INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
Basement failure diagnosis expert system

Diaz Suarez, Carlos Fernando, Ph.D.

The Ohio State University, 1993
BASEMENT FAILURE DIAGNOSIS EXPERT SYSTEM

DISSertation

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By

Carlos Fernando Diaz Suarez, Ph.D.

* * * * *

The Ohio State University

1993

Dissertation Committee:  Approved by
F.C. Hadipriono
R.E. Larew
W.E. Wolfe
J.F. Davis

Adviser
Department of Civil Engineering
DEDICATION

To my parents, my brothers, and my wife.
ACKNOWLEDGMENTS

To Dr. Fabian Hadipriono, my advisor, for his guidance throughout my graduate studies. To Dr. Richard Larew for his care during my graduate studies. To Dr. William Wolfe and Dr. James Davis for their advise during the preparation of this dissertation. To Dr. Stephen Pasternack whose knowledge was essential for the development of this dissertation. To Mr. Steve Bergman, Mr. Frank Bozworth, and Mr. David Caprio, who participated in the validation of the result of this dissertation. I express my sincere gratitude.
VITA

December 26, 1962..............Born- Zapatoca, Colombia

1986............................Ingeniero Civil, Universidad Industrial de Santander, Bucaramanga, Colombia

1989............................Master of Science, The Ohio State University, Columbus, Ohio

PUBLICATIONS


FIELDS OF STUDY

Major Field: Civil Engineering

Studies in construction, building foundations, and computer applications


TABLE OF CONTENTS

DEDICATION .................................. ii
ACKNOWLEDGMENTS .................................. iii
VITA ........................................ iv
LIST OF TABLES ................................... x
LIST OF FIGURES ..................................... xi

CHAPTER PAGE

I. INTRODUCTION ........................................ 1

  1.1 Background on the Study .................................. 3
  1.2 Objectives ............................................ 5
  1.3 Scope and Limitations .................................... 6
    1.3.1 Type of Structure ...................................... 7
    1.3.2 Type of Basement ...................................... 8
    1.3.3 Type of Footing ....................................... 8
    1.3.4 Causes of Basement Failure .............................. 9
    1.3.5 Signs of Basement Failure .............................. 11
  1.4 Expert Systems ...................................... 12
  1.5 Tasks in Developing BAFDES ............................... 14
    1.5.1 Task 1: Knowledge Acquisition ......................... 14
    1.5.2 Task 2: Knowledge Representation ....................... 16
    1.5.3 Task 3: Implementation of BAFDES ..................... 17
    1.5.4 Task 4: Testing and Refinement of BAFDES ............. 18
  1.6 Organization of the Dissertation ........................ 19
<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>II. SIGNS AND CAUSES OF BASEMENT FAILURE</td>
<td>21</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>21</td>
</tr>
<tr>
<td>2.2 Signs of Basement Failure</td>
<td>22</td>
</tr>
<tr>
<td>2.2.1 Signs of soil movement under wall footings</td>
<td>24</td>
</tr>
<tr>
<td>2.2.2 Signs of excessive lateral forces on basement walls</td>
<td>28</td>
</tr>
<tr>
<td>2.2.3 Signs of soil movement under basement floor slabs</td>
<td>34</td>
</tr>
<tr>
<td>2.2.4 Signs of chemical and physical reactions in the floor slab concrete</td>
<td>36</td>
</tr>
<tr>
<td>2.3 Causes of Basement Failure</td>
<td>39</td>
</tr>
<tr>
<td>2.3.1 Preconstruction Causes of Basement Failure</td>
<td>39</td>
</tr>
<tr>
<td>2.3.2 Postconstruction Causes of Basement Failure</td>
<td>55</td>
</tr>
<tr>
<td>2.4 Summary</td>
<td>56</td>
</tr>
<tr>
<td>III. KNOWLEDGE REPRESENTATION AND KNOWLEDGE ACQUISITION</td>
<td>60</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>60</td>
</tr>
<tr>
<td>3.2 Knowledge Acquisition</td>
<td>61</td>
</tr>
<tr>
<td>3.2.1 Knowledge Acquisition from Experts</td>
<td>61</td>
</tr>
<tr>
<td>3.2.1.1 Approaches for Knowledge Acquisition from Experts</td>
<td>62</td>
</tr>
<tr>
<td>3.2.1.2 Knowledge Acquisition Approach for BAFDES</td>
<td>65</td>
</tr>
<tr>
<td>3.2.2 Knowledge Acquisition from Documented Material</td>
<td>68</td>
</tr>
<tr>
<td>3.3 Knowledge Representation</td>
<td>70</td>
</tr>
<tr>
<td>3.3.1 Fault Tree Models</td>
<td>71</td>
</tr>
<tr>
<td>3.3.2 Semantic Net Models</td>
<td>75</td>
</tr>
<tr>
<td>3.4 Hierarchical Classification</td>
<td>80</td>
</tr>
<tr>
<td>CHAPTER</td>
<td>PAGE</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>IV. BAFDES IMPLEMENTATION</td>
<td>90</td>
</tr>
<tr>
<td>4.1 Introduction</td>
<td>90</td>
</tr>
<tr>
<td>4.2 Structure of BAFDES</td>
<td>90</td>
</tr>
<tr>
<td>4.3 Knowledge Base</td>
<td>94</td>
</tr>
<tr>
<td>4.3.1 Objects</td>
<td>94</td>
</tr>
<tr>
<td>4.3.2 Production Rules</td>
<td>96</td>
</tr>
<tr>
<td>4.3.2.1 Rules</td>
<td>97</td>
</tr>
<tr>
<td>4.3.2.2 Methods</td>
<td>98</td>
</tr>
<tr>
<td>4.4 Inference Engine</td>
<td>100</td>
</tr>
<tr>
<td>4.4.1 Internal Inference Engine</td>
<td>100</td>
</tr>
<tr>
<td>4.4.2 External Inference Engine</td>
<td>101</td>
</tr>
<tr>
<td>4.4.3 Hypothesis Search</td>
<td>104</td>
</tr>
<tr>
<td>4.4.4 Hypothesis Search in BAFDES</td>
<td>105</td>
</tr>
<tr>
<td>4.4.5 Knowledge Tree</td>
<td>108</td>
</tr>
<tr>
<td>4.5 User Interface</td>
<td>111</td>
</tr>
<tr>
<td>4.6 External File Interface</td>
<td>115</td>
</tr>
<tr>
<td>4.7 External Files</td>
<td>115</td>
</tr>
<tr>
<td>V. TESTING AND VALIDATION</td>
<td>117</td>
</tr>
<tr>
<td>5.1 Introduction</td>
<td>117</td>
</tr>
<tr>
<td>5.2 Accuracy and Efficiency Validation</td>
<td>119</td>
</tr>
<tr>
<td>5.3 Reasoning Validation</td>
<td>123</td>
</tr>
<tr>
<td>5.3.1 First Part of Reasoning Validation</td>
<td>124</td>
</tr>
<tr>
<td>5.3.2 Second Part of Reasoning Validation</td>
<td>125</td>
</tr>
<tr>
<td>5.3 Expertise Validation</td>
<td>128</td>
</tr>
<tr>
<td>VI. CONCLUSIONS AND RECOMMENDATIONS</td>
<td>133</td>
</tr>
<tr>
<td>6.1 General</td>
<td>133</td>
</tr>
<tr>
<td>6.2 Knowledge Acquisition Process</td>
<td>134</td>
</tr>
<tr>
<td>6.3 Knowledge Representation Models</td>
<td>134</td>
</tr>
<tr>
<td>6.4 Testing and Validation Results</td>
<td>136</td>
</tr>
<tr>
<td>6.5 Recommendations</td>
<td>137</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>139</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>PAGE</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>A. BAFDES USER'S GUIDE</td>
<td>141</td>
</tr>
<tr>
<td>A.1 Installing of BAFDES</td>
<td>142</td>
</tr>
<tr>
<td>A.2 Consulting BAFDES</td>
<td>143</td>
</tr>
<tr>
<td>A.3 Getting Help</td>
<td>145</td>
</tr>
<tr>
<td>A.4 Result of Consultations</td>
<td>146</td>
</tr>
<tr>
<td>A.5 Consultation Samples</td>
<td>147</td>
</tr>
<tr>
<td>B. VALIDATION TREE</td>
<td>177</td>
</tr>
<tr>
<td>C. VALIDATION FORMS AND RESULTS</td>
<td>186</td>
</tr>
<tr>
<td>D. BAFDES CODE</td>
<td>191</td>
</tr>
</tbody>
</table>
LIST OF TABLES

TABLE                                                     PAGE

5.1 Reasoning Validation Result . . . . 127
5.2 Expertise Validation Result . . . . 131
5.3 General Evaluation for BAFDES . . . . 132
<table>
<thead>
<tr>
<th>FIGURES</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Cracking Due to Soil Settlement Cracking</td>
<td>25</td>
</tr>
<tr>
<td>2.2 Typical Basement Wall Cracking Patterns Due to Soil Settlement</td>
<td>27</td>
</tr>
<tr>
<td>2.3 Case of Basement Wall Cracking Due to Soil Settlement</td>
<td>29</td>
</tr>
<tr>
<td>2.4 Basement Wall Cracking Due to Excessive Lateral Pressure</td>
<td>30</td>
</tr>
<tr>
<td>2.5 Cases of Basement Wall Cracking Due to Excessive Lateral Pressure</td>
<td>32</td>
</tr>
<tr>
<td>2.6 Typical Basement Floor Cracking Due to Soil Settlement</td>
<td>35</td>
</tr>
<tr>
<td>2.7 Typical Concrete Shrinkage Cracking in Basement Floor Slab</td>
<td>37</td>
</tr>
<tr>
<td>2.8 Typical Map Cracking</td>
<td>40</td>
</tr>
<tr>
<td>2.9 Increase of Lateral Pressure on Basement Walls Due to Increase in Backfill Height</td>
<td>43</td>
</tr>
<tr>
<td>2.10 Two Dimensional and Three Dimensional Models for Basement Walls</td>
<td>45</td>
</tr>
<tr>
<td>2.11 Cases of Off Set</td>
<td>47</td>
</tr>
<tr>
<td>2.12 Drainage Systems for Residential Basements</td>
<td>51</td>
</tr>
<tr>
<td>2.13 Increase of Hydrostatic Pressure on Basement Walls</td>
<td>52</td>
</tr>
<tr>
<td>2.14 Consequences of Hydrostatic Pressure</td>
<td>54</td>
</tr>
<tr>
<td>2.15 Typical Case of Soil Discontinuity</td>
<td>57</td>
</tr>
<tr>
<td>FIGURES</td>
<td>PAGE</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>3.1 Fault Tree for Excessive Hydrostatic Pressure</td>
<td>72</td>
</tr>
<tr>
<td>3.2 Semantic Net for Excessive Hydrostatic Pressure</td>
<td>76</td>
</tr>
<tr>
<td>3.3 Initial Classificatory Tree for Excessive Hydrostatic Pressure</td>
<td>82</td>
</tr>
<tr>
<td>3.4 Refined Classificatory Tree for Excessive Hydrostatic Pressure</td>
<td>83</td>
</tr>
<tr>
<td>3.5 Production Rules from Semantic Net Models</td>
<td>87</td>
</tr>
<tr>
<td>4.1 BAFDES Architecture</td>
<td>92</td>
</tr>
<tr>
<td>4.2 Object Structure</td>
<td>95</td>
</tr>
<tr>
<td>4.3 BAFDES Agenda</td>
<td>103</td>
</tr>
<tr>
<td>4.4 BAFDES Knowledge Tree</td>
<td>109</td>
</tr>
<tr>
<td>5.1 Validation Tree</td>
<td>121</td>
</tr>
<tr>
<td>A.1 Welcome Screen</td>
<td>148</td>
</tr>
<tr>
<td>A.2 Indication of Damaged Element Screen</td>
<td>149</td>
</tr>
<tr>
<td>A.3 Indication of Damage Screen</td>
<td>150</td>
</tr>
<tr>
<td>A.4 Major Problems Hyper Screen</td>
<td>151</td>
</tr>
<tr>
<td>A.5 Other Common Problems Hyper Screen</td>
<td>152</td>
</tr>
<tr>
<td>A.6 Cracking Selection Screen</td>
<td>153</td>
</tr>
<tr>
<td>A.7 Display of More Cracks Screen</td>
<td>154</td>
</tr>
<tr>
<td>A.8 Cracking Selection Expand Screen</td>
<td>155</td>
</tr>
<tr>
<td>A.9 Wall Dimensions Screen</td>
<td>156</td>
</tr>
<tr>
<td>A.10 Wall Dimensions Hyper Screen</td>
<td>157</td>
</tr>
<tr>
<td>A.11 First Intermediate Conclusion Screen</td>
<td>158</td>
</tr>
<tr>
<td>A.12 Moisture Signs Screen</td>
<td>159</td>
</tr>
<tr>
<td>A.13 Moisture Signs Hyper Screen</td>
<td>160</td>
</tr>
<tr>
<td>A.14 Ground Level Screen</td>
<td>161</td>
</tr>
<tr>
<td>FIGURES</td>
<td>PAGE</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>A.15 Ground Level Hyper Screen</td>
<td>162</td>
</tr>
<tr>
<td>A.16 Soil Characteristics Screen</td>
<td>163</td>
</tr>
<tr>
<td>A.17 Second Intermediate Conclusion</td>
<td>164</td>
</tr>
<tr>
<td>A.18 Sidewalk Settlement Screen</td>
<td>165</td>
</tr>
<tr>
<td>A.19 Final Conclusion Screen</td>
<td>166</td>
</tr>
<tr>
<td>A.20 Welcome Screen</td>
<td>167</td>
</tr>
<tr>
<td>A.21 Case One Screen</td>
<td>168</td>
</tr>
<tr>
<td>A.22 Case Two Screen</td>
<td>169</td>
</tr>
<tr>
<td>A.23 Case Three Screen</td>
<td>170</td>
</tr>
<tr>
<td>A.24 Case Four Screen</td>
<td>171</td>
</tr>
<tr>
<td>A.25 Case Five Screen</td>
<td>172</td>
</tr>
<tr>
<td>A.26 Floor Cracking Pattern Selection Screen</td>
<td>173</td>
</tr>
<tr>
<td>A.27 Floor Characteristics Screen</td>
<td>174</td>
</tr>
<tr>
<td>A.28 Level Difference Hyper Screen</td>
<td>175</td>
</tr>
<tr>
<td>A.29 Final Conclusion Screen</td>
<td>176</td>
</tr>
</tbody>
</table>
Failures and damage in basements are two of the most common problems in residential buildings in the United States. Specifications for solving a particular problem of moisture movement through the walls range from coating the interior of the walls with waterproofing paint to complete removal and replacement of backfill behind basement walls. For the same case, the price of the specified repairs can vary from one hundred to ten thousand dollars. It is of primary importance to correctly identify the causes of failure before a repair procedure is proposed.

An expert frequently is needed to assess the causes of basement failures. Hiring an expert to diagnose the cause of the damage to one single house is often more expensive than repairing the cracking caused by the basement failure. For this reason, many owners shy away from hiring consultants to inspect the condition of the basement. Instead, owners hire the services of home repair companies that may not have qualified personnel to perform proper diagnose of basement failures.
Previous studies show that failures of larger structures are not uncommon (Hadipriono, 1985, Hadipriono and Diaz, 1988). Failures of large structures have overshadowed failures in residential building basements. However, there are more than twenty companies who specialize in home repairs in the central Ohio area alone (Ameritech Pages Plus, 1991-1992). The monetary loss due to basement failures is further increased because after the repair of cracks, cracking usually reappears due to improper diagnosis of the failure, and repair work is needed again. Improper diagnosis occurs due to first, incorrect determination of the causes of failure, and second, due to the use of improper methods to correct the problems. Millions of dollars could be saved if home repair companies had an affordable tool that could automate the process of determining the causes of basement failures.

Although structural and soil mechanics theory is used to discover the causes of basement failures, experts frequently use intuition, rules of thumb, and heuristic approaches. Despite the fact that these approaches often are not quantifiable, an excellent and affordable diagnostic tool could be constructed if the opinions of these experts were to be incorporated into a computerized system. In general, computerized systems that use expert intuition, rules of thumb and heuristic approaches are
called expert systems.

This dissertation's findings head to the development of the Basement Failure Diagnosis Expert System, BAFDES, an expert system that can identify causes of basement failure. BAFDES is very user friendly, provides on-screen help and explanations at the user's request, and indicates how the conclusions of a consultation are reached. BAFDES also has graphic capabilities to show cracking patterns of basement components, moisture marks, and other characteristics of the failure.

The knowledge required to accomplish the objectives of this dissertation was gathered from building foundation experts and from shared sources accepted by most building foundation engineers. A methodology of gathering knowledge from experts, which collects first the line of reasoning and then specific pieces of information, is introduced.

This dissertation introduces a method for utilizing fault tree models to help in producing semantic net models, and then translating knowledge representation in the form of semantic net models into a classificatory tree.

1.1 Background on the Study

While basement failures are very common, most of them do not develop into a dangerous condition. However, when basement walls crack, underground water enters the basement
and causes damage to the finishes and property inside the basement. Basement failures can lead to deterioration and depreciation of buildings. Signs of basement failure can appear soon after construction or several years later.

The principal factors to keep in mind when designing and constructing basements are three. The first is the stability of the basement walls to withstand lateral pressure from the soil. The second is the stability of the soil that supports the vertical load of the basement walls. And third is the stability of the soil under the floor slab. The basement walls are considered stable when they can support the lateral forces of the soil without cracking. The soil supporting the vertical load of the basement walls is considered stable when its bearing capacity is enough to safely support the building and when the soil deformations do not cause damage to the building. The soil supporting the slab is considered stable when changes in the soil volume do not cause cracks in the floor slab.

The most common causes of failure of the basement walls are poor design and construction practices, and volume changes in the soil. The most common causes of failure of the soil to support the basement walls are excessive differential settlements due to short and long term consolidation. The most common causes of failure of
the floor slab are soil expansion and shrinkage due to changes in soil moisture, and concrete shrinkage. The following paragraphs give a background of expert systems that use expert's knowledge to solve problems.

Since 1980, expert systems often have been applied to areas of civil engineering. Such applications include water resources management, construction management and building design (Palmer, 1988, Hadipriono and Diaz, 1989). Expert systems are a type of computer program that is becoming popular in many areas where the experience of the experts is needed but not readily available. Expert system technology is being used, for example, by the National Aeronautics and Space Administration, NASA, to construct computer programs based on the knowledge and experience of its experts. This allows for the continued use of experts' knowledge after the experts have left the agency. In this proposal, expert systems are used to analyze cases of basement failure, and to reach the objective of the study.

1.2 Objectives

The objective of this dissertation is to construct an expert system that can automate the diagnosis of basement failures in residential low rise-buildings. For this purpose, BAFDES was constructed. BAFDES identifies causes of failure of basement walls and in basement floor slabs.
Among the signs of failure that BAFDES uses to determine the causes of basement failures are: cracking pattern of basement walls, cracking pattern of the concrete floor, doors and windows that cannot be opened or closed, leaning walls, and signs of water leakage through the walls or floor.

BAFDES is also a very friendly tool that home repair companies can consult for decision-making purposes. Extensive textual and graphic help is provided on screen. BAFDES indicates the most probable causes of the failure, and provides clear explanation on how the conclusion was reached. However, the final decision is left to the user's judgment.

Since every type of basement, footing, and structure is different and the types of problems and solutions are diverse, BAFDES has certain limitations.

1.3 Scope and Limitations

The scope and limitations of BAFDES need to be established due to the variety of buildings and the large amount of knowledge that is needed to find the cause of every type of basement failure. Another limitation of BAFDES, and in general of all expert systems, is the fact that the source of the knowledge is incomplete by nature, since the knowledge is acquired from experience. The next
paragraphs indicate the type of structure, footing, basement and failure covered in this dissertation.

1.3.1 Type of Structure

This section indicates the type of structure that BAFDES includes in its knowledge base. For the purpose of this study, the structure type is low-rise residential buildings. Thus, the structural components include:

1. Unreinforced masonry walls;
2. Reinforced grouted masonry (as illustrated in Council of American Building Officials, CABO, 1989, Pg. 75);
3. Reinforced hollow masonry walls (as illustrated in CABO, 1989, Pg. 76);
4. Horizontally and vertically reinforced masonry walls;
5. Wood or steel frame.

The type of roof can be concrete slab, and steel or wood frame. Although the knowledge used to develop BAFDES comes from experts in central Ohio, BAFDES can be used for cases of basement failure in areas with similar basement characteristics.
1.3.2 Type of Basement

This dissertation includes basements with walls, wall footings and a floor slab as components. The basement walls are concrete, masonry, or stone walls. The floor slab can be reinforced or unreinforced concrete slab. Most basements in residential buildings in Ohio follow this description.

1.3.3 Type of Footing

This section indicates the types of footing that BAFDES includes in its knowledge base. The footing types are shallow footings recommended for use in low-rise residential buildings (CABO, 1989). They include:

1. Concrete slab footings for bearing wall structures;
2. Concrete bearing wall footings;
3. Concrete masonry bearing wall footings.

The types of soil, identified as organic, clay, silt, sand or gravel, are acceptable for BAFDES.

After describing the physical characteristics of the structures covered in this dissertation, we need to define what basement failures are covered here. To do this, we describe the causes and signs of basement failures included in this dissertation.
1.3.4 Causes of Basement Failure

This dissertation incorporates into the knowledge base causes for the three most common types of failure in Ohio, namely, cracking of basement walls due to lateral pressure, settlement of basement walls, and cracking of basement floor due to changes in soil volume. These types of failure can also originate from more specific causes of failure. Chapter Two includes descriptions of common causes of failure in Ohio.

Lateral pressure in the walls can be caused by excessive hydrostatic pressure, excessive soil weight pressure, expansive soils, and volume increase of the soil due to freezing. However, basement walls can also fail due to defects that originated during design or construction of the walls as well as due to the backfill behind the walls. The most common defects are lack of drainage, improper backfill, insufficient reinforcement in the basement walls, and use of improper models for structural design and soil behavior. Other causes of wall defects are poor quality of materials such as cement and sand, improper concrete placing and curing.

Excessive settlement of the basement walls occurs when the actual settlement is larger than expected during the design process. Excessive settlement is in most cases due to settlement of unidentified pockets of poor soil and long
term consolidation. Among the factors that influence the amount of consolidation settlement are the void ratio of the soil, and stress applied on the consolidating soil. It is generally accepted that the amount of consolidation settlement can be adequately predicted; however, the amount of consolidation settlement for a given span of time is difficult to predict in preconsolidated soils.

Sometimes, bearing capacity failure occurs when loads imposed on the soil by the structure are higher than the bearing capacity of the soil. This type of failure is not included in this dissertation because, most of the time, failure due to soil settlement takes place before bearing capacity failure occurs.

The most common cause of damage in the basement floor slab is changes of volume in expansive soil present under the slab and concrete shrinkage. Failure due to expansive soil takes place when the wetting and drying of the soil produces excessive changes in soil volume. However, soil expansion is not a severe problem in Ohio and rarely causes problems to residential buildings.

Human errors in the geotechnical area of basement design and construction can also be the cause of failures. Failure to perform soil exploration and testing and to make predictions of soil behavior are some of the most common human errors.
All basement failures show signs that permit the identification of the cause of the basement failure. The next section covers the signs of basement failure used in this dissertation in order to determine the cause of the failure.

1.3.5 Signs of Basement Failure

This section includes the scope and limitations of the signs of basement failure and of the tests required to determine the type of failure that has occurred. The signs of failure included in the knowledge of BAFDES are: cracking pattern of basement walls, cracking pattern of the concrete floor, doors and windows that cannot be opened or closed, leaning walls, and signs of water leakage through the walls or floor. In addition, depending on the failure case, soil properties such as Atterberg limits, plasticity, and strength may be required from the user. Chapter Two includes descriptions of signs of failure generated by the most common causes of failure in Ohio.

This dissertation utilizes relations between signs and causes of basement failure in order to build an expert system that automates the process of determining the causes of basement failures.
1.4 Expert Systems

Expert systems may be defined as computer programs that capture, accommodate, and manipulate human knowledge and expertise to solve a particular problem (Hadipriono and Diaz, 1989). Rather than dealing with data, expert systems primarily deal with knowledge. Expert systems often use rules of thumb and subjective assessment to solve problems, and are typically user-friendly. They provide advice by asking for information about the problem and then calling upon available knowledge to provide an intelligent solution.

Expert systems have two basic components, the knowledge base and the inference engine. The knowledge of an expert system is often stored as a series of IF/THEN statements developed for particular situations. This type of expert system is called a rule-based expert system. BAFDES is a rule-based expert system. Each IF/THEN statement is called a production rule. Two examples of production rules follow:

IF cracks appear in the basement walls, and the cracks widen with time, THEN differential soil settlement under the footing occurred.

IF differential soil settlement has occurred, and there is a pocket of peat below the footing, THEN the cause of the basement failure is differential settlement of the peat pocket.
The inference engine controls the use of the knowledge to reach the goal of a consultation, the user interface, and in some cases, the execution of external programs.

Besides the knowledge base and the inference engine, expert systems interface with the user. The user interface involves the input of evidence, which leads to a decision-making process, explanation capability, help windows, and the explanation of the final conclusion of a consultation.

Software tools are used to facilitate the construction of expert systems. Several tools are available in the market. They range from simple shells, like EXSYS, to more sophisticated software, such as GURU. Different software packages are adequate for different rule-based expert systems. This section indicates software features that are considered more important in this dissertation.

Graphic capabilities are needed to identify cracking patterns and to provide a large amount of visual information to the user. A good user interface is necessary to provide the user with extensive on-screen help and explanation capabilities that help in making expert systems user-friendly. The software tool should also provide mechanisms to read and write external files. In addition, system requirements to run the expert system should be within the specifications of the average system that is available to a modern civil engineer. An appropriate
computer system consists of an IBM PS/2 microcomputer with
two MB RAM memory, hard drive, and VGA color monitor, with
Windows or OS/2 environment.

In this dissertation, the shell Level 5 Object was
used. Level 5 Object is a highly interactive and functional
rule-based tool with external interface capabilities that
are very useful for accommodating graphics and text written
with other packages. Furthermore, Level 5 Object has
extensive explanation capabilities, and a very user
friendly interface.

In order to assure a successful development of BAFDES,
this project followed a research strategy divided into
tasks.

1.5 Tasks in Developing BAFDES

This dissertation was carried out in several major
tasks. The major tasks are knowledge acquisition, knowledge
representation, implementation of BAFDES, and testing and
validation of BAFDES.

1.5.1 Task 1: Knowledge Acquisition

Knowledge acquisition includes the study of triggering
and enabling causes of basement failure, the mechanism of
failure, and the knowledge representation.

Triggering causes are those which are external to the
structure. For cases of basement failures, soil freezing and soil expansion are triggering causes of failure. The study of triggering causes includes literature research of soil/structure interaction and static forces that exist between the soil and the basement.

Enabling causes deal with errors in design or construction. For cases of basement failure, improper design of basement walls and improper compaction of backfill are enabling causes of failure. The study of enabling causes includes correct design and construction practices for basement components, and correct practices for soil exploration and stabilization.

The mechanism of failure is of primary importance when studying causes of failures in buildings. In this dissertation, the mechanism of failure is represented by the tree of cause-consequence relations that produced the basement failure. An example of mechanism of failure for a cracked basement wall is:

Cause: pocket of very soft soil.  
Consequence: settlement of basement wall.

Cause: settlement of basement wall.  
Consequence: excessive stresses in basement walls.

Cause: excessive stresses in basement walls.  
Consequence: basement wall cracking.

Cause: basement wall cracking.  
Consequence: water leakage into the basement.
The first step in the diagnosis of basement problems is to observe signs of instability, including observations of damage caused to the structure such as cracking of basement walls. Next, the mechanism of failure should be identified since it indicates the origin of the failure. Then, the characteristics of the basement and soil around and under the basement are determined. The last step is determining the causes of the basement failure. It may require a complete soil-structure analysis to indicate the basement deficiencies. The analysis, however, needs a substantial amount of information that in many cases is difficult or expensive to obtain. Heuristic assessments were used to overcome this weakness. Thus, to accomplish this task, the study used soil mechanics and foundation handbooks, case studies from consulting companies, and the experience of experts.

Along with knowledge acquisition, the task of knowledge representation is carried out.

1.5.2 Task 2: Knowledge Representation

The selection of the knowledge representation model is of primary importance. The selection of the knowledge representation model depends on the process that the expert follows when studying cases of basement failures. Experts use subgoals as part of the reasoning strategy to arrive at
the final goal. These subgoals and their order are clearly identified and included in the knowledge representation.

Fault trees and semantic nets are used to build an appropriate knowledge representation for BAFDES. Fault tree models follow a reasoning based on causal relationships. The fact that fault trees can represent causal relationships facilitates the representation and decompilation of experts' knowledge. Fault trees provide the basis to build a complete knowledge representation using semantic nets. These semantic nets result in a well-structured and clear knowledge representation.

Once the knowledge has been gathered and organized into a form of knowledge representation, the implementation of the expert system can be carried out.

1.5.3 Task 3: Implementation of BAFDES

The construction of the knowledge base includes the search algorithm, identification of parameters, construction of production rules and knowledge organization in the knowledge base.

The search algorithm of the expert system can be different than the reasoning strategy used by experts to arrive to the correct answer since computers do not process information in the same form humans do. The search algorithm needs to be determined before the knowledge is
entered in the knowledge base. BAFDES uses a search tree built from the knowledge representation to drive the reasoning process.

The first step during the implementation of BAFDES was to create a small prototype or a scaled-down model of the final knowledge base. This prototype is useful for testing the user interface, inference mechanism, data management, and integrity of the expert system. After successful testing of the prototype, BAFDES was expanded.

The knowledge is divided into problems due to lateral forces on basement walls, volume changes in the soil underneath the basement wall footings, and volume changes in the soil underneath the basement floor. Given the evidence of foundation problems, BAFDES indicates what type of information is necessary to properly evaluate the problem.

While an expert system is being developed, testing and refinements should be performed in order to obtain a sound final product.

1.5.4 Task 4: Testing and Refinement of BAFDES

Testing and refinement of BAFDES was carried out during and at the end of this dissertation. Case studies for residential buildings in Ohio were solved by experts and by BAFDES. Three types of tests were carried out to
ensure the correct functioning of BAFDES. In this project, the first type of testing examines the correctness of the search tree in Level 5 Object according to the knowledge representation.

The second type consists of cases given and solved by the expert who participated in the knowledge acquisition stage. This testing examines the conformity of the expert system answer to the expert's knowledge, completeness and accuracy.

The third type of testing consists of cases given and solved by experts not involved in the knowledge acquisition stage. This testing examines the possibility of conflicting answers and convenience of the user interface.

