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Rebar Computer Aided Design And Manufacturing

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Abstract

Reinforcement manufacturing received very little attention from the research Community (Bernold 1991). Until a few decades ago, the manufacturing of Reinforcement bars was done on site. This process was labor-intensive and Consequently expensive. As the construction industry started to move towards more Industrialized methods, the reinforcement manufacturing also began to adopt more Industrialized methods. The first step was to move the manufacturing process off-site to specialized manufacturing plants, which supplied the reinforcement bars according to Purchasing orders. In the 1950s and 1960s attention was given to the production of Reinforcing meshes and prefabricated reinforcing cages, while in the mid-1980s Numerically controlled (nc) rebar bending machines started to appear (kehl 1991). These machines straighten the steel, which is supplied to them in coils and bend and Cut them. The operation of the machine is numerically controlled by a computer (cnc), which determines the exact bending and cutting locations. The data is Programmed by the operator beforehand according to details in the shop drawings, which are normally prepared earlier at the fabricator's main office. The justification for such machines is primarily economic and is also influenced by the fact that it becomes constantly harder to recruit qualified workers, there is an increasing need for just-in-time supply and higher accuracy is required (deichmann 1991).

1. INTRODUCTION

The rebar production process begins with the design of the reinforced concrete element and ends with its fabrication (increasingly with cnc machines). The conventional design process is increasingly performed with the aid of computers (analysis and graphic programs). The end product of this phase is the shop-drawing, which details the concrete element and its reinforcement, in plans, elevations, sections and details. The shop-drawings are produced today mostly by computer graphics. Unfortunately, in most cases this design is done with 2-d drafting tools, which merely mimic the manual drafting methods. Its main advantage over the manual methods is that editing is largely improved with computer graphics. Clearly, a different approach Is needed to enable realization of the full potential of integrating the two processes of design and manufacturing. The integration, its potential and its realization in a computer model is the subject of this paper.

2. GENERAL DESCRIPTION OF THE INTEGRATED MODEL

The basic assumption underlying this research is that the two ends of the rebar manufacturing process are computer-based or assisted. The design stage ends with a graphic representation in the form of shop-drawings as shown in Fig. 1.

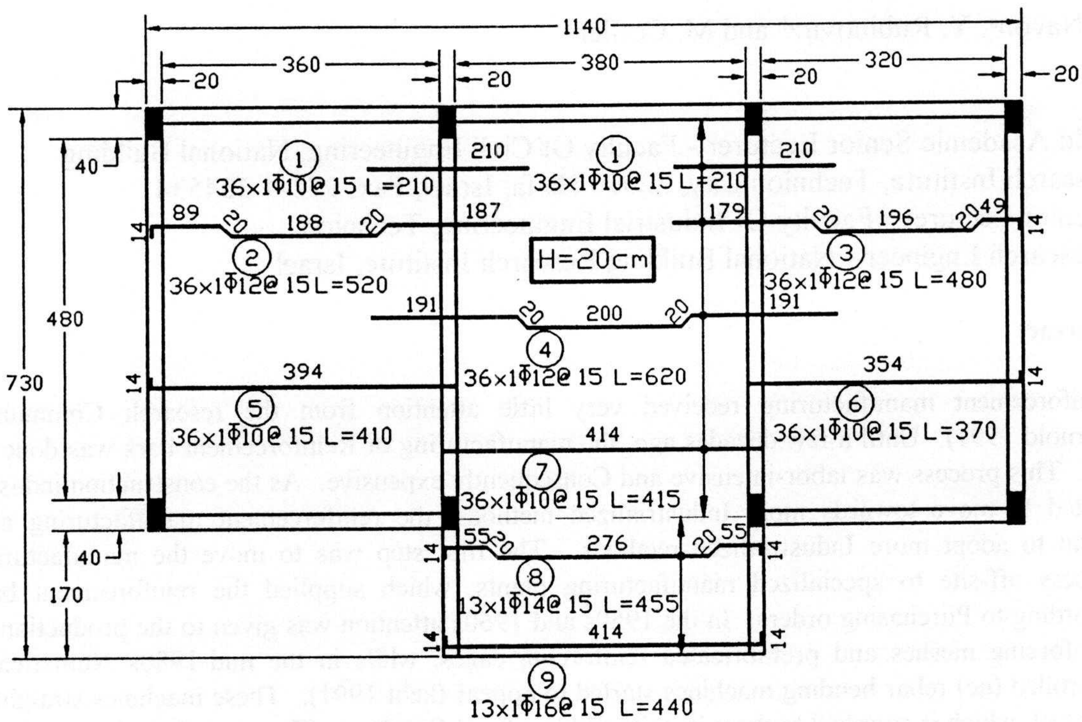

Fig. 1: Plan view of concrete solid slab

The drawing shows a concrete solid slab with the details of its reinforcement. For each reinforcement bar it specifies the serial number (encompassed by a circle), bar type, its length (L), the number of bars or their spacing (@), and bending point locations and bending details.

