WEB-BASED QUALITY CONTROL OF PRECAST CONCRETE

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ABSTRACT: Precast construction has been used to facilitate the construction process for several years. Precasting offers significant potential advantages as a construction method. One of the major items that should be taken into consideration to get maximum benefit of precast concrete is the quality of this product. The quality of the product is tremendously important for the structural safety. Many conventional methods have been developed for the quality control of precast concrete. Web-based quality control is one of the most effective ways for this purpose. The use of such technologies enables companies to be more efficient. This paper presents a web-based system for the quality control of precast concrete and examines the benefits of this system for the relevant industry.

Keywords: Precast concrete; Precast construction; Quality control; Web-based technology.

1. INTRODUCTION

The construction industry continuously renews itself by the advances in technology and it seeks new ways to improve construction performance. Precast concrete systems have been used extensively in many European countries (Arditi et al., 2000). Precast technology offers many benefits compared to site casting of concrete (British Precast). Such systems are widely used to speed up constructional steps since they are generally employed for the production of modular and standardized building elements (Neville, 1981). The concrete members are usually cast and cured in a protected environment away from the construction site and then they are installed their final location. Thus, precast concrete production can proceed independently from weather and season and therefore efficiency of the job is considerably increased in cold weather. Furthermore, the quality controls of concrete making materials and the workmanship are usually better than those of in-situ concrete. It should also be noted that the precast construction may decrease the construction costs owing to mass production of the members (International Bureau for Precast Concrete). Despite the late start of this technology in developing countries such as Turkey, the production of precast concrete elements has rapidly increased in a short time and the volume of precast production is expected to be higher in future. According to the annual report of Turkish Precast Concrete Association, production has reached to 1,185,787 m^3 by a total number of 106 companies in 2003 (Turkish Precast Concrete Association).

The quality of precast systems is very important since the elements are utilized especially in load-carrying parts of the structures. Web-based

management is an effective way of doing business for all industries as well as the precast construction industry. The quality of precast concrete can be controlled more easily and accurately by means of these technologies. This paper proposes a web-based system which develops the quality control processes, reduces paper works in documentation, and saves time and money by remedial action in production, transportation and erection stages of precast concrete members.

2. USE OF WEB-BASED SYSTEMS FOR QUALITY CONTROL OF PRECAST CONCRETE

A strong control mechanism should be established for the manufacturing, transportation and erection processes of these precast members. There are various definitions of quality control. According to Ishikawa (1985), it is an effective system for integrating the quality development, maintenance and improvement efforts of the groups in an organization so as to enable a cheaper production and service leading full customer satisfaction.

The production process of precast concrete consists of many phases such as designing, mixing, placing, compacting, curing and testing (Neville, 1981). Mix design should be carefully carried out according to the relevant standards and specifications since the quality of the concrete generally depends on the proper mixture of ingredients. The performances of the mixtures are tested by standard test specimens which are prepared, cured and tested according to relevant standards (TS EN 12390-4, ASTM C 39, ASTM C 192-90a, BS 1881: Part 108, BS 1881: Part 110). The compressive strength test is generally conducted on specimens and the values are compared with design parameters. Besides, laboratory test results for previously cast samples should also be reviewed before making a new mix design. A suitable curing process should be applied after concrete casting and steam curing is the most widely used method which supplies moisture and heat simultaneously. Finally, after sufficient curing, the products are removed from the molds and moved to the stockyard for transporting to the site.

Transporting the precast members from the production plant to the construction site is a critical phase, because the units may be exposed to damage due to stresses during this process. Therefore, the precast members should be properly loaded on vehicles to avoid undesired stresses, which are not taken into consideration in the design of the structural members. Lifting equipment should be suitable for the geometry of the structure, weight and size of the components (Elliot, 1996) so that it can lift and place the precast units without excessive efforts.

Erection is the last step for the precast construction. Elliott (1996) states that the sequence of erection can significantly be controlled by crane accessibility, structural forms and positions of stability walls. Design

calculations should be re-checked after erection in case the crack widths exceed the allowable dimensions. If necessary, repairs should be done for the cracks or the components should be re-placed or re-tested.