1.6 Organization of the Dissertation

This dissertation contains six chapters and three appendixes. Chapter One of this dissertation presents the introduction, background, objective, limitations, and the research plan of this dissertation; Chapter Two presents causes and signs of basement failure in Ohio; Chapter Three describes the knowledge acquisition process and the knowledge representation used to build BAFDES; Chapter Four details the implementation process used to build BAFDES; Chapter Five explains the testing validation of BAFDES; and Chapter Six presents the conclusions and recommendations.
from this dissertation. Appendix A includes the user's guide to BAFDES and a consultation run with BAFDES; Appendix B includes the validation tree for basement failure used during validation of BAFDES; Appendix C includes forms used for the validation of BAFDES by experts not involved during the development of the system. Appendix D includes the program source code.
CHAPTER II

SIGNS AND CAUSES OF BASEMENT FAILURE

2.1 Introduction

Signs and causes of basement failure are usually bound to each other since the signs of failure are usually the consequence of the failure.

Failure can be defined in different ways depending on the extent or type of damage, and the particular interests of the person who defines failure. For example, basement wall cracking that to the home owner is considered failure, to the builder may be normal or expected cracking. In this dissertation, failure includes excessive flexural deformation of basement structural components, cracking due to shear or flexure stresses, excessive vertical settlements, and moisture movement through the walls, from the view point of the home owner. Basement walls and the basement floor slab are the two main structural components of basements, with basement walls being of primary concern. Failures in basement walls are common since they are rarely designed from a structural point of view, and the loads applied on the walls may exceed their strength. Excessive
deformation of basement components leads to cracking, water
leakage, progressive structural damage, and quick
deterioration of buildings.

In order to determine the causes of basement failures,
experts frequently use intuition, rules of thumb, and
heuristic approaches related to the signs of basement
failure. This chapter presents observed types of basement
failures for low rise residential buildings in central
Ohio, causes of failure, and experts' experiential judgment
that can be used to identify causes of failure. More
specifically, the dissertation describes signs of failure
that appear when a given mechanism of failure occurs.
Experts and investigators use these signs to determine
causes of basement failure.

The signs of basement failure can be used to identify
the cause of the failure.

2.2 Signs of Basement Failure

Signs of basement failure come in the form of bowing
or cracking of basement walls or floor, deformation of
nonstructural elements such as window and door frames, and
moisture movement through the basement walls and slab.

The characteristics of the cracking that need to be
noticed in order to determine causes of basement failure
include: width, depth, distribution, pattern, location and
direction of the cracks. Excessive moisture or water
leakage through basement walls or floor is the most common
problem observed in basements. Although this may be a sign
of basement failure, most of the time this indicates poor
damp proofing and/or defective drainage around the
basement.

The signs of basement failure can be divided into four
groups. The first group includes signs that usually appear
when basement failures are caused by movement of the soil
under basement walls, such as soil settlement and soil
expansion. The second group of signs includes those that
usually appear when basement failures are caused by
excessive lateral forces on basement walls, such as high
hydrostatic pressure and expansion of soil behind basement
walls. The third group includes signs that usually appear
when basement failures are caused by movement of the soil
under the basement floor slab, such as soil settlement and
soil expansion. The fourth group includes signs that appear
when the concrete in the floor slab cracks due to chemical
and physical reactions in the concrete, such as excessive
evaporation rate after concrete placement or concrete
shrinkage. These four groups of cracking present particular
characteristics that are important when investigating
basement failures, and are described next.
2.2.1 Signs of soil movement under wall footings

The signs of soil movement under wall footings are cracking of walls -- either long and diagonal or vertical, wide cracks that go through the full thickness of the wall -- opening of joints, deformation of door and window frames, and in general, geometric distortion of elements in the basement. Cracking is the most frequent and noticeable sign of soil movement under basement walls.

Masonry, concrete, and stone walls can absorb large compression loads, but they are weak if loaded in tension. Cracks in masonry, concrete and stone walls due to soil movement are perpendicular to the isostatic tension lines of walls. This means that the cracking is caused by tension forces perpendicular to the cracks (Mana, 1978). Figure 2.1(a) illustrates the isostatic tension lines for a concrete wall of a house where settlement in one extreme of the wall occurred. Figure 2.1(b) indicates the cracking pattern that could develop from the settlement shown in Figure 2.1(a). A similar mechanism applies to basement walls. The described mechanism may also bring about loss of bearing of structural and constructive elements, distortion of elements in or attached to the walls, such as window and door frames, and some types of cracking in the ceiling of the basement.

Although the previous description assumes a single
(a) Isostatic Tension Lines

(b) Cracking Pattern

(c) Three-Dimensional Case

Figure 2.1 Cracking Due to Soil Settlement Cracking
concrete wall, the mechanism is also valid for the three-dimensional case shown in Figure 2.1(c). In this case, all the walls affected will follow the same mechanism of the single wall described earlier. Variations of cracking occur depending on the existence and location of openings such as windows and doors. These openings create weak spots in walls and influence the direction of isostatic lines and cracking. Figure 2.1(c) shows a building with two cracked walls. The first wall shows the cracking that would occur in a wall with a window, while the second wall shows the typical cracking in a wall without a window.

The cracking pattern in masonry, concrete, or stone walls indicates the type, place, and magnitude of the soil movement under the foundation. Cracks due to soil settlement are predominantly diagonal, and end perpendicular to the border of the wall. They can occur in corners or in the middle of the wall. A variation of the cracking consists of a dominant vertical crack in the middle of the wall or in steps down of the wall elevation. These cracks are usually wider at the top than at the bottom. Figure 2.2 shows commonly observed cracking patterns in concrete walls for different soil settlement situations. The same cracking patterns apply for masonry and stone walls, with the difference being that in masonry and stone walls the cracking usually follows the mortar
Figure 2.2 Typical Basement Wall Cracking Patterns Due to Soil Settlement
between blocks or stones. Figure 2.3 shows the detail of a crack due to soil settlement.

To determine the current status of the soil movement, it is important to determine the speed of the movement and if the process has already stopped. Some cases of basement failure develop in a matter of days, while others may take years to develop. A method to determine the speed of the soil movement is the gypsum plate method. This method consists of placing gypsum plates, or plaster, measuring about four by four inches on a crack. For a period of time, the plate is monitored for cracking and the magnitude of the cracking. If the plaster presents wide cracking after a few weeks, there is considerable increase of crack width in the cracked wall. On the other hand, if the plaster presents simply hairline cracking after a few weeks, the cracks in the cracked element are stationary.

2.2.2 Signs of excessive lateral forces on basement walls

The signs of excessive lateral forces on basement walls are cracking, and/or bowing of the basement walls. Cracking may appear in three forms. The first consists of diagonal narrow cracks starting in the lower corners of walls, and running up and away from the corner. This cracking is typical for walls where the length/height ratio is less than three [see Figure 2.4(a)]. The second consists
Figure 2.3 Case of Basement Wall Cracking Due to Soil Settlement
(Courtesy of Dr. Stephen Pasternack)
Figure 2.4 Basement Wall Cracking Due to Excessive Lateral Pressure

(a) Cracking Pattern for $L/H < 3$

(b) Cracking Pattern for $L/H > 3$

(c) Cracking Pattern for Soil Freezing
of a dominant horizontal crack typical for walls where the length/height ratio is more than three. This crack is wider in the middle of the wall and can be located approximately two thirds of the way up the basement wall [see Figures 2.4(b and c)]. These two cases of cracking are caused by excessive pressure applied over the whole height of the wall. For the first two cases, bowing of the wall can often be observed before visible cracks develop.

Figures 2.5 (a to c) show case studies of cracking due to excessive lateral pressure on the basement walls.

The third case occurs due to freezing of soil behind walls, and is similar to the cracking shown in Figures 2.4(b and c). For the third case, however, the crack is located two or three feet below the ground level. In Ohio, the top two or three feet of soil may freeze during winter. Freezing causes soil expansion, which in turn, produces large lateral pressure on the top part of basement walls. When the wall cannot withstand this pressure, a horizontal crack at the depth of the freezing soil appears. In Ohio, this depth is about two feet from ground level, but varies depending on the geographic location. In south east Ohio, for example, this type of cracking is not very common since the weather is not as severe as in northern Ohio.
Figure 2.5 Cases of Basement Wall Cracking Due to Excessive Lateral Pressure
(Courtesy of Dr. Stephen Pasternack)
2.2.3 Signs of soil movement under basement floor slabs

The signs of soil movement under a basement floor slab are cracking and bowing of the basement floor slab.

A floor slab is usually an unreinforced two to four inch thick concrete slab on ground. Due to the absence of reinforcement, the slab can easily crack when differential settlement of the soil underneath takes place. When soil settlement occurs, cracking of the slab usually appears after cracking in the walls has already occurred. For this reason, many times a study of the failure is done based on damage to the basement walls, before the floor slab cracks. A typical floor cracking due to differential soil settlement is shown in the three-dimensional case shown in Figure 2.6. When wide cracking occurs, it is common to see that cracks in the walls converge with cracks in the floor slab.

The characteristics of the cracking in the floor slab and basement walls, if any cracking is observed, indicate the type, place, and magnitude of the soil movement under the floor slab. Cracks in the floor slab due to soil settlement are usually accompanied by a differential vertical movement between the two sides of the cracks. Additionally, wide cracks usually converge with wide cracks in the basement walls. The location of the cracks indicates the magnitude of the settlement. Cracking in a corner of
Figure 2.6 Typical Basement Floor Cracking Due to Soil Settlement
the floor indicates the isolated settlement of the cracked corner, while wide cracks scattered over the slab indicate generalized settlement under the entire slab. Cracking around the floor slab accompanied by uplift of the slab strongly suggests the presence of expansive soil under the slab.

Bowing of the slab is also a sign of expansive soil under the slab, but in this case the consequences of soil movement are not so severe. Bowing of the slab produces narrow cracking, which in turn, may lead to water leakage or increase of moisture in the basement.

2.2.4 Signs of chemical and physical reactions in the floor slab concrete

The signs of chemical and physical reactions in the floor slab concrete are several patterns of cracking. The two most common patterns of cracking in this group are concrete shrinkage cracking and mapped cracking. Concrete shrinkage cracking shows as long parallel cracks, with no level difference between the two sides of the cracks [see Figures 2.7(a and b)]. Cracking can appear in one or two perpendicular directions. Concrete shrinkage cracking develops in a short time and the cracking does not spread any further after its original development. Mapped cracking appears as random short cracks that simulate a map [see
Figure 2.7 Typical Concrete Shrinkage Cracking in Basement Floor Slab
Figures 2.8(a and b)]. This cracking is typical of improper curing or finishing of the concrete. Note that shrinkage cracks are wider and more spaced than mapped cracks.

2.3 Causes of basement failure

The causes of basement failure can be divided into preconstruction and postconstruction causes. However, while basement failures can be attributed to postconstruction causes, most basement failures have a root in preconstruction errors.

2.3.1 Preconstruction causes of basement failure

Often, basement failures are caused by underestimating design standards and errors during design and construction; these are preconstruction causes of basement failure. According to experts, inadequate design of basement walls before construction probably accounts for 75 to 85 percent of all problems which occur (Pasternack, 1992). During the design of basements, several issues must be taken into account. Walls should be able to withstand external lateral forces and to keep water out of the basement. The floor slab should provide a level surface and, like basement walls, should keep water out of the basement. Wall footings must transmit the load of the building to the soil and distribute this load in such a way that the stresses
Figure 2.8 Typical Map Cracking
(Courtesy of Dr. Stephen Pasternack)
applied to the soil do not cause excessive settlement of the soil.

For most residential buildings, basement wall strength required by construction and design codes such as CABO One and Two Family Dwelling Code (1989) is adequate. However, in cases where poor soil conditions exist, caution should be used since codes assume average soil conditions. For example, for design of basement walls, CABO (1989) assumes that the soil behind basement walls applies a lateral pressure equivalent to the lateral pressure caused by a liquid that weighs 30 pcf (0.5 g/cm³). This assumption is acceptable for most cases, but sometimes the pressure due to the soil weight can exceed 30 pcf (0.5 g/cm³) of hydrostatic pressure.

In central Ohio, unreinforced eight inch masonry block is typically used in basement construction. Until recently, a common practice was to place a sixteen by sixteen inch pilaster every twelve feet of the wall length (Pasternack, 1992). Common construction procedures for drainage behind masonry or block basement walls was through weepholes in the bottom course of block to the interior underslab gravel. To worsen the situation, the backfill behind basement walls is done with on-site soils, usually cohesive. These practices result in poorly constructed drainage, under-reinforced walls, and underestimation of
the magnitude of the loads applied on the basement components. In commercial building basements however, failure rarely occurs due to the fact that commercial basements are designed using established engineering practices.

During construction, builders must follow the specifications given by the designer or by building codes. If changes are needed during or before construction, or if different conditions appear, the designer should be consulted. CABO (1989) indicates the recommended reinforcement for masonry basement walls for given heights of fill behind walls.

For the example in Figure 2.9, a fill four feet high, and lateral soil pressure of 30 pcf (0.5 g/cm³) equivalent fluid weight, would produce a load equal to 0.5 x 30 pcf x 4² ft, equal to 240 lb/lf of wall (355 kg/m of wall). In order to utilize the basement for living space, the builder may feel compelled to add one more block to the basement height, increasing the height of the fill by one block, to approximately four feet eight inches. If this were done, the lateral soil load would be equal to 327 lb/lf of wall (467 kg/m of wall). In this particular example, an increase of the wall height equal to ten percent causes a thirty-six percent increase of force on the wall (see Figure 2.9). It is likely that the original wall design would be inadequate
Figure 2.9 Increase of Lateral Pressure on Basement Walls Due to Increase in Backfill Height
for the real conditions of the basement.

Insufficient reinforcement in the basement walls to support the excessive lateral load could lead to bowing and cracking of the walls. When this is the case, two types of cracking can appear. The first is typical of walls where, as a rule of thumb, L/H is larger than three, and consists of a dominant long horizontal crack. The crack is usually long and narrow, but wider in the middle of the wall length [see Figures 2.4(b and c)]. The second is typical of walls where, as a rule of thumb, L/H is smaller than three, and consists of narrow diagonal cracks in the lower corners of the wall [see Figure 2.4(a)] (Pasternack, 1992).

A common cause of failure of basements is inadequate reinforcement in basement walls. Usually, reinforcement in basement walls is placed assuming that the structural behavior of the wall can be correctly simulated by the model shown in Figure 2.10(a). Here, the basement wall is simplified to a slab supported at the top and at the bottom. This assumption is correct for long walls where L/H is in general larger than three. However, for walls where L/H is smaller than three, the walls perpendicular to the wall under analysis may create a three-dimensional effect that is better represented by the model shown in Figure 2.10(b) (Pasternack, 1992). Here, the basement wall is supported on the sides by perpendicular walls and on the
Figure 2.10 Two Dimensional and Three Dimensional Models for Basement Walls
bottom by the wall footing. The use of the first model for the structural design of basement walls suggests much lower reinforcement requirements than a design that uses the more reliable three-dimensional model. Again, inadequate reinforcement in the basement walls could lead to bowing and cracking of the walls. Narrow diagonal cracks generally appear in the lower corners of the wall when the three-dimensional model should have been used but was not, causing the wall to be overloaded.

Lack of control joints in the basement floor slab is one of the most common omissions during construction. CABO (1989) recommends installing control joints every 30 ft (9 m) if the slab is not wire reinforced. This means that in most basements with unreinforced slab, only a couple of cracks would appear, since basements in most residential buildings are less than 60 ft (18 m) in each direction. However, the code also indicates that in a situation where the basement slab should have control joints at points of off set, omission of control joints could develop into extensive cracking in the basement floor slab. Figure 2.11 shows two typical cases of points of off set in basement slabs. Cases where lack of control joints is the cause of the cracking can be identified based on the cracking pattern. Since control joints do not exist, cracks usually develop in places where control joints should have been.
Figure 2.11 Cases of Off Set
This type of cracking is called concrete shrinkage cracking.

Builders must also make sure that construction methods and procedures utilized are appropriate. An example of improper construction procedure is the use of expansive soil as backfill material. The backfill material may lose moisture if it is exposed to the sun for a long time prior to the backfill operation. After backfill is performed, rain and runoff water may enter the soil increasing its water content, which in turn leads to soil expansion. Another example of error during construction is the complete omission of drainage system or the installment of a defective drainage system around the basement. Adequate drainage around basement walls is necessary to guard against hydrostatic pressure. A reliable drainage system is given by NCMA (1991).

The soil, with the exception of engineered fills, is heterogeneous by nature. This makes its behavior difficult to predict. The engineer has to use judgment when using commonly accepted methods to predict soil behavior. Soil testing and soil treatment are two of the major sources of error in predicting soil behavior.

Soil testing or exploration is rarely done for the construction of a single house. However, for larger projects such as multi-family projects, or where there is a
reasonable expectation of poor soil conditions, soil exploration should be performed.

Normally, soil testing is properly done but failure to recognize the limitations of the testing procedures may occur. Testing of the soil is performed only on a few samples. Since soil is not a man-made material and is not homogeneous, poor judgment in the interpolation of the testing results can lead to poor predictions of thickness of soil strata and location of pockets of soft clay.

In some projects, the developer builds streets and main utility lines, and designs the landscape, but the construction of houses is left to the customers. The developer simply sells lots. Soil fills during a landscape operation may not be engineered to support houses, but simply for recreational areas such as backyards. When this occurs, there is the danger of building on an uncontrolled fill. Soil fills are usually done in the borders of the development project and where small creeks existed. The topography of the area may reveal where a creek was filled.

Excessive hydrostatic pressure on basement walls is often the cause of basement wall cracking. Frequently, excessive hydrostatic pressure is due to the malfunction or omission of drainage in the perimeter of basement wall footings. Old buildings used to have drainage on the inside of the wall footings. New construction practices more often
place the drainage on the outside of the wall footings. The advantage of the latter method is that the water level is kept lower and the water is collected before it reaches the walls. Figure 2.12 shows the two methods of placing footing drainage. In some cases, the drainage gets obstructed due to deterioration or casual installation of the pipes during construction. Additionally, if the backfill behind basement walls does not have free drainage properties, it will be difficult for the water to reach the water collecting pipe in the foundation drainage. Even small increases in the water level can create large increases in hydrostatic pressure.

For the example shown in Figure 2.13, if no hydrostatic pressure is present, the lateral force would be caused only by the soil and would be equal to 0.5 x 30 pcf x 6 ft², equal to 540 lb/lf of wall (790 kg/m of wall). However, if the water table is three feet high, the lateral pressure on the wall would include hydrostatic pressure in addition to soil pressure. In this case, the hydrostatic force would be equal to 281 lb/lf of wall (410 kg/m of wall). In addition, the soil force would be equal to 491 lb/lf of wall (720 kg/m of wall). The total lateral pressure in this case would be 772 lb/lf of wall (1130 kg/m of wall) compared to 540 lb/lf of wall (790 kg/m of wall)
Figure 2.12 Drainage Systems for Residential Basements
Figure 2.13 Increase of Hydrostatic Pressure on Basement Walls
when hydrostatic pressure did not exist. The increase of the water table brings, in this example, a 43 percent increase of pressure on the wall (see Figure 2.13). Figures 2.14(a and b) show two cases of moisture marks in the basement walls that indicate build up of hydrostatic pressure behind the walls.

Basement walls are neither designed nor built to withstand hydrostatic pressure. Adequate drainage is the recommended method to avoid build up of hydrostatic pressure. Lack of sufficient reinforcement to withstand excessive lateral hydrostatic pressure against basement walls could lead to bowing and cracking of the walls similar to that caused by excessive soil pressure. The cracking consists of a dominant long horizontal crack two thirds of the way up the wall when $L/H$ is larger than three, and narrow diagonal cracks in the lower corners of the wall when $L/H$ is smaller than three [see Figures 2.4(a-c)]. Additionally, when there is hydrostatic pressure, water enters the basement, and signs of moisture in the walls become very obvious, especially in basement corners (wall-wall joints).
Figure 2.14 Consequences of Hydrostatic Pressure  
(Courtesy of Dr. Stephen Pasternack)
2.3.2 Postconstruction Causes of Basement Failure

Basement failures can be caused by movement of soil under the footing (foundation soil) and lateral pressure on the basement walls.

A type of soil settlement that causes substantial damage to buildings is consolidation of soil fills. When soil fills are not properly compacted during fill operations, the soil may settle considerably more than when the soil is properly compacted. The compaction process should be done by layers about one foot thick, but this is usually performed only when the fill is done with the purpose of building on it. Sometimes, residential buildings are constructed on nonengineered soil fills that were not projected for construction purposes. Other times houses may have been built on soft natural soil. Damage in basements occurs when soil settlement takes place in the basement foundation. Additionally, the weight of the new building can accelerate the settlement process. The damage produced by the described settlement mechanism can be so severe that the building may need to be demolished since settlement can cause severe cracking of the basement and building in general.

It is not uncommon to find that soil discontinuity has caused damage in residential basements. When a building is constructed on different types of soil, differential
settlement can take place causing cracking of basement walls. Although soil discontinuity appears in many different situations, a few examples include: a basement wall foundation supported partly on rock and partly on soil, or partly on hard soil and partly on soft material.

Differential settlement caused by variability in thickness of soil layers can be very significant. An illustration is the case of the building shown in Figure 2.15. Here, the soil stratigraphy includes a layer of soil with variable depth resting on bedrock. The amount of settlement of the soil will be higher as the depth of the soil layer increases. While the part of the building founded where the soil layer is thin will only slightly move, the part founded where the soil layer is thicker will settle substantially more.

Changes in volume of expansive soils can also cause considerable differential soil movement under the basement. However, this is not a serious problem in Ohio. Some of the causes of soil expansion are broken water or sewer lines, faulty shower pans, faulty drain waste valves, and leaking water or sewer line connections.

2.4 Summary

The causes of basement failure can be divided into preconstruction and postconstruction causes. Often,
Figure 2.15 Typical Case of Soil Discontinuity
basement failures are caused by errors during design and construction. These errors are preconstruction causes of failure. For most residential buildings the specifications of the basement components given by construction and design codes such as CABO (1989) are adequate. However, in cases where worse than average conditions exist, caution should be used since codes assume average loading conditions. In other cases, no consideration is given to the minimum recommendations given by design and construction codes, which leads to insufficient strength of basement components.

Common causes of basement failures are lack of reinforcement in basement walls, excessive lateral loads from soil weight pressure, hydrostatic pressure, soil freezing, settlement of fills, and poor design/construction practices. When the provided reinforcement in basement walls is insufficient to support excessive loads cracking can appear in two different forms. The first appears when the L/H is larger than three, and consists of a dominant, long, and narrow horizontal crack two thirds of the way up the wall. This crack is usually wider in the middle of the wall length. The second appears when the L/H is smaller than three, and consists of narrow diagonal cracks in the bottom corners of the wall.

Excessive hydrostatic pressure on basement walls is
often the cause of basement wall cracking. Frequently, excessive hydrostatic pressure is due to malfunction or complete omission of drainage in the perimeter of basement wall footings. New construction practices recommend placing the drainage on the outside of the wall footings, which has the advantage of keeping the water level lower. Additionally, if the backfill behind basement walls does not have free drainage properties, it would be difficult for the water to reach the water collecting pipe in the foundation drainage. Even a small increase in the water table can produce a large increase in hydrostatic pressure.

Sometimes, residential buildings are constructed on soil fills that were not intended for construction purposes. Damage in basements occurs when soil settlement takes place in the basement wall foundation.

Signs of basement failure come in the form of bowing or cracking of basement walls or floor slab, and deformation of non structural elements such as window and door frames. The cracking pattern basement walls indicates largely the type, place, and magnitude of the soil movement under the foundation. While investigating the causes of a basement failure, width, depth, distribution, location and direction of the cracks are very meaningful.
CHAPTER III

KNOWLEDGE REPRESENTATION AND KNOWLEDGE ACQUISITION

3.1 Introduction

This chapter presents the knowledge acquisition process carried out in this study and the knowledge representation built from the gathered knowledge. Knowledge was gathered from building foundation experts and from shared sources, such as textbooks and theories shared and accepted by most building foundation engineers.

The knowledge representation follows the form of semantic net models. Fault tree models are used for the initial development of the semantic net, and to represent the causality relation between events that lead to a structural failure. A hierarchical classification is built from the semantic net models in order to implement the search strategy. The hierarchical classification uses tests common to several hypotheses of basement failure to effectively guide the search.

A method for utilizing fault tree models to help in producing semantic net models, and then translating
knowledge representation in the form of semantic net models into a classificatory tree is introduced.

3.2 Knowledge acquisition

Knowledge acquisition is achieved in several ways. In this project, two sources of knowledge were used. The first is knowledge obtained from the experience of experts. The second source is documented material.

3.2.1 Knowledge Acquisition from Experts

In order to have successful knowledge acquisition, the selection of the expert is of primary importance. One may argue that the definition of "expert" is relative to the background of the person who makes the definition of "expert". A person may call a second person an expert when the second person has technical background or experience far beyond the first person. In basement related problems, a home owner may call an expert a person who has little technical background about the structural behavior of basements, but has worked several years waterproofing basement walls. On the other hand, a civil engineer with an advanced degree in soil mechanics and several years of related experience probably would not consider the same person an "expert".

An expert in a particular area may be defined as a
person who has the knowledge, experience, and high regard by peers in a specific area of expertise. A person who has the ability to provide correct explanations for observed behavior may also be called an expert. In general, the expert should have the best possible technical background combined with years of hands-on experience. In this study, we have the participation of an expert in basement failures who has a degree in civil engineering, a doctoral degree in soil mechanics, more than ten years of experience as a soil mechanics engineer, hundreds of cases of basement failure studied, and is highly recommended by his peers to study basement related problems. This person obviously possesses the technical background and the experience needed to qualify as an expert in basement failures.

3.2.1.1 Approaches for Knowledge Acquisition from Experts

Generally, knowledge acquisition from experts can be performed using two different approaches. The direct approach involves extracting knowledge from experts about generalized problem-solving techniques. This approach requires the expert to express the line of reasoning used to solve a problem. In contrast, the indirect approach uses case examples to determine variables considered important to the expert. This requires the decomposition of the problem into a series of smaller problems (Palmer, 1988).
The expert's knowledge can be collected from interviews, questionnaires, written reports, and case studies in which the expert was involved. This process often involves further questioning of the expert whenever the collected information is unclear or incomplete, or to make sure that there are no inconsistencies in the gathered knowledge.

Knowledge acquisition from case studies, the indirect approach, can be performed in two different forms, cause-consequence and consequence-cause. In the cause-consequence form, the probable signs of failure are determined based on known external events or causes of failure. The cause-consequence form is normally used to describe case studies in technical papers and textbooks. In the consequence-cause form, the cause of an event is determined based on the observed consequences (evidence or signs of failure).

The cause-consequence approach is advantageous because the production rules for the knowledge base are easy to construct. The knowledge engineer initially establishes the antecedent or IF portion of the production rules; the expert can complete the THEN portion. However, based on the author's experience, this approach has serious disadvantages if used alone. The first is that the knowledge engineer has to be an expert in the subject in order to establish the IF portions. Second, obtaining a reasonable amount of knowledge for the IF portions is very
likely to cause a combinatorial explosion where some hypotheses for causes of failure may be speculative. The third disadvantage is that even when the number of IF portions is limited, the experts have to spend excessive time trying to find answers to a multitude of questions.

By comparison, the consequence-cause method solves some of the problems of the cause-consequence method. Although the knowledge engineer needs to have some knowledge about the subject, the knowledge engineer does not have to become an expert to establish the IF portions. Furthermore, a combinatorial explosion of IF portions is now unlikely because the experts limit the types of cases of failure to those that they have experienced. Additionally, experts can answer questions in their own words and follow their own logic.

Nonetheless, this approach has two disadvantages. First, the production rules for the knowledge base are more complex to construct. The knowledge engineer needs to form parameters and relationships for the IF and THEN portions from the descriptions of the cases given by the expert. This can lead to misinterpretations on the part of the knowledge engineer. Second, the knowledge is not as well explored and refined as with the cause-consequence form, since the number of IF portions is now limited by the experience of the experts.
In this study, a combination of direct and indirect approaches was used for knowledge acquisition.

3.2.1.2 Knowledge Acquisition Approach for BAPDES

The author used the direct and the indirect approach to gather knowledge from the expert in two stages. In the first stage, the direct approach is used to identify the line of reasoning followed by the expert. In this stage, the expert explains through interviews the strategy followed to determine the causes of basement failures with minimum questioning from the interviewer. The interviews were tape recorded and the expert drew diagrams and sketches whenever necessary. The knowledge obtained in this stage included causality relationships of events that lead to basement failures, the most common causes of basement failure in central Ohio, and some of the signs that indicate the cause of failure. Sketches drawn by experts are very useful to provide help for the users of the expert systems.

To effectively use the direct approach, the interviewer must have good background about the problem under study in order not to waste the expert's time. The reasoning strategy is of primary importance because it determines the organization of the knowledge. During the
expert interview, the knowledge engineer should also identify subgoals that the expert may use to arrive at the final conclusion. Examples of subgoals for basement failures can be the identification of the basement element that failed, and to determine if the cause of the failure is external or internal (Chapter Two includes a description of external and internal causes of failure).

In the second stage, the indirect approach was used to build upon the previously gathered knowledge. Often, experts have compiled their knowledge, and the reasoning followed is not as obvious as in source knowledge. Compiled knowledge, in this paper, is used when the expert's reasoning process does not have to follow a reasoning path. Instead, the reasoning process may go from little information to an immediate conclusion, without intermediate steps. Knowledge is in deep form when the reasoning process is planned step by step. Humans use deep knowledge the first time the reasoning process takes place. However, when the same knowledge is used repetitively, humans do not need to plan the reasoning process step by step because they are familiar with the process. As humans become more familiar with the process, the knowledge is compiled and the reasoning becomes more a matter of common sense. When compiled knowledge is used, the reasoning process takes place at a much higher speed, and the step by
step reasoning process originally used with deep knowledge does not take place anymore.

The second stage of the interviewing process included questioning of the expert in consequence-cause and cause-consequence forms. The expert used photos of case studies and recent cases to reconstruct the process used to determine the causes of basement failure. The interviewer questioned the expert with variations of the cases being described. If the interviewer wanted to determine the reliability of a given sign of failure, questioning of the possible causes of failure that can lead to the sign under scrutiny would follow (consequence-cause). For example, the expert may first indicate that in a particular case study, a horizontal crack in a basement wall suggested lack of reinforcement in the wall. Then the interviewer asks the expert what other events can cause the same or similar cracking. If the expert states that other events can produce the same cracking, the fact that a horizontal crack appears is not sufficient to determine that the cause of the cracking is lack of reinforcement and not some other event.

