Computer Design of Prestressed Concrete

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Engineering, design, and producing companies can benefit by the judicious use of computers. Computer programs, prepared in advance, can be used to carry large work loads and to free valuable employees for their more productive tasks. There is, however, an understandable reluctance to use computers, especially for the first time. This stems from a lack of information about the steps and costs necessary to develop and use a computer program. This paper presents an outline of the steps and sources of cost in program development and use.

A program developed for a prestressed concrete manufacturing corporation forms the basis for these remarks. The program calculated the properties and load capacities of prestressed concrete single tee beams according to existing codes and according to two proposed codes. Several thousand beams with a wide range of dimensions and steel configurations were computed. The equations, the parameters, and the material specifications were all carefully selected.

Program development begins when the problem to be solved and the mathematical techniques have been selected. Development involves five major steps.

1. Organizing the problem.
2. Writing a source program.
3. Compiling a machine language from the source program.
4. Checking the computer program against hand calculations.
5. Correcting, recompiling and rechecking the computer program.

The problem is organized by laying out the municipal input, the equations, and the output in the order in which they are used or obtained. This step is done for hand calculations although it may be rather informal. Thus it is always necessary to organize the problem whether for machine or hand computations.

A simple flow diagram as shown in Fig. No. 1 is a valuable aid in organizing. The flow diagram clarifies the role and effects of decisions, features which are likely to be overlooked. The decisions appear as branches in the flow diagram. The first decision in Fig. No. 1 is based on U, the effective per cent steel. If U is greater than 0.3 the calculations for that beam are terminated. This result is printed and the beam dimensions are revised to new values.

After the problem is organized, a source program is written. The source program is a series of statements which specify the sequence of actions which the computer is to

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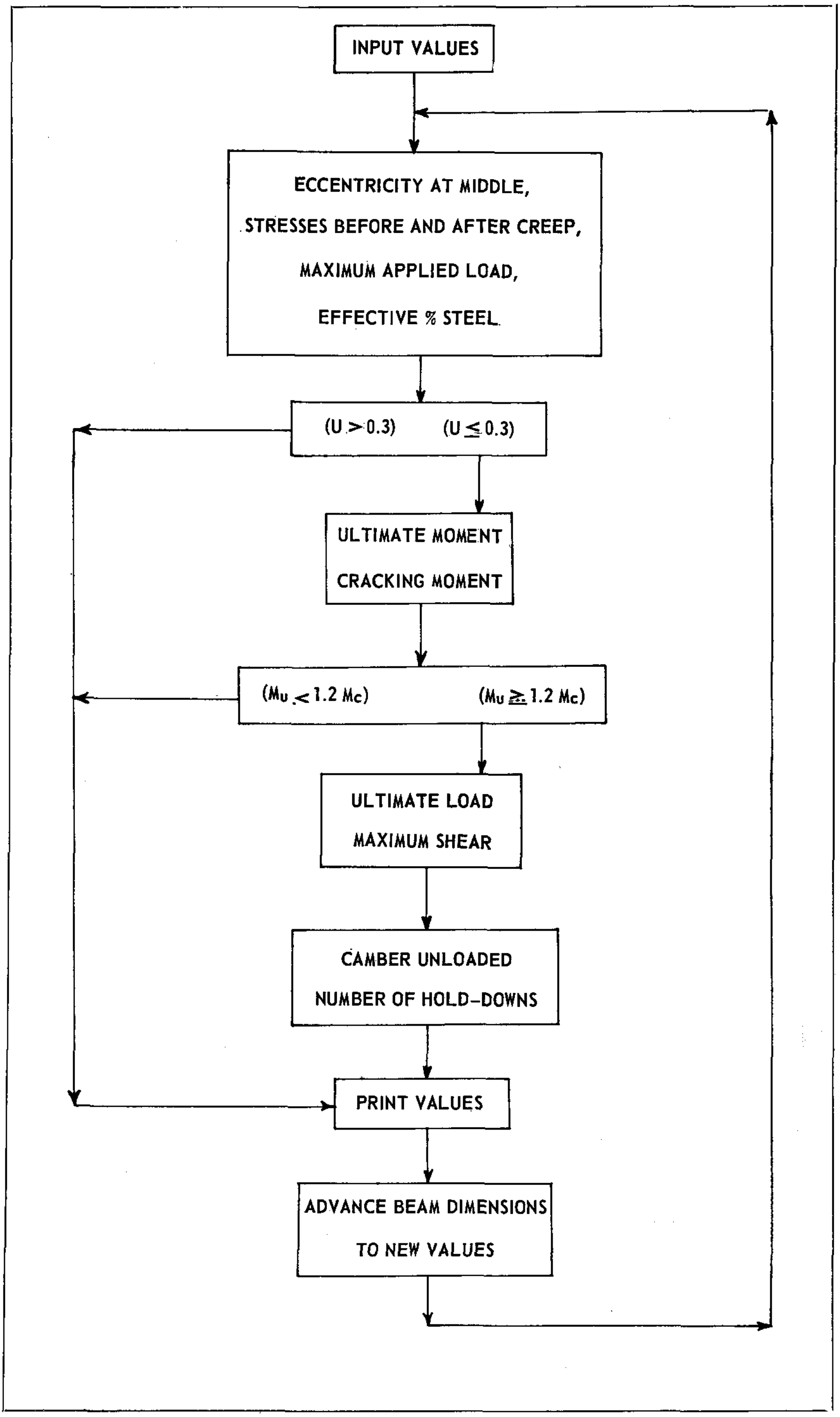