Information technology (IT) tools such as document management systems, database technologies and especially the Internet have tremendously been used to improve businesses in the construction processes (Rönneblad et al., 2003). Effective usage of IT tools may increase companies' market share. Furthermore, the company will gain a competitive edge by receiving the advantages such as cost reduction, speed up in business processes and improvement in customer-supplier relationships (Construction Confederation). All organizations involved in the construction industry should follow the technological developments in order to compete in near future. In today's business world, it is obvious that lacking network connectivity and employees with the skills to use the network tools will cause loss of business opportunities (Bridges, 1997).

Web-based management, which enables to perform business activities over the Internet, reduces overall costs and offers better organization. Quality control of the products is one of the activities that could be performed by this type of technology that ensures an effective way for the production control systems and significantly reduces paper works and costs, and saves time for the companies.

3. SYSTEM PROPERTIES

In this section, the web-based system for the quality control of precast concrete is examined. The aim of this program is to obtain the information during production, transportation and erection stages and checking considering the quality standards and specifications of precast concrete. The program controls the properties of the materials used in concrete production, dimensions of the products and irregularities at the production stage. The transportation and erection stages are also proceeded by this program. The manufacturer and the customer are able to follow easily the stages of the precast construction starting with the production of concrete and ending with the erection of the members in construction site. A simple flowchart of this system is shown in Fig. 1.

