A Selection of Fall Protection and Working at Height Research in the UK 2001-2008

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David's 20 years in fall protection started unwillingly when he was knocked-off a Chinook helicopter by a rotor blade as a result of a RAF pilot who, having ignored procedures, proceeded to start the engines. He fell some 12 feet onto wet, boggy ground, without injury. Driven by this and other accidents, David subsequently attempted to have anchor points incorporated into the helicopter's fuselage. After leaving the RAF, he joined Barrow Hepburn Sala, eventually becoming the Technical Director with the design authority for some 100 fall protection products and head of a 20-man technical team. At present, David practices through his own consultancy, Safety Squared, which provides technical assistance to manufacturing, installation and user companies, as well as advising UK Government. David has carried out five substantial research projects for the Health and Safety Executive (HSE), the Government body responsible for the enforcement of health and safety legislation in the UK. He has also been actively involved with British, European and ISO standards over a considerable time, and has chaired such committees as CEN/TC 160 WG1 and PG2.

Introduction

At the turn of the century, the HSE embarked on an extensive research program in the area of fall protection and working at height, driven in part by the desire to reduce fall-related accidents, but equally to review the existing knowledge base and to identify and remedy knowledge deficiencies in what is a rapidly developing market.

The fruit of that research program is the subject of this account, the contents of which should be a rich source of information to anyone with an interest in the subject.

The following information summarises the backgrounds to the individual projects and the abstracts from the resulting research reports. These have been published on the HSE website and are viewable and downloadable free of charge.

The presented Information includes the project title, organisation and individuals responsible for the conduct of the research, the research report number, and the specific web address details for download.

1. Industrial rope access - investigation into aspects of personal protective equipment

Lyon Equipment Ltd (A. Long, M. Lyon and G. Lyon)

Contract Research Report 364/2001

http://www.hse.gov.uk/research/crr_htm/2001/crr01364.htm

Synopsis:

An investigation into items of equipment used for work at height in industrial rope access and arboriculture. Techniques and equipment used in these areas have evolved rapidly in the last 15 years, opening up new working methods that are being deployed in equally rapidly expanding areas. The investigation comprises tests and evaluations of ropes and associated items such as lanyards, cow's tails, termination and other knots, and rope protectors. It proceeds to look at items of equipment that are attached to working and safety ropes to allow movement in all directions along them. These so-called rope adjustment devices include back-up devices, ascenders and descenders.

Testing included worst-case scenario dynamic loadings, some fall factor 2, and others fall factor 1. Evaluation includes discussion on how rope access and work positioning may be effected using the items tested to minimise or eliminate falls.

Reference has been made to existing and draft European standards, in particular, prEN 12841 (May 2000), 'Personal protective equipment for the prevention of falls from a height: Rope Access Work positioning systems – Rope adjustment devices', BS EN 1891:1998, 'Personal protective equipment for the prevention of falls from a height – Low stretch kernmantel ropes' and BS EN 353-2:1993, 'Personal protective equipment for the prevention of falls from a height: guided type fall arresters'.

2. Analysis and evaluation of different types of test surrogate employed in the dynamic performance testing of fall-arrest equipment

Safety Squared (D. Riches)

Contract Research Report 411/2002

http://www.hse.gov.uk/research/crr_htm/2002/crr02411.htm

Synopsis:

Over recent decades, workers have been protecting themselves from the harmful effects of falling from a height, by using fall-arresting systems (FAS). FAS limit the gravitational plummet resulting from an accidental fall, which is achieved by decelerating and stopping the worker in a relatively short distance, hence the term "fall-arrest". Testing of FAS to confirm the safety and performance of particular designs has, and remains to be a vital part of the validation process, whether statutory, ethical, for research purposes or in conformance with other requirements. In particular, dynamic performance testing, or "drop testing", as the method became known, simulates an arrested fall by using a test surrogate in place of a human being, and plays a central part in the assessment of FAS designs.

Over the course of time, and on an international basis, different types of test surrogate have been used for different reasons, and these have evolved in response to testing philosophy and experiences. The main problem posed by using test surrogates is that of understanding how the results of testing compare with the results of identical tests if they had been performed with a human being. Are the results representative, and if so, to what degree? And does one type of test surrogate produce more representative results than the other?

Despite previous studies, a number of interrelated issues have grown unchecked over the years, as a result of research being curtailed in this subject area. There is still considerable confusion and a lack of technical information in the fall-arrest market in regard to the appropriateness of test surrogates, test methods, and what the results of these tests actually mean, especially for those organisations that use FAS. This literature review studies previous research, draws conclusions, and presents recommendations for further work.

