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A DECISION TABLE FORMULATION OF THE SPECIFICATION FOR THE
DESIGN OF COLD-FORMED STEEL STRUCTURAL MEMBERS

by Paul A. Seaburg¹

INTRODUCTION

Difficulties in using specifications in their usual form have been observed in the process of incorporating them into computer programs. These applications generally attempt to cover all possible situations which occasionally results in misuse or extension of the specification beyond its intended scope. Clear documentation of the specification treatment within a computer program is also a somewhat difficult task to accomplish, yet vital to acceptance of a working program.

Formulation of specifications into the form of decision tables has been suggested as a reasonable solution to these problems (2). Such tables clearly communicate the provisions of a specification and their intended interaction. They are readily checked by the engineers responsible for their use and can be converted into working computer programs by experienced programmers who may be completely unfamiliar with the specification. The decision table format has another useful result in that it serves to identify all combinations of factors not specifically covered by the specification. This provides a direction for improved definition of the provisions or for possible future research in undefined areas.

This paper illustrates the application of decision tables to the Specification for the Design of Cold-Formed Steel Structural Members, 1968 Edition (1)², hereafter referred to as "the Specification." Several typical tables are included herein; the complete set of tables is currently under preparation.

GENERAL DESCRIPTION OF DECISION TABLES

A decision logic table has been described as a concise tabular display of all elements of a problem. The table shows all applicable conditions and the appropriate actions to be taken on the basis of responses to these conditions. A number of texts, such as reference 5, are available which describe decision tables and their use in detail. The following discussion is intended to provide a working knowledge of decision table techniques to the extent utilized herein.

Decision tables have four sections: the condition stub, the condition entry, the action stub and the action entry. These sections are arranged as illustrated in Figure 1. The four quadrants are, by convention, separated by double lines.

The condition stub consists of a listing of all the possible conditions applicable to a particular problem. The possible actions are listed in the action stub. The conditions are expressed in terms of questions having either yes (Y) or no (N) answers. The possible combinations of these answers are shown in the condition entry. Any particular set, i.e. one column, is

²Numerals in parenthesis refer to corresponding items in the References

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known as a rule. The proper action to be taken on the basis of this rule is indicated in the action stub by the letter Y on the line of the action. This scheme is shown in Figure 2. Actions can be a variety of items such as the correct formula for allowable stress, verification of a satisfactory or unsatisfactory design, or a designation to use another table.

Figure 2 shows eight possible rules and eight different actions based on three conditions. Since each condition has two possibilities (Y or N), there are for "n" conditions 2ⁿ possible unique combinations. Ten conditions, for example, have 2¹⁰ or 1024 different combinations. All the possible combinations do not always occur in practice (Reference 6 discusses this aspect in detail). Consider, for example, that in Figure 2 actions 1 and 2 are identical. The rules leading to these actions differ only in the responses to condition 3. Since both a Y and N response to condition 3 lead to the same action, this condition is really immaterial and need not be examined. The table could thus be shortened by combining rules 1 and 2 into a single rule which does not require a response to condition 3, but leads to the single action 1 in this case.

The number of possible rules associated with various conditions will also be reduced if certain of these conditions are what has been termed "mutually exclusive." Mutually exclusive means that a positive response to one condition also establishes a negative response to other conditions. Suppose, for example, that a flange element can be either curved or flat. A response indicating it is flat thus would necessarily prohibit it from also being curved. The curved condition could in fact be omitted from the decision table, however, for clarity of use, it is advisable to list both conditions.

An abbreviated decision table based on these two points is illustrated in Figure 3. In this table, conditions 3 and 4 are considered mutually exclusive meaning a Y response to one indicates a N response to the other, which need not be entered. It is further assumed here that one of these conditions must

Condition Stub	Condition Entry
Action Stub	Action Entry

Quadrants of a Decision Table
Figure 1

Rules	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Condition #1	Y	Y	Y	N	Y	N	N	N
Condition #2	Y	Y	N	Y	N	Y	N	N
Condition #3	Y	N	Y	Y	N	N	Y	N
Action #1	Y							
Action #2	Y							
Action #3	Y							
Action #4	Y							
Action #5	Y							
Action #6	Y							
Action #7	Y							
Action #8	Y							

A Complete Decision Table
Figure 2

be true in order to satisfy the physical problem. Rule 5 indicates that condition 2 is immaterial, since no response is required. If all the conditions in this table had been independent and always applicable, there would be 16 unique rules required. The reader may wish to convince himself that all but two of these are actually covered. These two rules consist of responses NY Y and NN Y. The omission indicated there is no recommended action for this particular situation. In the case of a specification decision table, this means either that the specification has overlooked some possibilities or that the conditions are believed to be of no practical value. To cover possible omissions, decision tables introduce an "ELSE RULE" to signal their existence. This is indicated by the "E" in the final column.