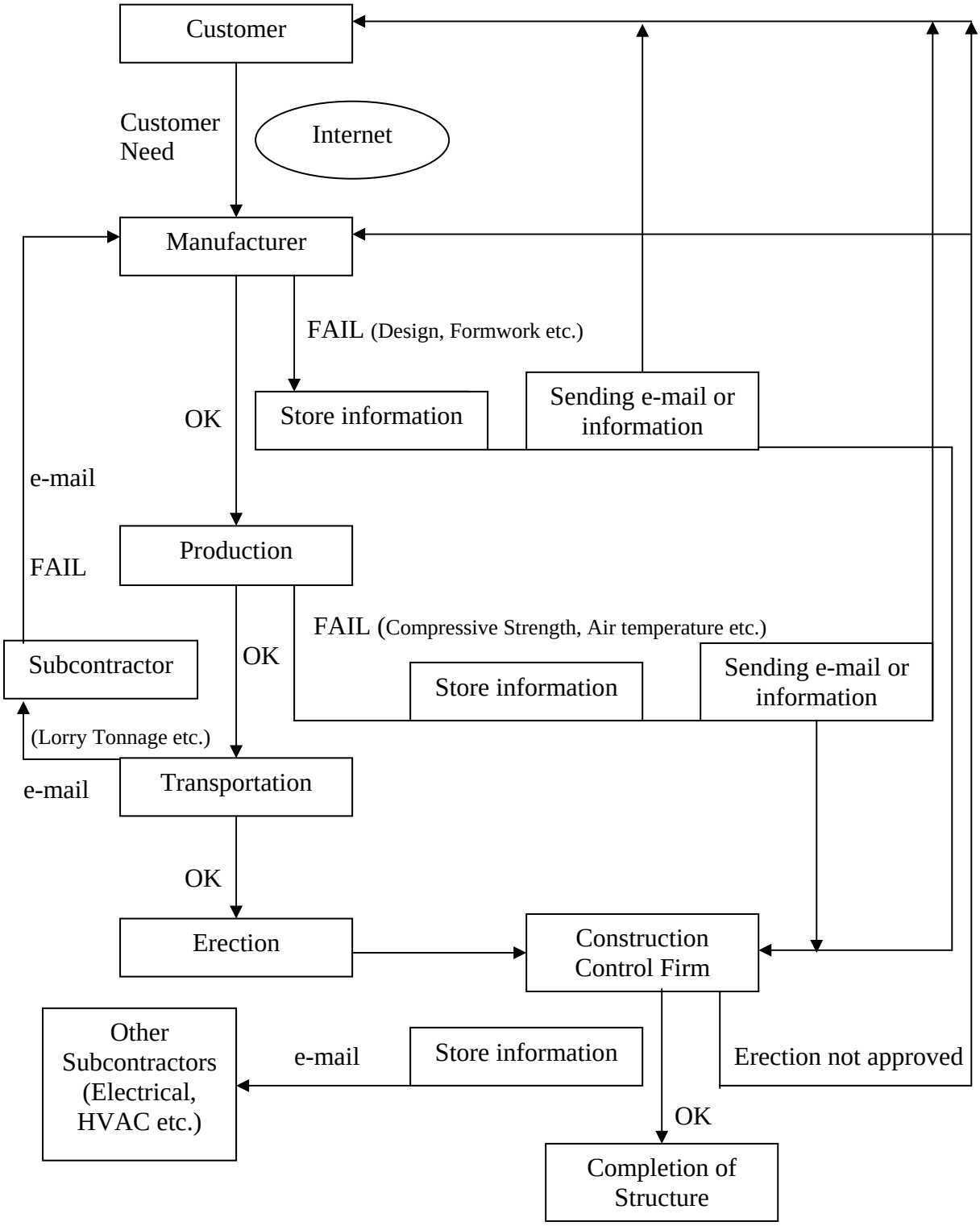

Fig. 1. Flowchart of the system

The system consists of five options in the main menu which includes customer, manufacturer, production control, transportation and erection control, and production records (Fig.2). The customer inputs the data about project details of the structure, the prospective delivery time, his or company's profile and other relevant information in the customer menu via Internet (Fig.3). The design order menu consists of some features of the structures, such as type of load, architectural details or a special concrete. The project detail option contains the dimensions of the building, maximum opening of the frame and the possibility of crane to be employed in site. Approximate cost, which is estimated and introduced by the manufacturer, would be available both in the manufacturer and customer menu. Customers may also enter a desired finish time of structure suitable to themselves.

Fig. 2. Main Menu

Having received project information from the customer, the manufacturer fills the relevant options in corresponding menu which includes six options such as design, stock conditions, bed conditions, loading, formwork and erection (Fig. 4). The manufacturers' design department carries out the design of the building, indicates the structural details and enters them into the system under the design option. Precast

walls and slabs are usually produced in permanent forms, known as casting beds. These beds have an average of 125 m in length, but can vary depending on the size of the manufacturing plant (Allen, 1998). The casting beds can be prepared according to the design of the project and checked by using the bed conditions option. The manufacturer can use the formwork option to control whether the required forms for producing necessary elements are available or not. Prefabricated elements that will be used in production and their availability in the stockyard can be checked by the manufacturer using the stock conditions option. The manufacturer can also control whether the elements in the stockyard are enough to complete the project and whether they are suitable for the production of the relevant design. As mentioned before, the precast members should be well loaded on vehicles to avoid undesired stresses. The manufacturer can check the availability of lifting equipment and determine whether loading the elements on the vehicle is possible or not by using the loading option. The last menu filled by the manufacturer is the erection option where the erection type can be selected according to some of the design criteria of the project. The relevant options in the manufacturer menu should fit the customer needs in order to continue the process. If any of these items would not satisfy the conditions, necessary adjustments, such as re-designing the project, should be made or the manufacturer should contact with the customer. The manufacturer can fill the result part manually by selecting one of the items in the ''match with customer orders'' option or this procedure can also be done automatically by the computer after each relevant option in the manufacturer menu is completed. Finally, the manufacturer sends the results via Internet to the customer who can follow the procedure of his/her project.

All phases during production can be controlled using the production control menu (Fig.5). The system checks the properties such as concrete class, compressive strength of the concrete, elongation and dimensions. The air temperature, concrete and curing temperatures are taken from the sensors which are placed in fresh concrete at the production plant. The input data, whether approved or not, will be supplied in the system manually by the manufacturer. If any of the results of these items would not be appropriate to the relevant standards or specifications and therefore wouldn't be approved, the system gives automatically a warning message. This step is especially important while the system gives the opportunity to the manufacturer to make necessary corrections immediately.