If the interviewer wanted to explore what signs the expert could inadvertently use to determine the cause of a basement failure, the questioning would come in the cause-consequence form. In this case the knowledge engineer would
ask the expert the consequences of a given cause of failure or event. The consequences of a failure are usually the signs of failure, such as cracking and bowing of basement walls.

The author noted that an efficient and reliable way to obtain accurate knowledge from the expert is by asking first general questions in the first stage and then very specific questions during the second stage. During the knowledge acquisition part of this project, the expert presented a case study and the interviewer would question the expert about the differences in its appreciation of the failure if a small variation in the failure is observed. This process leads to refinement of the knowledge, elimination of redundancies or signs that are not important for the diagnosis, identification of uncertainties, and elimination of events that do not take place.

Although a large portion of the knowledge for expert systems is usually gathered from experts, documented material is an important and inexpensive source of knowledge.

3.2.2 Knowledge Acquisition from Documented Material

Knowledge may be gathered from documented material. This material includes theoretic and experiential knowledge. Theoretic knowledge includes theories and
methods shared by most experts, for example, structural
analysis of concrete retaining walls. Documented material
includes experiential knowledge in the form of case studies
described in journals and professional publications.

Knowledge acquisition from documented material cannot
be overlooked during the development of an expert system.
The knowledge included in documented material is often more
descriptive that knowledge acquired from experts. Moreover,
if the knowledge is already documented, the knowledge
acquisition process can be greatly simplified.

In BAFDES, knowledge dealing with properties of the
soil such as the relation between Atterberg limits and soil
expansion, and amount of rebar required for basement walls
was found in documented material. In addition, some case
studies of basement wall and floor cracking were found in
professional literature.

Knowledge from the expert may conflict with knowledge
found in documented material. After carefully checking for
conflicts, the knowledge gathered from the expert
corresponds with the knowledge found in documented
material.

While knowledge acquisition is performed, the
knowledge engineer should also find a method to represent
the gathered knowledge. A proper knowledge representation
makes the knowledge more understandable for the knowledge
engineer, and provides a flexible knowledge organization that can be computerized.

3.3 Knowledge Representation

The knowledge representation in this study was built in three steps. In the first step, fault tree models for basement failure were built. In the second step, fault tree models were developed into semantic net models. Fault tree models are utilized to represent the causality relation between events that lead to a structural failure and follow the expert's deep knowledge closely. Semantic net models are a schematic and a flexible method of representing the meaning of objects and actions in such a way that inferences and relationships between them can be drawn. Since semantic nets were not directly supported by the software, in the third step a hierarchical classification was developed based on the semantic net models.

Although fault trees, semantic nets and hierarchical classification have been utilized in previous studies (Lapp and Powers, 1977; Shum, et. al., 1988; Hadipriono and Toh, 1989), this dissertation introduces an innovative methodology of implementing these techniques.
3.3.1 Fault Tree Models

Fault tree models are used to represent the causality relation between events that lead to a structural failure. In a fault tree, each branch represents a chain of causality related events that lead to the top event. The top event is the failure of interest (Hadipriono, 1989). Figure 3.1 shows part of a fault tree for a particular cause of cracking in basement walls. In this fault tree, the top event is *Excessive hydrostatic pressure*. This event can be caused by two events, namely *Accumulation of rain water* and *Underground water*. *Accumulation of rain water* can, in turn, be caused by *Poor exterior drainage* and *Retention of water by backfill material*. Although these are causes of wall cracking, they can be divided into other more specific causes of *Excessive hydrostatic pressure*.

*Poor exterior drainage* can be divided into *Lack of exterior drainage*, *Imperfect exterior drainage*, and *Blocked exterior drainage*. Since there is no causality relationship between *Lack of exterior drainage* and *Poor exterior drainage*, then *Lack of exterior drainage* is called "label". However, there is a causality relationship between *Accumulation of rain water* and the last three events. While in fault tree models every chain of events should follow a causality relation, we use labeling to facilitate the construction of the fault tree and have a more organized
Figure 3.1 Fault Tree for Excessive Hydrostatic Pressure
knowledge representation. The group of events in the highest level of refinement constitutes the minimum cut set.

The two main gates in fault tree models are "and" and "or" gates. The "and" gate indicates that the top event can occur only if all events that can lead to the top event occurs. On the other hand, an "or" gate indicates that the top event can occur if any event that can lead to the top event occur. In this dissertation, in order to simplify the occurrence of more than one event simultaneously, only "or" gates are used.

From literature concerning structural failures, we have noticed that experts describe step by step how each event leads to the next event until the failure of the structure occurs. This type of description very often follows a causal relation between events. If those events follow a causal relation and the expert is actually using that reasoning strategy, we can infer that the experts use deep knowledge to build fault tree models.

Humans are good at performing logic-driven tasks. Fault tree models represent the natural expression of logical causal relations, and can therefore be used as knowledge organization. Fault tree models also help the knowledge engineer in organizing the knowledge and understanding the reasoning strategy. Fault tree models
permit the addition of new knowledge to the knowledge base while avoiding conflicts and redundancies. The relationships between events in fault tree models are clearly defined as causal relationships.

There are two disadvantages in using fault tree models to represent the knowledge needed to determine the causes of basement failures. First, the information that fault tree models include is the causal relation of events that lead to basement failures. However, the knowledge also includes signs of basement failure, relationship between signs and causes of failure, and soil properties.

The second disadvantage is that when engineers are investigating a failure case they may not have the fault tree in mind; the fault tree is in the form of compiled knowledge. To take full advantage of this compiled knowledge in a fault tree form, the knowledge needs to be converted into deep knowledge. This conversion involves extensive questioning of the expert in order to identify intermediate steps in the expert's reasoning. An alternative to this conversion is complete redevelopment of the fault tree. However, the conversion of compiled knowledge into deep knowledge can also bring about subgoals in the expert's reasoning. Subgoals are intermediate goals that drive the reasoning. They are not represented in fault tree models but are useful in more sophisticated models for
knowledge representation, such as semantic net models. Semantic net models offer more flexibility than fault tree models and provide a more complete knowledge representation. However, fault tree models are needed to ensure that the causal relationships in the semantic net models are correct.

3.3.2 Semantic Net Models

Although semantic net models were originally conceived to represent the meaning of words, their application has been broadened to represent the meaning of actions or events. Semantic net models consist of nodes and arcs, where nodes represent objects or qualifiers, and arcs represent relationships between nodes [Rich, 1983]. In this dissertation, a set of nodes, classes and arcs was specifically designed for diagnosis tasks. Figure 3.2 shows a semantic net used in this study for excessive hydrostatic pressure.

In the semantic net models built in this study, we can group the nodes into principal and secondary nodes. Principal nodes include Major Causes, Refined Causes, Direct Causes, Signs, and Facts, (see Figure 3.2). Causes of failure are usually identified given existing signs and facts. Major Causes are those that specify the type of forces or events directly causing the failure; Refined
Figure 3.2 Semantic Net for Excessive Hydrostatic Pressure
Causes are those that specify the origin of the forces or events; and Direct Causes are those that indicate what causes the forces or events. Signs are consequences of the failure that can be observed without testing materials. Facts are details of materials or structures that are products of design and construction practices, and nature. In Figure 3.2 for example, Lack of exterior drainage and Imperfect exterior drainage are Direct Causes.

In the group of secondary nodes are Properties and Values. Properties are characteristics used to describe Signs or Facts, while Values are the values of those properties for particular Signs or Facts. In Figure 3.2, for example, Location is a property of Moisture marks. This property is connected to a Value node which indicates the value of the property for each case of moisture marks. The value of Location is Bottom of wall when the Direct Cause is Imperfect exterior drainage, while it is Random when the Direct Cause is Improper backfill material.

There are several types of relationships or arcs in semantic net models. Caused-by arcs indicate causal relationships between nodes and connect two causes of failure, since a Major Cause can be caused by a more refined cause of failure (Refined Cause or Direct Cause). An example of this is the caused-by arc connecting Excessive hydrostatic pressure and Lack of exterior...
drainage (see Figure 3.2). Caused-by arcs also connect signs of failure (Signs) with causes of failure since a sign of failure is produced by a cause of failure. An example of this case is the caused-by arc connecting Improper backfill material with Moisture marks.

Shown-by arcs connect causes of failure (Major Causes, Refined Causes, or Direct Causes) with Signs or Facts that suggest the cause of failure. In Figure 3.2, Lack of exterior drainage is shown-by No external pipe into sump pump, which is a Fact and not a Sign. Here, the Fact is not connected to the cause of failure by a caused-by arc since No external pipe into sump pump does not cause Lack of exterior drainage. On the other hand, if a shown-by arc connects a cause of failure with a sign of failure, they should also be connected by a caused-by arc. An example is the shown-by and caused-by arcs connecting the Direct Cause Imperfect exterior drainage with the Sign Moisture marks in Figure 3.2.

Is-a arcs are used to indicate if a primary node is a Major Cause, Refined Cause, Direct Cause, Sign, or a Fact. In Figure 3.2 for example, Moisture marks is a Sign, and Lack of exterior drainage is a Direct Cause. Has-a arcs connect primary nodes with properties, while Is arcs connect a property to the value of the property. In Figure 3.2, Moisture marks caused-by Imperfect exterior drainage
has-a Location property. The value of Location is Bottom of wall.

In order to ensure consistency of the semantic net models built in this study, two more arcing conditions should be met. First, every primary node is identified as a Major Cause, Refined Cause, Direct Cause, Sign, or Fact, by using Is-a arcs. This condition reduces the chance of mixing causes, signs and facts, and eliminates the possibility of using the wrong arc to connect these nodes. Moreover, this provides an intelligent way of understanding the relationships between signs and causes of basement failure.

The second condition is that caused-by arcs between causes of failure follow the hierarchical order Major Cause, Refined Cause, Direct Cause. The semantic net in Figure 3.2 would contradict this rule if Lack of exterior drainage were caused-by Excessive hydrostatic pressure. This ensures that hypotheses for causes of basement failure are properly refined.

The caused-by arcs in the semantic net models are a refinement of the fault tree models developed as a preliminary knowledge representation. The refinement of the causality relationships occurred during knowledge acquisition. Causes of failure that were not likely to occur were taken out, while other causes that were more
probable were added.

Semantic net models are a refinement over fault tree models since knowledge related to signs of basement failure and the relationships between signs and causes of basement failure are now included in the knowledge representation. Semantic net models also differentiate between causes and signs of basement failure, and circumstantial facts that surround basement failures.

Although semantic net models offer a flexible and organized form to represent knowledge, this form is not directly supported by computer systems and is difficult to implement in its original form. For these reasons, a hierarchical classification is built from the knowledge embedded in semantic net models.

3.4 Hierarchical Classification

Hierarchical classification is a method that uses a classificatory tree to search for a goal. The classificatory tree used for hierarchical classification is formed by nodes, branches and tests (Ramesh, et.al., 1992). Each node represents an alternative in the classificatory tree and each branch connects a parent alternative with its child classification. Each branch has one test attached. Tests indicate the conditions that should be met in order to allow the decision-making process to continue along the
branch.

In this study, a classificatory tree is constructed from the fault tree and semantic net models developed for knowledge representation. Figure 3.3 shows the initial classificatory tree corresponding to the semantic net in Figure 3.2, while Figure 3.4 shows a refined version of the classificatory tree in Figure 3.3. Hierarchical classification serves as the problem-solving strategy implemented in BAFDES. The fault tree and semantic net models developed for knowledge representation are very useful to organize the knowledge before knowledge implementation into a computer program. Moreover, these models facilitate the addition of new knowledge. However, these models are not directly implemented since expert system shells do not offer the flexibility inherent to semantic net models. For this reason, BAFDES uses hierarchical classification, which is simple to follow and can be easily implemented. A process of establishing and refining branches about the cause of the basement failure occurs when hierarchical classification uses the classificatory tree (Chandrasekaran, 1986).

In hierarchical classification, tests are used to determine if a branch can be established, and can be in the form of IF portions. When the IF portion of a branch in the classificatory tree is true, the branch can be established.
Figure 3.3 Initial Classificatory Tree for Excessive Hydrostatic Pressure
Figure 3.4 Refined Classificatory Tree for Excessive Hydrostatic Pressure
Unlike fault tree models, the classificatory tree does not have to follow causal relationship between parent and child alternatives. However, since this study is concerned with causes of failure, the branching in the classificatory tree for BAFDES usually follows a causal relationship due to the nature of the problem.

The hierarchical classification process is explained by using the classificatory tree in Figure 3.4. First assume that Excessive Hydrostatic Pressure has been established. Then, this branch is tested for refinement by considering whether or not any of the three branches can be established. The first branch, Lack of Exterior Drainage, is tried out by testing if No External Pipe into Sump Pump is true or false. If the result of this test is true, this branch is established. If, on the other hand, the result of this test is false, the next branch Bottom Moisture Marks is tried out. To try this branch, the hierarchical classification process tests if Location of Moisture Marks equals Bottom of Wall. If this is true, this branch is then established. Assuming that, for this example, Bottom Moisture Marks is established, the hierarchical classification process would start trying out branches of Bottom Moisture Marks. The process continues until no further refinement can be achieved.

The methodology of constructing the classificatory
tree is performed in three parts. The first part includes organizing causes of failure in the semantic net in a tree-like form. Causes of failure should be connected following the caused-by arcs in the semantic net. The last cause in any branch must be a Direct Cause in the semantic net. For illustration purposes, Figure 3.4 shows in detail only the part of the classificatory tree related to \textit{Excessive hydrostatic pressure}. The branching in classificatory trees built based on semantic net models must follow the arcs that refine hypotheses in the semantic net. In BAFDES, the branching follows the caused-by arcs in the semantic net shown in Figure 3.2. For BAFDES, caused-by arcs in the semantic net lead the reasoning from one hypothesis of causes of basement failure to more refined hypotheses.

In the second part, Signs, Facts and Values in the semantic net are attached to each cause of failure (branch) in the classificatory tree. This knowledge includes the conditions that must be met in order to approve each cause of failure in the semantic net. Each condition eventually becomes a test in the classificatory tree. However, the semantic net conditions need to be translated into a form that a classificatory tree can use as tests. Each condition attached to each cause of basement failure in the semantic net can be written as an IF portion for corresponding alternatives in the classificatory tree. Additional
conditions attached to the same causes in the semantic net are added to the IF portion of corresponding alternatives. They may be added as AND or OR statements.

An example of the methodology is shown in Figures 3.5(a) and 3.5(b). Here, Figure 3.5(a) shows the conditions attached to the cause of failure *Blocked exterior drainage*, in the semantic net. These conditions are the appearance of *Moisture marks*, and the values of the properties of *Moisture marks* (*Bottom of wall for Location* and *Not for Spread*). Accordingly, Figure 3.5(b) shows the same conditions in the form of tests that can be attached to the classificatory tree. Here, the first test (*Moisture marks exist*) includes the condition of appearance of *Moisture marks* in the semantic net model. Similarly, the other two conditions (*value of Bottom of wall for Location*, and *Not for Spread*) are included in two corresponding tests (*Located in bottom of wall* and *Not spread*). Figure 3.3 shows the classificatory tree obtained from the semantic net in Figure 3.2. This tree is refined during the third part of this translation methodology.

In the third and last part, tests are utilized to create intermediate levels of branching. This branching may not consist of causes of failure. The purpose of intermediate branching is to reduce the number of branches coming from the same cause of failure and, in turn,
IF Moisture marks exist
AND Located in bottom of wall
AND Not spread
THEN Blocked exterior drainage IS TRUE

Figure 3.5 Production Rules from Semantic Net Models
facilitating the search.

The process starts by grouping alternatives (causes of failure) that have tests in common and the same test result. An example of this is the intermediate branch Bottom moisture marks in Figure 3.5. This branch is not a cause of basement failure, but an observation about the moisture marks in the bottom of the basement wall. Since the causes of failure, Imperfect exterior drainage and Blocked exterior drainage, have the test, Moisture marks located in Bottom of the wall (see Figure 3.5(b) for Blocked exterior drainage tests) the two causes of failure can be grouped into an intermediate branch. This is the reason for inserting Moisture marks. This intermediate branching groups Imperfect exterior drainage and Blocked exterior drainage. After the intermediate branching is created, the tests common to the grouped alternatives (in this case, Moisture marks located in Bottom of the wall) are eliminated from each alternative and placed in the intermediate branch. Each grouped alternative keeps the remaining tests. In the case of Blocked exterior drainage, the remaining tests are Located in bottom of wall and Not spread shown in Figure 3.5(b).

The cited example results only in minor simplification, but the search is greatly simplified when intermediate branching is widespread in the classificatory
Although hierarchical classification can be implemented in an expert system, part of the knowledge included in the semantic net models is not supported by hierarchical classification. Pieces of knowledge, such as the concepts of sign and cause of basement failure, may be implemented as refinements of the expert system and should be taken directly from the semantic net models.

The hierarchical classification developed using this new methodology is utilized in the implementation of BAFDES to control and drive the reasoning of the system. Knowledge included in the semantic net models is used to enhance the expert system by giving the user explanations about the relationship between signs and causes of basement failures.
CHAPTER IV

BAFDES IMPLEMENTATION

4.1 Introduction

This chapter illustrates the implementation of BAFDES. During the implementation process, the gathered knowledge is organized and stored in the expert system. This knowledge was earlier described in Chapter Two. In order to store the knowledge in an organized form and to be able to utilize the knowledge, structures described in Chapter Three are implemented. The hierarchical classification described in Chapter Three is of particular importance in designing the search strategy of BAFDES. Additional knowledge represented in semantic net models is implemented to refine BAFDES and to make it user friendly and educational. The next section illustrates the structure of BAFDES. The following sections describe the basic components of this structure.

4.2 Structure of BAFDES

Expert systems perform four basic functions. They store knowledge, make inferences based on the knowledge,
interface with the user, and interface with other programs. To perform these tasks, BAFDES has five basic components: knowledge base, inference engine, user interface, external file interface, and external files (see Figure 4.1).

The knowledge base stores the knowledge used by BAFDES to reach a conclusion. This knowledge consists of rules of thumb and subjective assessments used by experts, as well as theoretical knowledge. Each piece of knowledge contains a piece of information embedded in the knowledge representation developed for BAFDES, and described earlier in Chapter Three. Pieces of knowledge include relationships between signs and causes of failure, as well as definitions of signs and causes of failure. This knowledge is an implementation of the semantic net models described in Chapter Three.

The inference engine drives the consultation by controlling the use of the knowledge, and the user interface. The inference engine is responsible for determining what relationships between signs and causes of failure should be used during a consultation, what information is needed to reach the conclusion, and how to obtain that information. Part of the inference engine is an implementation of the hierarchical classification described in Chapter Three.

The tasks of the user interface are to ask the user
Figure 4.1 BAFDES Architecture
for information, guide the user through the consultation, and display the answer for the consultation. The user interface component is connected to the inference engine, since the latter determines when and what information is needed from the user.

The external file interface allows BAFDES to read external files needed during the consultation. External files are those built with the purpose of storing data, text and graphics. The external files interface component is connected to the inference engine, since the latter determines when and what information is needed from an external file.

The external files contain text related to conclusions for causes of basement failure, and graphics that illustrate signs of basement failure and components of basements.

An object-oriented shell, Level 5 Object, was used to implement the knowledge base, the inference engine, the user interface, and the external file interface. Level 5 Object is a very user-friendly shell for both the developer and the end user. It can adequately organize and use knowledge, and results in an easy-to-use end product. External files were built using other software packages such as Microsoft Word (TM Microsoft Corporation), and Microsoft Paintbrush (TM Microsoft Corporation).
Each basic component has a specific structure that allows the component to perform its function efficiently.

4.3 Knowledge Base

In BAFDES, the knowledge base stores the knowledge in the form of objects and production rules (see Figure 4.1). Objects are used to store information related to characteristics of buildings and signs of failure.

4.3.1 Objects

Objects in the knowledge base of BAFDES are organized into a structure that defines classes, instances, and attributes. Objects are grouped into classes. A class groups and identifies objects with similar characteristics. An instance is an object that falls into that particular class. For this reason, each object is defined as an instance of a class. Attributes are characteristics used to define different classes.

An example of the described structure is shown in Figure 4.2. Here, a class called CRACK is defined. BAFDES uses class CRACK to describe observed cracking in basements.

The attributes of CRACK are LOCATION, WIDTH, CRACKING PATTERN, and DEPTH. Attribute LOCATION indicates if the crack is located in the floor slab or the walls of the
<table>
<thead>
<tr>
<th>CRACK</th>
<th>ATTRIBUTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>INSTANCES</td>
<td>LOCATIONS</td>
</tr>
<tr>
<td>WALL CRACK</td>
<td>WIDTH</td>
</tr>
<tr>
<td>FLOOR CRACK</td>
<td>CRACKING PATTERN</td>
</tr>
<tr>
<td></td>
<td>DEPTH</td>
</tr>
</tbody>
</table>
basement. Attribute WIDTH indicates the width of a crack. Attribute CRACKING PATTERN indicates a match between the observed cracking pattern and a group of typical cracking patterns. Attribute DEPTH indicates the depth of the crack. Additionally, each attribute has properties that indicate, among others, how to obtain the value for the attribute, what is the default value, and what to do when the value for the attribute is changed. Attributes are built as implementation of signs of basement failure and facts included in the semantic net models.

WALL CRACK and FLOOR CRACK are defined as instances of CRACK. During a consultation, BAFDES is able to classify a basement crack as WALL CRACK or FLOOR CRACK. However, the knowledge used to do this is in the form of production rules.

4.3.2 Production Rules

Production rules in BAFDES are stored as rules and methods. Rules are in the form of IF/THEN/ELSE portions developed for particular situations. When a rule is tested by BAFDES and the IF portion results true, the instructions in the THEN portion are executed. On the other hand, if the result is false, the instructions in the ELSE portion are executed. ELSE portions in BAFDES are optional. Methods are structures that contain instructions similar to rules, but
do not need to have any of the three components that rules have. Production rules are the implementation of tests included in the hierarchical classification.

4.3.2.1 Rules

In general, rules include tests about the signs of failure, characteristics of the building, and characteristics of the soil in the IF portion. If these tests are true during a consultation, the THEN portion is executed. THEN portions refine conclusions about causes of basement failure. Two examples of rules in BAFDES follow,

IF location OF wall crack IS wall
AND crack width OF wall crack IS thin
AND other signs IS separation of structural elements IS FALSE
THEN wall lateral pressure := "LATERAL1"

IF wall lateral failure = "LATERAL1"
AND moisture signs IS FALSE
AND fill OF building >= 8
THEN soil pressure := "SOIL1"

The IF portion in the first rule has three lines. In the first line, BAFDES tests if there is a crack in the basement wall. In the second line, BAFDES tests if the crack is thin. The third line in the IF portion is used to test if there is a separation of structural elements in the basement. The THEN portion indicates that the result for
the value of \textit{wall lateral pressure} (a cause of failure) is LATERAL1. LATERAL1 is a code that identifies the name of a file containing a description of the cause of failure.

The second rule shown is used by BAFDES to refine the conclusion reached by the first rule. The IF portion in the second rule has also, by coincidence, three lines. In the first line, BAFDES tests if the value of \textit{wall lateral pressure} is LATERAL1. In the second line, BAFDES tests if there are moisture signs in the walls of the basement. The third line is used to test if the value for the height of the backfill is larger than or equal to eight feet. The THEN portion indicates that the result for \textit{soil pressure} (a more refined cause of failure) is SOIL1. Like in the first rule, SOIL1 is a code that identifies the name of a file containing a description of the cause of failure. These files are read by BAFDES through the external file interface component, which is explained in a later section.

Due to the direct internal link between rules and the inference engine, rules are the preferred form of storing production rules. However, in some cases it is more convenient to store production rules as methods.

\textbf{4.3.2.2 Methods}

Methods are useful to store production rules in cases where instructions are executed given the value of one
single attribute, or given the need for a value of one attribute.

There are two types of methods: when needed methods, and when changed methods. Both methods are included as properties of attributes (attributes of classes). When needed methods include instructions that BAFDES executes when the value for the attribute is needed, and can be written in the same form as Rules. An example of a when needed method in BAFDES follows.

IF fill level OF residential basement wall IS First floor level
THEN fill height OF residential basement wall:= height OF residential basement wall

When changed methods are similar to when needed methods, but the instructions are executed when the value of the attribute changes. An example of a when changed method in BAFDES follows.

IF wsoil weight choice = "hollow vertical"
THEN filename OF conclusion text box := "HOLLOWV.TXT"
AND filename OF conclusion picture := "REBAR.BMP"

Although the two methods shown here contain an IF and a THEN portion, they are not required. The following is a when needed method attached to attribute ratio:
ratio of basement wall := length of basement wall/height of basement wall

Although the knowledge is stored in the knowledge base, this knowledge cannot make inferences and arrive at a final conclusion during a consultation by itself. An inference engine is needed to put pieces of knowledge together and determine a result.

4.4 Inference Engine

In BAFDES, the inference engine has two parts, an internal and an external part (see Figure 4.1). The subdivision of the inference engine into these two parts is more conceptual than physical, since the two parts cannot be separated. The internal part is the inference engine embedded in the expert system shell. The external part is problem specific and does not depend on the shell used, and is commonly known as "search" (Clancey, 1984).

4.4.1 Internal Inference Engine

The internal part of the inference engine is the procedure followed by the shell in order to find the goal of the consultation and can be defined as "forward or backward chaining". The shell has the ability to use forward as well as backward chaining. Forward chaining requires the establishment of the initial conditions and
evaluates the solution based on those conditions. Backward chaining tests hypothesis by comparing the conditions required for each hypotheses against the actual conditions of the case study. Backward chaining asks the user information needed to test specific hypotheses. Forward chaining has the advantage that, in diagnostic problems, the reasoning can be more easily followed step by step. However, when forward chaining is used, the user needs to provide information that often is not needed to find a conclusion.

4.4.2 External Inference Engine

The external part of the inference engine, or search, is given by the specific relationships between data and hypotheses given by the knowledge engineer. This part is designed by the knowledge engineer to achieve a smooth consultation for the user, and to control the internal part of the inference engine. In order to achieve these goals, the external part of the inference engine in BAFDES contains Agenda, Rules, and Search Order. If the knowledge engineer does not build the external part of the inference engine, the development shell uses only the internal part of the inference engine. This may result in a more sluggish and less user-friendly end product.

The Agenda is a tool provided by the shell that
utilizes an outline of subgoals leading to the final conclusion. The outline in the agenda specifies the search order of the subgoals during a consultation, and establishes a hierarchy for the subgoals. In BAFDES, the Agenda follows the hierarchical classification developed as described in Chapter Three. Figure 4.3 shows the Agenda built for BAFDES.

Rules are used by the inference engine to determine when the search should drastically change direction. For example, in the following rule, the search changes from causes of failure related to wall strength to causes of failure related to settlement in a corner.

```
IF wall choice = "wall strength a"
AND cracking pattern OF wall crack = 13
THEN wsupport choice := "corner"
```

Search Order is a property of attributes that indicates the order in which different methods to obtain the value for the attribute should be tried. For example, The Search Order for the attribute \textit{wlateral choice} is \textit{CONTEXT RULES DEFAULT}.

This Search Order indicates that the first method to obtain a value for \textit{wlateral choice} is using the previously assigned value, or context value. If this method is not
1. wall choice
   1.1. lateral choice
      1.1.1. whydro choice
      1.1.1.1. wdrain choice
      1.1.1.2. wbackfill choice
      1.1.2. wsoil weight choice
      1.1.2.1. whorizontal choice
      1.1.2.1.1. whorizontal one choice
      1.1.2.1.2. whorizontal two choice
      1.1.2.1.3. whorizontal three choice
      1.1.2.2. whorizontal hollow choice
      1.1.2.3. wvertical choice
      1.1.2.4. wvertical hollow choice
      1.1.2.4.1. wvertical hollow one choice
      1.1.2.4.2. wvertical hollow two choice
      1.1.2.4.3. wvertical hollow three choice
      1.1.2.4.4. wvertical hollow four choice
      1.1.2.5. wbrick choice
      1.1.2.6. wthin wall choice
      1.1.3. whigh original choice

2. support choice
   2.1. wcorner choice
   2.2. wlocal choice
      2.2.1. wlocal strength choice
      2.2.1.1. wlocal firm choice
      2.2.1.2. wlocal soft choice
   2.3. wgeneral choice
      2.3.1. wgeneral strength choice
      2.3.1.1. wgeneral firm choice
      2.3.1.2. wgeneral soft choice

3. wno crack support choice
   3.1. wno crack local choice
   3.2. wno crack general choice

4. floor choice
   4.1. fcase choice
   4.2. felevation choice
      4.2.1. fgeneral choice
      4.2.2. fssettle choice

Figure 4.3 BAFDES Agenda
successful, the next method should be tried. In this case, rules that can determine the value of \textit{w \text{ lateral choice}} are tested. If, again, this method is unsuccessful, the default value for \textit{w \text{ lateral choice}} is used.

The two parts of the inference engine work together to perform hypothesis search. In this process, BAFDES searches for the cause of a basement failure.

\subsection*{4.4.3 Hypothesis Search}

Hypothesis search can be data-first, hypothesis-first, and opportunistic (Clancey, 1984). Data-first search works from data to hypotheses. This means that for every search, the complete set of data is requested from the user before any analysis of the data is performed. A major advantage of using data-first search in expert systems is that all the information is available to drive the search. However, only part of this information is actually used during the search. Data-first search may lead to wrong interpretation of the expert system reasoning from the part of the user, since the system may ask the user for information that would not necessarily be used in the reasoning process. Moreover, the user may need to spend time and resources to come out with data asked by the system, but not needed for the search.

Hypothesis-first search works from hypotheses to match
the actual data. Here, the search requests from the user only that particular data that would be needed to determine if hypotheses are true or false. A major advantage of using hypothesis-first search in expert systems is that only the minimum information needed to drive the search is requested from the user. However, since the knowledge in expert systems is not complete, information not requested from the user may contradict the conclusion found with a partial set of information. Hypothesis-first search may not be able, at the end, to take advantage of information that the user may have.

Opportunistic search is a mix of data-first and hypothesis-first search. By using opportunistic search, BAFDES capitalizes on the advantages of data-first and hypothesis-first search, while avoiding their weaknesses.

4.4.4 Hypothesis Search in BAFDES

In BAFDES, data-first search and hypothesis-first search take place alternatively. The purpose of data-first search is to determine the subgoal that can be searched. In BAFDES, subgoals are intermediate steps that are taken in order to find the cause for a basement failure. Data-first search is performed by using the Agenda.

The first subgoals tested by BAFDES are in the first level of the outline. These are 1. wall choice and 2. floor
choice. If one of these subgoals is true, BAFDES tests the subgoals that follow the subgoal within the next level of the outline. The rest of the subgoals in the previous level of the outline are discharged from the consultation. The process continues until BAFDES cannot find more subgoals to test.