This drawing is normally used for a manual composition of a rebar schedule - a sorted list which enumerates the numbers of the various bars, their total required length and their total weight. The rebar schedule is produced either by the structural design firm, or by the rebar fabricator. The next stage is the preparation of shop-drawings for the **production** of the bars, at the fabricator's offices. These details are drawn manually on separate cards for each bar type.

At the other end of the manufacturing process the actual production is assumed to be done with an NC machine, such as the one shown in Fig. 2. Such machines are becoming increasingly popular. They are used for bars of up to 14-16 mm in diameter which are fed continuously from coils. The production process starts with the operator programming the machine's controller, inputting for each bar the cutting and bending point locations and the required number of identical bars. From this point the machine operates automatically to produce the bars.

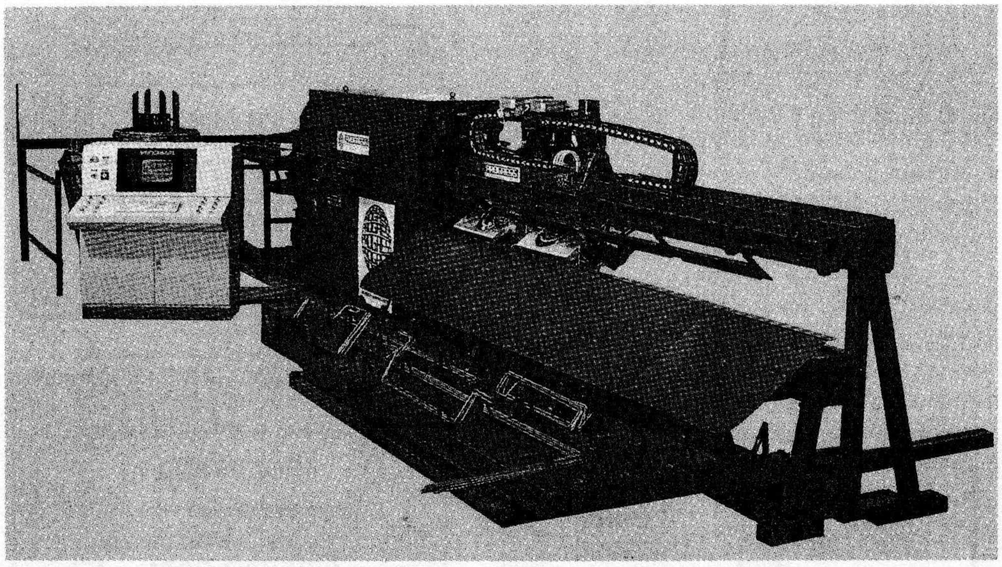

Fig. 2: Numerically controlled rebar cutting and bending machine

This design and manufacturing process is performed in two isolated islands of computerization and automation. A different approach and further development are needed in order to fully utilize the potential of integration. Actually, all the data needed to program the NC machine already exists in the design database, and theoretically can be automatically retrieved for this purpose. Thus double, and even tripe manual handling of data (described above) can be avoided saving all the inevitable human errors and their damaging economic consequences. In order to enable the automatic retrieval a comprehensive model, described in Fig. 3, was developed.

The system has four basic modules:

* Design module
* Data extraction module
* NC interface
* Automated manufacturing model

The design phase in the proposed model is performed with the same graphic driver as its conventional counterpart, which produces shop-drawing and rebar schedule hardcopies. After further manual processing these hardcopies are transformed to alphanumeric data, which is programmed manually into the automated rebar machine's controller. The hardcopies and the manual processing are obsolete using the proposed model. In this model the same graphic driver is not used as a **2D-drafting tool**, but rather as a **2-D modelling tool**. An in-depth discussion of the difference between them can be found in (Port 1989).

The 2-D modelling approach lays the ground for automatic extraction of data from the graphic database in a format which enables its processing into a Rebar Data File (RDF). The latter is used as an input for the NC interface, which produces a data file in a standard NC machine level programming language, called G-Code (ISO 1981). This file is transferred to the automated manufacturing machine. Thus the whole process is automated - from design to manufacturing. Data communication among the various modules can be automatic for higher autonomy of the system.

