DEVELOPMENT OF SAFER TRENCHING OPERATIONS

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Outline of the presentation

- The need
- Scope of the project
- Work in progress
- Findings to date
- Planned project extensions
Acknowledgments

- National Institute for Occupational Safety and Health (NIOSH) Grant No. 1 R01 OH07553-01
- Occupational Safety and Health Administration (OSHA)
- Bowen Engineering - Indianapolis
- R.L. Turner - Indianapolis
- Graycor Construction Company - Chicago
- Turner Corporation - Cincinnati
- Frank Messer and Sons - Cincinnati
- Hunt Construction Company - Indianapolis
- Duke Construction - Indianapolis
Context of the problem

Fatality rate = \( \frac{\text{# of fatalities}}{100,000 \text{ workers}} \)
Context of the problem

Fatalities in the construction industry Vs Fatalities in trenching operations (1997 – 2000)
No means of egress

Overhead load

Mobile Equipment

Spoil distance

No Protective System

Loose rock/soil

A typical trenching operation..
The Need

- Fatalities in trenching operations:
  - 1997: 69
  - 2000: 82
- Most deaths in trenching operations are from cave-ins

Source: Job Safety and Health Fall 1999
Scope of the project

- Analyze the causes of accidents in trenching operations
- Establish an information database on work risk factors associated with trenching operations
- Develop strategies to prevent and reduce injuries in trenching operations
Work in progress

- Analysis of historical data from BLS, OSHA and NIOSH
- Interviews with safety directors
- Review of successful safety practices implemented by construction companies
- Analysis of the chain of events leading to trenching accidents
Data Analysis

Causes of trench-related fatalities (OSHA 1997-2001)
Type of Accident Model (Hinze 1998)

- Struck by Object: 17%
- Caught-crushed in collapsing material: 55%
- Contact with electric current: 2%
- Explosion: 1%
- Oxygen deficiency: 2%
- Fall to lower level: 2%
- Others: 1%
- Caught-Compressed by equipment of objects: 1%
- Others: 1%
Causes of trench-related fatalities (OSHA 1997-2001)
Human Causes Model (Toole 2002)

1. Lack of proper training, 16.6%
2. Deficient enforcement of safety, 6.8%
3. Safe equipment not provided, 42.2%
4. Unsafe methods or sequencing, 27.0%
5. Unsafe site conditions, 0.3%
6. Not using provided safety Eq, 2.7%
7. Poor attitude toward safety, 0.7%
8. Isolated, sudden deviation, 3.7%
Chain of events

Planning

- Competent person
  - Specific training
- Site layout evaluation
- Utility location
- Selection safety equipment
- Work plan
- Training
  - Site conditions assessment
  - Provide safety equipment
- Plan and control methods or sequencing

Execution

- Enforcement of safety
- Use of safety equipment
  - Behavior of workers
- Isolated event
- Use of protective system
  - Collapsing materials
  - Electric current
  - Explosions
- Excavation
  - Pipe installation
  - Backfilling process
  - Struck by object

Strategies for preventing accidents

Trenching activities

Type of accident
Interviews with construction practitioners

- 16 interviews (11 companies)
- Objective: Identify the existing gaps between the strategies adopted by the construction industry and the strategies required to prevent trenching accidents
- 2 groups of questions:
  - Type of accident
  - Strategies to prevent accidents (Resources allocated to prevent trenching fatalities)
- Multiple comparison of strategies
# Interviews with construction practitioners