In BAFDES, hypothesis-first search is performed by simply taking advantage of the back-chaining capabilities of the shell.

An example that illustrates the way opportunistic search works in BAFDES follows. BAFDES starts data-first search by using the data provided by the Agenda. The Agenda indicates that the first subgoal is subgoal 1.wall choice. In BAFDES, the purpose of this subgoal is to determine if the basement problem is in the walls or in the floor slab. To reach this subgoal, BAFDES uses hypothesis-first search. This means that BAFDES tries the hypothesis that can reach a conclusion for wall choice. If this subgoal cannot be reached, BAFDES uses data-first search in order to determine the next subgoal that can be tried. In this case, the next subgoal must be in the same level of the outline. The only subgoal left in the same level is subgoal 2.floor choice. However, in this example, we assume that the 1.wall choice was reached.

Once a subgoal is reached, BAFDES uses, again, data-
first search to determine the next step in the consultation. In this example, the Agenda indicates that the next step is subgoal 1.1.\textit{wsupport choice}. This is the first subgoal in the next level of the outline. To reach this subgoal, BAFDES switches again to hypothesis-first search, and tests the rules that can conclude a value for 1.1.\textit{wsupport choice}. The purpose of this subgoal is to determine if wall failure was caused by a failure in the support of the wall (wall foundation). If this subgoal is not found, data-first search is then used to determine that the next subgoal is 1.2.\textit{wall strength choice}. This process of search of subgoals is followed until BAFDES cannot find more subgoals to test or until the search reaches the last level of the outline.

An important feature of BAFDES' inference engine lies in the fact that hypothesis search is done exhaustively. This means that BAFDES searches the Agenda until the only subgoals not tested are those whose parent subgoal could not be reached. A parent subgoal of a second subgoal is that in the previous hierarchy of the Agenda and in the same branch.

Hypothesis search is a process transparent to the user of expert systems. However, BAFDES provides a knowledge tree that can help the user understand the strategy followed during the consultation.
When subgoals are found, BAFDES determines intermediate conclusions. These conclusions may be refined by BAFDES if a child subgoal is found. The refinement process continues until the search stops. The most important advantage of this strategy of refining subgoals is that even if the search cannot reach the highest refinement, a general conclusion can still be made.

4.4.5 Knowledge Tree

BAFDES allows the user to follow the way subgoals are found through the knowledge tree. This tree shows subgoals, production rules and methods, and can be compressed or expanded to show the user less or more refinement of the knowledge. When the knowledge tree is compressed at its minimum, it shows only the goals and subgoals in the same form as they are organized in the Agenda. Each one of the goals or subgoals can be expanded in order to show the rules that can conclude a value for that goal or subgoal. Those are the rules that include that goal or subgoal in the THEN portion, and are shown as branches of that goal or subgoal. In turn, if a rule already shown in the knowledge tree is expanded, the knowledge tree would show each parameter included in the IF portion of the rule as a branch of that rule.

Figure 4.4 shows the knowledge tree of BAFDES
Figure 4.4 BAFDES Knowledge Tree
Figure 4.4 (Continuation)
compressed at its minimum, but with expansions of subgoal \textit{w}lateral choice, and Rule 1212 \textit{hydrostatic pressure}. Rules 1212 \textit{hydrostatic pressure}, 1211 \textit{soil weight}, 1214 \textit{fill height}, and 1216 \textit{soil expansion} are shown after subgoal \textit{w}lateral choice was expanded. These four rules are those that can conclude a value for subgoal \textit{w}lateral choice. In similar form, by expanding Rule 1212 \textit{hydrostatic pressure}, parameters \textit{wall strength choice}, \textit{signs of moisture}, and \textit{w}lateral choice are shown. These parameters are included in the IF or THEN portions of Rule 1212 \textit{hydrostatic pressure}.

Although the knowledge base and the inference engine store the knowledge and make inferences based upon the knowledge, the expert system needs a form of communicating with the user.

4.5 User Interface

The user interface of BAFDES has three major components: Screens, Help and Conclusions (see Figure 4.1). These components are built through the use of objects. Given the purpose of the objects, they are grouped into different classes. Examples of classes are DISPLAY, CHECKBOX GROUP, RADIOBUTTON, TRUE FALSE BOX, PROMPTBOX, TEXTBOX, PICTUREBOX, VALUEBOX, PUSHBUTTON, and HYPERREGION. These classes are predefined by Level 5 Object in order to facilitate the development of the user interface of expert
systems.

DISPLAY groups the screens used by an expert system during consultation. Note here that each screen is an instance of the class DISPLAY. This class is the basic structure of the user interface, while the rest of the classes group objects that may be included in a screen. The arrangement of objects in each screen determines the looks and functions of each screen.

CHECKBOX GROUP groups check boxes shown by screens to obtain information from the user about certain parameters in a check box-like manner. Depending on the value given to the attributes of instances of the class CHECKBOX GROUP, check boxes may show different values to choose for a parameter. Check boxes may also have different color, location in screen, and size, given the value assigned to the attributes. In check boxes, the user can select one or more choices.

RADIODIWBUTTON, TRUE FALSE BOX, and PROMPTBOX group objects used for similar purposes, but the user prompt is done in the form of radio button boxes, true or false boxes, and fill-in-the-value boxes, respectively. Depending on the value given to the attributes of instances of the class RADIODIWBUTTON, radio button boxes may show different values for choosing a parameter. True or false boxes, however, show only true and false for the user to select.
Fill-in-the-value boxes provide only a space where the user can type the answer for a given question. Radio button, true or false, and fill-in-the-value boxes may also have different color, location in screen, and size, given the value assigned to the attributes.

For PROMPTBOX, the instructions given to the user on how to fill-in-the-box are given through boxes that contain text. These boxes are grouped under the class TEXTBOX. Instances of this class can also be used to educate the user. The text displayed by text boxes is stored in an attribute. Text boxes may be framed or unframed, and have different color, location in screen, and size, given the value assigned to the attributes.

PICTUREBOX groups objects with similar purpose to TEXTBOX, but displays a graphic instead of text. This class is defined by attributes that indicate the file that contains the graphic, and whether the graphic is to be resized or clipped. Graphics are resized in such a way that they fit a defined frame. On the other hand, when graphics are clipped, they are cut so that they do not fall outside of the frame. Attributes of PICTUREBOX also indicate if the frame should be visible, the size of the frame and the location of the graphic within a screen.

VALUEBOX groups boxes used to display the value of parameters. These boxes may be framed or unframed, and have
different color, location in screen, and size, given the value assigned to the attributes. The parameters associated with these boxes are also set through attributes.

PUSHBUTTON groups keys that are placed in screens. When these keys are "pushed," programmed instructions are executed. These keys may be framed or unframed, and have different color, label, location in screen, and size, given the value assigned to the attributes.

HYPERREGION groups hyper regions. A HYPERREGION encloses a designated region on a screen. When the user clicks on a HYPERREGION, a screen with information related to the items enclosed by the hyper region (e.g., a prompt box for the width of a crack in the basement wall) is displayed. This new hyper region screen is also grouped under the class DISPLAY. Hyper regions may be visible or invisible (framed or unframed), and have different sizes, and locations in the screen, given the value assigned to the attributes.

Hyper region screens can have the same attributes and elements of standard screens. The use of a key (PUSHBUTTON) in hyper region screens to go back to the original screen is very convenient. Hyper region screens in BAFDES usually need to display figures that are stored in external files. To be able to read those files, BAFDES uses its external file interface. Explanatory knowledge shown in hyper region
screens is checked for conformity with the definitions established in the semantic net models developed for knowledge representation.

4.6 External File Interface

The purpose of the external file interface is to allow the BAFDES components designed with the shell to access information stored in files built with other software (see Figure 4.1). These files store information in the form of text or graphics. In BAFDES, the user interface component and the inference engine instruct the external file interface component on what file should be read and what type of information it contains (text or graphics).

The interface between the shell and the external files is done in two steps. In the first step, the component that requires information from external files instructs the external file interface to search and read information from an external file. In the second step, the external file interface component sends the required information to the component requiring the information.

4.7 External Files

In BAFDES, external files are of two types and have two purposes. The first type of external files are text files. These files are used to store descriptions such as
causes of failure and textual help, and have the extension TXT. The content of these files is displayed on screens by the use of text boxes. The second type are graphic files in the form of bit mapped files, which may contain up to 256 colors at a resolution of 640x480. Graphic files in BAFDES have the extension BMP. These files are used to store graphics called by picture boxes and displayed in screens, expand screens and hyper region screens.
CHAPTER V
TESTING AND VALIDATION

5.1 Introduction

The purpose of testing and validation of BAFDES is to ensure that the objective of this dissertation is accomplished. As indicated in Chapter One, the objective of this dissertation is to construct an expert system that can automate the diagnosis of basement failures in residential low-rise buildings in central Ohio.

Testing and validation of BAFDES was carried out during and at the end of this dissertation. Three types of testing were carried out to ensure the correct functioning of BAFDES. In this project, the first type of testing is done by the knowledge engineer (the author) and his advisor, and examines the correctness of the reasoning in BAFDES according to the knowledge representation, and the system's efficiency. In this dissertation, this testing is called accuracy and efficiency validation.

The second type is testing by the expert that participated in the knowledge acquisition stage, and examines the conformity of the expert system to the
expert's knowledge. In general, this testing checks the conformity between BAFDES reasoning and the expert's reasoning. In this dissertation, this testing is called reasoning validation.

The third type of testing is done by experts not involved in the knowledge acquisition stage, and examines the conformity of the expert system knowledge to other experts' knowledge, and to a wider selection of case studies. In this dissertation, this testing is called expertise validation.

Among the signs of failure that BAFDES uses to determine the causes of basement failures are: cracking pattern of basement walls, cracking pattern of the concrete floor, doors and windows that cannot be opened or closed, leaning walls, and signs of water leakage through the walls or floor. The knowledge used to induce the cause of basement failures from given signs of failure is based mostly on intuitive knowledge, rules of thumb, and heuristic approaches. Since these approaches are not quantifiable, it is impossible to present a quantitative proof of the validity of the expert system (Rick and Knight, 1991). For this reason, the second and third types of testing and validation of BAFDES are based on subjective evaluations of experts in the field of residential basements. Appendix C includes the form used by the experts
to evaluate the performance of BAFDES, as well as the completed forms.

Accuracy and efficiency validation was the first type of testing performed.

5.2 Accuracy and Efficiency Validation

Accuracy and efficiency validation is the part of the testing done exclusively by the knowledge engineer. The purpose of this testing is to examine the correctness of the reasoning in BAFDES, according to the knowledge representation, and the efficiency of the system. Accuracy and efficiency validation include checking for redundant rules, conflicting rules, and the external part of the inference engine.

While BAFDES was under development, testing and refinements were performed by the author and his advisor in order to maintain the programming correctness, and to assure maximum efficiency of the system. Maximum efficiency was achieved by leaving objects including long text or graphics in the external files part of BAFDES. By doing this, the size of the knowledge base was reduced to just ten percent of the total size of BAFDES. The final result is a program that runs fast and requires less computer memory to run, since text and graphics not required during a given consultation are not loaded into the computer memory.
In the final stages of development, a thorough accuracy test was performed. In order to facilitate the examination of accuracy for BAFDES, a slight modification was done to the classificatory tree described in Chapter Three. These modifications result in the Validation Tree included in Appendix B.

Part of the validation tree developed for BAFDES is shown in Figure 5.1. To construct the validation tree, the children of hypotheses are grouped into tables according to the result of the child subgoal. Figure 5.1 shows tables floor choice, floor case choice, floor crack choice, floor general choice, and floor settlement choice.

Tables are formed by columns and rows. The first column of a table includes the values found for the parent subgoal, while the last column includes the possible values for the child subgoal. Intermediate columns include parameters used to determine the value of the child subgoal. The first row of a table contains the labels for the parent and child subgoals, as well as the labels for each parameter in the table. Other rows include hypotheses that lead from the parent subgoal to the child subgoal (see Figure 5.1).

Each cell in a table contains the value of a subgoal or parameter for given hypotheses. Cells can be single valued, multiple valued, or empty. Single valued cells contain just one value for a parameter or subgoal. Cell A,3
Figure 5.1 Validation Tree
in table *floor crack choice* is an example of a single valued cell. Multiple valued cells are used when more than one value satisfies a hypothesis. These cells can include a list of values for parameters or subgoals, or a range for parameters. If the values are listed, they are separated by commas, as in the case of cell A,4 in table *floor crack choice*. If a range is given for a parameter, the first and last values of the range are listed and separated by a dash. An example is cell A,2 in table *floor crack choice*, which includes a range from four to six in addition to the values eight and eleven for the parameter *cracking pattern*.

In Figure 5.1, table *floor choice* was built to include the knowledge that ties the deformed basement element (walls or floor slab) to a subgoal used by the inference engine to test a group of cases of floor cracking. This group is included in table *floor case choice*. Note that the label of the last column of table *floor choice* is the same as the table of the first column of table *floor case choice*. This arrangement permits the creation of links between two tables, and is consistent throughout the entire validation tree.

The Validation Tree allows the knowledge engineer to test a classificatory expert system, such as BAFDES, by groups of hypotheses. The use of tables in the validation tree avoids a combinatorial explosion in the testing of the system. By using the validation tree, the knowledge
engineer can check for all possible combinations within tables instead of all combinations in the system. This helps in evaluating combinations without conclusion, or combinations that result in contradictions.

For this dissertation, all possible combinations in each table were tested with satisfactory results. Only a handful of combinations gave inconclusive results. After careful review of those combinations they were found to contain contradicting data, or very little information.

An error handling capability was included to block inconclusive results and handle cases with too little information. When BAFDES finds combinations of contradicting information, or combinations with insufficient information, BAFDES indicates why a result cannot be reached. In some cases, BAFDES even indicates what information is needed in order to run a successful consultation.

After the reasoning and efficiency validation was successful, knowledge validation was performed.

5.3 Reasoning Validation

Reasoning validation is done by the expert who participated in the knowledge acquisition stage. This testing examines the conformity of BAFDES reasoning and the expert's reasoning.
Reasoning validation was divided into two parts. The first part includes a review of the major decisions made in the classification built for the inference engine of BAFDES. The second part consists of a set of case studies run by the expert.

5.3.1 First Part of Reasoning Validation

For the first part of reasoning validation, the expert reviews the criteria used to make major decisions and evaluates whether or not they are valid. In BAFDES, major decisions are made after the review of the cracking pattern observed in the basement. The cracking pattern in the basement wall usually indicates if the failure is due to settlement or to lateral pressure in the walls. A minor error on the use of a cracking pattern was found and corrected. Chapter Two contains a detailed explanation about the relationship between cracking pattern and causes of basement failure.

A second major decision is made by BAFDES in order to determine if lateral pressure on the basement walls is due to excessive hydrostatic pressure or excessive fluid weight pressure of the soil on the walls. This decision is greatly based on the type of soil found in the backfill, and the presence of moisture marks on the basement walls. Other decisions of lesser importance were also checked in order to assure the correct reasoning followed by BAFDES.
It is important to note that during the first part of the reasoning validation, BAFDES proved to be helpful to the expert. The expert ran a case study of cracking to check if the system was making appropriate decisions. An intermediate conclusion given by BAFDES indicated that the failure was probably due to excessive lateral pressure on the basement wall. The expert disagreed with this result and indicated that the cause of the failure was soil settlement. The expert continued to further evaluation of the problem and the justifications given to the result by BAFDES. The expert then recognized that the geometry of the wall combined with lateral pressure on the wall resulted in a crack similar to the cracking due to soil settlement. BAFDES recognized the difference and its indicated evaluation of the failure was correct. Moreover, BAFDES went on to remind the expert of his own expertise.

For BAFDES, the result of the first part of the reasoning validation was satisfactory. After this part was completed, the expert performed the second part of the reasoning validation.

5.3.2 Second Part of Reasoning Validation

For the second part of the reasoning validation, a set of 13 case studies that covered common cases of basement failure were reviewed by the expert. For each case study the expert evaluated the result given by BAFDES in two
ways. First, the expert evaluated how close his answer was to the result given by BAFDES (see second column in Table 5.1). Second, the expert evaluated the reasonableness of the result given by BAFDES (see third column in Table 5.2). This determines if the answers given by BAFDES are justifiable and reasonable, even though they may be different than the answer given by the expert.

Table 5.1 shows the results obtained for the 13 cases run for the second part of the reasoning validation. The expert graded the results as very good, good, fair, poor, and very poor. The numbers in parenthesis show the equivalent in a scale 0 to 4. The last line on Table 5.1 shows the average for the 13 cases.

After the case studies were run, the expert was able to evaluate BAFDES as a whole. Here, the expert evaluates system completeness, user interface, system efficiency, and real world applicability. The system completeness is a measure of the amount of knowledge embedded in the system, which allows BAFDES to indicate causes of basement failure. Limitations in the scope of this dissertation limit the degree to which an excellent result for the evaluation of this aspect could be obtained. The user interface is a measure of the friendliness of the system, and evaluates, among other features, on-screen help, illustrations, and explanations given to conclusions.
Table 5.1 Reasoning Validation Result

<table>
<thead>
<tr>
<th>CASE NUMBER</th>
<th>RESULT MATCHES EXPERT</th>
<th>RESULT IS REASONABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>2</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>3</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>4</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>5</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>6</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>7</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>8</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>9</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>10</td>
<td>Poor (1)</td>
<td>Fair (2)</td>
</tr>
<tr>
<td>11</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>12</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>13</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>Good - Very Good (3.38)</td>
<td>Good - Very Good (3.46)</td>
</tr>
</tbody>
</table>
The following evaluations for BAFDES were given by the expert:

- System Completeness: Good
- User Interface: Very Good
- Efficiency: Very Good
- Real World Applicability: Good

After a successful reasoning validation, BAFDES was tested by other experts to determine the degree of expertise of BAFDES.

5.3 Expertise Validation

Expertise validation is done by experts not involved in the knowledge acquisition stage. There is a large amount of knowledge that is needed to find the cause of every type of basement failure in residential buildings, even under the limitations indicated in Chapter One. Moreover, the source of the knowledge is also incomplete by nature, since the knowledge is acquired from experience. These are two reasons to expect that the expertise validation will give results not as satisfactory as the reasoning validation.

Expertise validation evaluates the conformity of the expert system knowledge to the knowledge of experts not involved during the development of BAFDES. Since the expertise of a professional is evaluated by his/her peers, in this dissertation, BAFDES is also evaluated by other
experts in the field. Three experts in the area of soil mechanics, structures and architecture were involved in the expertise validation.

A total of 28 case studies that covered common cases of basement failure were reviewed by the experts. For each case study the expert evaluated the result given by BAFDES in the same form as the evaluation done for the second part of the reasoning evaluation. First, each expert evaluated how close his answer was to the result given by BAFDES (see second column in Table 5.2). Second, each expert evaluated the reasonability of the result given by BAFDES (see third column in Table 5.2).

Table 5.2 shows the results obtained for the 28 cases run for the expertise validation, while Table 5.3 shows the results obtained for the general evaluation of BAFDES. The grading of the results was done in a similar form as in the second part of reasoning validation.

The four case studies with fair or worse results were further evaluated to determine the cause of the unsatisfactory result. The cause for one very poor result was backtracked to the wrong selection of the crack. In this case, the expert was not sure about the location of a crack in the basement wall. In a similar consultation where the correct crack was selected, the evaluation of the result was very good. The cause of two fair results were backtracked to differences in subjective evaluations
between the participating experts and the non-participating experts. In only one case of fair result the cause of the unsatisfactory result was incomplete knowledge in BAFDES.
Table 5.2 Expertise Validation Result

<table>
<thead>
<tr>
<th>CASE NUMBER</th>
<th>RESULT MATCHING</th>
<th>RESULT IS REASONABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Good (3)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>2</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>3</td>
<td>Good (3)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>4</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>5</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>6</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>7</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>8</td>
<td>Very Poor (0)</td>
<td>Very Poor (0)</td>
</tr>
<tr>
<td>9</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>10</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>11</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>12</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>13</td>
<td>Good (3)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>14</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>15</td>
<td>Fair (2)</td>
<td>Fair (2)</td>
</tr>
<tr>
<td>16</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>17</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>18</td>
<td>Very Good (4)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>19</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>20</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>21</td>
<td>Good (3)</td>
<td>Fair (2)</td>
</tr>
<tr>
<td>22</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>23</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>24</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>25</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>26</td>
<td>Very Good (4)</td>
<td>Very Good (4)</td>
</tr>
<tr>
<td>27</td>
<td>Fair (2)</td>
<td>Good (3)</td>
</tr>
<tr>
<td>28</td>
<td>Good (3)</td>
<td>Good (3)</td>
</tr>
</tbody>
</table>

**AVERAGE**  
Good - Very Good  
(3.18)  
Good - Very Good  
(3.25)
Table 5.3 General Evaluation of BAFDES

<table>
<thead>
<tr>
<th>Measure</th>
<th>Expert 1</th>
<th>Expert 2</th>
<th>Expert 3</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Completeness</td>
<td>Very Good (4)</td>
<td>Good (3)</td>
<td>Very Good (4)</td>
<td>Good - Very (3.67)</td>
</tr>
<tr>
<td>User Interface</td>
<td>Very Good (4)</td>
<td>Good (3)</td>
<td>Good (3)</td>
<td>Good - Very (3.33)</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Very Good (4)</td>
<td>Good (3)</td>
<td>Good (3)</td>
<td>Good - Very (3.33)</td>
</tr>
<tr>
<td>Real World Applicability</td>
<td>Good (3)</td>
<td>Fair (2)</td>
<td>Good (3)</td>
<td>Fair - Good (2.67)</td>
</tr>
</tbody>
</table>
CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1 General

The objective of this dissertation was to provide an automated tool to determine the cause of basement failures in residential low rise buildings in Central Ohio. For this purpose, the Basement Failure Diagnosis Expert System, BAFDES, was developed.

BAFDES is a very user-friendly tool that engineers, technicians and landlords can consult for decision-making purposes. BAFDES provides on-screen help and explanations at the user's request, and indicates how the conclusions of a consultation are reached. In addition, BAFDES has graphic capabilities to show cracking patterns of basement components, moisture marks, and other characteristics of the failure. However, the final decision is left to the user's judgment.

This dissertation incorporates into BAFDES the most common types of failure in Ohio, namely, cracking of basement walls due to lateral pressure, settlement of basement walls, and cracking of basement floor due to soil
settlement and concrete shrinkage. More specific causes of failure are also included in BAFDES.

6.2 Knowledge Acquisition Process

The knowledge required to accomplish the objectives of the study was gathered from building foundation experts and from shared sources accepted by most building foundation engineers. The author of this dissertation found that a reliable form of knowledge acquisition from experts is by asking first general questions in a first stage of knowledge acquisition and then very specific questions during a second stage. The expert should first present case studies and the knowledge engineer would question the expert about the differences in evaluation of the failure if small variations are observed. This process leads to refinement of the knowledge, and elimination of redundancies and events that are unusual or speculative.

6.3 Knowledge Representation Models

Fault tree models and semantic net models can be used to build a knowledge representation model for diagnosis problems. Fault tree model facilitate the representation and decompilation of expert's knowledge since the causality relationship in fault tree models is very clear.

While fault tree models serve as the initial knowledge
representation, these models evolve into semantic nets as more knowledge is gathered during knowledge acquisition. Nodes, classes and arcs defined for the semantic net models built in this dissertation were specifically designed for diagnosis tasks. These models result in a well structured and clear knowledge representation. Fault tree models and semantic net models allow for minor to major refinement of the knowledge representation without losing the consistency of the knowledge. New knowledge can also be incorporated into the models without sacrificing the clarity of the knowledge representation. The study also shows that a classificatory tree can be built from the semantic net knowledge representation and can be used for hierarchical classification.

This dissertation introduces an innovative and effective method for the production of semantic net models based on fault trees. Semantic net models are then translated into a classificatory tree. The method accomplishes this through three steps that utilize the caused-by arcs in the semantic net, identify tests, and create intermediate branching by grouping alternatives in the classificatory tree.

The evolution from fault tree models to semantic net models and then to a classificatory tree takes place during knowledge acquisition. This new methodology was found
effective for developing the knowledge representation in diagnosis problems.

6.4 Testing and Validation Results

Testing and validation of BAFDES was carried out during and at the end of this dissertation. Case studies for residential buildings in Ohio were solved by experts and by BAFDES. Three types of testing were carried out to ensure the correct functioning of BAFDES.

The first type of testing examined the correctness of the search tree in Level 5 Object according to the knowledge representation.

The second type consisted of cases given and solved by the expert who participated in the knowledge acquisition stage. This testing examined the conformity of the expert system answer to the expert's knowledge, completeness and accuracy.

The third type of testing consisted of cases given and solved by experts not involved in the knowledge acquisition stage. This testing examined the possibility of conflicting answers and convenience of the user interface.

This testing approach caught major errors before the validation reaches the third type of testing. Minor errors due basically to incomplete knowledge in BAFDES and differences in opinion between experts were found during
the third type of testing.

During the second and third types of testing, BAFDES provided results very similar to those provided by experts. In few cases, however, BAFDES provided results different to those provided by experts. These latter cases were further examined, and the results given by BAFDES were found to be sound.

The results indicate that, in general, the system completeness, user interface, and efficiency of BAFDES range between good and very good. The applicability of BAFDES ranges between fair and good.

6.5 Recommendations

This dissertation provides an automated tool of determining the causes of failure of basements in residential buildings in central Ohio. However, this system has limitations that could be reduced with additional research.

The selection of the cracking pattern in BAFDES was inadequate for one case study. Additional research in the area of pattern matching should result in a more accurate form of cracking pattern identification.

The knowledge in BAFDES could be expanded to include causes of basement failure common in other areas in the United States. In addition, the involvement of more experts
for knowledge acquisition should result in a more complete system.

Since the knowledge in BAFDES does not consider the occurrence of multiple causes of failure, the addition of this knowledge would result in improvement of the applicability of BAFDES.

The addition of explanatory capabilities for the conclusions in BAFDES would improve the user interface and the clarity of the results. An expert suggested that two different levels of conclusions, one for engineers and another one for non-engineers would make conclusions more understandable for both.

Basement failures in residential buildings can be prevented by constructing engineered basements. This requires application of building codes, a movement from a trade designed product to an engineered code, and a willingness of contractors and owners to elevated initial housing costs.
LIST OF REFERENCES


Pasternack, S., Interview by Diaz, C. F., Columbus, Ohio, 1992.


APPENDIX A

BAFDES USER'S GUIDE
The user's guide for BAFDES is divided into installing BAFDES, consulting BAFDES, getting help, and result of consultations. The final section of this appendix includes a consultation sample.

A.1 Installing BAFDES

An appropriate system to run BAFDES should consist of an IBM PS/2 with an 80386, 16 MHz microprocessor, 4 MB of RAM, and 10 MB of hard disk space before installation of BAFDES. Software requirements are MS-DOS version 3.2 or higher and Microsoft Windows version 3.0 or higher. OS/2 version 2.0 or higher can be used instead of MS-DOS and Microsoft Windows. In addition Level 5 Object version 2.5 should be loaded before BAFDES can be run.

BAFDES comes on ten diskettes. The first diskette contains the system files and the external files with the extension TXT. The system files are stored in the root directory of the disk, while the TXT files are stored in a subdirectory named TXT. The other nine diskettes contain external files with the extension BMP.

To install BAFDES in the hard drive of the computer, create a subdirectory called BAFDES, and copy all the files in the root directory of the first diskette to subdirectory BAFDES in the hard drive. Next, change the current directory of the first diskette to subdirectory TXT, and
copy these files into subdirectory BAFDES in the hard drive. Last, copy all files in the remaining nine diskettes into subdirectory BAFDES in the hard drive.

A.2 Consulting BAFDES

Before running BAFDES, load Level 5 Object under Microsoft Windows or OS/2. The manual for the platform being used (Microsoft Windows or OS/2) should contain information on how to load programs. After Level 5 Object is loaded and running, click on the file option in the bar menu, and select load from the pull down menu. Then, select the file BAFDES.KNB from the list of files displayed. This process loads BAFDES and consultations can now be run.

To start a consultation, first click on the file option in the bar menu, and then select run from the pull down menu. An easier form of starting a consultation is by clicking on the "running man" icon displayed in the top of the screen. When you start a consultation, BAFDES displays the welcome screen. Click on the bottom bar to get information on how to use BAFDES. To return to the welcome screen, click on the bottom bar displayed on the bottom of the screen. To continue with the consultation, click again on the bar in the bottom of the screen.

If you want to quit or save your consultation, select file in the top bar menu, then select the appropriate
choice in the pull down menu. If, after you select file, you do not want to execute any of the options in the pull down menu, press the key labeled Esc in the top left part of your keyboard, or click file in the top bar menu once again.

During a consultation, BAFDES asks for information from the user. You may have to enter the information in YES/NO, or TRUE/FALSE boxes, multiple choice menus, check box menus, and fill-in-the-value boxes. For YES/NO prompts you can select YES or NO to a statement displayed by BAFDES. When you are answering to some YES/NO or TRUE/FALSE prompts, BAFDES may display an option labeled unknown in the top menu. Select unknown if you do not know the answer to the prompt.

In multiple choice menus (radio buttons) you can select only one of the choices in the menu. In check box menus (squared buttons) you can check as many choices as you want. Prompts in the form of multiple choice or check box menus include an unknown choice, and unknown will not be shown in the top menu as in the case of YES/NO, or TRUE/FALSE boxes. If you select unknown in a check box menu, you should not select other items in the menu, as this may result in contradictions.

After you are done entering information in a screen, click on the OK option in the top menu. After you click on
OK, BAFDES accepts the new information and takes you to the next screen.

If you do not answer to a prompt and click OK, BAFDES may automatically fill the prompts in the screen with the default value. This value is displayed for your information only. You may change the value, but the changes will not have any effect in the consultation since the default value was accepted when you clicked OK the first time. Note however, that default values are only used if you do not provide BAFDES with answers to the prompts.

A.3 Getting Help

BAFDES is designed to be a very interactive program, and provides extensive help to the user. This help may be obtained through hyper regions or the expand button.

During the consultation you will note that there is a dashed box or arch around some prompts. These dashed boxes or arches are called hyper regions. If you click on a hyper region around a prompt, a screen showing information related to that prompt is displayed. After you have read the information in the hyper region, do not press OK in the top bar menu. Instead, push the button labeled GO BACK TO THE PREVIOUS SCREEN in the bottom part of the screen.

Hyper regions are the usual and preferred form of providing help in BAFDES. However, in a few cases, this is
not possible due to space limitations and the organization of the screens. Instead of hyper regions, BAFDES provides help through the expand option in the top bar menu. When you are answering to some prompts, the top menu may show an option labeled Expand. If you click Expand, BAFDES displays a window with information related to the prompt you are answering. This small window is called expand screen. After you read the information in the expand screen, select OK in the expand screen to go back to the original screen.