3. Harness suspension: review and evaluation of existing information

P Seddon

Contract Research Report 451/2002

http://www.hse.gov.uk/research/crr_htm/2002/crr02451.htm

Synopsis:

A personal fall protection system comprises at least a body holding device, i.e. a harness of some type, a lanyard and a reliable anchor. A well thought-out system will seek to minimize the effects of any potential fall. If a fall does occur, that system will arrest the fall with a limited impact force. At this stage, the harness (and the rest of the components in the system) will have stopped the fall, hopefully, without it causing any injury.

The fall and the arrest of it are only part of the story, and not necessarily the most dangerous. After the fall and its arrest comes the suspension phase, when the casualty either rescues him or herself, if capable, or awaits rescue by another person or persons. After a fall, the body is likely to be in a state of shock. If the casualty is badly injured or unconscious, there is unlikely to be any movement of the legs and there can be serious consequences. The orientation of the body and the comfort of the suspended person, determined to a large extent by the design of the harness and the position of its attachment point to the system, also play their part in the outcome.

This review looks at the potential problems of the suspension phase of a fall, how the position of the attachment points on various harnesses play an important role in the comfort and survival of a casualty, and how a selection of harness standards address the issues surrounding suspension. The review reports on existing literature, gives background information to assist the reader, raises issues for discussion and gives recommendations for further work.

4. Falls from height – prevention and risk control effectiveness

BOMEL Ltd.

Research Report 116

http://www.hse.gov.uk/research/rrhtm/rr116.htm

Synopsis:

This report describes a pan-industry study into the underlying influences on, and control of, falls from height. The falls accidents reported via RIDDOR have been analysed for the last five years. The construction industry has the highest number of high falls, but agriculture and construction have similar fatality rates.

There are few fatalities due to low falls, but low falls make up around 60% of the overall number of falls, with service industries having the highest number of accidents but the lowest accident rate. Construction has the highest rate of low falls.

Influence Network workshops were held with a wide range of delegates representing key stakeholders in Agriculture, Construction, Roofing, Specialists/Utilities and Transport. Analyses have given an insight into: the underlying organisational and human factors influencing falls from height; risk control measures; and their potential effectiveness.

These indicate that there are many similarities pan-industry with human, cultural and organisational issue dominating. Of the Direct influences on falls from height, Competence, Situational awareness/risk perception, Compliance and Operational equipment are primary influences. Of the Organisational factors, Process design, Training, Management/supervision and Safety culture are significant. At the Policy level, key factors are Company culture and Safety management. The Regulator and the Market are considered to be the primary Environmental influences on falls.

Key areas for risk reduction and management were also identified. The biggest improvements are required in Compliance and Process design. Awareness needs to be raised of the risks associated with low-level falls given that there are so many if them. The economic benefits of better health and safety need to be demonstrated such that they can be communicated to industries where the culture is dominated by cost.

5. Recidivist risk takers who work at height

Ergonomics and Safety Research Institute, Loughborough University (V. Haines, D. Hitchcock, Z. Osman, E. Elton, M. Craven and M. Hussey)

Research Report 201

http://www.hse.gov.uk/research/rrhtm/rr201.htm

Research question: Why do individuals take risks when working at height and are some people more likely to have multiple falls from height accidents?

Method: detailed interviews with a mixture of those who had suffered injury as a result from falling from height, those who work at height but have not suffered a fall, and those who supervise the work.

Potential benefits: The research identifies a range of interventions aimed at reducing risk-taking behaviour and the obstacles to implementing these techniques.

Synopsis:

Assesses the reasons why individuals take risks when working at height and suggests that some people have a higher sensation-seeking tendency and, hence, risk taking propensity. Based on detailed interviews with a mixture of those who had suffered injury as a result from falling from height; those who work at height but have not suffered a fall and those who supervise the work. The research identifies a range of interventions aimed at reducing risk taking behaviour and the obstacles to implementing these techniques.

6. Preliminary investigation into the fall-arresting effectiveness of ladder safety hoops

Safety Squared (D. Riches)

Research Report 258

http://www.hse.gov.uk/research/rrhtm/rr258.htm

Research question: Can ladder safety hoops provide any form of fall-arresting capability?

Method: Update the current state of knowledge and understanding in regard to what ladder safety hoops actually are, what their intended purpose is, and to establish by preliminary testing whether or not they could provide any form of fall-arresting capability.