## Profile of the companies interviewed

<table>
<thead>
<tr>
<th>I.D.</th>
<th>Company</th>
<th>Role in the company</th>
<th>Volume of construction (US$)</th>
<th>Volume of trenching (US$)</th>
<th>% of Trenching</th>
<th>Type of Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Company 1</td>
<td>Safety Director</td>
<td>140,000,000</td>
<td>21,000,000</td>
<td>15%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>2</td>
<td>Company 1</td>
<td>Project Manager</td>
<td>140,000,000</td>
<td>21,000,000</td>
<td>15%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>3</td>
<td>Company 1</td>
<td>Superintendent</td>
<td>140,000,000</td>
<td>21,000,000</td>
<td>15%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>4</td>
<td>Company 2</td>
<td>Risk Manager</td>
<td>600,000,000</td>
<td>75,000,000</td>
<td>13%</td>
<td>C.M.</td>
</tr>
<tr>
<td>5</td>
<td>Company 2</td>
<td>Project Manager</td>
<td>600,000,000</td>
<td>75,000,000</td>
<td>13%</td>
<td>C.M.</td>
</tr>
<tr>
<td>6</td>
<td>Company 3</td>
<td>Safety Officer</td>
<td>2,000,000</td>
<td>400,000</td>
<td>20%</td>
<td>Subcontractor</td>
</tr>
<tr>
<td>7</td>
<td>Company 4</td>
<td>Superintendent</td>
<td>80,000,000</td>
<td>8,000,000</td>
<td>10%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>8</td>
<td>Company 5</td>
<td>Foremen</td>
<td>100,000,000</td>
<td>50,000,000</td>
<td>50%</td>
<td>Subcontractor</td>
</tr>
<tr>
<td>9</td>
<td>Company 6</td>
<td>Safety Director</td>
<td>2,100,000,000</td>
<td>30,000,000</td>
<td>1.4%</td>
<td>C.M.</td>
</tr>
<tr>
<td>10</td>
<td>Company 6</td>
<td>Project Manager</td>
<td>2,100,000,000</td>
<td>30,000,000</td>
<td>1.4%</td>
<td>C.M.</td>
</tr>
<tr>
<td>11</td>
<td>Company 7</td>
<td>Safety Director</td>
<td>40,000,000</td>
<td>2,000,000</td>
<td>5%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>12</td>
<td>Company 7</td>
<td>Project Manager</td>
<td>40,000,000</td>
<td>2,000,000</td>
<td>5%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>13</td>
<td>Company 8</td>
<td>Superintendent</td>
<td>45,000,000</td>
<td>4,500,000.0</td>
<td>10%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>14</td>
<td>Company 9</td>
<td>Superintendent</td>
<td>13,000,000</td>
<td>1,950,000</td>
<td>15%</td>
<td>Subcontractor</td>
</tr>
<tr>
<td>15</td>
<td>Company 10</td>
<td>Superintendent</td>
<td>20,000,000</td>
<td>7,000,000</td>
<td>35%</td>
<td>General Contractor</td>
</tr>
<tr>
<td>16</td>
<td>Company 11</td>
<td>Foremen</td>
<td>75,000,000</td>
<td>45,000,000</td>
<td>60%</td>
<td>Subcontractor</td>
</tr>
</tbody>
</table>
Results of the interviews

Type of Accident Model

<table>
<thead>
<tr>
<th>Type of Accident Model</th>
<th>Reports</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Struck by object</td>
<td>15.2</td>
<td>18.3</td>
</tr>
<tr>
<td>Caught by equipment</td>
<td>16.6</td>
<td>18.9</td>
</tr>
<tr>
<td>Caught in material</td>
<td>54.7</td>
<td>42.8</td>
</tr>
<tr>
<td>Contact elect. current</td>
<td>7.8</td>
<td>4.7</td>
</tr>
<tr>
<td>Explosion</td>
<td>2.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Others</td>
<td>3.3</td>
<td>12.5</td>
</tr>
</tbody>
</table>
Results of the interviews

Type of Accident Model – Bonferroni method

![Diagram showing the results of interviews]

Columns represent different types of accidents:
- Struck by object
- Caught by equipment
- Caught in material
- Others

The diagram illustrates the percentage of fatalities for each category.
Results of the interviews

Type of Accident Model – Type of company

![Graph showing the results of interviews with different types of accidents and the type of company involved. The graph includes bars for Struck by object, Caught by equipment, Caught in material, Fall to lower level, Electric current, Oxygen deficien., Explosion, and Others. The categories are further divided into C.M., General Contractors, Subcontractors, and Reports.]
Results of the interviews

Behavioral Causes Model

<table>
<thead>
<tr>
<th>% of Fatalities</th>
<th>Reports</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>16.6</td>
<td>13.6</td>
</tr>
<tr>
<td>Supervision</td>
<td>6.8</td>
<td>15.5</td>
</tr>
<tr>
<td>Safety Equipment</td>
<td>42.2</td>
<td>15.5</td>
</tr>
<tr>
<td>Plan-Control</td>
<td>27.0</td>
<td>16.2</td>
</tr>
<tr>
<td>methods</td>
<td></td>
<td>0.3</td>
</tr>
<tr>
<td>Assess site</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>conditions</td>
<td></td>
<td>2.7</td>
</tr>
<tr>
<td>Use safety</td>
<td>8.5</td>
<td>8.5</td>
</tr>
<tr>
<td>equipment</td>
<td></td>
<td>0.7</td>
</tr>
<tr>
<td>Behavior of</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>workers</td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td>Emotional/physical</td>
<td>2.5</td>
<td>2.5</td>
</tr>
</tbody>
</table>
Results of the interviews

Behavioral Causes Model - Bonferroni method

[Bar chart showing the percentage of fatalities in different categories: Training (12.5, 13.0, 14.6), Safety Equipment (19.7, 6.3, 16.6), Plan-Control methods (13.3, 19.2, 27.0), Others (14.2, 49.2, 53.9), 58.6%]
Results of the interviews