A.4 Result of Consultations

Results of consultations are provided by BAFDES during and at the end of the consultation. These conclusions are shown in a screen that indicates the cause of the basement failure, explanation on how the conclusion was reached, and preventive information or additional comments on the failure.

When the final conclusion is displayed, BAFDES displays a sign in the conclusion screen that reads "THIS IS THE FINAL REFINEMENT". BAFDES provides the user with intermediate conclusions that indicate in what direction the consultation is going. When an intermediate conclusion is displayed, BAFDES displays a sign in the conclusion screen that reads "YOU MAY BE ABLE TO REFINE THIS
CONCLUSION." Click OK in the top bar menu after you finish reading the result given by the intermediate conclusion.

If you want to restart the consultation or start another consultation, click file on the top bar menu, and select restart in the pull down menu. Then follow the same procedures described earlier in this chapter.

A.5 Consultation Samples

Two self explanatory consultation samples are included here. Figures A.1 to A.19 show the screens of a consultation sample for a case of wall cracking. Figure A.1 shows the welcome screen of BAFDES. While some screens are used to prompt the user for information, other screens (See Figures A.4, A.5, A.10, A.13 and A.15) are hyper screens used to provide help. This consultation shows two intermediate conclusions (see Figures A.11 and A.17) before arriving at the final conclusion (see Figure A.19).

Figures A.20 to A.29 show the screens of a consultation sample for a case of floor cracking. Figure A.20 shows the welcome screen of BAFDES. In this consultation, most screens are used to prompt the user for information. Figure A.28 is a hyper screen used to provide on-screen help. This consultation shows no intermediate conclusion, and the last screen (see Figure A.29) shows the final conclusion.
WHAT IS BAFDES

The Basement Failure Diagnosis Expert System (BAFDES) is a computerized system that can identify the causes of failure of basement walls and basement floor slabs. Among the signs of failure that BAFDES will use to determine the cause of the basement failure are: cracking pattern of basement walls, cracking pattern of the concrete floor, bowing of walls, and signs of water leakage through the walls or floor. BAFDES is a very friendly tool that engineers and technicians can consult for decision making purposes. BAFDES indicates the most probable cause of the failure based on information given by the user. However, the final decision will be left to the engineer's judgement.

Figure A.1 Welcome Screen
Figure A.2 Indication of Damaged Element Screen
These are major problems:
- Cracking
- Bowing

These are other common problems:
- Deformed window or door frames
- Vertical separation of elements
- None of the above

If present, these last problems are isolated: TRUE / FALSE

Figure A.3 Indication of Damage Screen
Figure A.4 Major Problems Hyper Screen
You may have one or all the deformations shown in this figure. Here, BAFDES shows from left to right details of three deformations in the same wall:
(1) distorted window frame, (2) separation between basement components, (3) distorted door frame.

Figure A.5 Other Common Problems Hyper Screen
If you observe that several cracking patterns are similar to the one you observe in the building you need to compare several factors.

Figure A.6 Cracking Selection Screen
You enter the crack number in the previous screen.

Figure A.7 Display of More Cracks Screen
ABOUT SELECTION OF CRACKING PATTERN:

If you observe that several cracking patterns are similar to the one you observe in the building you need to compare several factors.

Explanatory Information

The cracking pattern may indicate the following:
- Horizontal cracking is usually due to soil freezing or lateral overload of the wall.
- Diagonal cracking is usually due to soil settlement.
- Random cracking direction usually occurs due to soil settlement, or poor concrete performance.
- Cracking in a corner is usually due to settlement of the soil under the corner.
- Cracking two feet below ground level is usually due to soil freezing.
- Randomly distributed cracks are usually due to soil settlement, or poor concrete performance.

Figure A.8 Cracking Selection Expand Screen
If you observed a dominant horizontal crack in the wall, what is the distance from the ground level to the crack?

Figure A.9 Wall Dimensions Screen
Figure A.10 Wall Dimensions Hyper Screen
Based on the given information, the diagonal cracking is probably due to EXCESSIVE EXTERIOR LATERAL FORCES APPLIED ON THE BASEMENT WALL. Soil freezing does not seem to be the cause of the horizontal cracking since the cracking pattern does not match the typical cracking observed for cases of...

Figure A.11 First Intermediate Conclusion Screen
Do you observe signs of excessive moisture in the basement floor or walls?

- If you have observed moisture signs, where are they more evident?
  - Bottom of wall
  - Random
  - Unknown

Figure A.12 Moisture Signs Screen
STAINS and/or SPALLING OFF of the paint in basement floor or walls are the most common signs of excessive moisture. In some cases, if you place your hand on the basement wall you can feel WETNESS.

WATER ENTRY into the basement through cracks are also signs of

Figure A.13 Moisture Signs Hyper Screen
(Courtesy of Dr. Stephen Pasternack)
Figure A.14 Ground Level Screen
If the basement walls are built of MASONRY, each block is 8 in. high. If this is the case, 3 blocks are equivalent to 2 feet.

**Figure A.15 Ground Level Hyper Screen**
Excavate one foot into the ground behind the basement wall and provide the following information about the soil.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the soil is wet, does it leave your fingers dirty?</td>
<td></td>
</tr>
<tr>
<td>Does the soil contain dry vegetation or fibres from vegetation?</td>
<td></td>
</tr>
</tbody>
</table>

- **Soil color**
  - Dark
  - Brown
  - White
  - Unknown

Figure A.16 Soil Characteristics Screen
Based on the given information, the basement failure is probably due to EXCESSIVE EXTERIOR LATERAL PRESSURE APPLIED ON THE BASEMENT WALL. This pressure is likely to have been caused by EXCESSIVE LATERAL SOIL FLUID WEIGHT PRESSURE BEHIND THE AFFECTED BASEMENT WALL. This means that the backfill soil...
Do you observe settlement of the sidewalk around the house, and behind the damaged basement wall?

Signs of sidewalk settlement include:
- The lower two inches of the wall are NOT PAINTED.
- The bottom two inches of the wall have MARKS of soil.
- There is a WIDE CRACK between the SIDEWALK (if any) and the wall.

Figure A.18 Sidewalk Settlement Screen
(Courtesy of Owens, 1989)
Settlement of the sidewalk behind the basement wall suggest that the backfill soil behind the basement wall has settled due to the use of inadequate soil for the backfill and improper backfilling procedures. SETTLEMENT OF BACKFILL SOIL PROBABLY APPLIED EXCESSIVE PRESSURE ON THE BASEMENT WALL. The soil is probably an uncompacted clayey material found on site.

Figure A.19 Final Conclusion Screen
(Courtesy of Meyers, 1988)
WHAT IS BAFDES

The Basement Failure Diagnosis Expert System (BAFDES) is a computerized system that can identify the causes of failure of basement walls and in basement floor slabs. Among the signs of failure that BAFDES will use to determine the cause of the basement failure are: cracking pattern of basement walls, cracking pattern of the concrete floor, bowing of walls, and signs of water leakage through the walls or floor. BAFDES is a very friendly tool that engineers and technicians can consult for decision making purposes. BAFDES indicates the most probable cause of the failure based on information given by the user. However, the final decision will be left to the engineer's judgement.
In this case study, cracking appeared around a column, and the floor around the slab settled a little.

Does the cracking in your basement look like this?

Figure A.21 Case One Screen
In this case, cracking appeared around a column in the basement. The cracking also extended away from the column but stopped at a short distance. Additionally, the cracked floor slab close to the column was slightly pushed upward.

Does the cracking in your basement look like this?  

YES  NO

Figure A.22 Case Two Screen  
(Courtesy of Schild, 1981)
In this case, the cracking in the floor slab CONTINUES FROM THE CONTROL JOINTS. Note however, that the cracking is not as wide as the control joints.

Does the cracking in your basement look like this?  

YES  NO

Figure A.23 Case Three Screen
In this case, the basement floor slab damage includes local cracking, and the cracked pieces are pushed into the ground.

Figure A.24 Case Four Screen (courtesy of Thomas et al., 1987)

Does the cracking in your basement look like this?

YES  NO
In this case, the cracking is wide, and there is a level difference between the two sides of the crack.

Does the cracking in your basement look like this?

**YES**

**NO**

Figure A.25 Case Five Screen
(Courtesy of Meyers, 1988)
ABOUT SELECTION OF CRACKING PATTERN:

If you observe that several cracking patterns are similar to the one you observe in the building you need to compare several factors.

Figure A.26 Floor Cracking Pattern Selection Screen
Do you observe level difference between the two sides of the cracks?  YES  NO

Do you observe moisture coming from the cracks in the floor slab?  YES  NO

Does the floor slab have control joints?  YES  NO

Figure A.27 Floor Characteristics Screen
This is an example of difference in elevation between the two sides of a crack in a basement floor slab.

Figure A.28 Level Difference Hyper Screen
(Courtesy of Malish, 1990)
The indicated cracking suggest that the probable cause of failure is SOIL MOVEMENT UNDER BASEMENT FLOOR SLAB. Random cracking indicates that the settlement is affecting the ENTIRE BUILDING.

Figure A.29 Final Conclusion Screen
APPENDIX B

VALIDATION TREE
<table>
<thead>
<tr>
<th>lateral swalk</th>
<th>wall thick</th>
<th>v. rebar h. rebar length</th>
<th>original wsoil w order</th>
</tr>
</thead>
<tbody>
<tr>
<td>weight</td>
<td>TRUE</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>weight</td>
<td>Sol mas</td>
<td>Less</td>
<td>--</td>
</tr>
<tr>
<td>weight</td>
<td>Sol mas</td>
<td>--</td>
<td>&gt;=8</td>
</tr>
<tr>
<td>weight</td>
<td>Conc</td>
<td>Less</td>
<td>--</td>
</tr>
<tr>
<td>weight</td>
<td>Conc</td>
<td>--</td>
<td>&gt;=8</td>
</tr>
<tr>
<td>weight</td>
<td>Hol mas</td>
<td>Less</td>
<td>--</td>
</tr>
<tr>
<td>weight</td>
<td>Hol mas</td>
<td>--</td>
<td>&gt;=8</td>
</tr>
<tr>
<td>weight</td>
<td>Brick</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>weight</td>
<td>Stone</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>weight</td>
<td>--</td>
<td>TRUE</td>
<td>--</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>wsoil w length</th>
<th>h. rebar whor order</th>
</tr>
</thead>
<tbody>
<tr>
<td>hor &gt;=12</td>
<td>1 No 4 long 12 1</td>
</tr>
<tr>
<td>hor &gt;=12</td>
<td>2 No 3 long 12 1</td>
</tr>
<tr>
<td>hor &gt;=12</td>
<td>2 No 4 long 12 1</td>
</tr>
<tr>
<td>hor &gt;=12</td>
<td>Less long 12 1</td>
</tr>
<tr>
<td>hor &gt;=10+&lt;12</td>
<td>2 No 3 long 10 2</td>
</tr>
<tr>
<td>hor &gt;=10+&lt;12</td>
<td>2 No 4 long 10 2</td>
</tr>
<tr>
<td>hor &gt;=10+&lt;12</td>
<td>Less long 10 2</td>
</tr>
<tr>
<td>hor &lt;10</td>
<td>Less hor 3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>whor original whor1</th>
</tr>
</thead>
<tbody>
<tr>
<td>long 12 TRUE original</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>whor original whor2</th>
</tr>
</thead>
<tbody>
<tr>
<td>long 10 TRUE original</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>whor original whor3</th>
</tr>
</thead>
<tbody>
<tr>
<td>hor TRUE original</td>
</tr>
<tr>
<td>Vertical</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Less than 4</td>
</tr>
<tr>
<td>Less than 4</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Less than 5</td>
</tr>
<tr>
<td>More than 5</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>More than 5</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>More than 6</td>
</tr>
<tr>
<td>Less than 6</td>
</tr>
<tr>
<td>More than 6</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>More than 6</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>More than 7</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>Less than 7</td>
</tr>
<tr>
<td>element</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>WALL</td>
</tr>
<tr>
<td>WALL</td>
</tr>
<tr>
<td>WALL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>w sup.</th>
<th>cracking pattern</th>
<th>oth hous</th>
<th>wsupa</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>w sup a</td>
<td>4,13,14,41</td>
<td>--</td>
<td>corner</td>
<td>1</td>
</tr>
<tr>
<td>w sup a</td>
<td>5-12,15-21,33-38</td>
<td>TRUE</td>
<td>fill</td>
<td>2</td>
</tr>
<tr>
<td>w sup a</td>
<td>5-7,9-12,33,34,38</td>
<td>--</td>
<td>local</td>
<td>3</td>
</tr>
<tr>
<td>w sup a</td>
<td>8,15-21,35-37</td>
<td>--</td>
<td>general</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>wsupa</th>
<th>sewer</th>
<th>moist</th>
<th>w corner</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>corner</td>
<td>TRUE</td>
<td>TRUE</td>
<td>sewer</td>
<td>1</td>
</tr>
<tr>
<td>corner</td>
<td>--</td>
<td>--</td>
<td>pocket</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>wsupa</th>
<th>width</th>
<th>old fill</th>
<th>end</th>
<th>around</th>
<th>age</th>
<th>wlocal</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>local</td>
<td>Narrow</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE&lt;=2</td>
<td>fill</td>
<td>capacity</td>
</tr>
<tr>
<td>local</td>
<td>Wide</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>fill</td>
<td>5</td>
</tr>
<tr>
<td>local</td>
<td>--</td>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>old fill</td>
<td>4</td>
</tr>
<tr>
<td>local</td>
<td>--</td>
<td>--</td>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>street</td>
<td>2</td>
</tr>
<tr>
<td>local</td>
<td>--</td>
<td>--</td>
<td>FALSE</td>
<td>TRUE</td>
<td>--</td>
<td>around</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>wsupa</th>
<th>width</th>
<th>old fill</th>
<th>end</th>
<th>around</th>
<th>age</th>
<th>wgen</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>general</td>
<td>Narrow</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE&lt;=2</td>
<td>fill</td>
<td>capacity</td>
</tr>
<tr>
<td>general</td>
<td>Wide</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>fill</td>
<td>5</td>
</tr>
<tr>
<td>general</td>
<td>--</td>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>old fill</td>
<td>4</td>
</tr>
<tr>
<td>general</td>
<td>--</td>
<td>--</td>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>street</td>
<td>2</td>
</tr>
<tr>
<td>general</td>
<td>--</td>
<td>--</td>
<td>FALSE</td>
<td>TRUE</td>
<td>--</td>
<td>around</td>
<td>3</td>
</tr>
</tbody>
</table>
### element floor

<table>
<thead>
<tr>
<th>floor</th>
<th>floor 1</th>
<th>floor 2</th>
<th>floor 3</th>
<th>floor 4</th>
<th>floor 5</th>
<th>case</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>test fl</td>
<td>YES</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>case1</td>
<td>1</td>
</tr>
<tr>
<td>test fl</td>
<td>--</td>
<td>YES</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>case2</td>
<td>2</td>
</tr>
<tr>
<td>test fl</td>
<td>--</td>
<td>--</td>
<td>YES</td>
<td>--</td>
<td>--</td>
<td>case3</td>
<td>3</td>
</tr>
<tr>
<td>test fl</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>YES</td>
<td>--</td>
<td>case4</td>
<td>4</td>
</tr>
<tr>
<td>test fl</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>YES</td>
<td>case5</td>
<td>5</td>
</tr>
</tbody>
</table>

### element cracking pattern bowing fcrack order

<table>
<thead>
<tr>
<th>FLOOR</th>
<th>pattern</th>
<th>bowing</th>
<th>fcrack</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,5,6,8,11</td>
<td>--</td>
<td>general</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>--</td>
<td>local</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2,3</td>
<td>--</td>
<td>corner</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>--</td>
<td>curing</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>--</td>
<td>exp</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>--</td>
<td>settl</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

### fcrack el.diff. moist joints fgen order

<table>
<thead>
<tr>
<th>general</th>
<th>el.diff.</th>
<th>moist</th>
<th>joints</th>
<th>fgen</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>settle</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>plastic</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>TRUE</td>
<td>--</td>
<td>hydro</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

### fcrack isolated fsettl order

<table>
<thead>
<tr>
<th>settl</th>
<th>isolated</th>
<th>fsettl</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRUE</td>
<td>local</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>FALSE</td>
<td>general</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>type</td>
<td>limit</td>
<td>ind</td>
<td>expand</td>
</tr>
<tr>
<td>--------------</td>
<td>-------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>Clay</td>
<td>&gt;=60</td>
<td>&gt;=35</td>
<td>High</td>
</tr>
<tr>
<td>Clay</td>
<td>30-59</td>
<td>13-34</td>
<td>Medium</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt;30</td>
<td>&lt;15</td>
<td>Low</td>
</tr>
<tr>
<td>No clay</td>
<td>--</td>
<td>--</td>
<td>Nonexp</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>shovel</th>
<th>molded</th>
<th>3&quot; stick</th>
<th>hard</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>FALSE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>Hard</td>
<td>1</td>
</tr>
<tr>
<td>TRUE</td>
<td>FALSE</td>
<td>FALSE</td>
<td>Firm</td>
<td>2</td>
</tr>
<tr>
<td>--</td>
<td>TRUE</td>
<td>--</td>
<td>Soft</td>
<td>3</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>TRUE</td>
<td>Soft</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>fingers</th>
<th>fibres</th>
<th>color</th>
<th>consist</th>
<th>grain</th>
<th>settled</th>
<th>type</th>
<th>order</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRUE</td>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Organic</td>
<td>1</td>
</tr>
<tr>
<td>TRUE</td>
<td>--</td>
<td>Dark</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Organic</td>
<td>1</td>
</tr>
<tr>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>Squizes</td>
<td>--</td>
<td>--</td>
<td>Clay</td>
<td>2</td>
</tr>
<tr>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>Molded</td>
<td>inv</td>
<td>--</td>
<td>Clay</td>
<td>2</td>
</tr>
<tr>
<td>TRUE</td>
<td>--</td>
<td>--</td>
<td>inv</td>
<td>--</td>
<td>--</td>
<td>Clay</td>
<td>2</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Disint</td>
<td>--</td>
<td>--</td>
<td>Sand</td>
<td>3</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>bristles</td>
<td>--</td>
<td>--</td>
<td>Sand</td>
<td>3</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>almonds</td>
<td>--</td>
<td>--</td>
<td>Gravel</td>
<td>4</td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>TRUE</td>
<td>Clay</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>type</th>
<th>pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic</td>
<td>70</td>
</tr>
<tr>
<td>Clay</td>
<td>70</td>
</tr>
<tr>
<td>Sand</td>
<td>40</td>
</tr>
<tr>
<td>Gravel</td>
<td>30</td>
</tr>
</tbody>
</table>
APPENDIX C

VALIDATION FORMS AND RESULTS
<table>
<thead>
<tr>
<th>CASE NUMBER</th>
<th>RESULT MATCHING</th>
<th>RESULT IS REASONABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>2</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>3</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>4</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>5</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>6</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>7</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>8</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>9</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>10</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>11</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>12</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>13</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>14</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>15</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Completeness</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>User Interface</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>Efficiency</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>Applicability</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
</tbody>
</table>
**NAME:** Steve Benjamin  
**AFFILIATION:** ODOT  
**DEGREES:** BSCE  
**AREA OF EXPERTISE:** Structures  
**BASEMENT RELATED EXPERIENCE:** 5 years

<table>
<thead>
<tr>
<th>CASE NUMBER</th>
<th>RESULT MATCHING</th>
<th>RESULT IS REASONABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>2</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>3</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>4</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>5</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>6</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>7</td>
<td>VG(GOOD) FAIR POOR VP</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>8</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>9</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>10</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>11</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>12</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>13</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>14</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>15</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
</tbody>
</table>

**SYSTEM**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completeness</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>User Interface</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>Efficiency</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>Applicability</td>
<td>VG(GOOD) FAIR POOR VP</td>
</tr>
<tr>
<td>CASE NUMBER</td>
<td>RESULT MATCHING</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td></td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td><strong>1</strong></td>
<td><strong>VG GOOD FAIR POOR VP</strong></td>
</tr>
<tr>
<td>2</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>3</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>4</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>5</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>6</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>7</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>8</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>9</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>10</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>11</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>12</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>13</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>14</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>15</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
</tbody>
</table>

**SYSTEM**

Completeness: VG GOOD FAIR POOR VP
User Interface: VG GOOD FAIR POOR VP
Efficiency: VG GOOD FAIR POOR VP
Applicability: VG GOOD FAIR POOR VP
<table>
<thead>
<tr>
<th>CASE NUMBER</th>
<th>RESULT MATCHING</th>
<th>RESULT IS REASONABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>2</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>3</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>4</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>5</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>6</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>7</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>8</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>9</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>10</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>11</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>12</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>13</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>14</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>15</td>
<td>VG GOOD FAIR POOR VP</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
</tbody>
</table>

**SYSTEM**

<table>
<thead>
<tr>
<th>Category</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completeness</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>User Interface</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>Efficiency</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
<tr>
<td>Applicability</td>
<td>VG GOOD FAIR POOR VP</td>
</tr>
</tbody>
</table>
APPENDIX D

BAFDES CODE

191
CLASS basement wall
  WITH length NUMERIC
    DEFAULT 27
    QUERY FROM BAFDES wall dimensions display
    SEARCH ORDER CONTEXT QUERY WHEN NEEDED RULES DEFAULT
  WITH height NUMERIC
    DEFAULT 9
    QUERY FROM BAFDES wall dimensions display
    SEARCH ORDER CONTEXT QUERY WHEN NEEDED RULES DEFAULT
  WITH thickness COMPOUND
    Six inches or less,
    Eight inches,
    Ten inches,
    Twelve inches or more,
    Unknown
    QUERY FROM BAFDES wall type display
    SEARCH ORDER CONTEXT WHEN NEEDED RULES QUERY DEFAULT
  WITH type COMPOUND
    Brick,
    Solid masonry,
    Hollow masonry,
    Concrete,
    Stone,
    Unknown
    QUERY FROM BAFDES wall type display
    WITH ratio NUMERIC
    WHEN NEEDED
    BEGIN
      ratio OF basement wall := length OF basement wall / height OF basement wall
    END
    SEARCH ORDER CONTEXT WHEN NEEDED RULES DEFAULT
  WITH fill height NUMERIC
    DEFAULT 5
    WHEN NEEDED
    BEGIN
      IF fill level OF residential basement wall IS First floor level THEN
        fill height OF residential basement wall := height OF residential basement wall
      IF fill level OF residential basement wall IS Two feet below first floor level THEN
fill height of residential basement wall := height of residential basement wall - 2

END

QUERY FROM BAFDES fill height
SEARCH ORDER CONTEXT QUERY WHEN NEEDED RULES DEFAULT
WITH vertical rebar COMPOUND
No 3 @ 18,
No 4 @ 72,
No 5 @ 72,
No 5 @ 64,
No 6 @ 56,
No 6 @ 48,
More,
Less,
Unknown
QUERY FROM BAFDES reinforcement display
WITH horizontal rebar COMPOUND
Two No 3,
Two No 4,
Two No 5,
One No 4,
More,
Less,
Unknown
QUERY FROM BAFDES reinforcement display
WITH fill level COMPOUND
First floor level,
Two feet below first floor level,
Unknown
QUERY FROM BAFDES fill height

INSTANCE residential basement wall ISA basement wall

CLASS building
WITH sump pump pipe SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES sump pump display
WITH old fill SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES fill display
WITH street end SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES fill display
WITH sump pump SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES sump pump display
WITH settlement around SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES fill display
WITH age NUMERIC
QUERY FROM BAFDES building age display
WITH sewer SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES corner display
WITH sidewalk settlement SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES sidewalk settlement display
WITH control joints SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES floor level difference display
WITH slope COMPOUND
Flat lot,
Sloped lot
QUERY FROM BAFDES slope display

INSTANCE residential ISA building

CLASS case studies
WITH case floor1 SIMPLE
QUERY FROM BAFDES case floor 1 display
WITH case floor2 SIMPLE
QUERY FROM BAFDES case floor2 display
WITH case floor3 SIMPLE
QUERY FROM BAFDES case floor3 display
WITH case floor4 SIMPLE
QUERY FROM BAFDES case floor4 display
SEARCH ORDER CONTEXT WHEN NEEDED RULES QUERY DEFAULT
WITH case floor5 SIMPLE
QUERY FROM BAFDES case floor5 display

INSTANCE floor case studies ISA case studies

CLASS crack
WITH width COMPOUND
Narrow,
Wide
QUERY FROM BAFDES crack width display
WITH cracking pattern NUMERIC
EXPAND EXPA cracking pattern display
QUERY FROM BAFDES cracking pattern display
WITH depth NUMERIC
QUERY FROM BAFDES hydrostatic pressure display
WITH other houses SIMPLE
UNKNOWN PROMPTING
DEFAULT FALSE
QUERY FROM BAFDES other houses display
WITH other deformations MULTICOMPOUND
Deformed window or door frames,
Separation between structural elements,
None of the above
EXHAUSTIVE
QUERY FROM BAFDES damage display
WITH wider bottom SIMPLE
UNKNOWN PROMPTING
DEFAULT FALSE
QUERY FROM BAFDES corner display
WITH corner moisture SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES corner display
WITH isolated problem SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES damage display
WITH elevation difference SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES floor level difference display
WITH floor bowing SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES floor slab bowing display
WITH floor moisture SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES floor level difference display
WITH isolated crack SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES isolated floor crack display
WITH vertical SIMPLE
QUERY FROM BAFDES vertical movement display

INSTANCE wall crack ISA crack

INSTANCE floor crack ISA crack

CLASS soil
WITH type COMPOUND
Clay,
Sand,
CLASS soil
  WITH type COMPOUND
    Clay,
    Sand,
    Gravel,
    Organic
SEARCH ORDER CONTEXT RULES DEFAULT
WITH pressure NUMERIC
WHEN NEEDED
BEGIN
  IF type OF backfill IS Organic THEN
    pressure OF backfill := 70
  ELSE
    IF type OF backfill IS Clay THEN
      pressure OF backfill := 70
    ELSE
      IF type OF backfill IS Sand THEN
        pressure OF backfill := 40
      ELSE
        IF type OF backfill IS Gravel THEN
          pressure OF backfill := 30
        END
      END
    END
  END
END
SEARCH ORDER CONTEXT WHEN NEEDED RULES DEFAULT
WITH fibres SIMPLE
  UNKNOWN PROMPTING
QUERY FROM BAFDES organic soil display
WITH color COMPOUND
  Dark,
  Brown,
  White,
  Unknown
QUERY FROM BAFDES organic soil display
WITH fingers SIMPLE
  UNKNOWN PROMPTING
QUERY FROM BAFDES organic soil display
WITH consistency COMPOUND
  Squees between fingers,
  Molded with fingers,
  Disintegrates when dry,
  None of the above,
  Unknown
QUERY FROM BAFDES soil identification display
WITH grain size COMPOUND
  Like almonds,
WITH original SIMPLE
UNKNOWN PROMPTING
QUERY FROM BAFDES original soil display
WITH hardness COMPOUND
   Hard,
   Firm,
   Soft
SEARCH ORDER CONTEXT RULES DEFAULT
WITH strength MULTICOMPounder
   Soil can be excavated with shovel,
   Soil can be molded with hand,
   A three inch wide stick penetrates easily,
   None of the above,
   Unknown
EXHAUSTIVE
QUERY FROM BAFDES soil strength display
WITH liquid limit NUMERIC
QUERY FROM BAFDES expansive soil display
WITH plastic index NUMERIC
QUERY FROM BAFDES expansive soil display

