APPLICATION OF SOME DIGITAL COMPUTATION METHODS IN CIVIL ENGINEERING

by

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SCOPE AND METHOD OF STUDY: The purpose of this thesis is to assemble, analyze, and prepare for practical use a number of computer programs of special interest to civil engineers. It is felt that compiling these into one work will serve to benefit many engineers who would otherwise not gain exposure to such a wide range of proven computational methods. The method of study involved the assembly, analysis, modification for general application, revision for clarity of output, and description for use of computer programs from a variety of sources including the author's own files. The programs are presented from the standpoint of how to use them rather than how they work or were developed. Each program is complete with explanation of use, examples, and listings.

ADVISOR'S APPROVAL Hongsioe Oey

APPLICATION OF SOME

DIGITAL COMPUTATION METHODS

IN CIVIL ENGINEERING

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INTRODUCTION

In the course of study for an engineering degree many computer programs have been encountered and used in solving particular problems at particular times. In most cases these have become isolated experiences, and when the problems were solved, the programs were filed away, forgotten or lost.

During discussions with Dr. Oey it became evident to the author that these programs could be expanded, generalized, and/or simplified in order to cover a wider range of civil engineering problems.

Each of the programs contained in this thesis have been analyzed statement by statement and thoroughly checked for correctness of procedure. In some cases major additions were made to generalize the programs. One such case was the dynamic load deflection program which originally was written only for sinusoidal loads and used primarily for smokestack analysis. Other programs were written especially for inclusion in the thesis such as the backwater profile program. It was also necessary to determine the limitations of the techniques used. Most of these programs have been used for real problems by Dr. Oey in practical civil engineering work.

The thesis has been written on the premise that potential users would be unfamiliar with many of the techniques involved, too busy to develop the theories, and/or uninterested in such endeavors. Therefore, this project presents a variety of computer programs, describes what they will do, shows the user how to use them, and demonstrates their use

through examples.

Each program is presented with a general discussion of its purposes, capabilities, and limitations. Also presented, where needed, is a suggested procedure to follow for preliminary analysis. Included in the explanation is a list of coded input items with a definition of each. All this is summarized in a table which shows, card by card, what to put into the program followed by a general discussion of the output. The detailed working of examples is shown in order that one may see first hand how all the above will work. Finally, a listing of the program itself is included at the end of each chapter.

All of these programs have been adapted to the CDC 3100 system in use at this institution. Therefore, when adapting the programs for use with other computers it should be remembered that there will be several minor changes that will have to be made in the statements, formats, and input methods. Also, capacities of different machines will have to be considered. The programs contained herein generally are based on methods such that they may be used in the smaller computers of the type normally available to the practicing engineer. There may exist other, more sophisticated, procedures to solve these problems which require larger computers or more technical knowledge on the part of the user.

Finally, for those interested, very brief, generalized descriptions are included in the appendix for each program.

It is recognized that there are many other computer programs which would be of great value if exposed to potential users. Due to the limited time available it has been necessary to restrict the size of this work. However, it is suggested that a reference manual be developed which can be supplemented as new programs are encountered or developed.

BEAM ANALYSIS

This program is used for the analysis of single beams over a wide variety of static loading and/or support conditions.

Support conditions range from simple beams on point supports to partially supported continuous beams. These include virtually all support conditions normally encountered for beams.

Loading conditions include concentrated loads, uniform loads, and applied moments.

Results include deflection, slope, internal moment, internal shear, and loads. All the above values are reported for each specified station of a beam.

The accuracy of results depends on the length of increments between stations. Theoretically, the smaller the increment length, the greater the accuracy. The maximum number of increments (stations) is dependent on the capacity of the computer being used. Values for moment, shear, and load at point supports will be inaccurate. However, one will be able to readily recognize the obvious errors involved by sketching shear and moment diagrams from the data. Results reflecting extremely small values (xx.xxxE-08) very likely represent zero values.

In order to utilize this program it will be necessary to do some preliminary analysis. All values should be given in terms of kips and inches. A suggested procedure for this analysis follows:

1. Determine the EI value(s) for the beam.

2. Considering load and support locations, choose an appropriate

increment length.