A further illustration of a decision table is shown in Figure 4. In this case more than one action is indicated. It is convenient to require that the actions be accomplished in the order listed. With this convention, action 1, for example, could be used to designate an item of information that is needed to execute action 3. Under rule 2, as shown, information for action 3 item is found from action 2. Note that four possible rules are omitted in this table, namely those involving a N response to condition 1. All of these would be covered by the ELSE RULE.

DECISION TABLE FORMULATION OF THE AISI SPECIFICATION

Decision tables can be written in forms which either generate design information or check a given design. The latter is more consistent with the language of specifications and thus has been used in this application to the AISI Specification. The tables are intended to check a given design--member, connection or bracing--against the applicable provisions of the Specification. The design must be completely dimensioned. Web and flange elements must be so designated. Also, stiffening elements must be identified along with the elements they are intended to stiffen. A member is further assumed to be subject to known loading conditions which establish the values of applied moment, shear, axial load, etc.

All provisions of the AISI Specification are covered in the decision tables being developed. Applicable provisions are automatically invoked during the execution of the tables for a particular problem. The tables do not define all the analytical steps required in checking a design. They do not, for example, indicate how the section properties of members or stresses in connections are to be calculated, beyond the extent covered in the Specification. Such gaps must be supplied by the user.

The following types of investigations are covered in the tables:

Member Proportions--

Checks the member dimensions for limiting width to thickness ratios and maximum curling criteria.

Bending--

Checks a member subject only to bending.

Axial Load--

Checks a member subject to axial load only, either tension

Rules	(1)	(2)	(3)	(4)	(5)	
Condition #1	Y	Y	Y	Y	N	E
Condition #2	Y	Y	N	N		
Condition #3	Y		Y		Y	
Condition #4		Y		Y		
Action #1	Y					
Action #2		Y				
Action #3			Y			
Action #4				Y		
Action #5					Y	
Else Rule						Y

An Abbreviated Decision Table
Figure 3

Rules	(1)	(2)	(3)	
Condition #1	Y	Y	Y	E
Condition #2	Y	Y	N	
Condition #3	Y	N		
Action #1	Y			
Action #2		Y	Y	
Action #3	Y	Y		
Action #4			Y	
Else Rule				Y

Decision Table With Multiple Action Entries
Figure 4

or compression.

Bending and Axial Load--

Checks a member subject to combined bending and compression.

Shear and Bending--

Checks the shear and bending stresses in the web of a flexural member.

Web Crippling--

Checks a member for the web crippling effects of concentrated loads and reactions.

Connection--

Checks a bolted or welded connection.

Bracing--

Checks the bracing provided against the requirements for wall studs and channel and Z-sections used as beams.

These investigations utilize common decision tables in many instances.

Figure 5 shows a typical decision table. The format is patterned after that used in presenting the AISI Specification as decision tables (3). The table illustrated is for determining the allowable compressive stress, F_a , on an axially loaded compression member.

Execution of the table requires the use of the data items which are defined above the decision table. Some of these must be supplied by the user, a situation which is identified by an "X" in the column immediately following the data definition. In other cases, the data is obtainable through provisions of the Specification contained in other decision tables. These are referenced in the second column after the data definition. Note, for example, that F_{a1} --allowable average compressive stress under concentric loading, can be found from Table 3.6.1.1.a. This table is shown in Figure 6. This table likewise requires data obtainable from other tables. The tables are thus linked together through the data cross references. The extent of these ties for the investigation of a compression member is illustrated in Figure 7.

To use the table illustrated in Figure 5, the user matches his responses to the six conditions as listed. With the proper

TABLE 3.6.1.a AXIALLY LOADED COMPRESSION MEMBERS

Data Required		
Member is braced against twisting	X	Table 3.6.1.1.a (1)
Cylindrical tubular member	X	
Bracing or secondary member	X	
F_{a1} , allowable average compressive stress under concentric loading		Table 3.6.1.2.a (1)
F_{a2} , allowable average compression stress under concentric loading		Table 3.8.a (1)
F_r , allowable compressive stress in cylindrical tubular member		Table 2.3.a
L, unbraced length of member	X	
r, radius of gyration of full, unreduced cross-section	X	
Shape of member is doubly-symmetric or closed cross-section or point-symmetrical Z-shape	X	
Member can be shown not to be subject to torsional-flexural buckling	X	