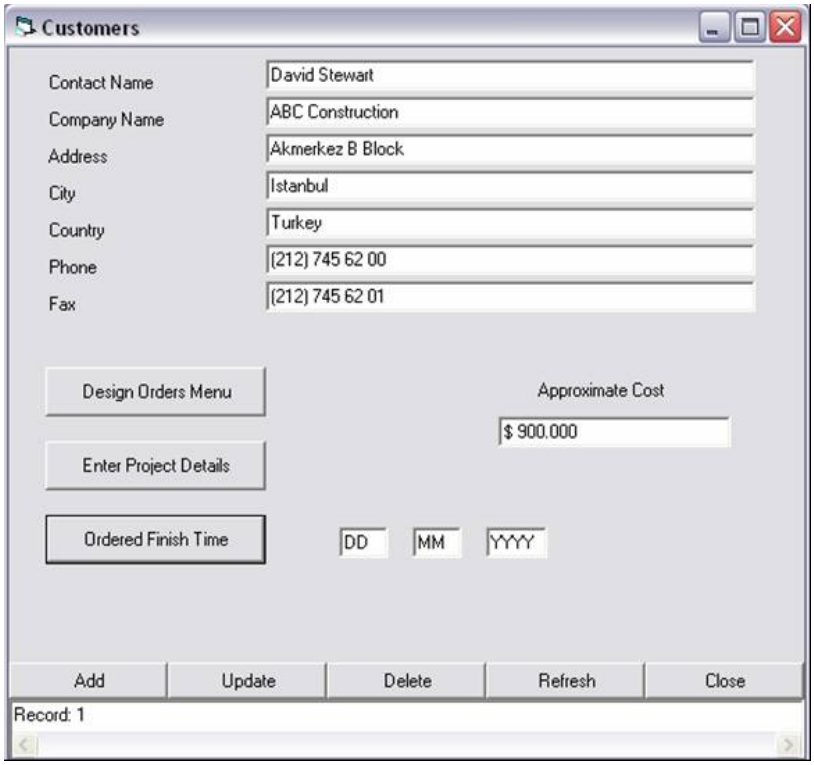

Fig. 3. Customer Menu

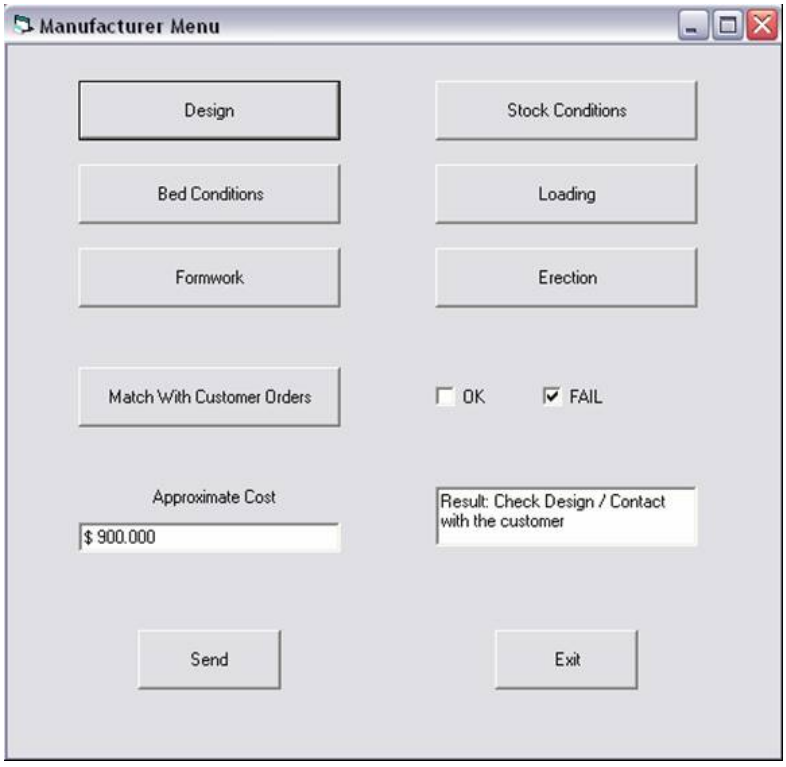

Fig. 4. Manufacturer Menu

Transportation and erection stages can be controlled from the corresponding menu (Fig.6). The distance between the factory and the construction site are previously entered by the customer. Therefore the system calculates the time needed to transport the sections suitable to size and weight of the precast units and informs the customer about the delivery time via e-mail. The system checks the sufficiency of the joints and connections that influence the design, construction and in-service behaviour of precast structures (Elliot, 1996). Similar to the production control menu, the input data will be contributed to the system manually by the manufacturer. Furthermore, the allowable crack size is also controlled by this system when such an event occurred. If the crack size reaches to a critical level, the system immediately warns the manufacturer. If necessary, the manufacturer carries out structural repairs or takes the section back to the production plant for flexural strength testing of that unit. Finally, the program approves the process if all phases are correctly performed.