3. Check for any transverse or angular restraints (i.e., a column support for a continuous beam). Angular restraints should be in kip-inches and transverse restraints in kips.

4. Determine the values (in kips) of the transverse loads, applied moments, and axial loads.

5. Determine the special conditions of specified slopes and/or deflections.

6. Number the stations of the beam from left to right beginning with zero for the extreme left end of the beam. The right end of increment number one becomes station one, the right end of the second increment becomes station two,etc.

The input data will consist of the following coded items as shown on the chart:

NPROBS = number of problems to be run,

NPR = problem number,

M = number of increments,

H = increment length,

NCT2 = number of lines in Table 2; the number of lines necessary to describe the beam-column (It is recommended that you complete Table 2 first to find the value of NCT2),

NCT3 = number of lines in Table 3; the number of stations at which the deflection is specified (Complete Table 3 first),

NCT4 = number of lines in Table 4; the number of stations at which the slope is specified (Complete Table 4 first),

I1, I2 = the interval, expressed as station numbers, through which the data following will be added to storage locations,

FN = EI for the interval,

QN = transverse load for the interval,

SN = transverse restraint (spring constant) for the interval,

TN = applied moment for the interval,

RN = angular restraint for the interval,

PN = applied axial load for the interval,

ISTA = station number at which the deflection or slope is specified,

YSP = value of the specified deflection,

DYSP = value of the specified slope.

PREPARATION OF DATA CARDS

	DATA TYPE	NUMBER OF CARDS	ITEMS ON CARDS
a	Control	1	NPROBS
b	Control	1	NPR M H
c	Control	1	NCT2 NCT3 NCT4
d	Specified properties (Table 2)	NCT2	I1 I2 FN QN SN TN RN PN
e	Specified deflections (Table 3)	NCT3	ISTA YSP
f	Specified slopes (Table 4)	NCT4	ISTA DYSP

The output consists of Tables 1 through 5.

Table 1 is an echo print of the control data for use as a check.

Table 2 is an echo print of the descriptive data.

Table 3 is an echo print of the specified deflections.

Table 4 is an echo print of the specified slopes.

Table 5 is the printout of the results desired station by station.

Column 1 is the station number.

Column 2 is the inclusive length of the beam through the station number.

Column 3 is the deflection at the station.

Column 4 is the slope at the station.

Column 5 is the moment.

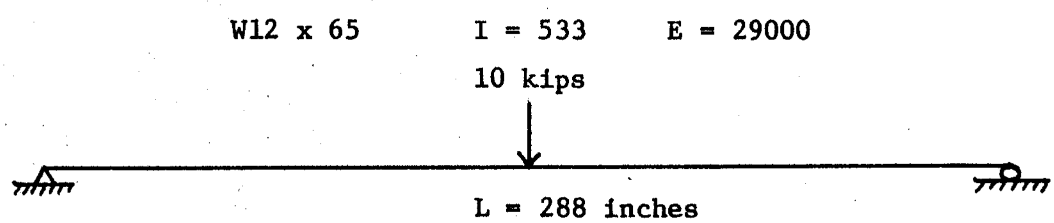
Column 6 is the shear.

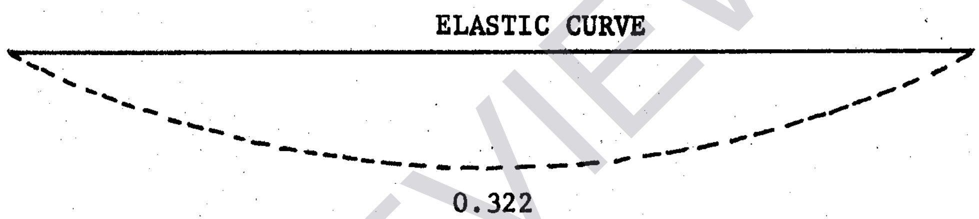
Column 7 is the load.