Potential benefits: This research has added to HSE's knowledge of the performance criteria of ladder safety hoops, and will inform future work about how the hoops should be used.

Synopsis:

Various legislative and guidance documents specify ladder safety hoops on fixed access ladders, (alternatively rendered as caged ladders), and give the impression that the purpose of the hoops is to protect workers from falling to the ground or other platform. Previous research has indicated that there is virtually a total lack of knowledge in regard to ladder safety hoops, and in conjunction with anecdotal accident evidence and a lack of test methods, uncertainties have been raised by persons conducting working at height risk assessments as to whether safety hoops can provide any form of fall-arresting capability.

The overall aim of this preliminary investigation was to update the current state of knowledge and understanding in regard to what ladder safety hoops actually are, what their intended purpose is, and to establish by preliminary testing whether or not they could provide any form of fall-arresting capability.

7. A review of the criteria concerning design, selection, installation, maintenance and training aspects of temporarily installed horizontal lifelines

Safety Squared (D. Riches)

Research Report 266

http://www.hse.gov.uk/research/rrhtm/rr266.htm

Research question: What criteria affect the selection of temporarily installed horizontal lifelines for work at height?

Synopsis:

This research gathers together and reviews technical information in order to provide a greater understanding into how these FAS are designed, how they work, and how they are controlled. This includes: key factors regarding selection, installation, use and maintenance; recommendations for those organisations that fabricate and install their own designs; recommendations for training; and information that could be put into HSE guidance.

8. Developing a prototype decision aid for determining risk of work systems at height when using temporary access systems

Heriot-Watt University (S.M. Whitaker, R.J. Graves, M. James, P. Mc Cann, C. Wilson, C. Dymiotis, J. Wolfram and M. Baker)

Research Report 268

http://www.hse.gov.uk/research/rrhtm/rr268.htm

Method: One method of supporting safe practices when working at height is the provision of prescriptive guidelines in a readily accessible format for workers at all levels involved with the work. Decision aids are one means of presenting information. The research described in this report aimed to develop and test appropriate decision aids for people involved in temporary access to height.

Potential benefits: The provision of decision aids will enable people to plan and organise work at height more effectively.

Synopsis:

Access to height has associated risks of falls of people and objects that can arise due to structural and procedural inadequacies. Previous research suggests that the basic risks are not sufficiently controlled across industry, and that the injury rate in work requiring access to height is disproportionately high. One method of supporting safe practices when working at height is the provision of prescriptive guidelines in a readily accessible format for workers at all levels involved with the work. Decision aids are one means of presenting information. The research described in this report aimed to develop and test appropriate decision aids for people involved in temporary access to height.

The analysis of a large sample of accidents and incidents occurring during work at height, and which were reported to the HSE over the last ten years, is described. This analysis provided information on the root-causes of the incidents as well as the more distal causes preceding the event, such as safety management deficiencies. Two work systems emerged as particularly well represented in the statistics in terms of absolute numbers of cases; these were temporary access scaffolds and work on roofs.

9. A technical guide to the selection and use of fall prevention and arrest equipment

Glasgow Caledonian University (I. Cameron, R. Duff and G. Gillan)

Research Report 302

http://www.hse.gov.uk/research/rrhtm/rr302.htm

The report was prepared by Glasgow Caledonian University, School of the Built and Natural Environment for the HSE and describes a study on fall prevention and arrest equipment available to the construction industry. The objectives of the research are to critically appraise:

- Purlin trolley systems
- Safety decking
- Fall arrest mats
- Safety netting
- Cable and track-based fall arrest systems
- NASC's SG4:00: The use of fall arrest equipment when erecting, altering and dismantling scaffold.

There is a large, and increasing, availability and diversity of such equipment and this research has collected data on each of the systems, currently available. The principles of the 'hierarchy of risk control' are important when selecting appropriate safety equipment for working at height; the order of preference being:

- Prevention - guardrails/barriers/purlin trolleys/safety decking
- Passive arrest - safety nets/fall arrest mats
- Active arrest - cable and track-based systems/SG4:00
- Mitigation of any consequences of an accident.

The risk of a fall must, wherever possible, be designed out. If this is not possible, the above hierarchy must be followed in equipment selection. The outcome of this research illustrates good practice, which was derived from interviews with system users, experts in selection and planning of accident protection methods, and observations of live case study sites.

10. Revision of body size criteria in standards - protecting people who work at height

Loughborough University and Aston Business School (V. Haines, E. Elton and M. Hussey)

Research Report 342

http://www.hse.gov.uk/research/rrhtm/rr342.htm

Research question: Do we need to revise body size criteria in the standards used to test personal protective equipment safety?