The production records option includes data about the past or ongoing productions if the manufacturer or someone else needs to recognize or follow the processes. The parties can easily communicate with each other using the mail options menu of the system.

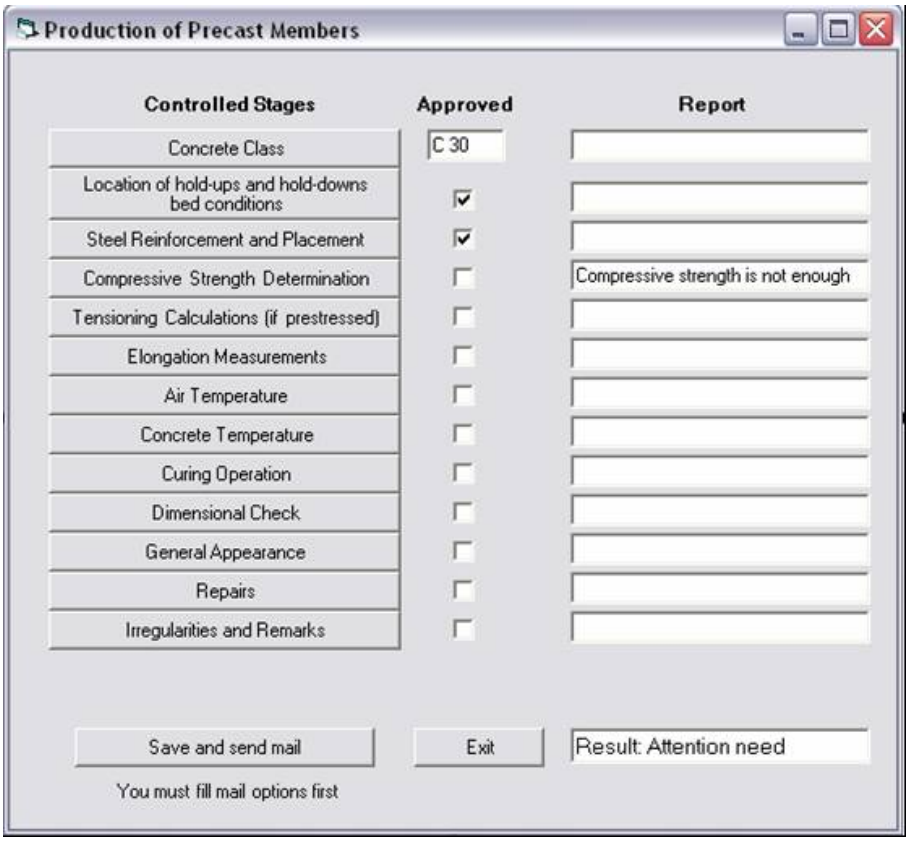

Fig. 5. Production Control Menu

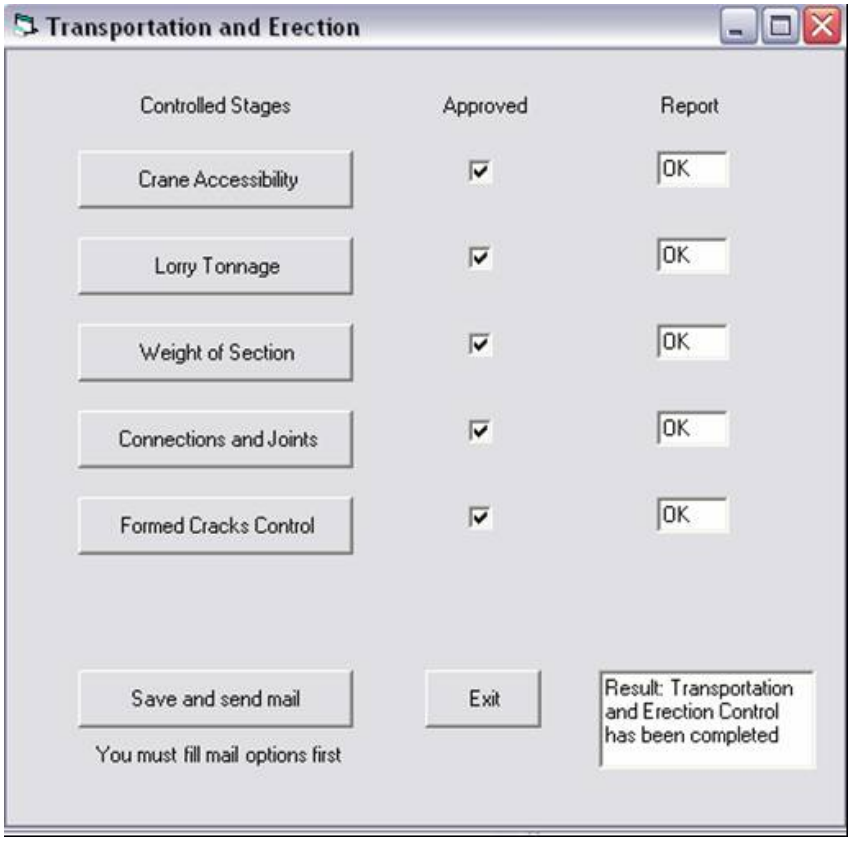

Fig. 6. Transportation and Erection Control Menu

4. COMPARISON OF WEB-BASED APPROACH TO A TRADITIONAL PRECAST PRODUCTION

In this part of the present study, a prefabrication period including the production and the erection of the elements has been discussed in order to explain the benefits of the proposed web-based system for a prefabrication plant which uses the traditional system. A middle-sized local prefabrication company which is located in Eskisehir region in Turkey has been considered. The company mostly constructs industrial buildings which consist of prefabricated columns, beams, wall panels and roof elements. The company contracts generally turnkey projects. The quality of the production is in the responsibility of product manager in plant and the constructions are executed by the corresponding site managers. Moreover, the quality control of both products and applications in the site are checked by independent construction control firms. The company does not prefer to stock the building components due to lack of available area. The company employs sub-contractors for some items such as electrical works, HVAC systems and painting.

In most of the projects, the customers prefer to contact with a single responsible person from the company. The customer presents the relevant requests regarding his/her structure generally by face-to-face

meetings. At this stage, customer-manufacturer relationships developed in a web-based system may accelerate the communication and reduce the paper work.