Decision Table

Shape of member is doubly-symmetric or closed cross-section or point-symmetrical Z-shape	Y	N	Y	N	Y	N	Y	N	E
Member can be shown not to be subject to torsional-flexural buckling	Y	N	Y	N	Y	N	Y	N	
Member is braced against twisting	Y	N	Y	N	Y	N	Y	N	
Cylindrical tubular member	N	N	Y	N	Y	N	Y	N	Y
Bracing or secondary member	N	N	N	N	Y	Y	Y	Y	Y
$L/r > 120$	N	N	N	N	Y	Y	Y	Y	Y
(1) $F_a = F_{a1}$	Y	Y	Y	Y	Y	Y	Y	Y	Y
(1) $F_a = \min(F_{a1}; F_{a2})$		Y		Y		Y		Y	
(1) $F_a = \min(F_{a1}; F_r)$		Y		Y		Y		Y	
(1) $F_{as} = F_a \frac{1.3-L}{400r}$						Y	Y	Y	Y
(1) $F_a = F_{as}$						Y	Y	Y	Y
(1) $F_a = \min(F_{as}; F_r)$									Y
Else rule									Y

Decision Table to Establish Allowable Compressive Stress on Axially Loaded Members
Figure 5

column thus located, the required action will be as designated in the lower part of the table. Actions are to be executed in the order listed with subsequent actions modifying or using data from previous actions. For the action of the fourteenth rule, for example, F_a is first defined as the smaller of the values for F_{a1} , and F_{a2} . Both of these must be then found by executing the referenced tables. This smaller value is then modified in a second action for the bracing or secondary mem-

TABLE 3.6.1.1.a SHAPES NOT SUBJECT TO TORSIONAL-FLEXURAL BUCKLING - ALLOWABLE COMPRESSION STRESS

Data Required		
K, effective length factor	X	Table 2.3.a
L, unbraced length of member	X	
r, radius of gyration of full, unreduced cross-section		(E = 29,500 ksi)
E, modulus of elasticity	X	Table 3.1.1.a (1)
F_y , yield point of steel		Table 3.6.1.1.b (1)
Q, stress and/or area factor		
t, thickness of material	X	Table 3.1.2.a (1)
Increase in allowable stress permitted		

Decision Table

$\frac{KL}{r} < \frac{C_c}{Q}$	Y	N	Y	Y	N	Y	Y
Q = 1			Y	N		Y	N
$t \geq 0.09$	N	Y	N		N	Y	Y
Increase in allowable stress	N	N	N	N	Y	Y	Y
(1) $F_{a1} + \frac{12}{23} Q F_y - \frac{3(QF_y)^2}{23^2 E} \left[\frac{KL}{r} \right]^2$	Y		Y	Y		Y	
(1) $F_{a1} = \frac{12\pi^2 E}{23 (KL/r)^2}$		Y			Y		
(1) $F_{a1} = \left[1 - \frac{(KL/r)^2}{2C_c^2} \right] F_y$			Y			Y	
(1) $F_{a1} = \frac{5}{3} + \frac{3}{8} \frac{(KL/r)}{C_c} - \frac{(KL/r)^3}{8C_c^2}$							
(1) $F_{a1} = 1.333 \times F_{a1}$						Y	Y

Note: $C_c = \sqrt{\frac{2\pi^2 E}{F_y}}$

Decision Table to Establish Allowable Compressive Stress on Axially Loaded Member Not Subject to Torsional-Flexural Buckling
Figure 6

ber provision. This value is then defined as the allowable compressive stress by a third action. Note also that the determination of responses to the conditions may also require execution of other tables (such as value of Q in Figure 6).

The tables illustrated in Figures 5 and 6 are termed working tables since their intent is to generate data. Two other general types, switching tables and checking tables, are used in the complete decision table formulation. Switching tables direct the user to other tables while checking tables make comparisons such as actual stress against allowable stress.

