AUTOMATION AND ROBOTICS IN CONSTRUCTION: STATE OF THE ART IN FINLAND

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ABSTRACT

The thrust area of Finnish construction automation is concrete component prefabrication. Also mobile on site robotics and other themes are developed. It is recognized that changes in organization, building systems and information management are needed in connection to the introduction of advanced automation in construction. National projects, which aim at triggering such changes, are underway.

Keywords: construction robotics, construction automation, industrialized construction, Finland

1 INTRODUCTION

The well-known barriers and difficulties encountered by construction R&D activities are existent in the Finnish construction industry, like in other corresponding countries. However, there are two factors which modify the Finnish situation: a high degree of prefabrication, and an active governmental technology policy.

Industrialization of construction has been a leading idea in Finland already from the 1960's. The degree of prefabrication is among the highest in the world. Thus, it is not surprising to find major development efforts focused on automation of component manufacturing and on related information transfer.

The governmental technology policy has been activated during the 1980's. In the framework of it, national technology programmes have been started. The programme focusing on construction has been directed to renew the industrial structure in construction, in order to achieve greater efficiency. As for automation and robotization, these programmes have an important enabling role.

2 MECHANIZATION, AUTOMATION AND ROBOTIZATION IN CONSTRUCTION

2.1 Construction materials industry

Large construction material and component firms have been quite active in product and process development.

For example, the hollow core slab technology has been subject to automation already from the beginning of the 1980's. Such firms as Elematic Engineering and Lohja Parma Engineering

LPE Ltd now offer highly mechanized and automated production lines for customers (1, 9).

Partek Concrete Ltd has recently developed a system for designing and constructing prefabricated concrete facades with detailed decorations or sophisticated three dimensional shapes (5, 15). The design of an individual facade component is carried out in a 3-dimensional CAD system. The design data is transmitted to a manufacturing centre, the heart of which is a 5-axis milling robot. In the manufacturing centre, freely shaped three dimensional moulds of recyclable mould matrix material are produced automatically. The system can also make the moulds in rubber or a number of other materials, including metals. Such a mould can be sent to any component manufacturer.

Lohja Corporation has developed a shotcreting method for the production of precast wall components and columns (9). The components to be cast move in vertical position along the assembly line from one work stage to another. The advantage of the process is that the production needs little space and the surface handling phase can be mechanized and automated. Here the application of mechanization and automation to the production of traditional sandwich wall panels has brought about a new arrangement of the whole production process.

Lohja Corporation is the leading partner in the Eureka project "Mechanization of bricklaying technology on the building site". In the first phase, currently underway, a new type of scaffoldings and material transfer equipment are developed for masonry work on the building site. The material transfer system includes both new types of brick lifts and mortar pumping equipment. Also a new type of working deck is developed. All the equipment that the bricklayer needs in his work are on the deck which is also a transport container of all equipment. In the second phase, the development work will be directed to the automation of masonry work, based on the mechanized system.

An example of the development efforts in steel construction is provided by the Eureka project CIMSTEEL, where three Finnish companies participate. The goal is to define, develop and evaluate a modular computer integrated manufacturing system for steel construction.

2.2 Construction machinery industry

The automation of underground drilling has been the thrust area of Tamrock, a manufacturer of hydraulic rock excavation technology. Since 1985, Tamrock has produced automated underground drilling rigs (7). Computerized drilling gives considerable savings by means of faster drilling cycle, improved profile control and controlled operation.

Recently, Tamrock has joined the PANORAMA project in the ESPRIT programme to develop technology for an autonomous drilling rig for surface applications (3). The aim is to develop a control system that enables completely unmanned machines to move unaided on surface worksites.

2.3 Research organizations

The Technical Research Centre of Finland (VTT) has researched construction robotics and automation in a number of years. The mobile tiling robot and its platform are described in two other presentations of this symposium (8, 10). The applicability of three dimensional measurements in construction has been investigated (11). On basis of this and earlier crane automation studies (2), a project on robotization of frame erection is now being launched.

The automation in the concrete component factory has also been studied by VTT (12). The research themes include process measurements, dimensional measurements and data transfer systems. For example, a demonstration system for automated measurements of the dimensions of a hollow core slab has been developed.

The Road and Traffic Laboratory of VTT currently develops a levelling design system for road maintenance. It will be a part of a wider system, comprising also an asphalt mixture design system and a system for redimensioning the bearing capacity of the road (when needed). The input data for the levelling system are collected by a surface monitoring system installed on a delivery van. This system, developed by VTT, measures the evenness, the ruth depth and the geometry of a road lane with a speed of 80 km/h. The levelling design system prepares an optimal levelling design by alternating levelling with mass and frasing, according to instructions provided by the user. These instructions include the minimum and maximum thickness of levelling mass and frasing, unit costs of different operations, the desired longitudinal evenness and the correction for slopes. The design results comprise the operations list with road position codes, the bill of mass quantities and the quality level of the pavement. The feasibility of using these data for the automatic control of frasing and asphalt paving machines will be studied.