Method: Collecting anthropometric data of the working at height population.

Synopsis:

This report serves to describe a programme of work undertaken to consider whether the body size criteria in standards which are used to test Personal Protective Equipment safety needed revision. It details the research methodology employed to ascertain a selection of anthropometric data of the working at height population, in order to accurately establish whether the dimensions and requirements of PPE test apparatus needs reviewing. This work is intended to improve safety measures for workers at height that use PPE and to further the knowledge about this population.

11. Issues surrounding the failure of an energy absorbing lanyard

Health and Safety Executive (D. Thomas)

Specialist Inspector Report 59

http://www.hse.gov.uk/pubns/sir59.pdf

Following concerns arising from the failure of an energy absorbing lanyard in Eire, the Health and Safety Executive's (HSE's) Technology Division (TD) undertook an investigation into the properties, resistance and degradation of man-made fibre lanyards used in energy absorbing lanyards. A number of recommendations were made.

The Report considers the issues surrounding the failure of an energy-absorbing lanyard. It gives brief details of the incident in Eire; summarises an HSE test programme; considers information provided by fall arrest equipment designers, manufacturers, suppliers and distributors; reviews several others sources of advice and contacts; lists the requirements of the relevant Standards, EC Directive and Legislation; considers artificial ageing Standards; gives the draft 'Aims' and 'Objectives' of the Personal Safety Manufacturers' Association (PSMA) 'Height and Access Committee'; discusses the findings and makes recommendations; and examines areas for further research.

12. Survivable impact forces on human body constrained by full body harness

Health and Safety Laboratory (H. Crawford)

Report HSL 03/09

http://www.hse. gov.uk/research/hsl_pdf/2003/hsl03-09.pdf

Synopsis:

This study was commissioned in an effort to reduce the potential for leg and ankle injury to construction and roofing workers employed in the construction and cladding of 'low roofs'. On structures of this type the workers often secure their harness lanyard to a strong point, or anchorage, at 'foot level'. If a fall should occur, the combination of 2m lanyard length plus extension of the energy absorber and the height from harness attachment to the worker's feet can exceed the height from the structural anchorage to the floor. The worker's feet may strike the ground or floor whilst the energy absorber is still deploying.

It has been suggested that reduction of the fall-arrest distance may reduce the potential for these injuries, but the laws of physics indicate this cannot be achieved without consequent increase of arrest forces on the body. This study investigates the possibility of raising the level of the fall-arrest force. It also suggests alternative solutions.

Analysis of the medical, physiological and other scientific literature regularly shows up the fact that "the learned" talk to "the learned" in terminology foreign to other educated readers. This paper seeks to 'demystify' the information and make it available and understandable to those whose interest is industrial fall-safety.

13. Assessment of factors that influence the tensile strength of safety harness and lanyard webbings

Health and Safety Laboratory (C. Wilson, R Parkin and L Robinson)

Reports HSL/2002/16 and HSL/2002/17 (supplementary information)

http://www.hse.gov.uk/research/hsl/hsl02-16.htm and

http://www.hse.gov.uk/research/hsl/hsl02-17.htm

Synopsis

Following the failure of an energy absorbing lanyard and a work-positioning belt, Mr David Thomas of YNSGCON requested HSL to carry out an investigation into factors that may affect the performance of a safety harness and lanyard webbing in service.

Currently, there is a lack of information available to employers regarding the discard criteria for webbing. This project, by isolating damaging factors and replicating levels of damage, gives information on factors that contribute to strength degradation and the extent to which this occurs.

At present, British Standards for newly manufactured lanyard webbing state minimum strength requirements without any consideration of loss of strength due to degradation. This report aims to increase the knowledge available when formulating such standards in the future.

The factors that were considered that may have an effect on the strength degradation of lanyards manufactured from webbing were considered to be:

- Ingress of dirt
- Edge damage
- Real time weathering - exposure to all weather conditions
- Real time weathering - exposure to sunlight

It was also proposed to investigate:

- Accelerated weathering - exposure to ultraviolet radiation

14. Karabiner safety in the arboricultural industry

Health and Safety Laboratory (J. Statham and B. Roebuck)

Report HSL/2003/18

http://www.hse.gov.uk/research/hslpdf/2003/hsl03-18.pdf

Synopsis

Following instances of inadvertent opening of three-way karabiners, HSE commissioned HSL to carry out research into the use of karabiners in the arboriculture industry. The objectives of the project were as follows:

1. Collection of background information, including types and range of karabiners available from suppliers, examples of incidents where karabiners had opened, standards for the design and manufacture of karabiners and information on the use of karabiners in other applications.