INSTANCE backfill ISA soil

INSTANCE foundation ISA soil

ATTRIBUTE test wall strength STRING
WHEN CHANGED
BEGIN
   IF test wall strength = "wall strength a" THEN
      filename OF conclusion text box := "LATERAL1.TXT"
   IF test wall strength = "wall strength b" THEN
      filename OF conclusion text box := "LATERAL2.TXT"
   IF test wall strength = "wall support a" THEN
      filename OF conclusion text box := "SETTLE1.TXT"
   IF test wall strength = "wall support b" THEN
      filename OF conclusion text box := "SETTLE2.TXT"
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wall strength choice STRING
WHEN CHANGED
BEGIN
   IF wall strength choice = "press a" THEN
      BEGIN
         filename OF conclusion text box := "PRESS1.TXT"
         filename OF conclusion picture := "PRESS1.BMP"
BEGIN
IF wall strength choice = "press b" THEN
BEGIN
  filename OF conclusion text box := "PRESS2.TXT"
  filename OF conclusion picture := "PRESS2.BMP"
END
IF wall strength choice = "press c" THEN
BEGIN
  filename OF conclusion text box := "PRESS3.TXT"
  filename OF conclusion picture := "PRESS3.BMP"
END
IF wall strength choice = "press d" THEN
BEGIN
  filename OF conclusion text box := "PRESS4.TXT"
  filename OF conclusion picture := "PRESS4.BMP"
END
IF wall strength choice = "freezing" THEN
BEGIN
  filename OF conclusion text box := "FREEZING.TXT"
  filename OF conclusion picture := "FREEZING.BMP"
END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wlateral choice STRING WHEN CHANGED
BEGIN
  IF wlateral choice = "expansive" THEN
  BEGIN
    filename OF conclusion text box := "EXPAN.TXT"
    filename OF conclusion picture := "EXPANSIVE.BMP"
  END
  IF wlateral choice = "hydrostatic pressure" THEN
  BEGIN
    filename OF conclusion text box := "HYDRO.TXT"
    filename OF conclusion picture := "DRAINAGE.BMP"
  END
  IF wlateral choice = "weight" THEN
  BEGIN
    filename OF conclusion text box := "WEIGHT.TXT"
    filename OF conclusion picture := "PRESSURE.BMP"
  END
  IF wlateral choice = "fill height" THEN
  BEGIN
    filename OF conclusion text box := "HEIGHT.TXT"
    filename OF conclusion picture := "HEIGHT.BMP"
  END
ATTRIBUTE cause STRING
EXHAUSTIVE
ATTRIBUTE deformation MULTICOMPOUND
  Cracking,
  Bowing
EXHAUSTIVE
QUERY FROM BAFDES damage display
SEARCH ORDER CONTEXT QUERY DEFAULT
ATTRIBUTE expansive soil COMPOUND
  High,
  Medium,
  Low,
  Nonexpansive,
  Unknown
DEFAULT Nonexpansive
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE signs of moisture SIMPLE
UNKNOWN PROMPTING
DEFAULT FALSE
QUERY FROM BAFDES hydrostatic pressure display
ATTRIBUTE whydro choice STRING
WHEN CHANGED
BEGIN
  IF whydro choice = "drainage" THEN
  BEGIN
    filename OF conclusion text box := "DRAIN.TXT"
    filename OF conclusion picture := "DRAIN.BMP"
  END
  IF whydro choice = "backfill" THEN
  BEGIN
    filename OF conclusion text box := "BACKFILL.TXT"
    filename OF conclusion picture := "BACKFILL.BMP"
  END
  IF whydro choice = "no drain" THEN
  BEGIN
    filename OF conclusion text box := "NODRAIN.TXT"
    filename OF conclusion picture := "NODRAIN.BMP"
  END
  IF whydro choice = "sump pump" THEN
  BEGIN
    filename OF conclusion text box := "SUMPPUMP.TXT"
    filename OF conclusion picture := "SUMPPPIPE.BMP"
END
IF whydro choice = "original" THEN
BEGIN
  filename OF conclusion text box := "ONSITEDR.TXT"
  filename OF conclusion picture := "ONSITEDR.BMP"
END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wsoil weight choice STRING
WHEN CHANGED
BEGIN
  IF wsoil weight choice = "hollow vertical" THEN
    BEGIN
      filename OF conclusion text box := "HOLLOWV.TXT"
      filename OF conclusion picture := "REBAR.BMP"
    END
  END
  IF wsoil weight choice = "vertical" THEN
    BEGIN
      filename OF conclusion text box := "VERTICAL.TXT"
      filename OF conclusion picture := "REBAR.BMP"
    END
  END
  IF wsoil weight choice = "hollow horizontal" THEN
    BEGIN
      filename OF conclusion text box := "HOLLOWH.TXT"
      filename OF conclusion picture := "HREBAR.BMP"
    END
  END
  IF wsoil weight choice = "horizontal" THEN
    BEGIN
      filename OF conclusion text box := "HORIZON.TXT"
      filename OF conclusion picture := "HREBAR.BMP"
    END
  END
  IF wsoil weight choice = "brick" THEN
    BEGIN
      filename OF conclusion text box := "BRICK.TXT"
      filename OF conclusion picture := "BRICK.BMP"
    END
  END
  IF wsoil weight choice = "thin" THEN
    BEGIN
      filename OF conclusion text box := "THIN.TXT"
      filename OF conclusion picture := "THIN.BMP"
    END
  END
  IF wsoil weight choice = "original" THEN
    BEGIN
      filename OF conclusion text box := "ORIGINAL.TXT"
      filename OF conclusion picture := "ORIGINAL.BMP"
    END
  END
IF wsoil weight choice = "sidewalk" THEN
BEGIN
filename OF conclusion text box := "SIDEWALK.TXT"
filename OF conclusion picture := "SIDEWALK.BMP"
END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE moisture COMPOUND
Bottom of wall,
Random,
Unknown
QUERY FROM BAFDES hydrostatic display
ATTRIBUTE whorizonal choice STRING
WHEN CHANGED
BEGIN
IF whorizonal choice = "horizontal" THEN
filename OF conclusion text box := "HORIZON1.TXT"
IF whorizonal choice = "long 10" THEN
filename OF conclusion text box := "HORTEN.TXT"
IF whorizonal choice = "long 12" THEN
filename OF conclusion text box := "HORTWEL.TXT"
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE floor choice STRING
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wsupport choice STRING
WHEN CHANGED
BEGIN
IF wsupport choice = "corner" THEN
BEGIN
filename OF conclusion text box := "CORNER.TXT"
filename OF conclusion picture := "CORNER.BMP"
END
IF wsupport choice = "local" THEN
BEGIN
filename OF conclusion text box := "LOCAL.TXT"
filename OF conclusion picture := "LOCAL.BMP"
END
IF wsupport choice = "general" THEN
BEGIN
filename OF conclusion text box := "GENERAL.TXT"
filename OF conclusion picture := "GENERAL.BMP"
END
IF wsupport choice = "fill" THEN
BEGIN
    filename OF conclusion text box := "FILL.TXT"
    filename OF conclusion picture := "FILL.BMP"
END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wcorner choice STRING
WHEN CHANGED
BEGIN
    IF wcorner choice = "sewer" THEN
        BEGIN
            filename OF conclusion text box := "CORNSEWE.TXT"
            filename OF conclusion picture := "SEWER.BMP"
        END
    IF wcorner choice = "pocket" THEN
        BEGIN
            filename OF conclusion text box := "CORNPOCK.TXT"
            filename OF conclusion picture := "POCKET.BMP"
        END
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wlocal choice STRING
WHEN CHANGED
BEGIN
    IF wlocal choice = "capacity" THEN
        filename OF conclusion text box := "LCAPACIT.TXT"
    IF wlocal choice = "old fill" THEN
        BEGIN
            filename OF conclusion text box := "LOLDFILL.TXT"
            filename OF conclusion picture := "LOLDFELL.BMP"
        END
    IF wlocal choice = "fill" THEN
        BEGIN
            filename OF conclusion text box := "LFILL.TXT"
            filename OF conclusion picture := "LFILL.BMP"
        END
    IF wlocal choice = "street" THEN
        BEGIN
            filename OF conclusion text box := "LSTREET.TXT"
            filename OF conclusion picture := "LSTREET.BMP"
        END
    IF wlocal choice = "around" THEN
        BEGIN
            filename OF conclusion text box := "LAROUND.TXT"
            filename OF conclusion picture := "LAROUND.BMP"
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wgeneral choice STRING
-WHEN CHANGED
-BEGIN
  IF wgeneral choice = "capacity" THEN
    filename OF conclusion text box := "GCAPACIT.TXT"
  END
  IF wgeneral choice = "old fill" THEN
    BEGIN
      filename OF conclusion text box := "GOLDFILL.TXT"
      filename OF conclusion picture := "GOLDFILL.BMP"
    END
  IF wgeneral choice = "fill" THEN
    BEGIN
      filename OF conclusion text box := "GFILL.TXT"
      filename OF conclusion picture := "GFILL.BMP"
    END
  IF wgeneral choice = "street" THEN
    BEGIN
      filename OF conclusion text box := "GSTREET.TXT"
      filename OF conclusion picture := "GSTREET.BMP"
    END
  IF wgeneral choice = "around" THEN
    BEGIN
      filename OF conclusion text box := "GAROUND.TXT"
      filename OF conclusion picture := "GAROUND.BMP"
    END
-BEGIN
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wvertical hollow choice STRING
-WHEN CHANGED
-BEGIN
  IF wvertical hollow choice = "No 5@72" THEN
    filename OF conclusion text box := "HOLLV1.TXT"
  END
  IF wvertical hollow choice = "No 5@64" THEN
    filename OF conclusion text box := "HOLLV2.TXT"
  END
  IF wvertical hollow choice = "No 6@56" THEN
    filename OF conclusion text box := "HOLLV3.TXT"
  END
  IF wvertical hollow choice = "No 6@48" THEN
    filename OF conclusion text box := "HOLLV4.TXT"
-BEGIN
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE whorizontal one choice STRING
-WHEN CHANGED
-BEGIN
  IF whorizontal one choice = "No 5@72" THEN
    filename OF conclusion text box := "HOLLV1.TXT"
  END
  IF whorizontal one choice = "No 5@64" THEN
    filename OF conclusion text box := "HOLLV2.TXT"
  END
  IF whorizontal one choice = "No 6@56" THEN
    filename OF conclusion text box := "HOLLV3.TXT"
  END
  IF whorizontal one choice = "No 6@48" THEN
    filename OF conclusion text box := "HOLLV4.TXT"
-BEGIN
BEGIN
    IF whorizontal one choice = "original" THEN
        filename OF conclusion text box := "HORONE.TXT"
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE whorizontal two choice STRING
WHEN CHANGED
BEGIN
    IF whorizontal two choice = "original" THEN
        filename OF conclusion text box := "HORTWO.TXT"
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE whorizontal three choice STRING
WHEN CHANGED
BEGIN
    IF whorizontal three choice = "original" THEN
        filename OF conclusion text box := "HORTHREE.TXT"
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE whorizontal hollow choice STRING
WHEN CHANGED
BEGIN
    IF whorizontal hollow choice = "original" THEN
        filename OF conclusion text box := "HHOLLORI.TXT"
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wvertical choice STRING
WHEN CHANGED
BEGIN
    IF wvertical choice = "onsite" THEN
        filename OF conclusion text box := "VERTONSI.TXT"
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wvertical hollow one choice STRING
WHEN CHANGED
BEGIN
    IF wvertical hollow one choice = "original" THEN
        filename OF conclusion text box := "HOLLV1OR.TXT"
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wvertical hollow two choice STRING
WHEN CHANGED
BEGIN
    IF wvertical hollow two choice = "original" THEN
        filename OF conclusion text box := "HOLLV2OR.TXT"
ATTRIBUTE wvertical hollow three choice STRING
WHEN CHANGED
BEGIN
    IF wvertical hollow three choice = "original" THEN
        filename OF conclusion text box := "HOLLV3OR.TXT"
    END
END

ATTRIBUTE wvertical hollow four choice STRING
WHEN CHANGED
BEGIN
    IF wvertical hollow four choice = "original" THEN
        filename OF conclusion text box := "HOLLV4OR.TXT"
    END
END

ATTRIBUTE wbrick choice STRING
WHEN CHANGED
BEGIN
    IF wbrick choice = "original" THEN
        filename OF conclusion text box := "BRIKORIG.TXT"
    END
END

ATTRIBUTE within wall choice STRING
WHEN CHANGED
BEGIN
    IF within wall choice = "original" THEN
        filename OF conclusion text box := "THINORIG.TXT"
    END
END

ATTRIBUTE wbackfill choice STRING
WHEN CHANGED
BEGIN
    IF wbackfill choice = "no drain" THEN
        filename OF conclusion text box := "NODRAIN2.TXT"
    IF wbackfill choice = "original" THEN
        filename OF conclusion text box := "ONSITEBK.TXT"
    IF wbackfill choice = "sump pump" THEN
        filename OF conclusion text box := "SUMPPUM2.TXT"
    END
END

ATTRIBUTE wdrain choice STRING
WHEN CHANGED
BEGIN
    IF wdrain choice = "no drain" THEN
        filename OF conclusion text box := "NODRAIN2.TXT"
    IF wdrain choice = "original" THEN
        filename OF conclusion text box := "ONSITEBK.TXT"
    END
    IF wdrain choice = "sump pump" THEN
        filename OF conclusion text box := "SUMPPUM2.TXT"
    END
END
filename OF conclusion text box := "NODRAIN1.TXT"
IF wdrain choice = "original" THEN
  filename OF conclusion text box := "ONSITE1.TXT"
IF wdrain choice = "sump pump" THEN
  filename OF conclusion text box := "SUMPPUM1.TXT"
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE whigh original choice STRING
WHEN CHANGED
BEGIN
  IF whigh original choice = "original" THEN
    filename OF conclusion text box := "HIGHORIG.TXT"
  END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE deformed element COMPOUND
WALL,
FLOOR
WHEN CHANGED
BEGIN
  IF deformed element IS WALL THEN
    BEGIN
      filename OF cracks picture := "CRACKW.BMP"
      filename OF crack pattern explanation := "CRACKW.TXT"
      filename OF more cracks picture := "CRACKW2.BMP"
    END
  ELSE
    IF deformed element IS FLOOR THEN
      BEGIN
        filename OF cracks picture := "CRACKF.BMP"
        filename OF crack pattern explanation := "CRACKF.TXT"
        filename OF more cracks picture := "CRACKF2.BMP"
      END
    END
  END
END
QUERY FROM BAFDES cracked element display
SEARCH ORDER CONTEXT QUERY DEFAULT
ATTRIBUTE test wall support STRING
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wno crack support choice STRING
WHEN CHANGED
BEGIN
  IF wno crack support choice = "local" THEN
    BEGIN
      filename OF conclusion text box := "LOCNC.TXT"
      filename OF conclusion picture := "LOCNC.BMP"
    END
  END

IF wno crack support choice = "general" THEN
BEGIN
filename OF conclusion text box := "GENNC.TXT"
filename OF conclusion picture := "GENNC.BMP"
END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wno crack general choice STRING
WHEN CHANGED
BEGIN
IF wno crack general choice = "old fill" THEN
BEGIN
filename OF conclusion text box := "NCGOFILL.TXT"
filename OF conclusion picture := "GOLDFILL.BMP"
END
ELSE
IF wno crack general choice = "street" THEN
BEGIN
filename OF conclusion text box := "NCGSTREE.TXT"
filename OF conclusion picture := "GSTREET.BMP"
END
ELSE
IF wno crack general choice = "around" THEN
BEGIN
filename OF conclusion text box := "NCGAROUN.TXT"
filename OF conclusion picture := "GAROUND.BMP"
END
END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE wno crack local choice STRING
WHEN CHANGED
BEGIN
IF wno crack local choice = "old fill" THEN
BEGIN
filename OF conclusion text box := "NCLOFDLL.TXT"
filename OF conclusion picture := "LOLDFILL.BMP"
END
ELSE
IF wno crack local choice = "street" THEN
BEGIN
filename OF conclusion text box := "NCLSTREE.TXT"
filename OF conclusion picture := "LSTREET.BMP"
END
ELSE
IF wno crack local choice = "around" THEN
BEGIN
  filename OF conclusion text box := "NCLAROUN.TXT"
  filename OF conclusion picture := "LAROUND.BMP"
END

SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE fcase choice STRING
WHEN CHANGED
BEGIN
  IF fcase choice = "case1" THEN
    BEGIN
      filename OF conclusion text box := "CASE1C.TXT"
      filename OF conclusion picture := "CASE1C.BMP"
    END
  ELSE
    IF fcase choice = "case2" THEN
      BEGIN
        filename OF conclusion text box := "CASE2C.TXT"
        filename OF conclusion picture := "CASE2C.BMP"
      END
    ELSE
      IF fcase choice = "case3" THEN
        BEGIN
          filename OF conclusion text box := "CASE3C.TXT"
          filename OF conclusion picture := "CASE3C.BMP"
        END
      ELSE
        IF fcase choice = "case4" THEN
          BEGIN
            filename OF conclusion text box := "CASE4C.TXT"
            filename OF conclusion picture := "CASE4C.BMP"
          END
        ELSE
          IF fcase choice = "case5" THEN
            BEGIN
              filename OF conclusion text box := "CASE5C.TXT"
              filename OF conclusion picture := "CASE5C.BMP"
            END
          END
    END
  ELSE
    IF fcase choice = "corner" THEN
      BEGIN

    END
END

SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE fcrack choice STRING
WHEN CHANGED
BEGIN
  IF fcrack choice = "corner" THEN
    BEGIN

    END
ELSE
    IF fcrack choice = "local" THEN
    BEGIN
        filename OF conclusion text box := "FLOCAL.TXT"
        filename OF conclusion picture := "FLOCAL.BMP"
    END
    ELSE
        IF fcrack choice = "curing" THEN
        BEGIN
            filename OF conclusion text box := "FCURING.TXT"
            filename OF conclusion picture := "CURING.BMP"
        END
        ELSE
            IF fcrack choice = "expansion" THEN
            BEGIN
                filename OF conclusion text box := "FEXPAN.TXT"
                filename OF conclusion picture := "FEXPAN.BMP"
            END
            ELSE
                IF fcrack choice = "settlement" THEN
                BEGIN
                    filename OF conclusion text box := "FSETTLE.TXT"
                    filename OF conclusion picture := "FLOCAL.BMP"
                END
        END
    END
SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE fgeneral cracking choice STRING
WHEN CHANGED
BEGIN
    IF fgeneral cracking choice = "settle" THEN
    BEGIN
        filename OF conclusion text box := "FGENERAL.TXT"
        filename OF conclusion picture := "FSETTLE.BMP"
    END
    ELSE
        IF fgeneral cracking choice = "plastic" THEN
        BEGIN
            filename OF conclusion text box := "FPLASTIC.TXT"
            filename OF conclusion picture := "FPLASTIC.BMP"
        END
        ELSE
            IF fgeneral cracking choice = "hydro" THEN
BEGIN
  filename OF conclusion text box := "FHYDRO.TXT"
  filename OF conclusion picture := "FHYDRO.BMP"
END

SEARCH ORDER CONTEXT RULES DEFAULT
ATTRIBUTE fsettlement choice STRING
WHEN CHANGED
BEGIN
  IF fsettlement choice = "general" THEN
    BEGIN
      filename OF conclusion text box := "FGENERAL.TXT"
      filename OF conclusion picture := "FSETTLE.BMP"
    END
  ELSE
    IF fsettlement choice = "local" THEN
      BEGIN
        filename OF conclusion text box := "FLOCAL.TXT"
        filename OF conclusion picture := "FLOCAL.BMP"
      END
    END
END
SEARCH ORDER CONTEXT RULES DEFAULT

INSTANCE the application ISA application
  WITH unknowns fail := TRUE
  WITH threshold := 50
  WITH title display := BAFDES title display
  WITH conclusion display := BAFDES conclusion display
  WITH ignore breakpoints := FALSE
  WITH reasoning on := FALSE
  WITH numeric precision := 8
  WITH simple query text := "Is it true that:
    *
    is
    *
  WITH numeric query text := "What is(are):
    *
    of
    *
  WITH string query text := "What is(are):
    *
    of
    *
  WITH time query text := "What is(are):
    *
of
  *
WITH interval query text := "What is(are):
  *
of
  *
WITH compound query text := "What is(are):
  *
of
  *
WITH multicompound query text := "What is(are):
  *
of
  *
WITH demon strategy IS fire first
WITH visible file menu := TRUE

INSTANCE deformation prompt ISA checkbox group
  WITH location := 199,110,411,211
  WITH frame := TRUE
  WITH group label := "These are major problems"
  WITH show current := TRUE
  WITH attachment := deformation

INSTANCE soil strength tests prompt ISA checkbox group
  WITH location := 151,164,477,330
  WITH pen color := 0,0,255
  WITH fill color := 255,255,255
  WITH frame := TRUE
  WITH group label := "Results of foundation soil testing"
  WITH show current := TRUE
  WITH attachment := strength OF foundation

INSTANCE open joints prompt ISA checkbox group
  WITH location := 156,251,476,369
  WITH frame := TRUE
  WITH group label := "These are other common problems"
  WITH show current := TRUE
  WITH attachment := other deformations OF crack

INSTANCE BAFDES wall dimensions display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := crack depth HR
  WITH items [2] := HR ratio
WITH items [3] := crack depth prompt
WITH items [4] := crack depth value
WITH items [5] := length of wall value
WITH items [6] := ground height value
WITH items [7] := wall height prompt
WITH items [8] := wall length prompt
WITH items [9] := basement dimensions title

INSTANCE BAFDES wall type display ISA display
    WITH wait := TRUE
    WITH delay changes := TRUE
    WITH items [1] := HR wall thickness
    WITH items [2] := HR basement wall type
    WITH items [3] := basement wall type prompt
    WITH items [4] := basement wall thickness prompt
    WITH items [5] := wall type title

INSTANCE BAFDES fill height ISA display
    WITH wait := TRUE
    WITH delay changes := TRUE
    WITH items [1] := fill height HR
    WITH items [2] := ground level HR
    WITH items [3] := fill height value
    WITH items [4] := fill height text
    WITH items [5] := fill level prompt
    WITH items [6] := fill height title

INSTANCE BAFDES reinforcement display ISA display
    WITH wait := TRUE
    WITH delay changes := TRUE
    WITH items [1] := horizontal rebar HR
    WITH items [2] := HR vertical rebar
    WITH items [3] := vertical rebar prompt
    WITH items [4] := horizontal rebar prompt
    WITH items [5] := reinforcement title

INSTANCE HR settlement around display ISA display
    WITH wait := TRUE
    WITH delay changes := TRUE
    WITH items [1] := UNDETERMINED
    WITH items [2] := UNDETERMINED
    WITH items [3] := UNDETERMINED
    WITH items [4] := UNDETERMINED
    WITH items [5] := UNDETERMINED
    WITH items [6] := UNDETERMINED
WITH items [7] := settlement around picture
WITH items [8] := go to fill display button
WITH items [9] := textbox 96

INSTANCE BAFDES sump pump display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := sump pump pipe value
WITH items [2] := sump pump title
WITH items [3] := sump pump pipe prompt
WITH items [4] := sump pump picture
WITH items [5] := sump pump prompt
WITH items [6] := sump pump value

INSTANCE BAFDES fill display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := settlement around HR
WITH items [2] := street end HR
WITH items [3] := UNDETERMINED
WITH items [4] := old fill value
WITH items [5] := old fill prompt
WITH items [6] := UNDETERMINED
WITH items [7] := UNDETERMINED
WITH items [8] := street end value
WITH items [9] := fill display title
WITH items [10] := street end prompt
WITH items [12] := settlement around value

INSTANCE BAFDES corner display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := corner moisture HR
WITH items [2] := UNDETERMINED
WITH items [3] := sewer HR
WITH items [4] := UNDETERMINED
WITH items [5] := sewer true false box
WITH items [6] := corner display text
WITH items [7] := sewer text box
WITH items [8] := corner moisture text
WITH items [9] := corner moisture prompt
WITH items [10] := UNDETERMINED

INSTANCE BAFDES sidewalk settlement display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1 ] := sidewalk settlement picture
WITH items [2 ] := sidewalk settlement additional text
WITH items [4 ] := sidewalk text
WITH items [5 ] := sidewalk settlement prompt

INSTANCE BAFDES crack width display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := HR crack width
  WITH items [2 ] := crack width prompt
  WITH items [3 ] := crack width title

INSTANCE EXPA cracking pattern display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := ESPA crack direction text
  WITH items [2 ] := remember picture

INSTANCE BAFDES cracking pattern display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := cracking pattern title
  WITH items [2 ] := cracking pattern prompt
  WITH items [3 ] := cracks picture
  WITH items [4 ] := go to more cracks display
  WITH items [5 ] := crack pattern explanation

INSTANCE BAFDES hydrostatic pressure display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := HR signs of moisture
  WITH items [2 ] := moisture location HR
  WITH items [3 ] := moisture signs prompt
  WITH items [4 ] := moisture prompt
  WITH items [5 ] := moisture signs text
  WITH items [6 ] := excessive pressure title

INSTANCE BAFDES other houses display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := other houses value
  WITH items [2 ] := other houses prompt
WITH items [3 ] := UNDETERMINED
WITH items [4 ] := other houses title

INSTANCE BAFDES damage display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := joints HR
  WITH items [2 ] := HR bowing
  WITH items [3 ] := open joints prompt
  WITH items [4 ] := deformation prompt
  WITH items [5 ] := crack info title
  WITH items [6 ] := spread prompt
  WITH items [7 ] := spread text box

INSTANCE BAFDES organic soil display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := soil color prompt
  WITH items [3 ] := fibres button
  WITH items [4 ] := fingers button
  WITH items [5 ] := fingers prompt
  WITH items [6 ] := fibres prompt

INSTANCE BAFDES soil identification display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := grain size HR
  WITH items [2 ] := consistency HR
  WITH items [3 ] := soil consistency prompt
  WITH items [5 ] := grain size prompt

INSTANCE BAFDES original soil display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := original soil check box
  WITH items [2 ] := original soil title
  WITH items [3 ] := original soil backfill picture
  WITH items [4 ] := original soil prompt
  WITH items [5 ] := original soil extra text

INSTANCE HR sidewalk settlement ISA display
  WITH wait := FALSE
  WITH delay changes := FALSE
WITH items [1] := UNDETERMINED

INSTANCE BAFDES soil strength display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := soil strength tests prompt
  WITH items [2] := UNDETERMINED
  WITH items [3] := soil strength title

INSTANCE BAFDES expansive soil display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := liquid limit value
  WITH items [2] := expansive soil title
  WITH items [3] := plastic index value
  WITH items [4] := liquid limit prompt
  WITH items [5] := plastic index prompt
  WITH items [6] := expansive text

INSTANCE BAFDES hydrostatic display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := moisture prompt
  WITH items [2] := UNDETERMINED
  WITH items [3] := UNDETERMINED
  WITH items [4] := UNDETERMINED
  WITH items [5] := hydro title

INSTANCE HR cracked element display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := crack expanded text
  WITH items [2] := UNDETERMINED
  WITH items [3] := UNDETERMINED
  WITH items [4] := UNDETERMINED
  WITH items [5] := UNDETERMINED
  WITH items [6] := go to cracked element display

INSTANCE BAFDES cracked element display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := hyperregion cracked element display
  WITH items [2] := UNDETERMINED
  WITH items [3] := element selection button
  WITH items [4] := cracked element title
WITH items [5] := basement picture

INSTANCE BAFDES conclusion display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := conclusion picture
WITH items [2] := conclusion text box
WITH items [3] := final refinement sign

INSTANCE HR crack width display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := HR crack width text
WITH items [2] := go to joints display
WITH items [3] := crack width picture

INSTANCE BAFDES title display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := welcome box
WITH items [2] := introduction text file
WITH items [3] := BAFDES picture
WITH items [4] := go to instructions screen

INSTANCE HR moisture signs display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := HR moisture signs text
WITH items [2] := UNDETERMINED
WITH items [3] := stains picture
WITH items [4] := go to hydrostatic pressure display

INSTANCE HR moisture location display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := hr picture for moisture stains2
WITH items [2] := go to hydrostatic pressure display

INSTANCE HR ratio display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := ratio picture
WITH items [2] := go to wall dimensions display

INSTANCE HR wall type display ISA display
WITH items [1] := welcome box
WITH items [2] := introduction text file
WITH items [3] := BAFDES picture
WITH items [4] := go to instructions screen

INSTANCE HR moisture signs display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := HR moisture signs text
  WITH items [2] := UNDETERMINED
  WITH items [3] := stains picture
  WITH items [4] := go to hydrostatic pressure display

INSTANCE HR moisture location display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := hr picture for moisture stains2
  WITH items [2] := go to hydrostatic pressure display

INSTANCE HR ratio display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := ratio picture
  WITH items [2] := go to wall dimensions display

INSTANCE HR wall type display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := brick picture
  WITH items [2] := UNDETERMINED
  WITH items [3] := go to wall type display

INSTANCE HR vertical reinforcement display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := go to reinforcement display
  WITH items [2] := masonry rebar picture
  WITH items [3] := UNDETERMINED
  WITH items [4] := UNDETERMINED
  WITH items [5] := vertical rebar hr help

INSTANCE HR bowing display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
INSTANCE HR fill height ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := ground level picture
WITH items [2] := go to fill height display
WITH items [3] := HR fill height text

INSTANCE HR street end display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := go to fill display button
WITH items [2] := UNDETERMINED
WITH items [3] := UNDETERMINED
WITH items [4] := street end picture
WITH items [5] := hr street end text

INSTANCE HR crack depth display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := crack depth picture
WITH items [2] := go to wall dimensions display

INSTANCE HR horizontal rebar display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := horizontal reinforcement HR text
WITH items [2] := go to reinforcement display
WITH items [3] := horizontal rebar picture
WITH items [4] := UNDETERMINED
WITH items [5] := UNDETERMINED
WITH items [6] := horizontal rebar hr help

INSTANCE HR joints display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := joints picture
WITH items [2] := joints HR text
WITH items [3] := goto damage screen

INSTANCE BAFDES more cracks display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1] := more cracks picture
WITH items [2] := more cracks text
WITH items [3 ] := go to crack pattern display

INSTANCE BAFDES intermediate conclusion display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := conclusion text box
  WITH items [2 ] := conclusion picture
  WITH items [3 ] := refine conclusion text

INSTANCE HR sewer display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := sump pump picture
  WITH items [2 ] := sewer hr text
  WITH items [3 ] := UNDETERMINED
  WITH items [4 ] := go to corner display

INSTANCE HR corner moisture display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := corner moisture picture
  WITH items [2 ] := go to corner display
  WITH items [3 ] := cracked corner text

INSTANCE HR wall thickness display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := wall thickness picture
  WITH items [2 ] := go to wall type display

INSTANCE BAFDES instructions display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := go to welcome display
  WITH items [2 ] := instructions text

INSTANCE BAFDES case floor 1 display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := case floor1 picture
  WITH items [2 ] := case floor 1 description
  WITH items [3 ] := cases floor text
  WITH items [4 ] := case floor 1 prompt

INSTANCE BAFDES case floor2 display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1 ] := case floor2 picture
WITH items [2 ] := case floor2 description
WITH items [3 ] := cases floor text
WITH items [4 ] := case floor2 prompt

INSTANCE BAFDES case floor3 display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := case floor3 picture
  WITH items [2 ] := case floor3 description
  WITH items [3 ] := cases floor text
  WITH items [4 ] := case floor3 prompt

INSTANCE BAFDES case floor4 display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := case floor4 picture
  WITH items [2 ] := case floor4 description
  WITH items [3 ] := cases floor text
  WITH items [4 ] := UNDETERMINED
  WITH items [5 ] := UNDETERMINED
  WITH items [6 ] := UNDETERMINED
  WITH items [7 ] := case floor4 prompt

INSTANCE BAFDES case floor5 display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := case floor5 picture
  WITH items [2 ] := case floor5 description
  WITH items [3 ] := cases floor text
  WITH items [4 ] := case floor5 prompt

INSTANCE BAFDES building age display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := building age prompt
  WITH items [2 ] := age of the building text
  WITH items [3 ] := UNDETERMINED

INSTANCE BAFDES floor level difference display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1 ] := hyperregion control joints
WITH items [2] := hyperregion floor cracks moisture
WITH items [3] := hyperregion level difference
WITH items [4] := level difference text
WITH items [5] := floor crack moisture text
WITH items [6] := UNDETERMINED
WITH items [7] := level difference prompt
WITH items [8] := floor moisture text
WITH items [9] := UNDETERMINED
WITH items [10] := level difference screen text
WITH items [12] := control joints prompt

INSTANCE HR level difference display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := level difference picture
  WITH items [2] := UNDETERMINED
  WITH items [3] := go to level difference display
  WITH items [4] := level difference HR text

INSTANCE HR floor moisture display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := go to level difference display
  WITH items [2] := UNDETERMINED
  WITH items [3] := floor cracks moisture picture
  WITH items [4] := floor cracks moisture HR text

INSTANCE BAFDES isolated floor crack display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := isolated floor cracking text
  WITH items [2] := isolated floor crack prompt

INSTANCE BAFDES floor slab bowing display ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := floor bowing text
  WITH items [2] := floor bowing prompt
  WITH items [3] := floor bowing picture

INSTANCE HR control joints ISA display
  WITH wait := TRUE
  WITH delay changes := TRUE
  WITH items [1] := go to level difference display
WITH items [2 ] := control joints picture

INSTANCE BAFDES vertical movement display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1 ] := vertical prompt text
WITH items [2 ] := vertical prompt
WITH items [3 ] := vertical text help
WITH items [4 ] := vertical picture

INSTANCE BAFDES slope display ISA display
WITH wait := TRUE
WITH delay changes := TRUE
WITH items [1 ] := slope prompt
WITH items [2 ] := UNDETERMINED
WITH items [3 ] := UNDETERMINED
WITH items [4 ] := slope title
WITH items [5 ] := slope picture