After the final agreement between the customer and manufacturer, design details will be submitted to the production department. In production stages of the precast members an immediate action related to design problems may be required. In such conditions, the use of a web-based system may reduce the time consumption. After the production, the transportation of the members to the erection site is carried out by subcontractors. The corresponding construction control firm supervises when any problem is faced during and / or after the erection stage. The problem and the solution are recorded and necessary information will be submitted to the relevant parties. The company uses fax and phone for communication with the customers and other parties. The implementation of web-based system will improve the communication between the parties and prevent the loss of documents.

5. CONCLUSION

Advances in technology changes the way of doing business in all areas of the construction industry. Companies that insist on traditional methods in construction process don't have the chance to get success in today's competitive business environment. Adoption to the new trends in technology is a necessity for the success of companies and the development of this industry.

The web-based system offers many advantages in the quality control process of precast concrete. It considerably reduces mistakes and increases construction speed. Moreover, the system reduces paper works and creates a better manufacturer-customer relationship. Saving time and money are the other important advantages. Obviously a better quality control mechanism is obtained by using this system. The only expenses for the precast company will be the cost of Internet infrastructure and regular Internet connection payments.

In this study, first, the benefits of precast concrete have been discussed. It has been revealed that precast concrete has several advantages over cast-in-place concrete. Then, production, transportation and erection stages of precast concrete and quality control of these parts have been briefly examined. Finally, a web-based system for the quality control of precast concrete has been presented.

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