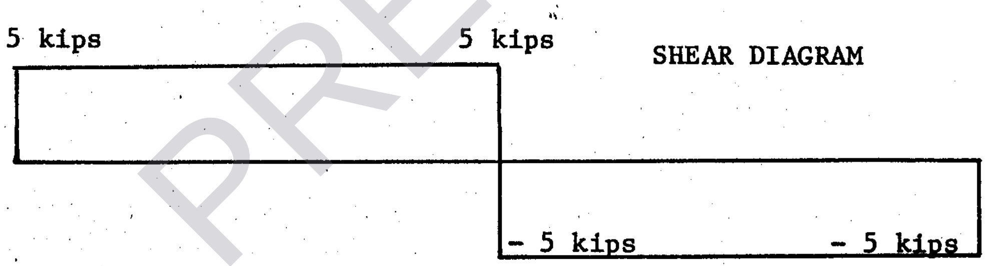
It must be noted that, when entering the intervals by station number, one must NOT enter an EI value for a particular station on more than one card (line in table 2). For example, you should enter stations 1 through 9 and 10 through 50 rather than 1 through 10 and 10 through 50. In the latter it can be seen that station 10 will have the EI value entered twice.

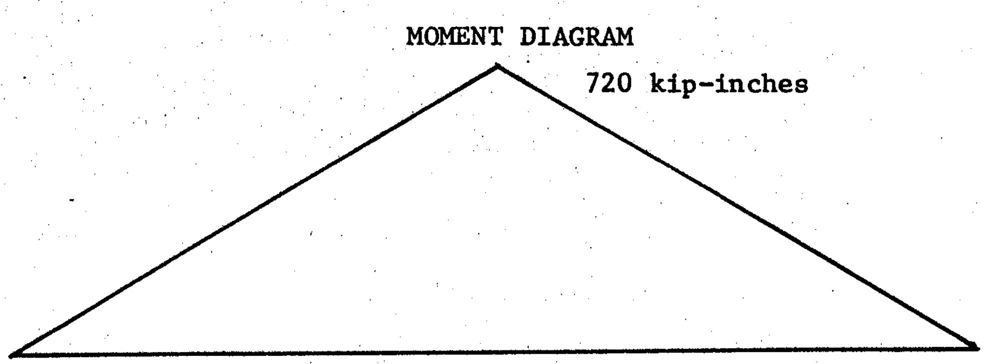
REFERENCES 8, 9

For the first example we will choose a simple beam with a concentrated load at the center as shown in the sketch. This problem can be easily calculated by hand to yield the answers shown. The results, using the computer program, follow for the purpose of comparison.









PROBLEM NUMBER 1

TABLE 1. CONTROL DATA

NUM INCREMENTS = 24
INCREMENT LENGTH = 12.00 INCHES
NUM CARDS TABLE 2 = 2
NUM CARDS TABLE 3 = 2
NUM CARDS TABLE 4 = 0

TABLE 2. STRUCTURE DATA FOR SPECIFIED INTERVALS

INTERVAL STA	THRU	EI	TRANSVERSE LOAD	TRANSVERSE RESTRAINT	APPLIED MOMENT	ANGULAR RESTRAINT	AXIAL LOAD
0	24	1.546E 07	0	0	0	0	
12	12	0	-1.000E 01	0	0	0	

TABLE 3. SPECIFIED DEFLECTIONS

STA	VALUE (INCHES)
0	0
24	0

TABLE 4. SPECIFIED SLOPE VALUES

STA	VALUE (RADIANS)