INSTANCE HR signs of moisture ISA hyperregion
WITH location := 113,128,422,173
WITH visible := TRUE
WITH display attachment := HR moisture signs display

INSTANCE HR ratio ISA hyperregion
WITH location := 165,144,334,225
WITH visible := TRUE
WITH display attachment := HR ratio display

INSTANCE HR basement wall type ISA hyperregion
WITH location := 82,127,231,160
WITH visible := TRUE
WITH display attachment := HR wall type display

INSTANCE HR vertical rebar ISA hyperregion
WITH location := 110,81,208,116
WITH visible := TRUE
WITH display attachment := HR vertical reinforcement display

INSTANCE HR bowing ISA hyperregion
WITH location := 213,96,391,126
WITH visible := TRUE
WITH display attachment := HR bowing display

INSTANCE HR crack width ISA hyperregion
WITH location := 226,153,377,188
WITH visible := TRUE
WITH display attachment := HR crack width display

INSTANCE consistency HR ISA hyperregion
WITH location := 323,133,523,166
WITH visible := TRUE
WITH display attachment := HR consistency

INSTANCE grain size HR ISA hyperregion
WITH location := 60,134,230,169
WITH visible := TRUE
WITH display attachment := HR grain size screen

INSTANCE ground level HR ISA hyperregion
WITH location := 199,161,373,195
WITH visible := TRUE
WITH display attachment := HR ground level

INSTANCE fill height HR ISA hyperregion
WITH location := 230,117,314,150
WITH visible := TRUE
WITH display attachment := HR fill height

INSTANCE street end HR ISA hyperregion
WITH location := 74,278,347,322
WITH visible := TRUE
WITH display attachment := HR street end display

INSTANCE crack depth HR ISA hyperregion
WITH location := 99,288,400,343
WITH visible := TRUE
WITH display attachment := HR crack depth display

INSTANCE horizontal rebar HR ISA hyperregion
WITH location := 365,84,483,116
WITH visible := TRUE
WITH display attachment := HR horizontal rebar display

INSTANCE joints HR ISA hyperregion
WITH location := 173,233,462,267
WITH visible := TRUE
WITH display attachment := HR joints display

INSTANCE moisture location HR ISA hyperregion
WITH location := 79,210,515,241
WITH visible := TRUE
WITH display attachment := HR moisture location display

INSTANCE sewer HR ISA hyperregion
WITH location := 75,123,365,164
WITH visible := TRUE
WITH display attachment := HR sewer display

INSTANCE corner moisture HR ISA hyperregion
WITH location := 75,194,363,235
WITH visible := TRUE
WITH display attachment := HR corner moisture display

INSTANCE HR wall thickness ISA hyperregion
WITH location := 338,129,518,161
WITH visible := TRUE
WITH display attachment := HR wall thickness display

INSTANCE hyperregion cracked element display ISA hyperregion
WITH location := 80,157,170,192
WITH visible := TRUE
WITH display attachment := HR cracked element display

INSTANCE hyperregion level difference ISA hyperregion
WITH location := 96,144,378,191
WITH visible := TRUE
WITH display attachment := HR level difference display

INSTANCE hyperregion floor cracks moisture ISA hyperregion
WITH location := 96,205,378,252
WITH visible := TRUE
WITH display attachment := HR floor moisture display

INSTANCE hyperregion control joints ISA hyperregion
WITH location := 95,269,376,314
WITH visible := TRUE
WITH display attachment := HR control joints

INSTANCE settlement around HR ISA hyperregion
WITH location := 74,337,350,383
WITH visible := TRUE
WITH display attachment := HR settlement around display

INSTANCE basement picture ISA picturebox
WITH location := 262,53,573,322
WITH clipped := TRUE
WITH filename := "basement.bmp"

INSTANCE BAFDES picture ISA picturebox
  WITH location := 198,81,422,170
  WITH clipped := TRUE
  WITH frame := FALSE
  WITH filename := "bafdes.bmp"

INSTANCE remember picture ISA picturebox
  WITH location := 5,12,116,86
  WITH clipped := TRUE
  WITH filename := "remember.bmp"

INSTANCE stains picture ISA picturebox
  WITH location := 293,28,603,362
  WITH clipped := TRUE
  WITH frame := TRUE
  WITH filename := "moisture.bmp"

INSTANCE hr picture for moisture stains2 ISA picturebox
  WITH location := 59,15,563,363
  WITH clipped := TRUE
  WITH frame := TRUE
  WITH filename := "stains2.bmp"

INSTANCE ratio picture ISA picturebox
  WITH location := 109,119,499,348
  WITH clipped := TRUE
  WITH filename := "ratio.bmp"

INSTANCE brick picture ISA picturebox
  WITH location := 107,44,481,352
  WITH clipped := TRUE
  WITH frame := TRUE
  WITH filename := "C:\L5O25\BAFDES\WALLTYPE.BMP"

INSTANCE masonry rebar picture ISA picturebox
  WITH location := 15,99,479,345
  WITH clipped := TRUE
  WITH filename := "rebar.bmp"

INSTANCE cracks picture ISA picturebox
  WITH location := 15,87,612,433
WITH clipped := TRUE
WITH frame := TRUE
WITH filename := "cracks.bmp"

INSTANCE bowing picture ISA picturebox
  WITH location := 42,93,573,332
  WITH clipped := TRUE
  WITH filename := "bowing.bmp"

INSTANCE consistancy picture ISA picturebox
  WITH location := 171,234,422,333
  WITH clipped := TRUE
  WITH filename := "claysize.bmp"

INSTANCE gravel size picture ISA picturebox
  WITH location := 247,64,574,224
  WITH clipped := TRUE
  WITH filename := "gravsize.bmp"

INSTANCE sand size picture ISA picturebox
  WITH location := 280,236,519,347
  WITH clipped := TRUE
  WITH filename := "sandsize.bmp"

INSTANCE original soil backfill picture ISA picturebox
  WITH location := 67,171,561,402
  WITH clipped := TRUE
  WITH filename := "sitesoil.bmp"

INSTANCE ground level picture ISA picturebox
  WITH location := 36,107,410,340
  WITH clipped := TRUE
  WITH filename := "level.bmp"

INSTANCE sump pump picture ISA picturebox
  WITH location := 48,139,587,392
  WITH clipped := TRUE
  WITH filename := "sumppump.bmp"

INSTANCE street end picture ISA picturebox
  WITH location := 64,171,545,354
  WITH clipped := TRUE
  WITH filename := "street.bmp"

INSTANCE crack depth picture ISA picturebox
WITH location := 76,24,512,363
WITH clipped := TRUE
WITH filename := "depth.bmp"

INSTANCE conclusion picture ISA picturebox
WITH location := 21,144,595,430
WITH clipped := TRUE
WITH frame := FALSE
WITH filename := "blank.bmp"

INSTANCE horizontal rebar picture ISA picturebox
WITH location := 223,115,438,333
WITH clipped := TRUE
WITH filename := "hrebar.bmp"

INSTANCE joints picture ISA picturebox
WITH location := 59,101,566,372
WITH clipped := TRUE
WITH filename := "joints.bmp"

INSTANCE more cracks picture ISA picturebox
WITH location := 11,9,620,370
WITH clipped := TRUE
WITH frame := TRUE
WITH filename := "crackw2.bmp"

INSTANCE corner moisture picture ISA picturebox
WITH location := 228,15,420,354
WITH clipped := TRUE
WITH filename := "cormoist.bmp"

INSTANCE wall thickness picture ISA picturebox
WITH location := 194,91,401,343
WITH clipped := TRUE
WITH frame := TRUE
WITH filename := "thicknes.bmp"

INSTANCE crack width picture ISA picturebox
WITH location := 179,25,612,337
WITH clipped := TRUE
WITH frame := FALSE
WITH filename := "width.bmp"

INSTANCE case floor1 picture ISA picturebox
WITH location := 247,70,561,303
WITH clipped := TRUE
WITH filename := "case1.bmp"

INSTANCE case floor2 picture ISA picturebox
  WITH location := 266, 37, 592, 303
  WITH clipped := TRUE
  WITH filename := "case2.bmp"

INSTANCE case floor3 picture ISA picturebox
  WITH location := 179, 66, 625, 295
  WITH clipped := TRUE
  WITH filename := "case3.bmp"

INSTANCE case floor4 picture ISA picturebox
  WITH location := 174, 2, 621, 320
  WITH clipped := TRUE
  WITH frame := FALSE
  WITH filename := "C:\L5O25\BAFDES\CASE4.BMP"

INSTANCE case floor5 picture ISA picturebox
  WITH location := 223, 47, 603, 312
  WITH clipped := TRUE
  WITH frame := FALSE
  WITH filename := "C:\L5O25\BAFDES\CASE5.BMP"

INSTANCE sidewalk settlement picture ISA picturebox
  WITH location := 31, 91, 575, 361
  WITH clipped := TRUE
  WITH filename := "C:\L5O25\BAFDES\SOILDOWN.BMP"

INSTANCE level difference picture ISA picturebox
  WITH location := 98, 94, 448, 343
  WITH clipped := TRUE
  WITH filename := "C:\L5O25\BAFDES\LEVELDIF.BMP"

INSTANCE floor cracks moisture picture ISA picturebox
  WITH location := 120, 96, 394, 315
  WITH clipped := TRUE
  WITH filename := "C:\L5O25\BAFDES\MOISTFLO.BMP"

INSTANCE floor bowing picture ISA picturebox
  WITH location := 52, 133, 573, 392
  WITH clipped := TRUE
  WITH filename := "C:\L5O25\BAFDES\FLOORBOW.BMP"
INSTANCE control joints picture ISA picturebox
  WITH location := 82,101,527,335
  WITH clipped := TRUE
  WITH filename := "C:\L5025\BAFDES\CONTJOIN.BMP"

INSTANCE vertical picture ISA picturebox
  WITH location := 181,148,609,368
  WITH clipped := TRUE
  WITH filename := "C:\L5025\BAFDES\VERTICAL.BMP"

INSTANCE slope picture ISA picturebox
  WITH location := 191,116,613,326
  WITH clipped := TRUE
  WITH filename := "C:\L5025\BAFDES\SLOPE.BMP"

INSTANCE settlement around picture ISA picturebox
  WITH location := 264,149,573,316
  WITH clipped := TRUE
  WITH filename := "C:\L5025\BAFDES\AROUND.BMP"

INSTANCE length of wall value ISA promptbox
  WITH location := 350,145,400,170
  WITH justify IS left
  WITH frame := TRUE
  WITH show current := TRUE
  WITH attachment := length OF residential basement wall

INSTANCE ground heigth value ISA promptbox
  WITH location := 350,195,400,220
  WITH justify IS left
  WITH frame := TRUE
  WITH show current := TRUE
  WITH attachment := height OF residential basement wall

INSTANCE fill height value ISA promptbox
  WITH location := 329,120,389,145
  WITH justify IS left
  WITH frame := TRUE
  WITH show current := TRUE
  WITH attachment := fill height OF residential basement wall

INSTANCE cracking pattern prompt ISA promptbox
  WITH location := 164,29,194,54
  WITH pen color := 0,0,255
  WITH fill color := 255,255,255
WITH justify IS left
WITH frame := TRUE
WITH show current := TRUE
WITH format := "#######"
WITH attachment := cracking pattern OF wall crack

INSTANCE crack depth value ISA promptbox
  WITH location := 415,310,450,335
  WITH justify IS left
  WITH frame := TRUE
  WITH show current := TRUE
  WITH attachment := depth OF crack

INSTANCE liquid limit value ISA promptbox
  WITH location := 350,135,400,160
  WITH justify IS left
  WITH frame := TRUE
  WITH show current := TRUE
  WITH attachment := liquid limit OF backfill

INSTANCE plastic index value ISA promptbox
  WITH location := 350,195,400,220
  WITH justify IS left
  WITH frame := TRUE
  WITH show current := TRUE
  WITH attachment := plastic index OF backfill

INSTANCE building age prompt ISA promptbox
  WITH location := 376,116,422,141
  WITH justify IS right
  WITH frame := TRUE
  WITH show current := TRUE
  WITH format := "#######"
  WITH attachment := age OF building

INSTANCE goto damage screen ISA pushbutton
  WITH location := 100,380,500,400
  WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
  WITH display attachment := BAFDES damage display

INSTANCE go to crack pattern description ISA pushbutton
  WITH location := 258,275,355,312
  WITH label := "CONTINUE"
  WITH display attachment := BAFDES cracking pattern display
INSTANCE go to wall dimensions display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES wall dimensions display

INSTANCE go to reinforcement display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES reinforcement display

INSTANCE go to soil identification screen ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES soil identification display

INSTANCE go to wall type display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES wall type display

INSTANCE go to fill height display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES fill height

INSTANCE go to fill display button ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES fill display

INSTANCE go to joints display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES crack width display

INSTANCE go to crack pattern display ISA pushbutton
WITH location := 210,384,610,404
WITH label := "PUSH HERE TO RETURN TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES cracking pattern display

INSTANCE go to more cracks display ISA pushbutton
WITH location := 33,60,176,82
WITH label := "SEE MORE CRACKS"
WITH display attachment := BAFDES more cracks display
INSTANCE go to hydrostatic pressure display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES hydrostatic pressure display

INSTANCE go to corner display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES corner display

INSTANCE go to instructions screen ISA pushbutton
WITH location := 90,393,510,418
WITH label := "Push here for INSTRUCTIONS on how to move around BAFDES"
WITH display attachment := BAFDES instructions display

INSTANCE go to welcome display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PUSH HERE TO GO BACK TO PREVIOUS SCREEN"
WITH display attachment := BAFDES title display

INSTANCE go to cracked element display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES cracked element display

INSTANCE go to level difference display ISA pushbutton
WITH location := 100,380,500,400
WITH label := "PRESS HERE TO GO BACK TO THE PREVIOUS SCREEN"
WITH display attachment := BAFDES floor level difference display

INSTANCE crack width prompt ISA radiobutton group
WITH location := 208,171,401,257
WITH frame := TRUE
WITH group label := "Check one crack width"
WITH show current := TRUE
WITH attachment := width OF wall crack

INSTANCE moisture prompt ISA radiobutton group
WITH location := 61,226,538,348
WITH frame := TRUE
WITH group label := "If you have observed moisture signs, where are th\
ey more evident"
WITH show current := TRUE
WITH attachment := moisture
INSTANCE basement wall type prompt ISA radiobutton group
WITH location := 68,146,267,353
WITH frame := TRUE
WITH group label := "Type of wall"
WITH show current := TRUE
WITH attachment := type OF residential basement wall

INSTANCE basement wall thickness prompt ISA radiobutton group
WITH location := 324,146,537,328
WITH frame := TRUE
WITH group label := "Thickness of wall"
WITH show current := TRUE
WITH attachment := thickness OF residential basement wall

INSTANCE vertical rebar prompt ISA radiobutton group
WITH location := 95,100,231,353
WITH frame := TRUE
WITH group label := "Vertical Rebar"
WITH show current := TRUE
WITH attachment := vertical rebar OF residential basement wall

INSTANCE horizontal rebar prompt ISA radiobutton group
WITH location := 351,100,501,315
WITH frame := TRUE
WITH group label := "Horizontal Rebar"
WITH show current := TRUE
WITH attachment := horizontal rebar OF residential basement wall

INSTANCE soil color prompt ISA radiobutton group
WITH location := 240,254,356,390
WITH frame := TRUE
WITH group label := "Soil color"
WITH show current := TRUE
WITH attachment := color OF soil

INSTANCE soil consistency prompt ISA radiobutton group
WITH location := 310,150,540,350
WITH frame := TRUE
WITH group label := "Soil consistency"
WITH show current := TRUE
WITH attachment := consistency OF soil

INSTANCE grain size prompt ISA radiobutton group
WITH location := 50,150,240,350
WITH frame := TRUE
WITH group label := "Approximate grain size"
WITH show current := TRUE
WITH attachment := grain size OF soil

INSTANCE fill level prompt ISA radiobutton group
WITH location := 184,176,445,332
WITH frame := TRUE
WITH group label := "Approximate ground level"
WITH show current := TRUE
WITH attachment := fill level OF basement wall

INSTANCE element selection button ISA radiobutton group
WITH location := 67,176,185,261
WITH frame := TRUE
WITH group label := "Select one"
WITH show current := TRUE
WITH attachment := deformed element

INSTANCE slope prompt ISA radiobutton group
WITH location := 24,166,199,286
WITH frame := TRUE
WITH group label := "Topography of the lot"
WITH show current := TRUE
WITH attachment := slope OF building

INSTANCE compound query textbox ISA textbox
WITH location := 10,10,512,80
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH scroll := TRUE
WITH text := "What is(are):
* of
*"

INSTANCE interval query textbox ISA textbox
WITH location := 10,10,512,80
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH scroll := TRUE
WITH text := "What is(are):
*"
INSTANCE multicompound query textbox ISA textbox
  WITH location := 10,10,512,80
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH scroll := TRUE
  WITH text := "What is(are):
  *
  of
  *

INSTANCE numeric query textbox ISA textbox
  WITH location := 10,10,512,80
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH scroll := TRUE
  WITH text := "What is(are):
  *
  of
  *

INSTANCE simple query textbox ISA textbox
  WITH location := 10,10,512,80
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH scroll := TRUE
  WITH text := "Is it true that:
  *
  is
  *

INSTANCE string query textbox ISA textbox
  WITH location := 10,10,512,80
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH scroll := TRUE
  WITH text := "What is(are):
  *
  of
INSTANCE time query textbox ISA textbox
WITH location := 10,10,512,80
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH scroll := TRUE
WITH text := "What is(are): *
*  
 of
*"

INSTANCE agenda query textbox ISA textbox
WITH location := 10,10,320,30
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH text := "Can you identify the area of interest?"

INSTANCE welcome box ISA textbox
WITH location := 172,8,462,72
WITH pen color := 102,0,0
WITH fill color := 255,255,255
WITH justify IS center
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "WELCOME TO BAFDES
by Carlos F. Diaz"

INSTANCE cracked element title ISA textbox
WITH location := 15,11,202,67
WITH pen color := 0,0,0
WITH fill color := 0,255,255
WITH justify IS center
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "INDICATE A DAMAGED ELEMENT IN THE BASEMENT"

INSTANCE crack info title ISA textbox
WITH location := 10,15,219,69
WITH pen color := 0,0,0
WITH fill color := 0,255,255
WITH justify IS center
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "ENTER THE FOLLOWING INFORMATION ABOUT THE
DAMAGE YOU OBSERVED"

INSTANCE crack expanded text ISA textbox
  WITH location := 115,126,482,326
  WITH pen color := 255,0,0
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "Times"
  WITH font style IS bold
  WITH font size := 10
  WITH frame := TRUE
  WITH text := "DAMAGE in the elements of the basement includes, CRACKS OR BOWING in basement walls and floor."

In the menu, select the element where you observe damage and then press OK! on the top left part of the screen.

If you observe damage in the basement walls as well as in the basement floor slab. Run one consultation selecting WALL and a second consultation selecting FLOOR. The cause of failure of the walls may be different from the cause of failure of the floor slab."

INSTANCE HR crack width text ISA textbox
  WITH location := 3,45,178,337
  WITH pen color := 0,0,255
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "Helv"
  WITH font style IS bold
  WITH font size := 10
  WITH frame := TRUE
  WITH text := "The crack width may indicate the following:
WIDE CRACKS are usually due to FOUNDATION MOVEMENT.
NARROW CRACKS are usually due to EXCESSIVE LATERAL FORCES applied on the wall, or INSUFFICIENT WALL STRENGTH."
In BAFDES, a crack is considered wide if you can completely push, with your fingers, a coin into the crack."

INSTANCE excessive pressure title ISA textbox
   WITH location := 17,20,325,87
   WITH pen color := 0,0,0
   WITH fill color := 0,255,255
   WITH justify IS center
   WITH font := "Tms Rmn"
   WITH font style IS bold
   WITH font size := 10
   WITH frame := TRUE
   WITH text := "PROVIDE THE FOLLOWING INFORMATION IN ORDER TO DETERMINE THE PRESENCE OF WATER BEHIND THE BASEMENT WALLS"

INSTANCE ESPA crack direction text ISA textbox
   WITH location := 166,11,509,272
   WITH pen color := 0,0,255
   WITH fill color := 255,255,255
   WITH justify IS left
   WITH font := "Helv"
   WITH font style IS bold
   WITH font size := 10
   WITH frame := TRUE
   WITH text := "The cracking pattern may indicate the following:
   Horizontal cracking is usually due to soil freezing or lateral overload of the wall.
   Diagonal cracking is usually due to soil settlement.
   Random cracking direction usually occurs due to soil settlement, or poor concrete performance.
   Cracking in a corner is usually due to settlement of the soil under the corner.
   Cracking two feet below ground level is usually due to soil freezing.
   Randomly distributed cracks are usually due to soil settlement, or poor concrete performance."

INSTANCE moisture signs text ISA textbox
   WITH location := 117,131,417,171
   WITH justify IS left
   WITH font := "System"
   WITH font size := 10
   WITH text := "Do you observe signs of excessive moisture in the basement floor or walls?"
NARROW CRACKS are usually due to EXCESSIVE LATERAL FORCES applied on the wall, or INSUFFICIENT WALL STRENGTH.

In BAFDES, a crack is considered wide if you can completely push, with your fingers, a coin into the crack.

PROVIDE THE FOLLOWING INFORMATION IN ORDER TO DETERMINE THE PRESENCE OF WATER BEHIND THE BASEMENT WALLS

The cracking pattern may indicate the following:
Horizontal cracking is usually due to soil freezing or lateral overload of the wall.
Diagonal cracking is usually due to soil settlement.
Random cracking direction usually occurs due to soil settlement, or poor concrete performance.
Cracking in a corner is usually due to settlement of the soil under the corner.
Cracking two feet below ground level is usually due to soil freezing.
Randomly distributed cracks are usually due to soil settlement, or poor concrete performance.
Do you observe signs of excessive moisture in the basement floor or walls?

STAINS and/or SPALLING OFF of the paint in basement floor or walls are the most common signs of excessive moisture. In some cases, if you place your hand on the basement wall you can feel WETNESS.

WATER ENTRY into the basement through cracks are also signs of excessive moisture.

Liqud limit and plastic index are used to determine the degree of potential soil expansion. Some experts classify the degree of potential soil expansion as very high, high, medium and low, where:

HIGH: volume changes of more than 30 percent.
MEDIUM: volume changes between 10 and 30 percent.
LOW: volume changes up to 10 percent.

The volume changes refered here are due to moisture changes in the soil, from dry to wet. The amount of volume change can be determined accurately only by extensive testing. BAFDES can, however, determine approximately how expansive the soil is.
WITH text := "ENTER HERE THE CRACKING PATTERN YOU OBSERVED:

INSTANCE basement dimensions title ISA textbox
    WITH location := 31,20,266,73
    WITH pen color := 0,0,0
    WITH fill color := 0,255,255
    WITH justify IS center
    WITH font := "Tms Rmn"
    WITH font style IS bold
    WITH font size := 10
    WITH frame := TRUE
    WITH text := "ENTER THE FOLLOWING INFORMATION ABOUT THE CRACKED WALL DIMENSIONS"

INSTANCE fill height text ISA textbox
    WITH location := 237,123,311,143
    WITH justify IS left
    WITH font := "System"
    WITH font size := 10
    WITH frame := FALSE
    WITH text := "Fill height"

INSTANCE hr pressure text ISA textbox
    WITH location := 15,23,210,225
    WITH pen color := 0,0,255
    WITH fill color := 255,255,255
    WITH justify IS left
    WITH font := "Helv"
    WITH font style IS bold
    WITH font size := 10
    WITH frame := TRUE
    WITH text := "The soil pressure is usually represented by an equivalent fluid pressure where the fluid density is 30 pcf. Depending on the type of soil the equivalent fluid pressure is:

gravel: 30 pcf
sand: 30 - 40 pcf
clay: 40 - 70 pcf"

INSTANCE conclusion text box ISA textbox
    WITH location := 22,28,603,143
    WITH pen color := 0,0,255
    WITH fill color := 255,255,255
    WITH justify IS left
EXCAVATE ONE FOOT INTO THE GROUND BEHIND THE BASEMENT WALL AND PROVIDE THE FOLLOWING INFORMATION ABOUT THE SOIL:

When the soil is wet, does it leave your fingers dirty?

Does the soil contain dry vegetation or fibres from vegetation?

With the soil identification title ISA textbox

WITH location := 100,120,365,160
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH frame := TRUE
WITH text := "When the soil is wet, does it leave your fingers dirty?"

WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "EXCAVATE ONE FOOT INTO THE GROUND BEHIND THE BASEMENT WALL AND PROVIDE THE FOLLOWING INFORMATION ABOUT THE SOIL"

INSTANCE fingers prompt ISA textbox

WITH location := 100,190,365,230
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH frame := TRUE
WITH text := "Does the soil contain dry vegetation or fibres from vegetation?"
clay: 40 - 70pcf

INSTANCE conclusion text box ISA textbox
WITH location := 22,28,603,143
WITH pen color := 0,0,255
WITH fill color := 255,255,255
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH frame := TRUE
WITH scroll := TRUE
WITH filename := "nogo.txt"
WITH text := ""

INSTANCE organic soil identification title ISA textbox
WITH location := 15,14,269,98
WITH pen color := 0,0,0
WITH fill color := 0,255,255
WITH justify IS center
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "EXCAVATE ONE FOOT INTO THE GROUND BEHIND THE BASEMENT WALL AND PROVIDE THE FOLLOWING INFORMATION ABOUT THE SOIL"

INSTANCE fingers prompt ISA textbox
WITH location := 100,120,365,160
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH frame := TRUE
WITH text := "When the soil is wet, does it leave your fingers dirty?"

INSTANCE fibres prompt ISA textbox
WITH location := 100,190,365,230
WITH justify IS left
WITH font := "System"
WITH font size := 10
WITH frame := TRUE
WITH text := "Does the soil contain dry vegetation or fibres from vegetation?"
PROVIDE THE FOLLOWING INFORMATION IN ORDER TO DETERMINE IF THE TYPE OF SOIL BEHIND THE BASEMENT WALLS IS CLAY

The diameter of the soil grains can be like the diameter of the grains in a SAND CLOCK, the grains of rough SAND PAPER, or a brush bristles.

The diameter of the soil particles can be like ALMONDS, or LITTLE ROCKS that can fit in a closed hand.

The soil, when wet, can be SQUIZED from the hand and between the fingers

or Little Rocks that can fit in a closed hand.
The soil, when wet, can be MOLDED with the hand into a small ball and other shapes, without disintegrating.

EXCAVATE ONE FOOT DEEP HOLES, ONE FOOT FROM THE WALL AND 6 FEET FROM THE WALL. THEN PROVIDE THE FOLLOWING INFORMATION.

The soil found one foot from the wall is clayey and similar to the soil found 6 feet from the wall?

ENTER THE FOLLOWING INFORMATION ABOUT THE BASEMENT WALL

The soil found one foot from the wall is clayey and similar to the soil found 6 feet from the wall?

ENTER THE FOLLOWING INFORMATION ABOUT THE BASEMENT WALL

ENTER THE FOLLOWING INFORMATION ABOUT THE BASEMENT WALL

ENTER THE FOLLOWING INFORMATION ABOUT THE BASEMENT WALL

ENTER THE FOLLOWING INFORMATION ABOUT THE BASEMENT WALL
Signs of sidewalk settlement include:
- The lower two inches of the wall are NOT PAINTED.
- The bottom two of the wall have MARKS of soil.
- There is a WIDE CRACK between the SIDEWALK (if any) and the wall.

ENTER THE FOLLOWING INFORMATION ABOUT THE GROUND LEVEL

If the basement walls are build of MASONRY, each block is 8 in. high. If this is the case, 3 blocks are equivalent to 2 feet.

The fill height is the distance from the BASEMENT SLAB to the GROUND LEVEL. If the basement walls are build of MASONRY, each block is 8 in. high. In this form, 3 blocks are equivalent to 2 feet.
PROVIDE THE RESULTS OF THE FOLLOWING SIMPLE TESTS ON THE SOIL UNDER THE FOOTING

Was the building the last one to be constructed in the development?

INDICATE THE WIDTH OF THE CRACKING YOU HAVE OBSERVED IN THE BASEMENT

CRACK DEPTH

CRACK WIDTH
PLEASE PROVIDE THE FOLLOWING INFORMATION IN ORDER TO DETERMINE THE CAUSE OF SOIL SETTLEMENT.

PROVIDE THE RESULTS OF THE FOLLOWING SIMPLE TESTS ON THE SOIL UNDER THE FOOTING:

Was the building the last one to be constructed in the development?

Introduction text file

Crack width title
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "INDICATE THE WIDTH OF THE CRACKING YOU HAVE OBSERVED IN THE BASEMENT"

INSTANCE crack depth prompt ISA textbox
  WITH location := 100,290,359,341
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH frame := FALSE
  WITH text := "If you observed a dominant horizontal crack in the wall, what is the distance from the ground level to the crack ?"

INSTANCE expansive soil title ISA textbox
  WITH location := 26,26,265,95
  WITH pen color := 0,0,0
  WITH fill color := 0,255,255
  WITH justify IS center
  WITH font := "Tms Rmn"
  WITH font style IS bold
  WITH font size := 10
  WITH frame := TRUE
  WITH text := "PROVIDE THE FOLLOWING INFORMATION IN ORDER TO DETERMINE THE IF THE SOIL IS EXPANSIVE"

INSTANCE liquid limit prompt ISA textbox
  WITH location := 120,140,300,160
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH text := "Liquid limit of backfill soil"

INSTANCE plastic index prompt ISA textbox
  WITH location := 120,200,300,220
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH text := "Plastic index of backfill soil"
Do you observe settlement of the soil around the building?

You may be able to refine this new conclusion.

Enter the age of the building in years:

Enter the following information about the cracked corner of the basement.
RESTART THE CONSULTATION !!!

 Does the basement has a sump pump ?

 Do you observe settlement of the soil around the building?

 YOU MAY BE ABLE TO REFINE THIS NEW CONCLUSION.

 Enter the age of the building in years:


WITH pen color := 0,0,0
WITH fill color := 0,255,255
WITH justify IS center
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
WITH text := "ENTER THE FOLLOWING INFORMATION ABOUT THE
SIDEWALK AROUND
THE BUILDING"

INSTANCE sidewalk text ISA textbox
  WITH location := 81,51,440,91
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH text := "Do you observe settlement of the sidewalk around the house, and behind the damaged basement wall?"