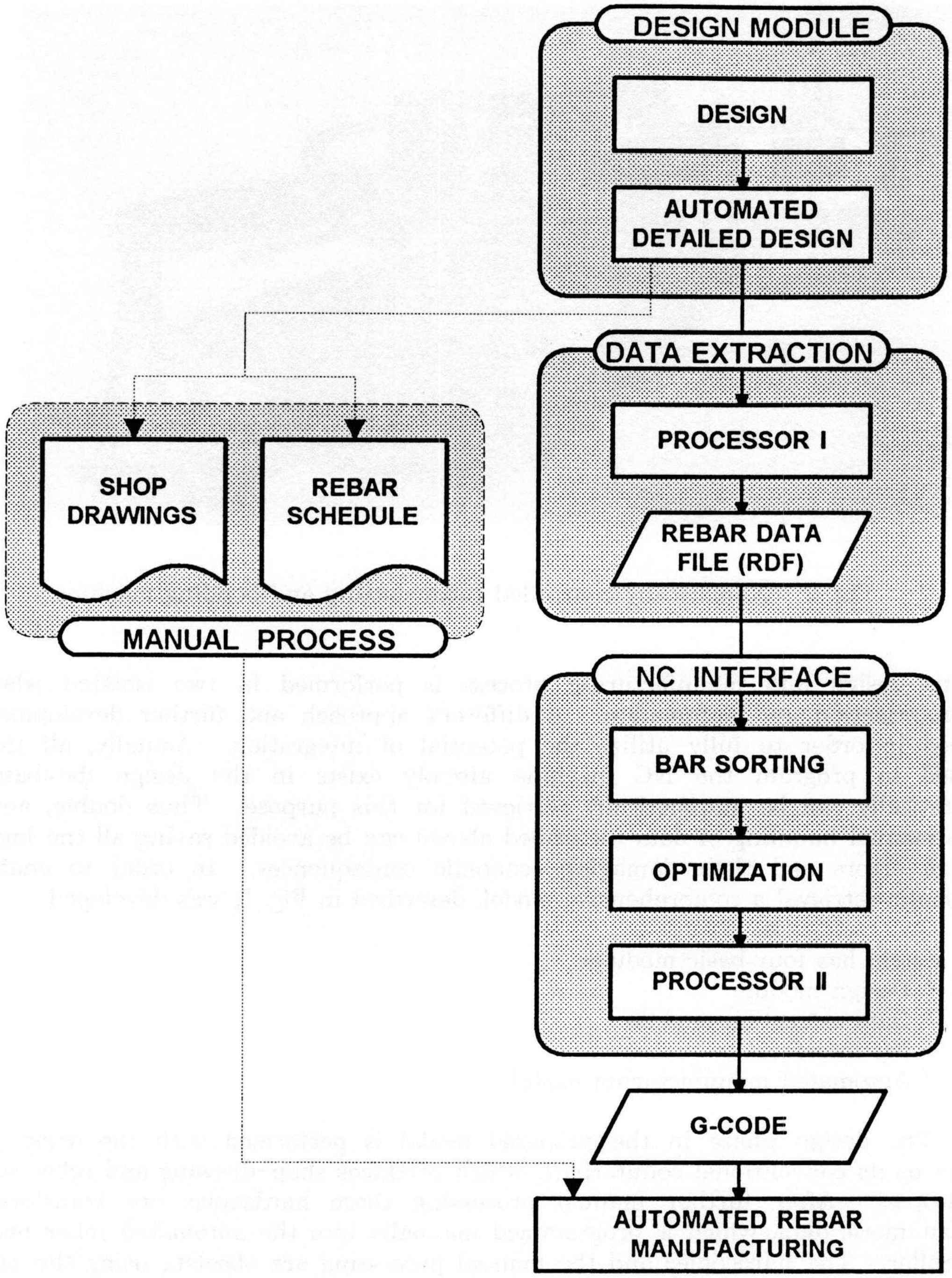

Fig. 3: A comprehensive rebar CAD/CAM model

3. APPLICATION OF THE DESIGN PHASE

The graphic driver, which was selected for the application, was AutoCAD. In addition, a rebar design program, called 2BARS, was adopted as the design tool for automated detailed design. Apart from being the only software of its kind, to the best of our knowledge, we could use 2BARS because we received its source and were permitted to adapt it to our purposes, as will be explained below. The advantage of the AutoCAD, for our purposes, was that it is an open system, which allows tailoring it to our needs.

As far as rebar automation goes, the drafting of concrete elements can be done in any desired method (2-D drafting, 2-D modelling, or other). When this is completed the automated detailed design is performed with 2BARS. This is done by selecting figures of bars from a predetermined library. The library has different configurations of rebars for beams, slabs, stairs and foundations. When a bar was selected the designer had to specify its type, serial number (could be given automatically), location and specify the required number of bars. Alternatively, the designer can just specify the range of the bar location and spacing, and the software will calculate the required number of bars. Another mode of operation is by specifying the spans and other physical parameters of the concrete element and the software will design the rebar configuration according to design codes and standards. If fully automatic design is not desired, or the existing library does not include the requested configuration, the designer can draw his own, as long as he conforms with the 2-D modelling approach. The meaning in this case is that he or she draws the bar using a **continuous** line of a specific type.

