ROBOT ORENTED DESIGN
OF A RAPID JOINING SYSTEM WITH INTEGRATED SERVICING

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ABSTRACT

The concept of “ROD”(1) or robot oriented design had been developed during my doctorate dissertation at the university of Tokyo between 1984 and 1988. It has been further developed in order to quickly assemble buildings which can be moved into only 24 hours after the beginning of their construction. Time is money, all the more as about 2/3 of the total costs of a building are apportioned to the costs of assembly in construction. Consequently, the most promising way to reduce these costs is to develop and optimise planning, manufacturing, logistics, and construction in a comprehensive process. In order to reach this goal the Chair for Building Realisation and Informatics at the TU Munich is engaged in research in an interdisciplinary team in the fields of research and economy.
The project entitled "Installation and Dismantling in Wood Construction via Quick-action Fasteners" is a prelude to follow-up projects which are to be combined in a cooperative approach.

Key words: Robotics, Construction, building system, joining system, design

Introduction

The most promising potential for cutting down costs lies in reaching a maximum degree of prefabrication by integrating different crafts. This could considerably reduce the time necessary for interior finishing and completion. For this reason parallel processes must replace sequential processes during manufacturing and construction. The decisive theme for changing the current manufacturing and construction processes in wood construction is the connection of constructional elements at their mutual intersections. Connecting elements have to be examined with regard to positioning, adjustment, and fixation. Transition to automated manufacturing processes should be implemented in current processes of predominant manual installation and assembly, meaning in the fields of mechanical services and interior finishing. Development of plug-in systems of quick-action fasteners for structural components will result in new methods of installation and interior finishing. Similar to developments in vehicle construction, prefabrication of systemic structural components for electrical and heating water installation will

create new fields of work in the supply industry for wood construction.
These developments are to be continued in a cooperative project on the basis of this research project.

The project entitled "Ways to an Economical Manufacturing of Wood Houses through Modern Manufacturing and Logistics Methods" too is to be sponsored by the Federal Ministry for Education and Research, which is to run for 3 years. The cooperative project consists of several sub-projects which are to be summarised by the three segments Customer Management, Product Management, and Production Management.

In cooperation with the IWF-Braunschweig, the project "Automation and Manufacturing Concepts" conceives plants and procedures for a predominantly automated production on the basis of developments in the product segment. The way they function can be visualised by help of photo-realistic simulation software and is tested with regard to their capability to integrate into current production processes. Logistics and work material flow are optimised in a further simultaneous sub-project in cooperation with the Fraunhofer Institute for Production Engineering and Automation.

Realisation of the research results in the building practice will be tested at the TU Munich by way of building a prototype together with partners from the building trade.

RAPID CONSTRUCTION

Building a house in Germany is not only expensive, but also a very tedious affair. Customers have to deal with very complex planning permission regulations and also have the extra stress and difficulties of directly dealing with contract firms. For these reasons, suppliers of prefabricated houses have been able to extend their share of the market. The advantage of having just one construction company enables a prefabricated house to be constructed within three days. But still the sequential interior fitting which takes between 4 to 6 weeks has to be completed. This means the rapid construction of a conventional prefabricated house can rarely be taken advantage of and only at extra expense for the buyer.

The concept of consumer-oriented construction allows the customer to design and construct his house as he pleases. With this method of building the plans and decisions are made by the buyer and taken away from the experts. To allow this cost-effective principle to work, a manufacturing system is needed that allows individual adaptation without increasing costs unnecessarily.

ROD - this could be the future name of buildings which can be moved into only 24 hours after the beginning of their construction. This means that within three eight-hour working days the house is ready for occupation. On the first day the construction of the house is carried out, on the second day the inside and finishing work will be done, and on the third day the house is ready to be occupied.
“ROD “ allows an individual choice: terraced, detached and semi-detached houses can be constructed without losing the cost advantages of prefabricated houses.

Modern production plants make it possible to produce individually and flexibly and stop monotony and standardisation.
CADCAM systems can directly convert architects´ plans into production plans to run the machine.

