What causes accidents?

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What causes accidents?

This paper describes aspects of the findings of a three-year research project, Construction Accident Causality (ConCA), funded by the UK Health and Safety Executive. The project developed a causality model, through a combination of focus groups and detailed study of 100 construction accidents, using an ergonomics systems approach, to identify where safety is compromised and why. It concludes that stakeholders responsible for the immediate accident circumstances, shaping factors and originating influences must all work hard to remove flaws in their safety systems to ensure that accidents are reduced.

This paper describes aspects of the findings of a three-year research project, Construction Accident Causality (ConCA), funded by the UK Health and Safety Executive (HSE). ConCA used a combination of focus groups and a detailed study of 100 construction accidents using an ergonomics systems approach, to identify where safety is compromised and why. Other aspects of this major study have been published elsewhere.

Although the British construction industry is one of the safest in Europe, one third of all work fatalities occur in construction and construction workers are six times more likely to be killed at work than employees in other sectors. A similar situation exists for non-fatal accidents. Although previous research has led to a good understanding of the extent and pattern of accidents in the construction industry, there has been only limited objective analysis of the full range of contributory managerial, site and individual factors. With this background, ConCA had the following aims.

To collect rich, detailed data on the full range of factors involved in a large sample of construction accidents.

Using this information, to describe the processes of accident causation, including the contribution of management, project, site and individual factors in construction industry accidents.

Drawing together the findings, ConCA proposed an accident model, illustrating the hierarchy of influences in construction accidents (Fig. 1). The model describes how accidents arise from a failure in the interaction between the work team, workplace, equipment and materials. These immediate accident circumstances, which relate to the site of the accident or incident, are affected by the actions, behaviour, capabilities and communication of the work team are affected by their attitudes, motivations, knowledge, skills, supervision, health and fatigue. The workplace is affected by site constraints, work scheduling and housekeeping. The suitability, usability, condition and, therefore, safety of materials and equipment depend on their design, specification and supply/availability. These shaping factors are subject to originating influences, including the permanent works design, project management, construction processes, safety culture, risk management, client requirements, economic climate and education provision. ConCA concluded that achieving a sustained improvement in safety in the industry would require concerted efforts by all stakeholders, directed at all levels in the influence hierarchy.

Relating to other theories

Many research teams have sought to explain the causes of accidents. Early attempts were somewhat simplistic. More recent efforts...
have acknowledged the complexity of real-life accidents, such as Petersen’s human error reduction approach,\(^6\) Hinze’s distractions theory,\(^7\) Loosemore’s chain of events model\(^8\) and Suraji et al.’s constraint-response theory.\(^9\) Abdelhamid and Everett’s model\(^10\) acknowledges complexity but concentrates on site issues only.\(^11\)

In his book *Human Error*,\(^12\) James Reason introduces a model to describe the causes of accidents. His work concentrates on major incidents such as Chernobyl, the Challenger space shuttle and London’s Kings Cross Underground fire and he argues that most safety systems have a number of layers, or plates. Each of these plates aims to prevent a potential incident passing through them. However, according to Reason, due to human error, none of the plates are impervious—they all have holes. These holes allow the potential incident to pass through the plate, or that layer of the safety system. In most cases, the next layer in the system will intercept the potential incident and prevent its occurrence. However, Reason’s theory explains that when holes in all the plates line up, the potential incident becomes a reality—the accident actually occurs. This theory neatly illustrates the role of chance in accident causality. Reason’s approach brings in the possibility of multi-causality, as a number of different holes could line up to allow the trajectory of accident opportunity.

While Reason’s model was based on major incidents, the authors have applied the approach to the ConCA accident causality results. Thus the plates become the immediate circumstances, shaping factors and originating influences (Fig. 2).

