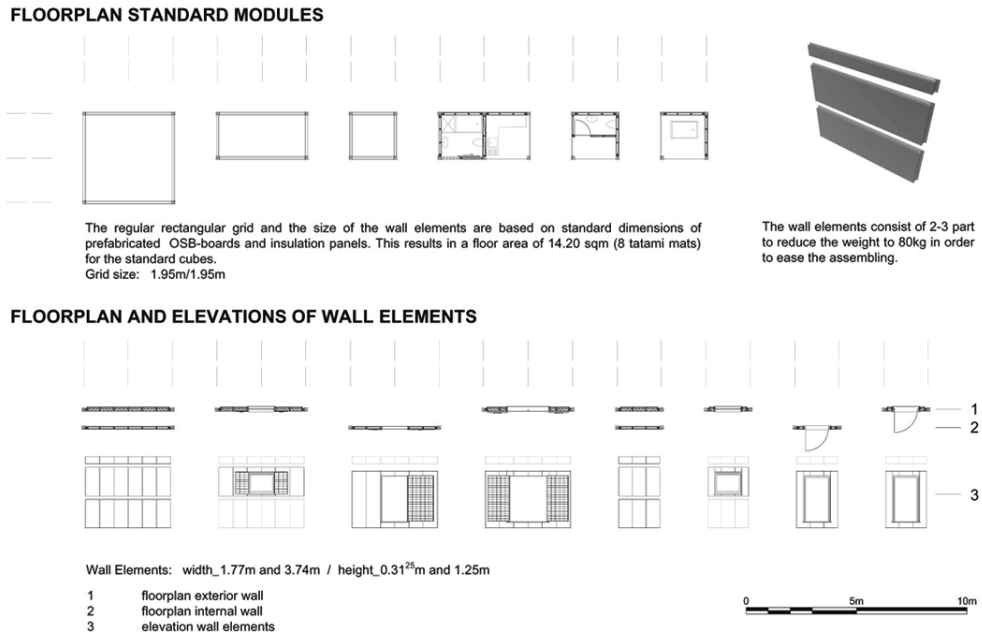

Fig. 3. Modular elements of the KIT system

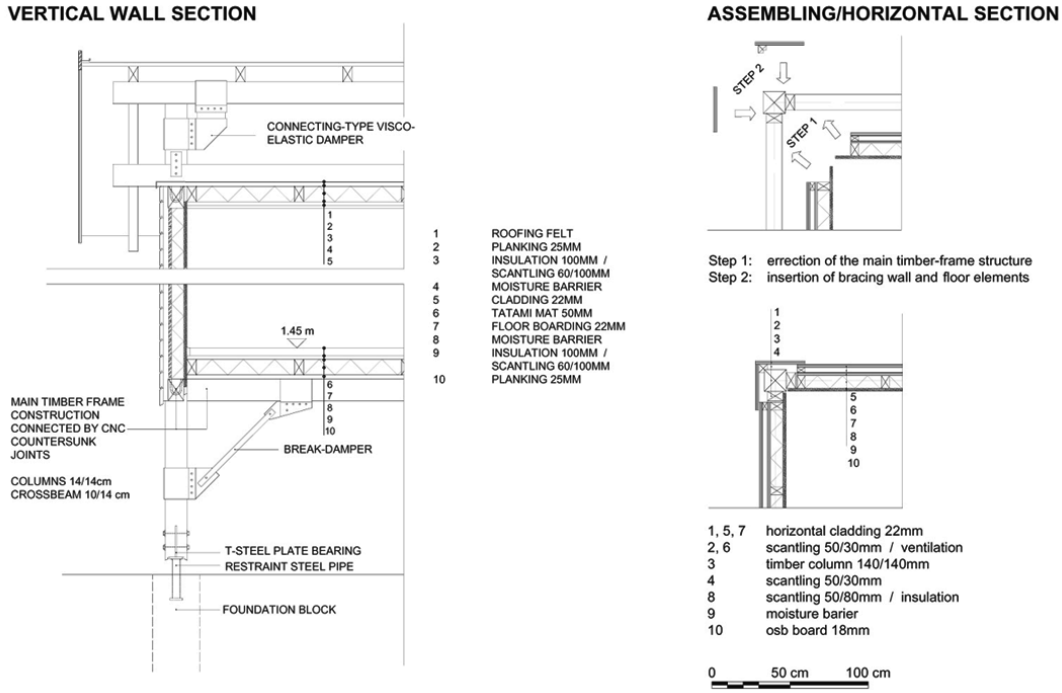

Fig. 4. Details of assembly

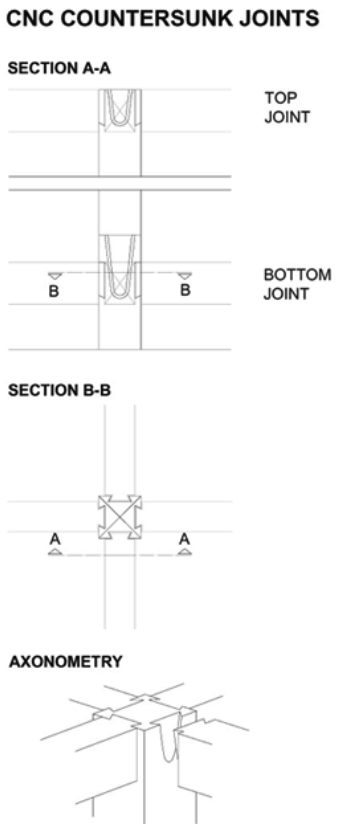

Fig. 5. CNC-countersunk joints

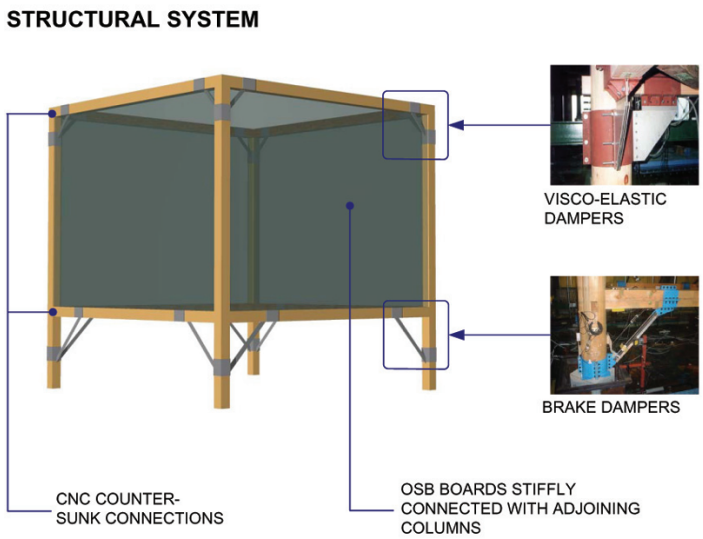

Fig. 6. Structural system

Fig. 7. Models of phase1 (minimal housing unit) to phase 4

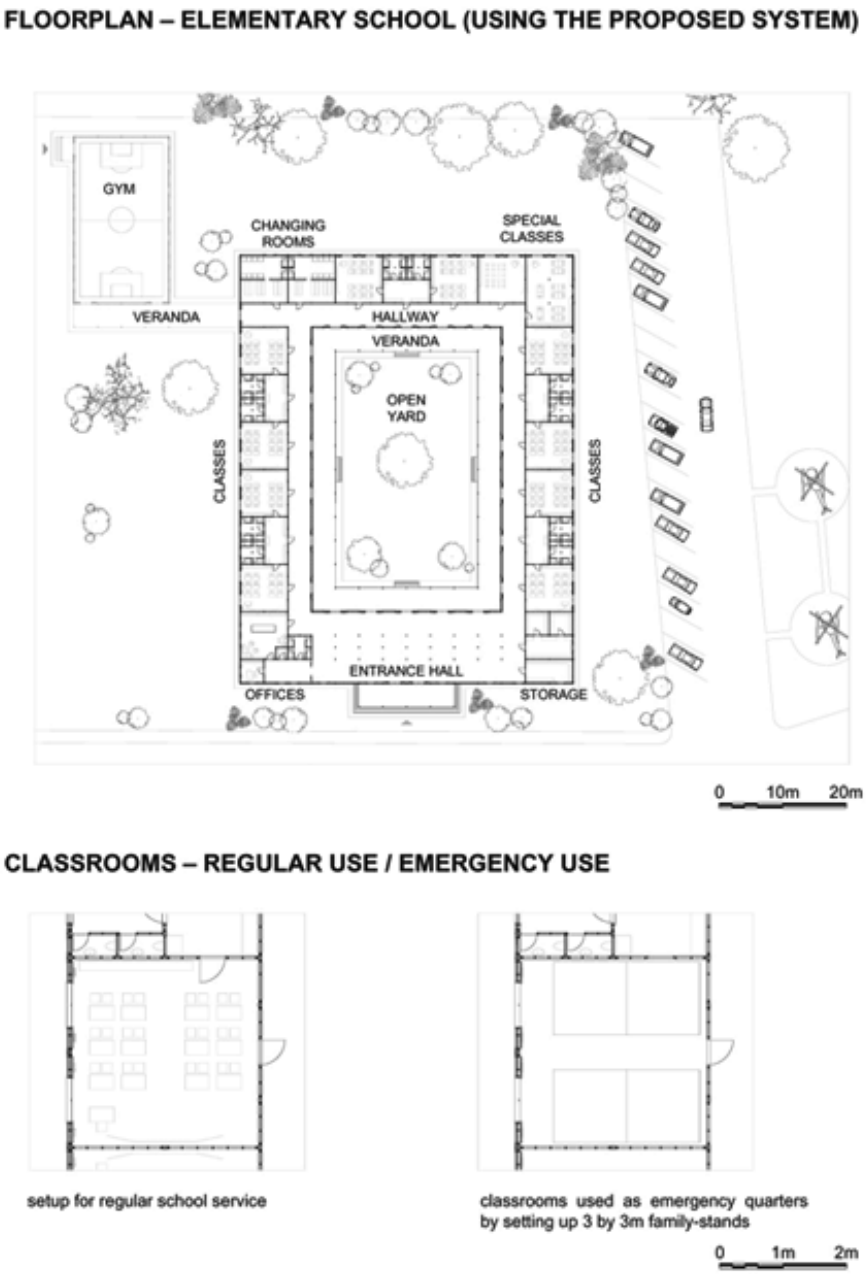

Fig. 8. Example for a school building

Core House (Design: K. Klepers)

The idea was to create a detached family house based on traditional elements like the pagoda and the Japanese bath in order to regain confidence after a loss of identity. The bathroom, as the most intimate room, was chosen as the central core from which further modules with various functions can be added. The size of the resulting units can vary from 18 to 72m^2 on one level and can reach up to 144m^2 on two levels.

The core is a solid timber construction, including the bathroom. The main construction's four pillars are divided into four posts ($4 \times 140 \times 140$mm) which carry the floor and roof crossbeams. These cantilevered crossbeams bear the weight of the platform and roof construction. The entire structure is base isolated to resist horizontal forces caused by earthquakes.