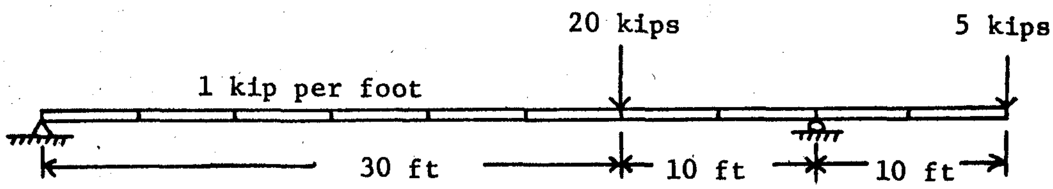
PROBLEM NUMBER 1

TABLE 5. RESULTS

STA	LENGTH (INCHES)	DEFLECTION (INCHES)	SLOPE (RADIANS)	MOMENT (KIP-INCHES)	SHEAR (KIPS)	LOAD (KIPS)
0	0	0	-3.353E-03	0	2.500E 00	5.000E 00
1	1.200E 01	-4.024E-02	-3.330E-03	6.000E 01	5.000E 00	-3.260E-08
2	2.400E 01	-7.992E-02	-3.260E-03	1.200E 02	5.000E 00	6.488E-08
3	3.600E 01	-1.185E-01	-3.144E-03	1.800E 02	5.000E 00	3.322E-08
4	4.800E 01	-1.554E-01	-2.981E-03	2.400E 02	5.000E 00	1.298E-07
5	6.000E 01	-1.900E-01	-2.771E-03	3.000E 02	5.000E 00	1.956E-07
6	7.200E 01	-2.219E-01	-2.515E-03	3.600E 02	5.000E 00	-1.950E-07
7	8.400E 01	-2.504E-01	-2.212E-03	4.200E 02	5.000E 00	1.304E-07
8	9.600E 01	-2.750E-01	-1.863E-03	4.800E 02	5.000E 00	-1.950E-07
9	1.080E 02	-2.951E-01	-1.467E-03	5.400E 02	5.000E 00	3.912E-07
10	1.200E 02	-3.102E-01	-1.025E-03	6.000E 02	5.000E 00	2.633E-07
11	1.320E 02	-3.197E-01	-5.356E-04	6.600E 02	5.000E 00	-1.304E-07
12	1.440E 02	-3.230E-01	-3.032E-12	7.200E 02	-1.304E-07	-1.000E 01
13	1.560E 02	-3.197E-01	5.356E-04	6.600E 02	-5.000E 00	6.519E-07
14	1.680E 02	-3.102E-01	1.025E-03	6.000E 02	-5.000E 00	-1.950E-07
15	1.800E 02	-2.951E-01	1.467E-03	5.400E 02	-5.000E 00	2.614E-07
16	1.920E 02	-2.750E-01	1.863E-03	4.800E 02	-5.000E 00	-2.595E-07
17	2.040E 02	-2.504E-01	2.212E-03	4.200E 02	-5.000E 00	1.950E-07
18	2.160E 02	-2.219E-01	2.515E-03	3.600E 02	-5.000E 00	6.519E-08
19	2.280E 02	-1.900E-01	2.771E-03	3.000E 02	-5.000E 00	0
20	2.400E 02	-1.554E-01	2.981E-03	2.400E 02	-5.000E 00	1.614E-08
21	2.520E 02	-1.185E-01	3.144E-03	1.800E 02	-5.000E 00	9.794E-08
22	2.640E 02	-7.992E-02	3.260E-03	1.200E 02	-5.000E 00	3.236E-08
23	2.760E 02	-4.024E-02	3.330E-03	6.000E 01	-5.000E 00	3.260E-08
24	2.880E 02	0	3.353E-03	0	-2.500E 00	5.000E 00

The second example problem will point out some of the errors which may be encountered in the computer program.

Consider a beam overhanging one support and loaded as shown in the diagram.



W18 x 40   E = 29000 ksi   I = 612 in^4

Preliminary analysis for the computer program yields the following input values:

EI = 29000 x 612 = 17,748,000 kip-sq. in.,

Deflection at supports = 0,

Number of increments = 50,

Increment length = 12 in.

A total of seven data cards are required for this problem. Following the guide given in the table, the cards are prepared as shown:

CARD 1 NPR=2 M=50 H=12.

2 NCT2=3 NCT3=2 NCT4=0

3 I1=0 I2=50 FN=17748000. QN=-1. SN, TN, RN, PN=0.

4 I1=30 I2=30 FN=0. QN=-20. SN, TN, RN, PN=0.

5 I1=50 I2=50 FN=0. QN=-5. SN,TN, RN, PN=0.

6 ISTA=0 YSP=0.

7 ISTA=40 YSP=0.

The results are shown in the following printouts:

PROBLEM NUMBER 2

TABLE 1. CONTROL DATA

NUM INCREMENTS = 50
INCREMENT LENGTH = 12.00 INCHES
NUM CARDS TABLE 2 = 3
NUM CARDS TABLE 3 = 2
NUM CARDS TABLE 4 = 0

TABLE 2. STRUCTURE DATA FOR SPECIFIED INTERVALS

INTERVAL STA	THRU	EI	TRANSVERSE LOAD	TRANSVERSE RESTRAINT	APPLIED MOMENT	ANGULAR RESTRAINT	AXIAL LOAD
0	50	1.775E 07	-1.000E 00	0	0	0	
30	30	0	-2.000E 01	0	0	0	
50	50	0	-5.000E 00	0	0	0	