2. Liaison with users in the arboriculture industry, including consultation with a peer review group whose members were to be put forward by industry trade associations or other stakeholders.

3. Two site visits to observe the use of karabiners, to discuss problems with users and to obtain samples of used karabiners.

4. Examination and photography of different types of karabiners.

5. Internal examination of karabiners to enable materials comparisons and consideration of lubrication methods.

6. Testing of karabiners to include: the effects of rope snagging; swivelling of the karabiner; the effects of dirt and debris; the effects of different loading conditions, including external forces on the gate; an assessment of the risk of roll out; and, an assessment of the factors affecting the risk of roll out, including knurling on the barrel, the mode of opening and the design of the nose of the karabiner.

7. Production of a formal report that could be made available to users and suppliers. The report would identify problem areas and provide recommendations for improvements in both design and use and recommendations for maintenance and care.

Work in Progress

15. Investigation into the fall-arresting effectiveness of ladder safety hoops, when used in conjunction with various fall-arrest systems

Safety Squared and TUV-NEL (D. Riches, L. Hunter, D. Hare, T. Gallagher and D. J. Wright)

Research Report RR657

(publishing pending)

Synopsis

It was established in previous HSE research that safety hoops on fixed access ladders (alternatively rendered as caged ladders) could not provide positive fall-arrest capability. The working at height industry has anticipated this finding, which has led to the "upgrading" of caged ladders by installing fall-arresting systems (FAS) inside the cage. The rationale is that a FAS can make good the cage's fall-arresting deficiency, and since the removal of the cage from a ladder is envisaged as being difficult, hazardous and expensive, it is simpler, safer, and less expensive to install a FAS with the cage left in place.

This approach appears to be commendable, but from a safety and enforcement of legislation viewpoint, it raises some important questions. For instance, if a fall occurs inside a cage whilst a worker is connected to a FAS, will impacts with the cage interfere to such an extent with the operation of the FAS, that the fall will not be arrested? If the fall is arrested, will this done without causing serious injury to the worker?

To address these questions, further research was commissioned to determine what might happen when a worker falls inside a three-upright caged ladder manufactured in accordance with BS 4211 (1994), whilst attached to various types of FAS.

Sixty-eight fall simulation tests were carried out by using an instrumented anthropomorphic test dummy (ATD). In each test the ATD was inserted inside a caged ladder and was attached to a FAS, before being released in one of three falling postures. Seventeen different FAS were evaluated, which included retractable fall-arresters, energy-absorbing lanyards, sliding fall-arresters on rope, rail and cable, and eight different harnesses. The equipment tested was a good, representative sample of that on offer in the UK.

Twenty-three recommendations are made in regard to the findings of this research, including directions for further work.

16. A review of retractable fall-arresters and their use in non-overhead and other applications not catered for by the test methods within BS EN 360

Safety Squared and TUV-NEL (D. Riches and L. Hunter)

(publishing pending)

Synopsis

Justifiable doubt has arisen over the performance of retractable fall-arresters when used in non-overhead applications and in other configurations which are not catered for by the test requirements within the BS EN 360 standard.

The tests within BS EN 360 do not recreate the falling conditions that can occur in non-overhead applications and in other configurations, so the retractable fall-arrester's ability to arrest a fall cannot be assessed, and therefore remains unknown. The retractable fall-arrester might be able to perform safely, or it may fail catastrophically, resulting in serious or fatal injuries to the worker it is seeking to protect.

One of the aims of the research was therefore to establish if manufacturers recommended, or if brochures or instructions suggested or implied that retractable fall-arresters could be used in these applications, whether their products had been tested for use in that manner, and whether the tests addressed all the conditions that could occur. The second aim was to recommend the criteria, testing or otherwise, that retractable fall-arresters should be required to satisfy if they were to be used in a non-overhead application or other configuration.

Overall, the research demonstrated that BS EN 360 as a standard is grossly deficient in its ability to assess the performance and other technical aspects of retractable fall-arresters, and therefore cannot be relied upon to provide a presumption of conformity in order for a product to demonstrate compliance with the PPE Regulations (2002).

Thirty-nine recommendations are made in regard to the findings of this research, including proposals for new test specifications and further research work. A considerable number refer to serious safety issues which warrant urgent attention.