When the rebar detailing is completed, a hardcopy of a shop-drawing is produced, as shown in Fig. 1 above. The software also produces automatically a rebar schedule in a tabular form by searching the graphic database. An example of a rebar schedule for the slab in Fig. 1 is given in Fig. 4.

REBAR SCHEDULE

DRAWING FILE: A:FIG1
PAGE NUMBER: 1
DATE: 16-12-1993

BAR SERIAL NUM.	NUM. OF BARS	TOTAL NUM. OF BARS	BAR LENGTH (cm)	TOTAL LENGTH (m)	TOTAL WEIGHT (Kg)	
10mm RIBBED BARS						
1	1	36	L=210	76	47	
1	1	36	L=210	76	47	
5	1	36	L=410	148	92	
6	1	36	L=370	133	83	
7	1	36	L=415	149	93	
10mm RIBBED BAR TOTAL WEIGHT (Kg)						361
12mm RIBBED BARS						
2	1	36	L=520	187	167	
16mm RIBBED BAR TOTAL WEIGHT (Kg)						91
RIBBED BAR TOTAL WEIGHT (ton)						1.04

Fig. 4: Rebar schedule for the slab in Fig. 1

The rebar design program (2BARS), in its original form, is a structural design tool and is not production planning oriented. There was one major shortcoming that had to be addressed to enable the software to give the right data needed for production planning, namely that the software gave as an output only the total length and weight of each bar. For manufacturing purposes the exact **geometry** of each bar is needed. Consequently, the use of 2BARS was limited to selecting the bars from the library and detailing them, as explained above.

A new module was developed (processor I in Fig. 3 above), which searches the graphic database systematically, extracts all the required data and writes it into a Rebar Data File (RDF). This data is (for each bar): the bar's serial number, bar type, quantity, and all the relevant geometric data. This file is transferred to the NC interface, which transforms it into a form that the NC machine understands (G-Code).

4. PLANS FOR CONTINUED RESEARCH

As the paper relates to an ongoing research, it describes only part of the work. We plan to continue working on the following items:

* development of the NC interface;
* NC machine design;
* graphic simulation; and
* economic evaluation.

Our plan is to complete the research prior to the symposium and consequently we hope to report about most of the above at the symposium.

The NC interface will first sort the RDF according to the bar type, its serial number and production batches. This will enable production planning based on procurement requirements and will be the basis for the optimization process. Optimization to minimize waste is needed when the raw material - the bars are supplied to the machine in a discrete form, as separate bars. This is indeed the case when processing bars of diameter larger than 16 mm. These bars cannot be supplied in coils, which is the way it is done in most of the existing machines.

The next item is the design of an NC machine for large diameter bars (>16 mm). The design will be based on the same principles as existing machines for smaller diameters and will relate to the following points:

* raw material supply (in a discrete form);
* waste handling;
* machine design; and
* finished production collection.

Based on this design, a technological feasibility study will be conducted with the aid of a graphic simulation system, as explained in (Navon 1989, Navon 1990, Warszawski and Navon 1991, Navon and Warszawski 1992). The simulation will also contribute to the establishment of some economic parameters, such as the system productivity.

The research will conclude with an economic analysis which will be based on information gathered at the previous stages, as well as field studies pertaining to productivity of manual and automated methods and the way work is carried out today.

5. CONCLUSIONS

The paper presents a comprehensive model for rebar CAD/CAM, which automates the process of rebar production - from the design stage to the manufacturing. The integration and automation of the whole process has great potential and prospective benefits, compared to the way rebar is produced today.

The main benefits are:

* After the design is completed, data is processed automatically by the computer, thus saving the triple handling of data in the conventional process. The manual data handling means, in effect, reading drawings and tables, processing it and rewriting it in a different format. This is a source for numerous potential human errors. The automation of this data handling and processing can reduce these errors to zero.

* Saving in additional costs - incurred by erroneous production, which are the cost of the materials and the cost of delays in the actual construction on site.

* Saving in manhour inputs for data handling, processing and programming the NC machine.

* Reduction in raw material waste due to the optimization process. In practice, sometimes the raw material waste is not so great, but this is achieved at the cost of manhour input for searching in the "waste heap" instead of using a new bar.

* Flexibility in the manufacturing strategy, enabling the batches to be produced by building elements or any other sorting criterion.

* Due to data availability, it is possible to order raw materials in varying lengths, according to the actual production. This, together with the optimization process, may reduce the raw material waste nearly to zero.

* Improved communication between designers, fabricators and contractors to avoid mistakes, especially in case of change orders.

* Enabling just-in-time delivery due to the elimination of errors and improved communication.

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