TABLE 3. SPECIFIED DEFLECTIONS

STA	VALUE (INCHES)
0	0
40	0

TABLE 4. SPECIFIED SLOPE VALUES

STA	VALUE (RADIANS)

PROBLEM NUMBER 2

TABLE 5. RESULTS

STA	LENGTH (INCHES)	DEFLECTION (INCHES)	SLOPE (RADIANS)	MOMENT (KIP-INCHES)	SHEAR (KIPS)	LOAD (KIPS)
0	0	0	-2.609E-02	0	1.094E 01	2.188E 01
1	1.200E 01	-3.131E-01	-2.600E-02	2.625E 02	2.138E 01	-1.000E-00
2	2.400E 01	-6.240E-01	-2.574E-02	5.130E 02	2.038E 01	-1.000E 00
3	3.600E 01	-9.308E-01	-2.531E-02	7.515E 02	1.938E 01	-1.000E-00
4	4.800E 01	-1.231E 00	-2.473E-02	9.780E 02	1.838E 01	-1.000E-00
5	6.000E 01	-1.524E 00	-2.399E-02	1.193E 03	1.738E 01	-1.000E-00
6	7.200E 01	-1.807E 00	-2.312E-02	1.395E 03	1.638E 01	-1.000E-00
7	8.400E 01	-2.079E 00	-2.211E-02	1.586E 03	1.538E 01	-1.000E 00
8	9.600E 01	-2.338E 00	-2.098E-02	1.764E 03	1.438E 01	-1.000E-00
9	1.080E 02	-2.582E 00	-1.973E-02	1.931E 03	1.338E 01	-1.000E 00
10	1.200E 02	-2.811E 00	-1.837E-02	2.085E 03	1.238E 01	-1.000E-00
11	1.320E 02	-3.023E 00	-1.691E-02	2.228E 03	1.138E 01	-1.000E 00
12	1.440E 02	-3.217E 00	-1.536E-02	2.358E 03	1.038E 01	-1.000E 00
13	1.560E 02	-3.392E 00	-1.373E-02	2.477E 03	9.375E 00	-1.000E 00
14	1.680E 02	-3.547E 00	-1.202E-02	2.583E 03	8.375E 00	-1.000E 00
15	1.800E 02	-3.680E 00	-1.024E-02	2.678E 03	7.375E 00	-1.000E-00
16	1.920E 02	-3.792E 00	-8.401E-03	2.760E 03	6.375E 00	-1.000E 00
17	2.040E 02	-3.882E 00	-6.511E-03	2.831E 03	5.375E 00	-1.000E-00
18	2.160E 02	-3.949E 00	-4.578E-03	2.889E 03	4.375E 00	-1.000E 00
19	2.280E 02	-3.992E 00	-2.609E-03	2.936E 03	3.375E 00	-1.000E 00
20	2.400E 02	-4.011E 00	-6.121E-04	2.970E 03	2.375E 00	-1.000E-00
21	2.520E 02	-4.007E 00	1.404E-03	2.993E 03	1.375E 00	-1.000E 00
22	2.640E 02	-3.978E 00	3.431E-03	3.003E 03	3.750E-01	-1.000E-00
23	2.760E 02	-3.924E 00	5.460E-03	3.002E 03	-6.250E-01	-1.000E-00