3 ENABLING PRACTICES AND TECHNOLOGIES

3.1 National research programmes

During the 1980's, a cluster of development projects with wide participation have been initiated in Finland in order to create the necessary basis for a second wave of industrialization of construction. The projects have been realized in the the national research programme "Industrialized Building Technology", initiated and coordinated by the Technology Development Center (TEKES). The targets include (13)

- a new process for construction and practice of contracting
- an open construction system based on prefabricated components
- a national framework for computer integrated construction
- a national quality system for construction.

A new construction process was proposed in the project "Construction Mode 2000". The leading idea is to separate the conceptual design and the production oriented design. Sketch designs and performance specifications are to be used in tendering. The potential main contractors divide the building into subproducts and give tenders according to their building systems and the technology of subcontractors. In fact, the subcontractors act as subproduct suppliers, which are responsible for the design, manufacturing, assembling and finishing of the respective subproduct. The responsibility for the subproduct from its design to finish will stimulate the development of prefabricated products, production methods, installation methods and quality assurance. Also, the areas of responsibility of the parties in the construction process will better correspond functional and integrated wholes.

The project for precast concrete component construction of housing and office buildings "TAT" started in 1986. The project further develops the Finnish BES-system, an open concrete component system set up in the 1960's and 1970's. The resultant TAT building system is a hierarchic, modular and open system for building design and construction (4). The building is divided for design purposes into subsystems which are studied on five different hierarchical levels. The subsystems are functional and spatial systems, structural system, plumbing system, air conditioning system, electrical and information technology system and waste management

system. These systems are bound together by the principles of compatibility, dimensional coordination and tolerance system. When compared with classical prefabrication technology, the TAT system especially provides for a higher level of flexibility.

The national RATAS project aims at defining the basic structure of the computing environment of the construction industry. The first phase resulted in a visionary model of what the computer aided design and building process of the 1990's should look like. The second phase was carried out in four expert groups, which considered, respectively, general data bases, data exchange methods, definition of a standard project data base structure, and new types of design documents and the design process. The third phase of RATAS, now underway, covers product classification, directory data base for construction data bases, and the specification of a limited building product data model (containing the information needed by the main contractor in order to make a bill of quantities and a cost estimate). The long term goal of the RATAS project is computer integrated construction based on a building product data model. This development is seen as a necessary complement to the changes in the construction process and in the building system (13).

These three projects have been realized principally in 1987 - 1991. After the creation of basic frameworks as a national effort, the companies are now introducing new ideas, methods and standards in their products and production processes. A new technology programme, to be started in 1992, is now prepared in order to support this implementation process.

Unlike the previous three projects, the project for a construction quality system has only recently been launched by the Technology Development Center. A quality infrastructure will be developed so that it will meet the requirements of ISO 9000 and so that the quality systems of individual companies will work as a part of the whole system. The basis for the system is the new construction mode and the open building system. They make it possible to clarify the responsibilities and liabilities of project participants, and to use a hierarchical quality specification system by expressing the requirements of end users with performance specifications.

3.2 Cooperative research by construction companies

The Federation of the Finnish Building Industry, where practically all construction firms are members, has established a system of co-operative R&D. This has been motivated on the one hand by the big number of small and middle-sized companies, which cannot easily start their own R&D activities, and on the other hand by the observation that there are a lot of common problems to be solved.

A number of research committees, nominated by the Federation, initiate and fund contract research projects, carried out by VTT, universities and consultants. The major research themes are codes and information files, construction management systems, production technology, product development and personnel development.

The information file for construction machines provides an example for activities initiated. It contains information useful in the planning of the machine input on site: choice criteria for various machine types, their capabilities, safety considerations and other aspects to be taken into account. Obviously, this kind of structured information becomes more important with increasing mechanization and automation level.

Although focused on more immediate problems and present day technology, this effort of

collective research is important from the point of view of robotization, because it nurturs an active R&D culture in the contracting industry.

3.3 Development on the company level

Sasmo Windows, a part of the Paloheimo group, provides an example of the restructuring, that seems to be necessary for wider implementation of advanced technology in construction. This restructuring has been based on a new manufacturing philosophy, originated in the Japanese car industry and diffused later to other countries and industries (the reference (14) provides a good overview). In this manufacturing philosophy, the gradual introduction of automation comes after that a necessary level of control of the manufacturing process has been reached.

Since the mid-eighties, Sasmo Windows has carried out profound changes as for the markets, products, and production (6):

- The market focus has changed from distribution of catalogue products through wholesale dealers and retail stores to system deliveries: the firm participates in design, the products are customized and they are delivered and installed on the site with one hour accuracy.
- The product assortment has been changed: from standard, bulk products to customized products.
- The production is based on numerically controlled machines, which allow for economical manufacturing of customized products.

The leading ideas are custom-oriented, flexible production and constant strive for enhanced efficiency. In order to reach these goals, an efficient order processing system, shortening of throughput times and the elimination of non-productive activities in the logistic chain have been first needed.

This particular restructuring is based on a competitive strategy. However, it perfectly fits in with the results of the national programmes, explained above, and exemplifies the development anticipated in the construction industry in general. This development will provide for the enhanced construction process control necessary for wider automation.

4 CONCLUSIONS

The level of activities related to automation and robotization in the Finnish construction is considerably higher than, say, three years ago. However, the practical applications are still rather scarce. It is now recognized that changes in organization, building systems, information management and process control are needed in connection to the introduction of advanced automation in construction. National projects, which aim at triggering such changes, are underway.

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