It can therefore be seen that failures by stakeholders responsible for action in each of these three areas can contribute to causing an accident. This approach has received support from a series of workshops involving more than 1000 industry practitioners and has been found to be a useful way of explaining the complex nature of accident causality and the interaction of roles of all the major stakeholders. Efforts made to reduce holes in each of the plates will reduce the chance of accidents occurring, but will never prevent them completely. The ConCA work also identified a compelling reason why designers may feel frustrated by the lack of effect of their efforts to design-out hazards—in many cases, site health and safety practice was so poor that any efforts made by designers and project management teams were being wasted at site level; in other words, using Reason’s model, the immediate accident circumstances plate was so full of holes that any hazards not removed pre-site were almost certainly going to result in accidents on site.

Adapting the original ConCA accident causality model slightly, the ConCA/Reason model can be used to simplify the message and challenge for the construction industry. The site team, who are largely responsible for the immediate circumstances, need to concentrate on reducing their own holes (i.e. site environment, workplace, worker and tools and equipment issues). The project management team and detailed designers (the main influencers of the shaping factors) should ensure that they work at the preconstruction planning and design aspects to reduce risk and hence close holes in their
plate. Finally, the client team, concept designers and others who have influence over the industry as a whole can work to reduce risk both at a project and at an industry level. It is only through such a collaborative effort that the number of accidents can be reduced.

Accident studies

The ConCA model was developed following detailed studies of 100 accidents, to collect further evidence on the issues raised by earlier focus groups. Sampling was on a quota basis, ensuring a spread of accidents across construction build type and RIDDOR accident categories (Reporting of Injuries, Diseases and Dangerous Occurrences – the UK HSE’s categories for reporting accidents and incidents). Criteria for inclusion in the study were that the accident was not subject to investigation by HSE, that the accident had occurred within the preceding two months, and that the accident victim and supervisor/manager were still on site and willing to participate in the research.

Site-based data collection entailed interviews with accident-involved personnel and their supervisor or manager, inspection of the accident site and review of relevant documentation, such as accident notification forms, risk assessments and method statements. A report of the site-based findings was reviewed by an expert pairing of construction and ergonomics specialists from the research team which suggested areas for further follow-up examination. Where possible, issues identified were pursued directly with the designers, manufacturers and suppliers relevant to the incident. In many of the studies, however, this proved impossible due to difficulty identifying appropriate individuals to contact and then securing their cooperation. In these cases, the issues were instead discussed with other professionals, independent of the accident but qualified to comment.

Due to the need to avoid incidents subject to HSE investigation, most of the accidents studied were not reportable under RIDDOR. Following assessment of the possible outcomes of each accident, more than a third were judged to have had the potential to cause a fatality and more than two-thirds could have been ‘major’ as classified under RIDDOR. On this basis, it is argued that it is reasonable to generalise the findings concerning causation from this sample to more serious accidents. Summaries from accident studies are set out below.

Overturning of self-loading/unloading truck

A truck was delivering scaffold to a site. The driver was trying to manoeuvre the load towards the drop zone when the truck tipped over, though no damage was caused (Fig. 3). The stabiliser feet (outrigger) had been put

<table>
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<tr>
<th>Immediate accident circumstances</th>
<th>Shaping factors</th>
<th>Originating influences</th>
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<tbody>
<tr>
<td><strong>Worker</strong></td>
<td>Actions</td>
<td>Fatigue</td>
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<td></td>
<td></td>
<td>Culture</td>
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<td></td>
<td>Knowledge/skills</td>
<td>Management/processes/culture</td>
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<td>Client requirements</td>
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<td></td>
<td>Economic climate</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td></td>
<td>Risk management (no risk assessment)</td>
</tr>
<tr>
<td><strong>Site</strong></td>
<td>Congested work area</td>
<td>Site constraints</td>
</tr>
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<td></td>
<td></td>
<td>Permanent works design/client requirements</td>
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<tr>
<td><strong>Overlapping trades</strong></td>
<td>Scheduling</td>
<td>Project management/processes</td>
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<tr>
<td><strong>Equipment</strong></td>
<td>Useability</td>
<td>Design (controls)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Design (outrigger)</td>
</tr>
</tbody>
</table>

**Table 1. Analysis of self-loading/unloading truck incident**
down to the ground, but had not been extend-
ed beyond either side of the truck beforehand. 
An analysis of the circumstances, factors and 
influences is shown in Table 1.