24	2.880E 02	-3.847E 00	7.485E-03	2.988E 03	-1.625E 00	-1.000E 00
25	3.000E 02	-3.745E 00	9.497E-03	2.963E 03	-2.625E 00	-1.000E 00
26	3.120E 02	-3.619E 00	1.149E-02	2.925E 03	-3.625E 00	-1.000E 00
27	3.240E 02	-3.469E 00	1.345E-02	2.876E 03	-4.625E 00	-1.000E-00
28	3.360E 02	-3.296E 00	1.537E-02	2.814E 03	-5.625E 00	-1.000E-00
29	3.480E 02	-3.100E 00	1.725E-02	2.741E 03	-6.625E 00	-1.000E 00
30	3.600E 02	-2.882E 00	1.907E-02	2.655E 03	-1.763E 01	-2.100E 01
31	3.720E 02	-2.642E 00	2.075E-02	2.318E 03	-2.863E 01	-1.000E-00
32	3.840E 02	-2.384E 00	2.220E-02	1.968E 03	-2.963E 01	-1.000E 00
33	3.960E 02	-2.109E 00	2.341E-02	1.607E 03	-3.063E 01	-1.000E 00
34	4.080E 02	-1.822E 00	2.437E-02	1.233E 03	-3.163E 01	-1.000E-00
35	4.200E 02	-1.524E 00	2.508E-02	8.475E 02	-3.263E 01	-1.000E 00
36	4.320E 02	-1.220E 00	2.551E-02	4.500E 02	-3.363E 01	-1.000E-00
37	4.440E 02	-9.122E-01	2.568E-02	4.050E 01	-3.463E 01	-1.000E 00
38	4.560E 02	-6.038E-01	2.556E-02	-3.810E 02	-3.563E 01	-1.000E-00
39	4.680E 02	-2.986E-01	2.516E-02	-8.145E 02	-3.663E 01	-1.000E 00
40	4.800E 02	0	2.446E-02	-1.260E 03	-1.106E 01	5.213E 01
41	4.920E 02	2.884E-01	2.367E-02	-1.080E 03	1.450E 01	-1.000E-00
42	5.040E 02	5.680E-01	2.299E-02	-9.120E 02	1.350E 01	-1.000E 00
43	5.160E 02	8.403E-01	2.243E-02	-7.560E 02	1.250E 01	-1.000E-00
44	5.280E 02	1.106E 00	2.197E-02	-6.120E 02	1.150E 01	-1.000E-00
45	5.400E 02	1.367E 00	2.160E-02	-4.800E 02	1.050E 01	-1.000E-00
46	5.520E 02	1.625E 00	2.131E-02	-3.600E 02	9.500E 00	-1.000E-00
47	5.640E 02	1.879E 00	2.111E-02	-2.520E 02	8.500E 00	-1.000E 00
48	5.760E 02	2.131E 00	2.097E-02	-1.560E 02	7.500E 00	-1.000E-00
49	5.880E 02	2.382E 00	2.089E-02	-7.200E 01	6.500E 00	-1.000E-00
50	6.000E 02	2.633E 00	2.087E-02	0	3.000E 00	-6.000E 00