This makes it more and more important for the architects to know the manufacturing potential and limitations of the assembly lines in order to manufacture flexibly and cost-effectively.
Time is money, all the more as about 2/3 of the total costs of a building are apportioned to the costs of construction. Consequently, the most promising way to reduce these costs is to develop and optimise planning, manufacturing, logistics, and construction in a comprehensive process.

In order to reach this goal the Chair for Building Realisation and Informatics at the TU Munich is engaged in research in an interdisciplinary team in the fields of research and economy.
The project entitled "Installation and Dismantling in Wood Construction via Quick-action Fasteners" is a prelude to follow-up projects which are to be combined in a cooperative approach.

The most promising potential for cutting down costs lies in reaching a maximum degree of prefabrication by integrating different crafts. This could considerably reduce the time necessary for interior finishing and completion. For this reason parallel processes must replace sequential processes during manufacturing and construction.

CUTTING COSTS

Some 20 %of net building costs go on housing technology. Installation work has been considered without craft costs, as electricity and heating mains as well as freshwater and waste water pipes are subject to the similar regimes. All these crafts make use of sequential fabrication. First comes the installation basics and then the finishing , i.e. the plastering and flooring . Yet the latter make up the third largest cost factor – after basic construction and comprehensive interior finishing .

In complex installations the costs can certainly run higher and are, generally speaking, wage intensive. And yet there is no easy road to automating the construction site, as installation work on the latter involves much moving around. Then again many installation strands need to be “intelligently” woven together. To achieve this even industrial prefabrication is unable to do without human judgement.

INTEGRATED PLANNING

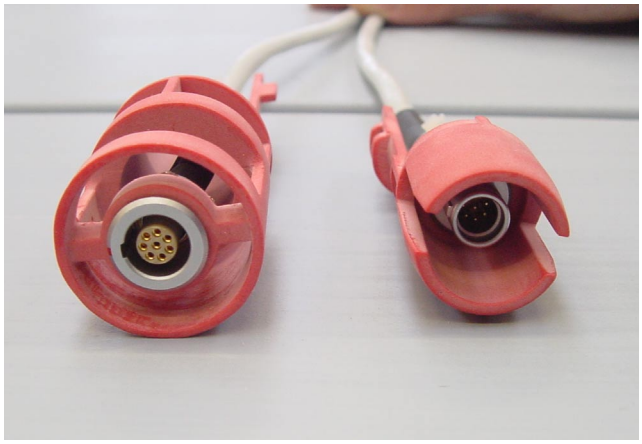
The best option would seem to be prefabrication of sanitary installations-semi-automated, prefabricated pre-wall installations that are assembled on the construction site. Such units will in future be further developed for broad-based use, with cells ready made for installation simply brought to the site for assembly there as spatial cells.
But if this is to happen, it will be necessary to precisely define, at the planning stage, just where such cells are to be positioned, anologous to the spatial cells for ready made baths. This yields the shortest pathways and cuts assembly time .

AUTOMATED FABRICATION

As housing construction standards are often similar, modern CAD-CAM systems can flexibly prefabricate such units on a semiautomated basis. Such installation cells might even contain, extraneously assembled, plug in interfaces in both walls and ceilings.
With regard to wall fittings, the installation task should no longer be seen as a thing apart - it can be offered as a part of the overall wall system. Thus further system solutions are called for, whereby destruction proof fittings can be blended into the automation produced wall panels.