Manual handling steelwork
Two men of significantly differing heights 
were moving steel angles by hand. One injured 
his hand while ‘dropping’ the angle to the 
floor (Fig. 4). An analysis of the circumstanc-
es, factors and influences is shown in Table 2.

Concrete pump accident
Concrete-pump pipes were being ‘blown 
through’, a cleaning process in which a wet foam ball is placed inside the pipe and is prop-
pelled to the other end with pressurised air, at 
the end of the workday. The accident report 
states that an operative was standing over the 
pipe (Fig. 5) and that with the force of propul-
sion as the last of the concrete and the wet ball came through, this threw him backwards 
onto a column. He sustained a groin and back 
injury and was off work for a week. An analy-
ysis of the circumstances, factors and influences is shown in Table 3.

ConCA results and implications for 
industry
The results of the research of the ConCA 
project and the implications for industry are 
summarised as follows.

- Problems arising from workers or the 
  work team, especially worker actions or 
  behaviour and worker capabilities, were 
  judged to have contributed to over two-
  thirds (70%) of the accidents. This points 
  to inadequate supervision, education and 
  training.

- Poor communication within work teams 
  contributed to some accidents, due to the 
  physical distance between work colleagues 
  or high levels of background noise.

- Many accidents occurred when those 
  involved were not actually performing a 
  construction task (e.g. moving around 
  site).

- Workplace factors, notably poor house-
  keeping and site layout and space avail-
  ability problems, were considered to have 
  contributed in half (49%) of the accident 
  studies. Standards of housekeeping and 
  workplace layout are low in construction 
  compared to other industrial sectors.

- Despite poor weather often being cited as 
  one of the reasons for construction’s poor 
  safety record, ConCA found little evidence 
  in support of this.

- Shortcomings with equipment, including 
  personal protective equipment (PPE), 
  were identified in over half (56%) of the 
  incidents. Poor equipment design and 
  inappropriate use of equipment for the 
  task were prominent aspects. Designers, 
  suppliers and purchasers of equipment 
  appear to give insufficient attention to the 
  safety of users.

- Deficiencies with the suitability and condi-
  tion of materials, including packaging, 
  featured in more than a quarter (27%) 
  of incidents. The operation of the supply/
  purchase chain at present appears to act 
  as a barrier to innovation as far as safety 
  is concerned.

- Originating influences, especially inade-
  quacies with risk management, were 
  considered to have been present in almost 
  all (94%) of the accidents. Frequently, 
  no risk assessment had been undertaken 
  covering the circumstances involved in 
  the accident. Where a risk assessment 
  had been carried out, it was often found to be 
  superficial and unlikely to have prevented 
  the accident.

- PPE appears to be relied upon habitu-
  ally as a substitute for risk elimination or 
  reduction at source.

- It was judged that up to half of the accidents 
  could have been mitigated through a design 
  change and it was found that, despite the 
  Construction (Design and Management) 
  Regulations (CDM), many designers are 
  still failing to address the safety implications 
  of their designs and specifications.