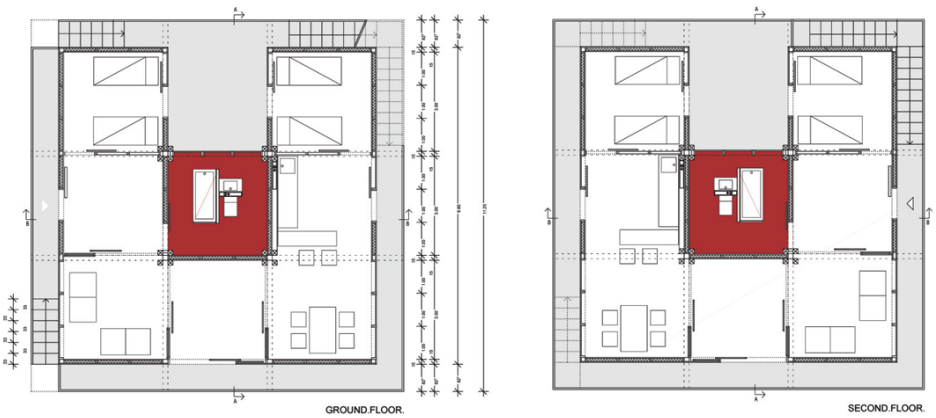

Fig. 9. Core House — first and second floor plan

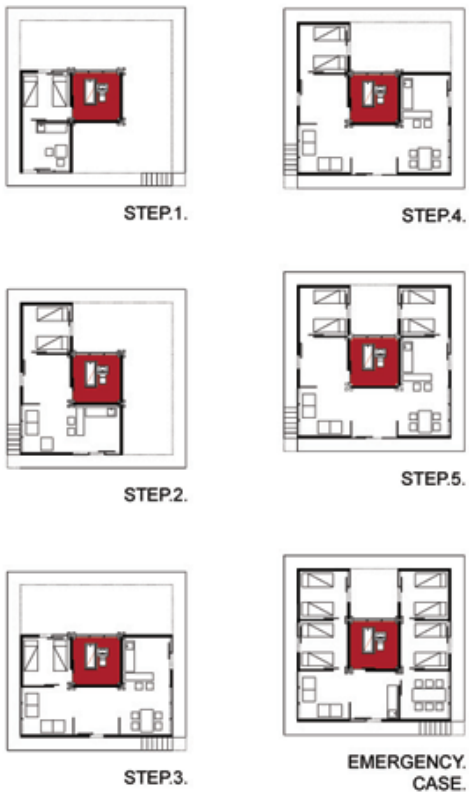

Fig. 10. Possibilities of extension

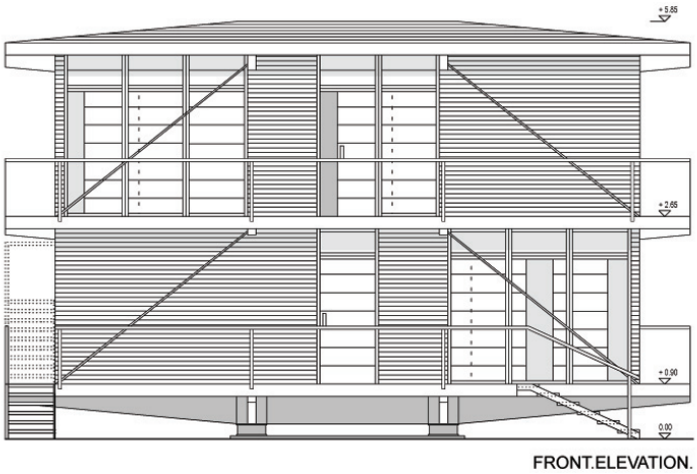

Fig. 11. Elevation

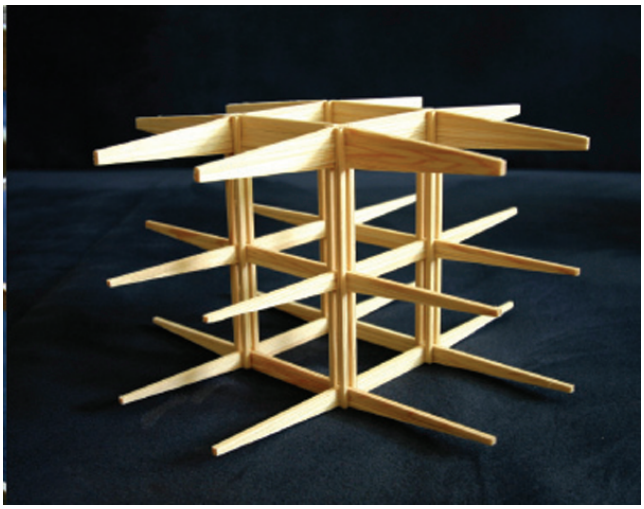

Fig. 12. Structural System

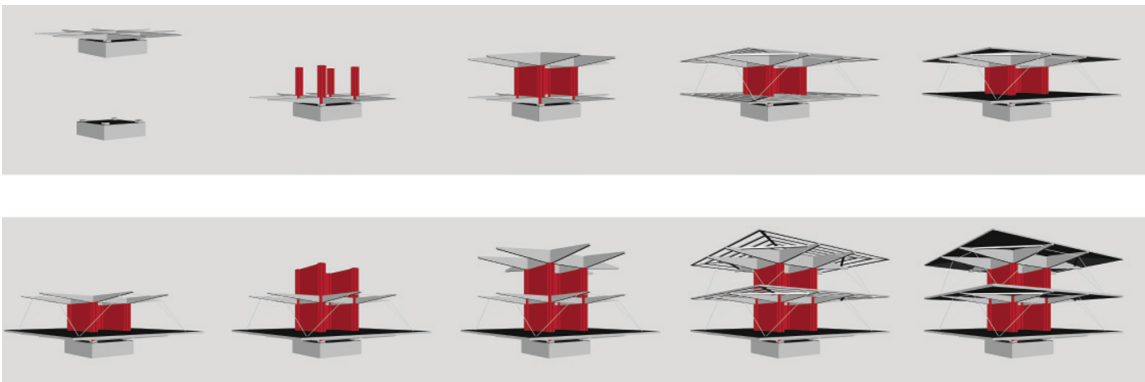

Fig. 13. Assembly Procedure

Heavy Snow Load

This year's design program for the "Niigata Project" was concerned about the heavy snow load which occurs in the rural areas of the Niigata prefecture. Roof constructions of the "Building KIT System" have been reshaped and reinforced with the aid of structural engineers.

Furthermore the problem of high snow as an obstacle to traffic has been considered. As a further development of traditional passageways for pedestrians connecting several houses, this project suggests to build a covered access to each private house and public facilities in the village on the ground level (first floor). The main road for traffic is raised to the second floor and forms the structural cover of the space beneath, which is used as a snow-free passage mainly for pedestrians in winter time. All infrastructural necessities of a settlement should be also accessible from this route.

Resort Village

In order to facilitate the financing of the above construction and to enhance the economical situation of such settlements, which often suffer from excess of age of the population, it would be considerable to make use of the first floor for guest rooms. This could be an alternative retreat especially for town people, who would like to enjoy the natural beauty of the landscape of Niigata prefecture. If this concept proves successful it is possible to gradually improve and develop this area as a favored tourist center by adding facilities like onsen etc.

Conclusions

After a disaster occurred, in order to enable the people to regain their identity, the immediate help is provided by elaborating a program which guarantees a quick reconstruction of their homes by encouragement and assistance for self-help. It is very important to give the affected population hope for the future by developing new ideas and projects including public discussions.

It is necessary to generate new, innovative and practice-oriented concepts which include long-term economical advantages for the Niigata prefecture. The realization, however, is possible only, if also the population is willing to actively participate in the evolvement of their future.

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