Behavioral Causes Model - Role in the company

<table>
<thead>
<tr>
<th>Category</th>
<th>% of Fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>13</td>
</tr>
<tr>
<td>Supervision</td>
<td>16</td>
</tr>
<tr>
<td>Safety Equip.</td>
<td>18</td>
</tr>
<tr>
<td>Plan meth</td>
<td>15</td>
</tr>
<tr>
<td>Assess site</td>
<td>20</td>
</tr>
<tr>
<td>Use safety equip</td>
<td>22</td>
</tr>
<tr>
<td>Beha. of work</td>
<td>0</td>
</tr>
<tr>
<td>Emot./phy.</td>
<td>3</td>
</tr>
</tbody>
</table>

Legend:
- **Foremen+superintendent**
- **Managers**
- **Reports**
## Successful safety practices

<table>
<thead>
<tr>
<th>Practice</th>
<th>Construction phase</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety planning meetings</td>
<td>Planning</td>
<td>Design team, subcontractors, project engineers, foremen, a representative of the owner, insurance company, and contractor’s safety officer</td>
</tr>
<tr>
<td>Daily safety meetings</td>
<td>Execution</td>
<td>Foremen, subcontractors</td>
</tr>
<tr>
<td>Safety training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>General safety training</td>
<td>Planning</td>
<td>Engineers, foremen, workers</td>
</tr>
<tr>
<td>Specific safety training</td>
<td>Execution</td>
<td>Subcontractors</td>
</tr>
<tr>
<td>Incentive programs</td>
<td>Execution</td>
<td>Engineers, foremen, subcontractors, administrative personnel</td>
</tr>
<tr>
<td>Top management support</td>
<td>Execution</td>
<td>Top management, project engineers</td>
</tr>
<tr>
<td>Owner’s role</td>
<td>Planning</td>
<td>Representative of the owner</td>
</tr>
<tr>
<td></td>
<td>Execution</td>
<td></td>
</tr>
<tr>
<td>Accounting practices</td>
<td>Execution</td>
<td>Project engineers, financial division</td>
</tr>
<tr>
<td>Increasing accountability of workers</td>
<td>Execution</td>
<td>Project engineers, foremen, workers</td>
</tr>
<tr>
<td>Control of minor accidents</td>
<td>Execution</td>
<td>Project engineers, foremen</td>
</tr>
</tbody>
</table>
Successful safety practices

- Planning meetings:
  - Overall safety planning meeting
  - Daily safety meetings
- Training:
  - General training (use of Personal Protective Equipment)
  - Specific training in trenching operations
- Incentive programs:
  - Project basis
  - Worker basis
  - Behavior basis
- Top management support
Successful safety practices

- Increased involvement by owner
  - Safety as a major factor in awarding contracts
- Accounting practices
  - Charge the indirect and direct costs of the accident directly to the cost of the project
- Control of minor accidents
  - Accident prevention
  - Higher level of commitment from the management
- Increasing accountability of workers
  - Need for workers to accept responsibility for their own actions
Summary of research findings - I

- 64% of the fatalities occurred in trenches less than 3 m (10 ft) deep, and 98% of the fatalities occurred in trenches less than 6.1 m (20 ft) deep.

- 72% of the fatalities occurred in projects costing under US$ 1 million.

- 36% of the fatalities occurred in projects with fewer than 10 workers AND costs under US$ 250,000.

- 63% of the fatalities in occurred in projects with fewer than 10 workers on site.
Summary of research findings - II

- The major causes of fatalities can be addressed by the existing OSHA standards.
- The construction industry has a clear understanding of the different types of accidents involved in trenching operations.
- The construction industry does not consider a single strategy as most important to prevent trenching accidents.
- The construction industry has implemented strategies to prevent accidents, but the focus is not necessarily on the major strategies based on the Behavioral Causes Model.
Recommendations for future work

Quantitative analysis
- It is necessary to evaluate the cost/benefit ratio for the identified safety strategies
- It is important to do an in-depth analysis of small construction companies involved in trenching operations.

Qualitative analysis
- Analysis of the workers’ behavior in trenching operations. “Tough guy culture”
Dissemination of findings

• Publications:
Planned project extensions

- Evaluating the relationship between safety and productivity in steel erection (special emphasis on the new safety standards in steel erection)
- Using new technologies to overcome the challenges in safety inspections
- Evaluation of the cost/benefit ratio for the identified safety strategies
- Assessment injury rates among women and minority workers in construction operations
- Analysis of the workers’ behavior - “Tough guy culture” in trenching operations
Thank You

Questions?