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Table 2. Analysis of manual handling steelwork incident

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<td>Knowledge/skills</td>
</tr>
<tr>
<td></td>
<td>Capabilities</td>
<td>Knowledge/skills</td>
</tr>
<tr>
<td>Site</td>
<td>Congested work area</td>
<td>Site constraints</td>
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<td></td>
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<tr>
<td>Materials</td>
<td>Useability</td>
<td>Design for handling</td>
</tr>
<tr>
<td>Equipment</td>
<td>Suitability</td>
<td>availability</td>
</tr>
</tbody>
</table>

Table 3. Analysis of concrete pump accident

<table>
<thead>
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<tbody>
<tr>
<td>Worker</td>
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<td>Supervision</td>
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<td>Fatigue</td>
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</tr>
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<td></td>
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<td>Housekeeping</td>
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<td>Equipment</td>
<td>Useability</td>
<td>Scheduling</td>
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<td>Design</td>
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</table>
Accident investigation by employers or supervising contractors was frequently superficial and of little value to improving safety. HSE investigations seem to focus on safety failures in the activity being undertaken, without capturing the upstream influences upon these.

The influence from clients on safety appeared limited in the construction sectors predominant in this research (civil engineering, major building, residential). This was, again, despite the responsibilities on clients imposed by CDM.

Many of the incidents were caused by commonplace hazards and activities that will continue to occur on site whatever design changes might be made. The widespread presence of the many generic safety risks accompanying construction needs to be tackled before the benefits of design improvements will be realised.

Together, these factors point to failings in education, training and safety culture in the industry. A large majority of those working in construction, both on and off site, continue to have only a superficial appreciation of health and safety considerations.

Conclusions and recommendations

Drawing together the findings from the research, an accident model has been proposed (Figs 1 and 2), illustrating the hierarchy of influences in construction accidents. The model describes how accidents arise from a failure in the interaction between the work team, workplace, equipment and materials. These immediate accident circumstances are affected by shaping factors, whereby the actions, behaviour, capabilities and communication of the work team are affected by their attitudes, motivations, knowledge, skills, supervision, health and fatigue.

The workplace is affected by site constraints, work scheduling and housekeeping. The suitability, usability, condition and, therefore, safety of materials and equipment depend on their design, specification and supply/availability. These shaping factors are subject to originating influences, including the permanent works design, project management, construction processes, safety culture, risk management, client requirements, economic climate and education provision.

Achieving a significant and sustained reduction in accidents will require concerted efforts directed at all levels of the hierarchy of causation. Important points are as follows.

- Responsibility for safety needs to be owned and integrated across the project team, from designers and engineers through to skilled trade personnel and operatives.
- Other research has shown how the lead given by front-line supervisors has a strong influence on safety performance. Worker participation in managing safety is important, to generate ideas and to build ownership and responsibility.
- Where safety depends on communication and coordination, it is important that a robust safe system of work is established.
- A step change is required with standards of site layout and housekeeping. Principal contractors should raise expectations of what constitutes acceptable practice.
- Greater attention should be given to the design and selection of tools, equipment and materials. Safety, rather than price, should be the paramount consideration.
- There needs to be greater sophistication with the design and use of PPE. Current PPE is often uncomfortable and impedes performance. Forcing workers to wear PPE when risks are not present may even be counterproductive. PPE should be last, rather than first, resort for risk management.
- There is a need across the industry for proper engagement with risk assessment and risk management. Emphasis should be on actively assessing and controlling risk, rather than treating risk assessment as merely a paper exercise.
- Construction should be encouraged to benchmark its safety practices against other industries. The excuse that construction is ‘different’ does not stand up to scrutiny.
- Greater opportunity should be taken to learn from failures, with implementation of accident investigation procedures, both by employers and HSE, structured to reveal contributing factors earlier in the causal chain.
- It is important that ‘safety’ is disassociated from ‘bureaucracy’.
- Frequently, safety does not have to come at a price. Where there are cost implications, however, regulatory bodies and trade associations should work to make sure there is a level playing field.

Most of the changes depend on achieving widespread improvement in understanding of health and safety. Education is needed over training, so as to promote intelligent knowledge rather than unthinking rule-based attention to safety.

Returning to the ConCA/Reason model (Fig. 2), each set of stakeholders must work hard to reduce the flaws in their ‘systems’ to reduce the likelihood of an upward trajectory of accident opportunity occurring.

References


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