Fig. 1—Flow diagram.

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P=(AS*WN)/12./B/D$
FSU=(-0.5*P*FSP+FCP)*FSP/FCP$
U=(P*FSU)/FCP$
IF (U-0.3) 24, 24, 83$
24 UU=1.4*D*U$
83 PRINT, H, B, X, WN$
GO TO 87$
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Fig. 2—A sample of FORTRAN statements.

perform. There is no universal format for these statements and the format used must correspond to the computer (and compiler) which will be employed.

The source statements have the general form of instructions or algebraic equations. A sample of FORTRAN statements is shown in Fig. No. 2. The statement which reads

IF (U-0.3) 24, 24, 83

corresponds to the decision based on effective per cent steel.

Skill in writing source programs is easily acquired by engineers. Courses in programming are available at schools and are also offered by computer manufacturers.

The completed source program is used just once by the computer to generate a set of detailed instructions called the object program. The process is called compilation. The object program is punched in cards or placed on tape by the computer. This is the program which can be stored and subsequently loaded into the computer whenever the calculations are needed.

If there were no possibility of errors, the program would be developed at this point. In practice it is necessary to use the computer program and compare the results with hand computation. The calculations should be chosen to test every possible path through the program (as shown in the flow diagram). In a sizeable program, errors will be made so that the source program must be corrected and a new object program compiled.

The activities and cost for the single tee program are shown in Table No. 1. The times listed are for a moderately experienced programer without detailed knowledge of prestressed design. The monetary values are for a minimum capacity IBM 1620 with punched tape input. (A higher capacity IBM 1620 with card input would increase cost per hour to about \$50. The compiling and loading times would be reduced while the time to calculate and print each case would remain the same.)

There may be a tendency to avoid the use of large, high speed computers because of their high hourly cost. Computer costs are compared in Table No. 2. The IBM 7090 is much larger and faster than the

ACTIVITY	*COST*
Organize problem	3 man days
Write source program	5.5 man days
Compile into computer language program (Obtain test cases with desk calculator)	1 hr. (\$30)
Load and check computer program	5 min. load + 15 sec. cal. (\$2.50) (\$0.125)
Correct program	5 man days
Calculate desired cases	5 min. load + 15 sec./case (\$2.50) + (\$0.125/case)

Table 1—Sources of Cost.

	COMPUTER TIME AND COST			
ACTIVITY	*IBM 1620*	*IBM 7090*	+	*IBM 1401*
Compile	1 hr. ($30)	1 min. ($10.40)	+	15 sec. ($0.21)
Load program	5 min. ($2.50)	3 sec. ($0.52)		15 sec. ($0.21)
Load data	30 sec. ($0.25)	Negligible		Negligible
Calculate one beam	15 sec. ($0.125)	0.14 sec. ($0.024)		1 sec. ($0.018)

Table 2—Comparison of computer costs.

1620. The 7090 is used with a high speed printer, the 1401, and provides the best economy for all operations.

The computer cost for calculating and printing a single beam is attractive. It is very attractive if several calculations are made while the program is loaded. There is, however, an investment in program development before this low cost can be realized. The investment for development can be avoided by using computer programs offered by engineering and consultant firms. Descriptions of these programs are available and have been published in some cases so that the designer-user need not lose touch with the problem. In comparing the fees charged for program use and the tabulated values in this paper, it should be recalled that the present calculations are relatively simple and straight forward. A program which selects a "best" design will necessarily require considerably more development and computer time.

After the program is developed, the engineer plays two important monitoring roles. First, he makes sure the program (and its incorporated techniques) is used within its limitations. Secondly, he should inspect important numerical results with the same critical attitude used for hand calculations.

In conclusion, the same technical skills which are required to organize hand calculations are also sufficient for program organization. The person with these technical skills easily learns the source program format. The choice between hand and computer calculations then hinges on the balance between the investment to develop a program and the benefits accruing from fast and inexpensive solutions. The decision is simplified when the use of an existing program is purchased since the cost of development is included.