Hand calculation of data at selected points will demonstrate the amount of error involved and emphasize the care one must use in interpreting results.

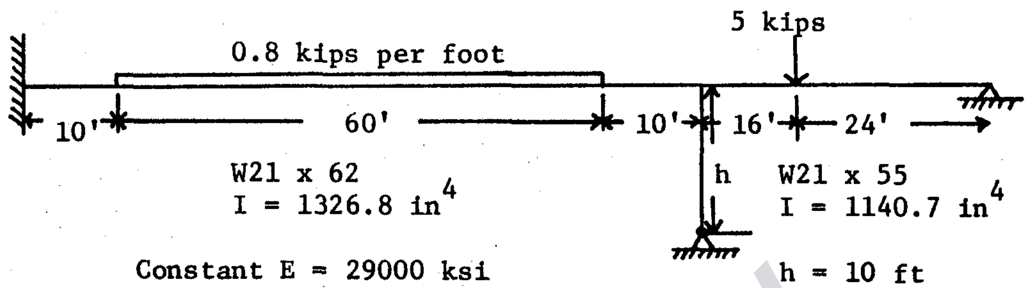
First, values calculated by hand and by computer are tabulated in the chart shown below.

STA	LOAD		SHEAR		MOMENT		DEFLECTION	
	HAND	MACH	HAND	MACH	HAND	MACH	HAND	MACH
0	22.5	21.88	22.5	10.94	0	0	0	0
10	-1.0	-1.0	12.5	12.38	2250	2085	-2.84	-2.81
20	-1.0	-1.0	2.5	2.38	3000	2970	-4.06	-4.01
30	-21.	-21.	-27.5	-17.63	2700	2655	-2.92	-2.88
40	52.5	52.13	-15.	-11.06	-1200	-1260	0	0
50	-6.0	-6.0	0	3.0	0	0	2.72	2.63

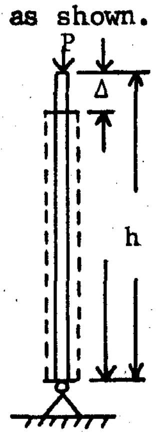
A comparison of results shows that hand calculation of reactions at stations 0 and 40 yield 22.5 kips and 52.5 kips respectively. Computer values are 21.88 and 52.13. Other values and magnitudes of error may be compared from the table in order to satisfy oneself concerning the accuracy of results.

It should be remembered that discrepancies in results are not due to computer errors, rather they are due to the use of finite difference approximations.

The third problem will demonstrate the program's ability to provide necessary data on a more complicated beam. No attempt has been made to verify these results since the first two examples have established the accuracy of predictions. Consider the following beam.



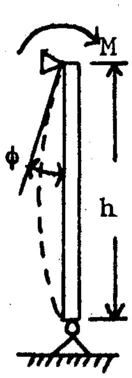
In this problem there will be a transverse restraint due to the spring constant associated with the column. This is calculated by hand as shown.



$\Delta = Ph/AE$, set $\Delta = 1$ inch and solve for P

$P = AE/h = 15.59 \times 29000/120 = 3760$ kips

The column also causes an angular restraint calculated below.



$\phi = Mh/3EI$, set $\phi = 1$ radian and solve for M

$M = 3EI/h = 3 \times 15720000/120 = 392500$ kip-in.

Summarizing the data values, we choose the number of increments as 120, each 12 inches long. The EI values are 38500000 and 33000000. Transverse loads are 0.8 kip/ft and 5 kip. The transverse restraint is 3760 kips and angular restraint is 392500 kip-in. Deflection will be specified as zero at each end of the beam. Due to the fixed end, the slope will be specified as zero at that point. This data will be entered as follows:

CARD 1 NPR=3 M=120 H=12.

2 NCT2=6 NCT3=2 NCT4=1

3 I1=0 I2=9 FN=38500000 QN, SN, TN, RN, PN=0.

4 I1=10 I2=70 FN=38500000 QN=-.8 SN, TN, RN, PN=0.

5 I1=71 I2=79 FN=38500000 QN, SN, TN, RN, PN=0.

6 I1=80 I2=80 FN=38500000 QN=0. SN=3760. TN=0.
RN=392500 PN=0.

7 I1=96 I2=96 FN=0. QN=-5. SN, TN, RN, PN=0.

8 I1=81 I2=120 FN=33000000 QN, SN, TN, RN, PN=0.

9 ISTA=0 YSP=0.

10 ISTA=120 YSP=0.

11 ISTA=0 DYSP=0.

Note that uniform data is added over an interval and point data is added at a point. Also note on card 7 that the EI value was entered as zero. This is due to the fact that station 96 is included in the interval 81 - 120 shown on card 8 for which EI is already entered.

Results are shown on the following printouts.

PROBLEM NUMBER 3

TABLE 1. CONTROL DATA

NUM INCREMENTS = 120
INCREMENT LENGTH = 12.00 INCHES
NUM CARDS TABLE 2 = 6
NUM CARDS TABLE 3 = 2
NUM CARDS TABLE 4 = 1

TABLE 2. STRUCTURE DATA FOR SPECIFIED INTERVALS

INTERVAL STA	THRU	EI	TRANSVERSE LOAD	TRANSVERSE RESTRAINT	APPLIED MOMENT	ANGULAR RESTRAINT	AXIAL LOAD
0	9	3.850E 07	0	0	0	0	
10	70	3.850E 07	-8.000E-01	0	0	0	
71	79	3.850E 07	0	0	0	0	
80	80	3.850E 07	0	3.760E 03	0	3.925E 05	
96	96	0	-5.000E 00	0	0	0	
81	120	3.300E 07	0	0	0	0	

TABLE 3. SPECIFIED DEFLECTIONS

STA	VALUE (INCHES)
0	0
120	0

TABLE 4. SPECIFIED SLOPE VALUES

STA	VALUE (RADIANS)
0	0