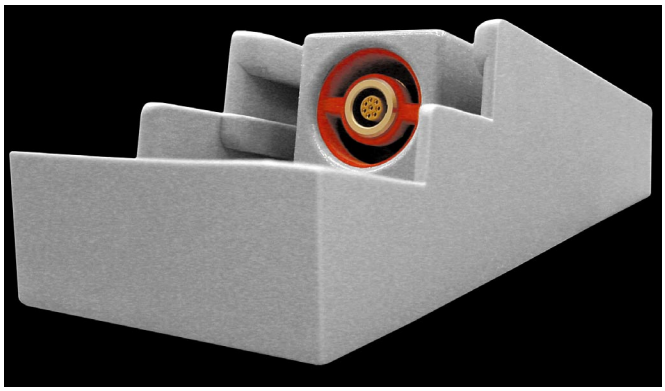
CUTTING BUILDING TIME BY INTEGRATING SERVICING NETWORK

A further step would be for all electrial cables to be integrated into the wall panels, with individual cables being hooked up via plugin ltrarapid links. In this way, the entire electrical installation can be integrated at the prefabrication stage.



Ultrarapid electronic component in HOMES 24 fast connectors

The Technical University of Munich has developed and patented a connecting system which helps to save time by installing heating pipes, water pipes and electrical cables in the wall panels during the prefabrication stages.

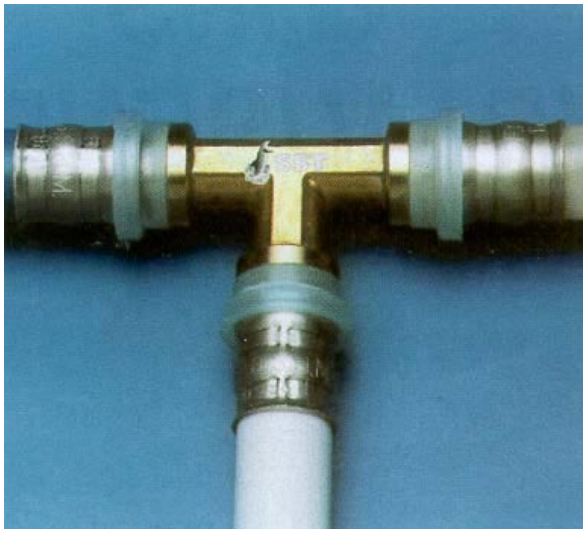


patented fast connector system for the integration of water and electrical supply

A stage further and these functions can be handled by robots in a single assembly unit . One developmental stage more and the same functions can be combined with the sanitary installations. Also feasable for the heating pipes is it to be relocated to the prefabrication stage. Relocation to the prefabrication stage requires a considerably greater scale of advanced planning than conventional installation does.As a result of the seamless integration of these systems, the flush fitting wall panels are of higher quality than conventionally prefabricated walls. The risk of erroneous assembly is reduced and building time cut since follow-up interior finishing can be commenced earlier. Mechanical fabrication permits wage costs to be further cut, thus yielding an additional cost edge.

The decisive theme for changing the current manufacturing and construction processes in wood construction is the connection of con-

structional elements at their mutual intersections. Connecting elements have to be examined with regard to positioning, adjustment, and fixation. Transition to automated manufacturing processes should be implemented in current processes of predominant manual installation and assembly, meaning in the fields of mechanical services and interior finishing. Development of plug-in systems of quick-action fasteners for structural components will result in new methods of installation and interior finishing



Prefabricated heating pipes distributor

Similar to developments in vehicle construction, prefabrication of systemic structural components for electrical and heating water installation will create new fields of work in the supply industry for wood construction.

Change of suppliers from part manufacturers to system suppliers

INTEGRATION OF ROD RAPID CONNECTOR INTO TOTAL BUILDING SYSTEM

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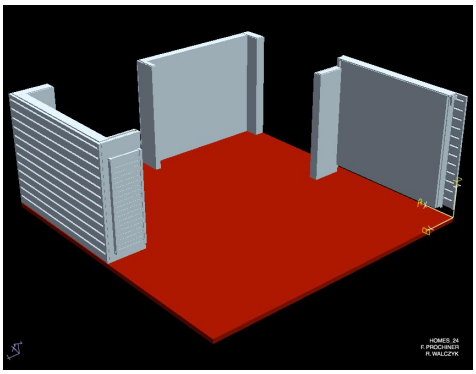