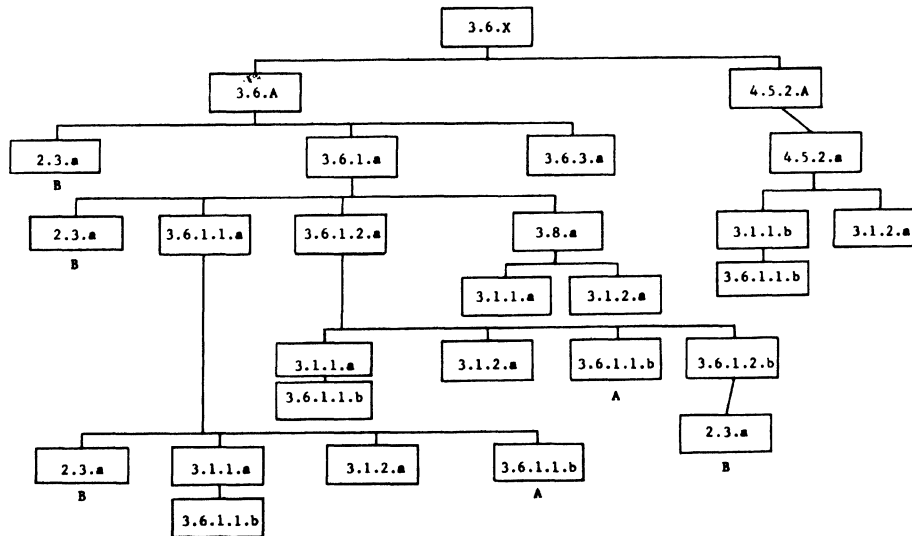


Table Cross-References for Investigation of Member Subject to Axial Load Only

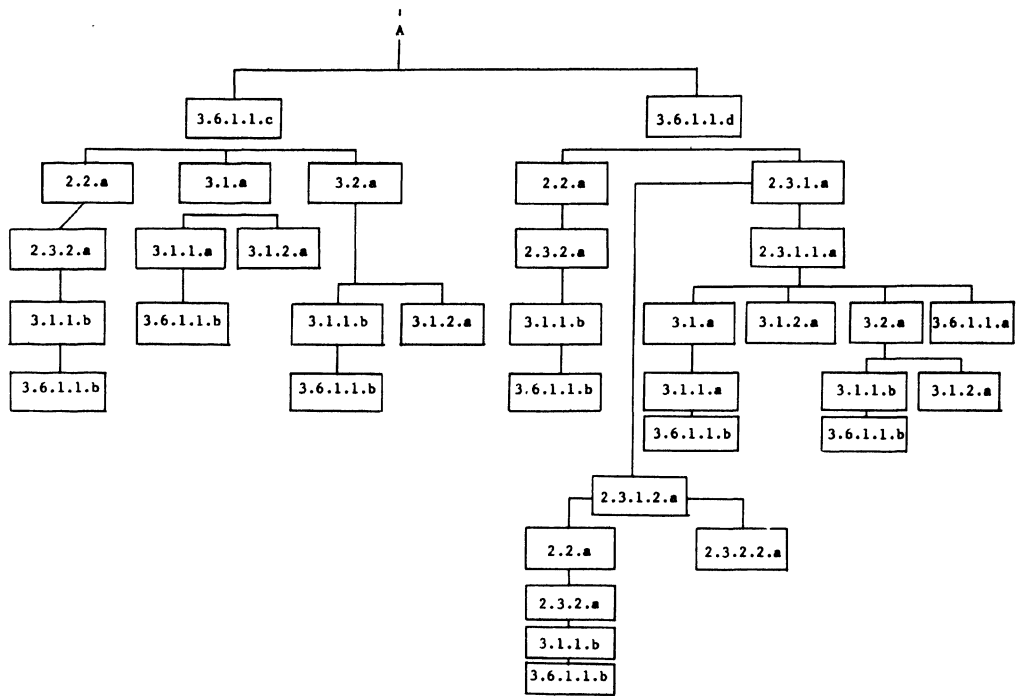


Figure 7 (continued)

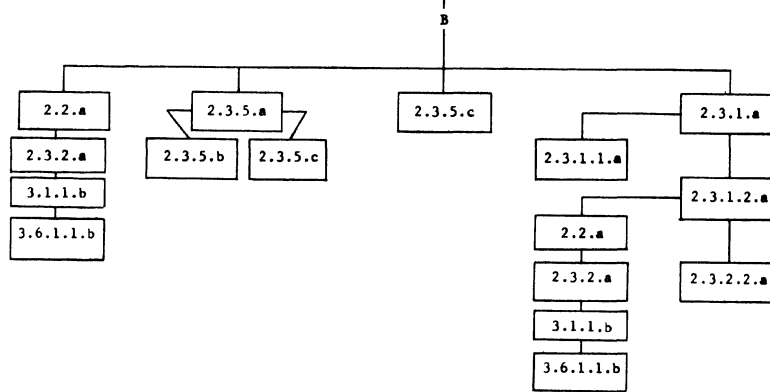


Figure 7 (continued)

COMPUTER APPLICATIONS

The decision tables should be principally useful in preparing computer programs which utilize the Specification provisions. The tables can serve both as a guide in preparing the programs and as documentation of the contents.

Conversion of decision tables into computer programs is discussed in reference 5. Also, a program (4) is now available which directly converts decision tables into Fortran Programming

Language.

The tables as written are somewhat narrative in form. This was considered to be more readable and thus more suitable for this initial presentation. Computer applications will require additional symbols to be introduced in some cases. Also judicious rearrangement of the condition entries would be advantageous in order to reduce the execution time required to check a table.

CONCLUSIONS

Decision tables greatly simplify the interpretation of complex interrelated provisions. As such, they are useful tools for expressing engineering specifications particularly to the inexperienced user. The author is of the opinion that specification writers should consider originating future specifications in a decision table format. This should assist the writers in locating unintentional omissions and help the user avoid initial misinterpretations.

ACKNOWLEDGEMENT

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