INSTANCE more cracks text ISA textbox
  WITH location := 12,377,200,412
  WITH pen color := 255,0,0
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH frame := TRUE
  WITH text := "You enter the crack number in the previous screen"

INSTANCE cracked corner text ISA textbox
  WITH location := 91,205,225,256
  WITH pen color := 0,0,255
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH frame := TRUE
  WITH text := "This is an example of moisture in the cracked corner"

INSTANCE case floor 1 description ISA textbox
  WITH location := 44,72,241,138
  WITH pen color := 0,0,255
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "System"
WITH frame := TRUE
WITH text := "If present, these last problems are isolated"

INSTANCE instructions text ISA textbox
  WITH location := 63,89,537,334
  WITH pen color := 0,0,255
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH frame := TRUE
  WITH scroll := TRUE
  WITH filename := "help.txt"
  WITH text := "textbox 74"

INSTANCE sidewalk settlement title ISA textbox
  WITH location := 7,6,329,42
  WITH pen color := 0,0,0
  WITH fill color := 0,255,255
  WITH justify IS center
  WITH font := "Tms Rmn"
  WITH font style IS bold
  WITH font size := 10
  WITH frame := TRUE
  WITH text := "ENTER THE FOLLOWING INFORMATION ABOUT THE SIDEWALK AROUND THE BUILDING"

INSTANCE sidewalk text ISA textbox
  WITH location := 81,51,440,91
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH text := "Do you observe settlement of the sidewalk around the house, and behind the damaged basement wall?"

INSTANCE more cracks text ISA textbox
  WITH location := 12,377,200,412
  WITH pen color := 255,0,0
  WITH fill color := 255,255,255
  WITH justify IS left
  WITH font := "System"
  WITH font size := 10
  WITH frame := TRUE
WITH text := "THIS IS THE FINAL REFINEMENT FOR THIS CASE"

INSTANCE case floor4 description ISA textbox
WITH location := 9,86,171,192
WITH pen color := 0,0,255
WITH fill color := 255,255,255
WITH justify IS left
WITH font := "System"
WITH frame := TRUE
WITH text := "In this case, the basement floor slab damage includes local cracking, and the cracked pieces are pushed into the ground."

INSTANCE case floor5 description ISA textbox
WITH location := 40,82,217,153
WITH pen color := 0,0,255
WITH fill color := 255,255,255
WITH justify IS left
WITH font := "System"
WITH frame := TRUE
WITH text := "In this case, the cracking is wide, and there is a level difference between the two sides of the crack."

INSTANCE level difference text ISA textbox
WITH location := 100,150,373,187
WITH justify IS left
WITH font := "System"
WITH text := "Do you observe level difference between the two sides of the cracks?"

INSTANCE floor crack moisture text ISA textbox
WITH location := 100,210,367,248
WITH justify IS left
WITH font := "System"
WITH text := "Do you observe moisture coming from the cracks in the floor slab?"

INSTANCE level difference screen text ISA textbox
WITH location := 12,14,291,68
WITH pen color := 0,0,0
WITH fill color := 0,255,255
WITH justify IS center
WITH font := "Tms Rmn"
WITH font style IS bold
WITH font size := 10
WITH frame := TRUE
In this case, the cracking in the floor slab CONTINUES FROM THE CONTROL JOINTS. Note however, that the cracking is not as wide as the control joints.

THIS IS THE FINAL REFINEMENT FOR THIS CASE

In this case, the basement floor slab damage includes local cracking, and the cracked pieces are pushed into the ground.

In this case, the cracking is wide, and there is a level difference between the two sides of the crack.

 INSTANCE level difference text ISA textbox
 WITH location := 100,150,373,187
 WITH justify IS left
Do you observe level difference between the two sides of the cracks?

Do you observe moisture coming from the cracks in the floor slab?

This is an example of moisture coming from the cracks in the basement floor slab.

This is an example of difference in elevation between the two sides of a crack in a basement floor slab.
Is the indicated cracking restricted to one isolated area in the basement?

Do you observe bowing of the basement floor slab?

Does the floor slab have control joints?

In the menu, select More if the vertical rebar is more than 0.92 sq.in. per linear foot of wall. Select Less if the rebar is less than 0.27 sq.in. per linear foot of wall.

In the menu, select More if the rebar in the bond beam is more than 0.62 sq.in. Select Less if the rebar in the bond beam is less than 0.20 sq.in.
WITH location := 400,190,460,230
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := fibres OF soil

INSTANCE fingers button ISA true false box
WITH location := 400,120,460,160
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := fingers OF soil

INSTANCE original soil check box ISA true false box
WITH location := 412,105,476,145
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := original OF soil

INSTANCE sump pump pipe value ISA true false box
WITH location := 390,95,440,135
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := sump pump pipe OF building

INSTANCE other houses value ISA true false box
WITH location := 359,175,422,215
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := other houses OF crack

INSTANCE old fill value ISA true false box
WITH location := 380,215,430,260
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := old fill OF building

INSTANCE street end value ISA true false box
WITH location := 380,280,430,325
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := street end OF building

INSTANCE sump pump value ISA true false box
WITH location := 390,55,440,90
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := sump pump OF building

INSTANCE settlement around value ISA true false box
WITH location := 380,335,430,380
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := settlement around OF residential

INSTANCE sewer true false box ISA true false box
WITH location := 375,125,450,160
WITH true label := "TRUE"
WITH false label := "FALSE"
WITH show current := TRUE
WITH attachment := sewer OF building

INSTANCE corner moisture prompt ISA true false box
WITH location := 375,195,450,230
WITH true label := "TRUE"
WITH false label := "FALSE"
WITH show current := TRUE
WITH attachment := corner moisture OF crack

INSTANCE spread prompt ISA true false box
WITH location := 392,375,467,414
WITH true label := "TRUE"
WITH false label := "FALSE"
WITH show current := TRUE
WITH attachment := isolated problem OF crack

INSTANCE sidewalk settlement prompt ISA true false box
WITH location := 461,46,536,89
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := sidewalk settlement OF residential
INSTANCE case floor 1 prompt ISA true false box
  WITH location := 441,325,501,365
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := case floor1 OF floor case studies

INSTANCE case floor2 prompt ISA true false box
  WITH location := 447,329,512,366
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := case floor2 OF floor case studies

INSTANCE case floor3 prompt ISA true false box
  WITH location := 445,330,514,370
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := case floor3 OF floor case studies

INSTANCE case floor5 prompt ISA true false box
  WITH location := 447,331,519,373
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := case floor5 OF floor case studies

INSTANCE case floor4 prompt ISA true false box
  WITH location := 449,329,518,369
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := case floor4 OF floor case studies

INSTANCE level difference prompt ISA true false box
  WITH location := 379,149,449,191
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := elevation difference OF floor crack

INSTANCE floor moisture text ISA true false box
  WITH location := 379,208,449,251
  WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := floor moisture OF floor crack

INSTANCE isolated floor crack prompt ISA true false box
WITH location := 388,156,459,198
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := isolated crack OF floor crack

INSTANCE floor bowing prompt ISA true false box
WITH location := 368,76,438,117
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := floor bowing OF wall crack

INSTANCE control joints prompt ISA true false box
WITH location := 378,269,448,313
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := control joints OF residential

INSTANCE vertical prompt ISA true false box
WITH location := 372,81,440,129
WITH true label := "YES"
WITH false label := "NO"
WITH show current := TRUE
WITH attachment := vertical OF wall crack

INSTANCE main window ISA window
WITH location := 6,18,636,464
WITH full screen := TRUE
WITH style IS moveable, sizeable, closeable
WITH title := "BAFDES by Carlos F. Diaz"
WITH visible := TRUE
WITH visible OK button := TRUE

INSTANCE expand window ISA window
WITH location := 66,118,632,472
WITH style IS moveable, sizeable, closeable
WITH title := "Explanatory Information"
WITH visible := FALSE
AGENDA
1. wall strength choice OF domain WITH BAFDES intermediate conclusion display
   1.1 wLateral choice OF domain WITH BAFDES intermediate conclusion display
      1.1.1 whydro choice OF domain
      1.1.1.1 wdrain choice OF domain
      1.1.1.2 wbackfill choice OF domain
      1.1.2 wsoil weight choice OF domain WITH BAFDES intermediate conclusion display
         1.1.2.1 whorizontal choice OF domain
            1.1.2.1.1 whorizontal one choice OF domain
            1.1.2.1.2 whorizontal two choice OF domain
            1.1.2.1.3 whorizontal three choice OF domain
         1.1.2.2 whorizontal hollow choice OF domain
         1.1.2.3 wvertical choice OF domain
         1.1.2.4 wvertical hollow choice OF domain
            1.1.2.4.1 wvertical hollow one choice OF domain
            1.1.2.4.2 wvertical hollow two choice OF domain
            1.1.2.4.3 wvertical hollow three choice OF domain
            1.1.2.4.4 wvertical hollow four choice OF domain
         1.1.2.5 wbrick choice OF domain
         1.1.2.6 wthin wall choice OF domain
      1.1.3 whigh original choice OF domain
2. wsupport choice OF domain WITH BAFDES intermediate conclusion display
   2.1 wcorners choice OF domain
   2.2 wlocal choice OF domain WITH BAFDES intermediate conclusion display
   2.3 wgeneral choice OF domain WITH BAFDES intermediate conclusion display
3. wno crack support choice OF domain
   3.1 wno crack local choice OF domain
   3.2 wno crack general choice OF domain
4. floor choice OF domain
   4.1 fcase choice OF domain
   4.2 fcrack choice OF domain
      4.2.1 fgeneral cracking choice OF domain
      4.2.2 fsettlement choice OF domain

RULE 121 a lateral pressure
IF test wall strength = "wall strength a"
AND cracking pattern OF wall crack = 1
INSTANCE control joints prompt ISA true false box
  WITH location := 378,269,448,313
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := control joints OF residential

INSTANCE vertical prompt ISA true false box
  WITH location := 372,81,440,129
  WITH true label := "YES"
  WITH false label := "NO"
  WITH show current := TRUE
  WITH attachment := vertical OF wall crack

INSTANCE main window ISA window
  WITH location := 6,18,636,464
  WITH full screen := TRUE
  WITH style IS moveable, sizeable, closeable
  WITH title := "BAFDES by Carlos F. Diaz"
  WITH visible := TRUE
  WITH visible OK button := TRUE

INSTANCE expand window ISA window
  WITH location := 66,118,632,472
  WITH style IS moveable, sizeable, closeable
  WITH title := "Explanatory Information"
  WITH visible := FALSE
  WITH visible OK button := TRUE

AGENDA
  1. wall strength choice OF domain WITH BAFDES intermediate conclusion display
     1.1 wylateral choice OF domain WITH BAFDES intermediate conclusion display
        1.1.1 whydro choice OF domain
        1.1.1.1 wdrain choice OF domain
        1.1.1.2 wbackfill choice OF domain
        1.1.2 wsoil weight choice OF domain WITH BAFDES intermediate conclusion display
        1.1.2.1 whorizontal choice OF domain
        1.1.2.1.1 whorizontal one choice OF domain
        1.1.2.1.2 whorizontal two choice OF domain
        1.1.2.1.3 whorizontal three choice OF domain
        1.1.2.2 whorizontal hollow choice OF domain
FALSE
AND other deformations of wall crack is Separation between structural elements = FALSE
THEN test wall strength := "wall strength b"
AND wall strength choice := "press c"

RULE 1212 hydrostatic pressure
IF wall strength choice = "press a"
OR wall strength choice = "press b"
OR wall strength choice = "press c"
OR wall strength choice = "press d"
AND signs of moisture
THEN wlateral choice := "hydrostatic pressure"

RULE 1211 soil weight
IF wall strength choice = "press a"
OR wall strength choice = "press b"
OR wall strength choice = "press c"
OR wall strength choice = "press d"
AND fill height of residential basement wall < 9
AND fill height of residential basement wall > 4
AND pressure of backfill > 30
THEN wlateral choice := "weight"

RULE 1214 fill height
IF wall strength choice = "press a"
OR wall strength choice = "press b"
OR wall strength choice = "press c"
OR wall strength choice = "press d"
AND fill height of residential basement wall >= 9
THEN wlateral choice := "fill height"

RULE 1216 soil expansion
IF wall strength choice = "press a"
OR wall strength choice = "press c"
AND signs of moisture = FALSE
AND expansive soil is High
THEN wlateral choice := "expansive"

RULE 12121 drainage
IF wlateral choice = "hydrostatic pressure"
AND moisture is Bottom of wall
THEN whydro choice := "drainage"

RULE 12122 backfill
IF w lateral choice = "hydrostatic pressure" 
AND moisture IS Random
THEN whydro choice := "backfill"

RULE 12123 no drain
IF w lateral choice = "hydrostatic pressure"
AND moisture IS Unknown
AND slope OF residential IS Flat lot
AND sump pump OF residential = FALSE
THEN whydro choice := "no drain"

RULE 12125 no external drainage
IF w lateral choice = "hydrostatic pressure"
AND moisture IS Unknown
AND slope OF residential IS Flat lot
AND sump pump OF residential
AND sump pump pipe OF residential = FALSE
THEN whydro choice := "sump pump"

RULE 12124 original soil
IF w lateral choice = "hydrostatic pressure"
AND moisture IS Unknown
AND original OF backfill
THEN whydro choice := "original"

RULE 121211 no drainage
IF whydro choice = "drainage"
AND slope OF residential IS Flat lot
AND sump pump OF residential = FALSE
THEN wdrain choice := "no drain"

RULE 121212 on site soil
IF whydro choice = "drainage"
AND original OF backfill
THEN wdrain choice := "original"

RULE 121213 no external drainage
IF whydro choice = "drainage"
AND slope OF residential IS Flat lot
AND sump pump OF residential
AND sump pump pipe OF residential = FALSE
THEN wdrain choice := "sump pump"

RULE 121221 no drainage
IF whydro choice = "backfill"
AND slope OF residential IS Flat lot
AND sump pump OF residential = FALSE
THEN wbackfill choice := "no drain"

RULE 121222 on site soil
IF whydro choice = "backfill"
AND original OF backfill
THEN wbackfill choice := "original"

RULE 121223 no external drainage
IF whydro choice = "backfill"
AND slope OF residential IS Flat lot
AND sump pump OF residential
AND sump pump pipe OF residential = FALSE
THEN wbackfill choice := "sump pump"

RULE 12118 sidewalk settlement
IF wlateral choice = "weight"
AND sidewalk settlement OF residential
THEN wsoil weight choice := "sidewalk"

RULE 12111 vertical rebar
IF wlateral choice = "weight"
AND type OF residential basement wall IS Solid masonry
OR type OF residential basement wall IS Concrete
AND vertical rebar OF residential basement wall IS Less
THEN wsoil weight choice := "vertical"

RULE 12112 horizontal rebar
IF wlateral choice = "weight"
AND type OF residential basement wall IS Solid masonry
OR type OF residential basement wall IS Concrete
AND length OF residential basement wall >= 8
THEN wsoil weight choice := "horizontal"

RULE 12113 horizontal rebar in hollow
IF wlateral choice = "weight"
AND type OF residential basement wall IS Hollow masonry
AND horizontal rebar OF residential basement wall IS Less
THEN wsoil weight choice := "hollow horizontal"

RULE 12114 vertical rebar in hollow
IF wlateral choice = "weight"
AND type OF residential basement wall IS Hollow masonry
THEN wsoil weight choice := "hollow vertical"
RULE 12115 brick
IF w Later choice = "weight"
AND type OF residential basement wall IS Brick
OR type OF residential basement wall IS Stone
THEN wsoil weight choice := "brick"

RULE 12116 thin wall
IF w Later choice = "weight"
AND thickness OF residential basement wall IS Six inches or less
THEN wsoil weight choice := "thin"

RULE 12117 original soil
IF w Later choice = "weight"
AND original OF backfill
THEN wsoil weight choice := "original"

RULE 121121 horizontal rebar1
IF wsoil weight choice = "horizontal"
AND length OF residential basement wall >= 12
AND horizontal rebar OF residential basement wall IS One No 4
OR horizontal rebar OF residential basement wall IS Two No 3
OR horizontal rebar OF residential basement wall IS Two No 4
OR horizontal rebar OF residential basement wall IS Less
THEN whorizontal choice := "long 12"

RULE 121122 horizontal rebar2
IF wsoil weight choice = "horizontal"
AND length OF residential basement wall >= 10
AND length OF residential basement wall < 12
AND horizontal rebar OF residential basement wall IS Two No 3
OR horizontal rebar OF residential basement wall IS One No 4
OR horizontal rebar OF residential basement wall IS Less
THEN whorizontal choice := "long 10"

RULE 121123 horizontal rebar3
IF wsoil weight choice = "horizontal"
AND length OF residential basement wall < 10
AND horizontal rebar OF residential basement wall IS Less
THEN whorizontal choice := "horizontal"

RULE 1211211 horizontal rebar1 original soil
IF whorizontal choice = "long 12"
AND original OF backfill
THEN whorizontal one choice := "original"
RULE 121122 horizontal rebar2 original soil
IF whorizontal choice = "long 10"
AND original OF backfill
THEN whorizontal two choice := "original"

RULE 121123 horizontal rebar3 original soil
IF whorizontal choice = "horizontal"
AND original OF backfill
THEN whorizontal three choice := "original"

RULE 121131 horizontal rebar in hollow original soil
IF wsoil weight choice = "hollow horizontal"
AND original OF backfill
THEN whorizontal hollow choice := "original"

RULE 121111 vertical rebar original soil
IF wsoil weight choice = "vertical"
AND original OF backfill
THEN wvertical choice := "onsite"

RULE 121144 vertical rebar in hollow4
IF wsoil weight choice = "hollow vertical"
AND fill height OF residential basement wall > 7
AND vertical rebar OF residential basement wall IS No 6 @ 56
OR vertical rebar OF residential basement wall IS No 5 @ 64
OR vertical rebar OF residential basement wall IS No 5 @ 72
OR vertical rebar OF residential basement wall IS No 4 @ 72
OR vertical rebar OF residential basement wall IS Less
THEN wvertical hollow choice := "No 6@48"

RULE 121143 vertical rebar in hollow3
IF wsoil weight choice = "hollow vertical"
AND fill height OF residential basement wall > 6
AND vertical rebar OF residential basement wall IS No 5 @ 64
OR vertical rebar OF residential basement wall IS No 5 @ 72
OR vertical rebar OF residential basement wall IS No 4 @ 72
OR vertical rebar OF residential basement wall IS Less
THEN wvertical hollow choice := "No 6@56"

RULE 121142 vertical rebar in hollow2
IF wsoil weight choice = "hollow vertical"
AND fill height OF residential basement wall > 5
AND vertical rebar OF residential basement wall IS No 5 @ 72
OR vertical rebar OF residential basement wall IS No 4 @ 72
OR vertical rebar OF residential basement wall IS Less
THEN wvertical hollow choice := "No 5@64"

RULE 121141 vertical rebar in hollow1
IF wsoil weight choice = "hollow vertical"
AND fill height OF residential basement wall > 4
AND vertical rebar OF residential basement wall IS No 4 @ 72
OR vertical rebar OF residential basement wall IS Less
THEN wvertical hollow choice := "No 5@72"

RULE 1211411 vertical rebar in hollow1 original soil
IF wvertical hollow choice = "No 5@72"
AND original OF backfill
THEN wvertical hollow one choice := "original"

RULE 1211421 vertical rebar in hollow2 original soil
IF wvertical hollow choice = "No 5@64"
AND original OF backfill
THEN wvertical hollow two choice := "original"

RULE 1211431 vertical rebar in hollow3 original soil
IF wvertical hollow choice = "No 6@56"
AND original OF backfill
THEN wvertical hollow three choice := "original"

RULE 1211441 vertical rebar in hollow4 original soil
IF wvertical hollow choice = "No 6@48"
AND original OF backfill
THEN wvertical hollow four choice := "original"

RULE 121151 brick original soil
IF wsoil weight choice = "brick"
AND original OF backfill
THEN wbrick choice := "original"

RULE 121161 thin wall original soil
IF wsoil weight choice = "thin"
AND original OF backfill
THEN within wall choice := "original"

RULE 12141 original soil fill height
IF wlateral choice = "fill height"
AND original OF backfill
THEN whigh original choice := "original"
RULE 111 corner
IF test wall support = "wall support a"
AND cracking pattern OF wall crack = 13
OR cracking pattern OF wall crack = 14
OR cracking pattern OF wall crack = 4
OR cracking pattern OF wall crack = 32
OR cracking pattern OF wall crack = 41
THEN wsupport choice := "corner"

RULE 114 large fill settlement
IF test wall support = "wall support a"
AND cracking pattern OF wall crack = 5
OR cracking pattern OF wall crack = 6
OR cracking pattern OF wall crack = 7
OR cracking pattern OF wall crack = 9
OR cracking pattern OF wall crack = 10
OR cracking pattern OF wall crack = 11
OR cracking pattern OF wall crack = 12
OR cracking pattern OF wall crack = 33
OR cracking pattern OF wall crack = 34
OR cracking pattern OF wall crack = 38
OR cracking pattern OF wall crack = 8
OR cracking pattern OF wall crack = 15
OR cracking pattern OF wall crack = 16
OR cracking pattern OF wall crack = 17
OR cracking pattern OF wall crack = 18
OR cracking pattern OF wall crack = 19
OR cracking pattern OF wall crack = 20
OR cracking pattern OF wall crack = 21
OR cracking pattern OF wall crack = 35
OR cracking pattern OF wall crack = 36
OR cracking pattern OF wall crack = 37
AND other houses OF wall crack
THEN wsupport choice := "fill"

RULE 112 local settlement
IF test wall support = "wall support a"
AND cracking pattern OF wall crack = 5
OR cracking pattern OF wall crack = 6
OR cracking pattern OF wall crack = 7
OR cracking pattern OF wall crack = 9
OR cracking pattern OF wall crack = 10
OR cracking pattern OF wall crack = 11
OR cracking pattern OF wall crack = 12
OR cracking pattern OF wall crack = 33
OR cracking pattern OF wall crack = 34
OR cracking pattern OF wall crack = 38
THEN wsupport choice := "local"

RULE 113 general settlement
IF test wall support = "wall support a"
AND cracking pattern OF wall crack = 8
OR cracking pattern OF wall crack = 3
OR cracking pattern OF wall crack = 15
OR cracking pattern OF wall crack = 16
OR cracking pattern OF wall crack = 17
OR cracking pattern OF wall crack = 18
OR cracking pattern OF wall crack = 19
OR cracking pattern OF wall crack = 20
OR cracking pattern OF wall crack = 21
OR cracking pattern OF wall crack = 31
OR cracking pattern OF wall crack = 35
OR cracking pattern OF wall crack = 36
OR cracking pattern OF wall crack = 37
AND other houses OF wall crack = FALSE
THEN wsupport choice := "general"

RULE 1111 sewer in corner
IF wsupport choice = "corner"
AND sewer OF residential
AND corner moisture OF wall crack
THEN wcorner choice := "sewer"

RULE 1113 pocket in corner
IF wsupport choice = "corner"
THEN wcorner choice := "pocket"

RULE 1124 capacity
IF wsupport choice = "local"
AND width OF wall crack IS Narrow
AND old fill OF residential = FALSE
AND street end OF residential = FALSE
AND settlement around OF residential = FALSE
AND age OF residential <= 2
THEN wlocal choice := "capacity"

RULE 1123 street end
IF wsupport choice = "local"
AND street end OF residential
THEN wlocal choice := "street"
RULE 1125 settlement around
IF wsupport choice = "local"
AND street end OF residential = FALSE
AND settlement around OF residential
THEN wlocal choice := "around"

RULE 1121 old fill
IF wsupport choice = "local"
AND old fill OF residential
THEN wlocal choice := "old fill"

RULE 1122 fill
IF wsupport choice = "local"
AND width OF wall crack IS Wide
THEN wlocal choice := "fill"

RULE 1134 capacity
IF wsupport choice = "general"
AND width OF wall crack IS Narrow
AND old fill OF residential = FALSE
AND street end OF residential = FALSE
AND settlement around OF residential = FALSE
AND age OF residential <= 2
THEN wgeneral choice := "capacity"

RULE 1133 street end
IF wsupport choice = "general"
AND street end OF residential
THEN wgeneral choice := "street"

RULE 1135 around
IF wsupport choice = "general"
AND street end OF residential = FALSE
AND settlement around OF residential
THEN wgeneral choice := "around"

RULE 1131 old fill
IF wsupport choice = "general"
AND old fill OF residential
THEN wgeneral choice := "old fill"

RULE 1132 fill
IF wsupport choice = "general"
AND width OF wall crack IS Wide
THEN wgeneral choice := "fill"

RULE 115 local settlement no crack
IF test wall support = "wall support b"
AND isolated problem OF wall crack
THEN wno crack support choice := "local"

RULE 116 general settlement no crack
IF test wall support = "wall support b"
AND isolated problem OF wall crack = FALSE
THEN wno crack support choice := "general"

RULE 1153 street end
IF wno crack support choice = "local"
AND street end OF residential
THEN wno crack local choice := "street"

RULE 1155 settlement around
IF wno crack support choice = "local"
AND street end OF residential = FALSE
AND settlement around OF residential
THEN wno crack local choice := "around"

RULE 1151 old fill
IF wno crack support choice = "local"
AND old fill OF residential
THEN wno crack local choice := "old fill"

RULE 1163 street end
IF wno crack support choice = "general"
AND street end OF residential
THEN wno crack general choice := "street"

RULE 1165 around
IF wno crack support choice = "general"
AND street end OF residential = FALSE
AND settlement around OF residential
THEN wno crack general choice := "around"

RULE 1161 old fill
IF wno crack support choice = "general"
AND old fill OF residential
THEN wno crack general choice := "old fill"

RULE 2 floor concrete
IF deformed element IS FLOOR THEN floor choice := "test floor"

RULE 211 case1
IF floor choice = "test floor" AND case floor1 OF floor case studies THEN fcase choice := "case1"

RULE 212 case2
IF floor choice = "test floor" AND case floor2 OF floor case studies THEN fcase choice := "case2"

RULE 213 case3
IF floor choice = "test floor" AND case floor3 OF floor case studies THEN fcase choice := "case3"

RULE 214 case4
IF floor choice = "test floor" AND case floor4 OF floor case studies THEN fcase choice := "case4"

RULE 215 case5
IF floor choice = "test floor" AND case floor5 OF floor case studies THEN fcase choice := "case5"

RULE 221 general
IF floor choice = "test floor" AND cracking pattern OF wall crack = 4 OR cracking pattern OF wall crack = 5 OR cracking pattern OF wall crack = 6 OR cracking pattern OF wall crack = 8 OR cracking pattern OF wall crack = 11 THEN fcrack choice := "general"

RULE 222 local
IF floor choice = "test floor" AND cracking pattern OF wall crack = 1 THEN fcrack choice := "local"

RULE 223 corner
IF floor choice = "test floor" AND cracking pattern OF wall crack = 2
OR cracking pattern OF wall crack = 3
THEN fcrack choice := "corner"

RULE 224 curing
IF floor choice = "test floor"
AND cracking pattern OF wall crack = 7
THEN fcrack choice := "curing"

RULE 225 expansive
IF floor choice = "test floor"
AND cracking pattern OF wall crack = 9
AND floor bowing OF wall crack
THEN fcrack choice := "expansion"

RULE 226 settlement
IF floor choice = "test floor"
AND cracking pattern OF wall crack = 10
THEN fcrack choice := "settlement"

RULE 2211 general settlement
IF fcrack choice = "general"
AND elevation difference OF floor crack
THEN fgeneral cracking choice := "settle"

RULE 2212 shrinkage
IF fcrack choice = "general"
AND elevation difference OF floor crack = FALSE
AND floor moisture OF floor crack = FALSE
AND control joints OF residential = FALSE
THEN fgeneral cracking choice := "plastic"

RULE 2213 hydro
IF fcrack choice = "general"
AND floor moisture OF floor crack
THEN fgeneral cracking choice := "hydro"

RULE 2261 local
IF fcrack choice = "settlement"
AND isolated crack OF floor crack
THEN fsettlement choice := "local"

RULE 2262 general
IF fcrack choice = "settlement"
AND isolated crack OF floor crack = FALSE
THEN fsettlement choice := "general"
RULE 12 a wall strength
IF deformed element IS WALL
AND deformation IS Cracking
AND other deformations OF wall crack IS Deformed window or door frames = FALSE
AND other deformations OF wall crack IS Separation between structural elements = FALSE
THEN test wall strength := "wall strength a"

RULE EXPANSIVE 1
IF type OF backfill IS Clay
AND liquid limit OF backfill >= 60
AND plastic index OF backfill >= 35
THEN expansive soil IS High

RULE EXPANSIVE 2
IF type OF backfill IS Clay
AND liquid limit OF backfill >= 30
AND liquid limit OF backfill < 60
AND plastic index OF backfill >= 15
AND plastic index OF backfill < 35
THEN expansive soil IS Medium

RULE EXPANSIVE 3
IF type OF backfill IS Clay
AND liquid limit OF backfill < 30
AND plastic index OF backfill < 15
THEN expansive soil IS Low

RULE EXPANSIVE 4
IF type OF backfill IS Clay = FALSE
THEN expansive soil IS Nonexpansive

RULE 11 a wall support
IF deformed element IS WALL
AND deformation IS Cracking
THEN test wall support := "wall support a"

RULE 11 b wall support
IF deformed element IS WALL
AND other deformations OF wall crack IS Deformed window or door frames
OR other deformations OF wall crack IS Separation between structural elements
AND other deformations OF wall crack IS None of the above = FALSE
THEN fcrack choice := "corner"

RULE SOIL ORGANIC
IF fingers OF backfill
AND fibres OF backfill
OR color OF backfill IS Dark
THEN type OF backfill IS Organic

RULE SOIL CLAY
IF fingers OF backfill
AND grain size OF backfill IS Invisible
OR consistency OF backfill IS Squeezes between fingers
OR consistency OF backfill IS Molded with fingers
THEN type OF backfill IS Clay

RULE SOIL SAND
IF grain size OF backfill IS Like broom bristles
OR consistency OF backfill IS Disintegrates when dry
THEN type OF backfill IS Sand

RULE SOIL GRAVEL
IF grain size OF backfill IS Like almonds
THEN type OF backfill IS Gravel

RULE FIRM SOIL
IF strength OF foundation IS Soil can be excavated with shovel
AND strength OF foundation IS Soil can be molded with hand = FALSE
AND strength OF foundation IS A three inch wide stick penetrates easily \ = FALSE
THEN hardness OF foundation IS Firm

RULE HARD SOIL
IF strength OF foundation IS Soil can be excavated with shovel = FALSE
AND strength OF foundation IS Soil can be molded with hand = FALSE
AND strength OF foundation IS A three inch wide stick penetrates easily \ = FALSE
THEN hardness OF foundation IS Hard

RULE SOFT SOIL
IF strength OF foundation IS Soil can be molded with hand
OR strength OF foundation IS A three inch wide stick penetrates easily
THEN hardness OF foundation IS Soft

END