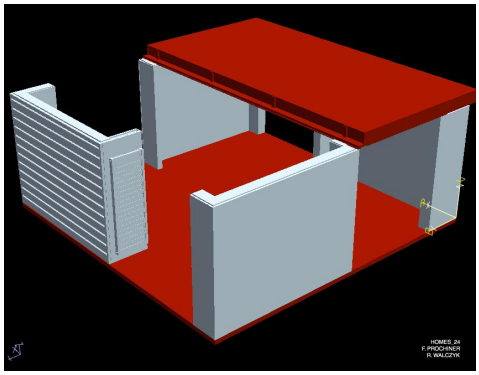

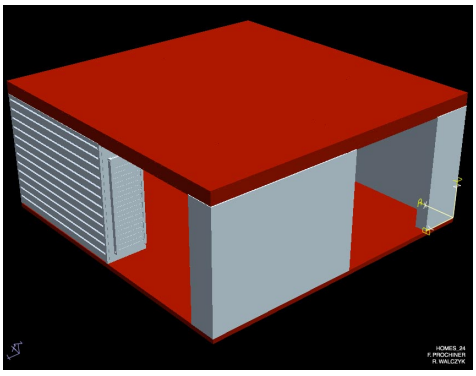

What we clearly have here is a sequence of many small Stepps which for systemic reasons, have been skipped subsequently in final assembly, yet which, may, in their aggregate, comprise a giant step towards cost-sensitivity" final assembly". Only if a high degree of prefabrication can be achieved during the manufacturing of the components can they be used effectively in the complete process to save time and money.

This enables small and medium-sized firms to do contract work for the manufacturers. This allows a vast product range and the customers´ individual wishes to be met.
Because the planning and manufacturing of „ROD " is computer-aided a high degree of adaptability can be reached and makes it economically viable to produce small quantities.

„ROD" BUILDING SYSTEM – CONSUMER-ORIENTED BUILDING THROUGH MASS INDIVIDUALISATION

Mass individualisation is a lot more advanced in other manufacturing industries, e.g. the textile industry. A computer-designed virtual model can be altered according to individual measurements taken from clients so that their bodies can serve as models. Once in the computer the client will become a regular customer because he will save the time-consuming fitting which can now be executed on the computer. It is not only possible for these tasks to be carried out on an expensive 400,000 DM machine, it can also be done on a pc in the comfort of his own home.
Once decided, the fully automatic cutting procedure can be started in the factory. That makes it possible today through the internet to buy made to measure shirts for nearly the same price as mass-produced goods.
If it was possible to adapt these principles to the building industry, it would enable the high-tech production line to work to its full limits and be more cost-effective. This way individual

buildings can be constructed. The main aim is not to rationalize the automated processes but to fulfil the individual wishes of the customer and to keep the costs low.
This means, the prefabricated house brochures of the future will replace those of the past. Types and models with strange names will be replaced by flexible modules as in „ROD“.

The new system architects
should be able to acquire more know-how regarding system prefabrication during their training. This makes it possible through computer-aided design to develop individual drafts which do not have to be converted but, similar to the robots in the textile industry´s cutting process, can be directly applied within the factory. Using virtual show-rooms and animations, the client can form an idea of how his new “ROD ” will be.
This would not only contribute to more rationalized manufacturing, but would enable prefabricated houses to be produced more cost-effectively and still maintain our high standards of architecture.

Aside from the cost advantage that firms reap, which is naturally their primary concern, the enhanced quality levels achieved on construction sites represent no small gain.
Modified assembly methods- plus the assembly teams trained in these – can help translate higher grade final assembly into an inhanced corparate image. As opposed to conventional construction sites, fabricants of ready-made housing can achieve superior levels of accuracy, cleanliness and rapidity. The driving goal must therefore be not simply to cut building costs; it must also be to build simpler, better and faster.

(1) “Robot Oriented Design”, T. Bock, Shokukokusha Publishing, Mai 1988; www.rod.de
(2) “Schnellverbinder”, F. Prochiner, TU Munich, Rosenheimer Holzbautage,Sept.2000