RISK ASSOCIATED WITH INADEQUATE SITE INVESTIGATION PROCEDURES UNDER DESIGN AND BUILD PROCUREMENT SYSTEMS

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Research has shown that the use of Design and Build procurement system is rapidly increasing in the UK construction industry. A Client needing to have one point of responsibility that is willing to take all of the construction risk seems to be one of the main reasons for the spiral increase.

As part of an on going research programme the work described in this paper has indicated that a large proportion of design-and-build contractors have reported difficulties when carrying out substructure works as a result of uncertain ground conditions. The research has established that these were mainly due to the direct consequence of actual site conditions being different to those portrayed by the initial Site Investigation (SI) reports. SI reports are generally based upon current procedures outlined by the Building Research Establishment (BRE, 1987, 1989) and the Building Standards Institution (BSI) *Code of Practice for Site Investigations* (BS 5930:1981). This paper has identified the factors that bring about discrepancies in SI information and has reported significant problems that result from inadequate SI procedures.

This paper is based on data and information collected using 1000 questionnaires sent to construction practitioners. The work is also supported by case studies of selected construction projects in the UK.

Keywords: site investigation; uncertainty; risk management; design and build, procurement

INTRODUCTION

The work described in this paper is the initial stage of a global research aimed at developing a system designed for the reduction of risk associated with uncertain ground conditions. The aim of this paper is to establish the adequacy of current SI procedures.

Despite the level of sophistication available for the determination of risk and uncertainty associated with ground work operations, in a review of 5000 industrial building projects by the National Economic Development Office (NEDO, 1983) it showed that 37% of the projects suffered delays due to ground related problems. Without exception on redevelopment sites unforeseen ground conditions were met during construction. When 8000 commercial buildings were examined 50% of the sample were found to have suffered unforeseen ground difficulties (NEDO, 1988). If this needed reinforcing, the financial scale of the problem was confirmed by the National Audit Office (1994), in a report that recorded 210 premature failures during construction works costing £260 million, and that geotechnical failures were a major concern. Perhaps the most compelling evidence for the need to improve the SI process, if Egan's annual reductions of 10% in construction time and cost are to be

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achieved (1998), was Alhalby and Whyte's research that concluded "90% of risk to projects originate from unforeseen ground conditions which could often have been avoided by adequate and full site investigation" (1994).

METHODOLOGY

The research methodology selected for this work comprised of a literature review, a questionnaire and statistical analysis of the data, and a review of case studies relating to problems associated with uncertain ground conditions.

A postal questionnaire was considered appropriate to achieve the extensive coverage desired. Using the lessons learnt from earlier pilot studies (Ashton, 1997) a survey was carried out from September 2000 to February 2001. A letter was sent explaining the survey design and highlighted the need for such research.

It was seen as being most important to recognize and understand how 'bias' might influence the quality of data recorded. Oppenheim (1973, p.60) provided examples of how questions could be *loaded* or contain *bias*. Bradburn (1979) emphasized such dangers saying, "expectations, agreement or condemnation must be guarded against, maintaining absolute neutrality at all times" (p.56). The questionnaire design went to great lengths to eliminate bias.

The questionnaires employed both open and closed questions. The use of trigger questions were employed to encourage the respondents to reveal case studies or contact references that may be followed by further research.

A *responsive evaluation* study was chosen, in accordance with Stake's model (Guba and Lincoln, 1981,p.25-6), where the following steps were carried out:

- talk to those in and around the programme in order to gain a purpose for the study;
- limit the scope of the study to the available resources and time;
- discover, through the preceding activities, the concerns of those involved;
- select the most appropriate approach for the data collection;
- conceptualize on the issues of the preliminary data and address such in the researcher's proposed system, and;
- assemble the information in a formal report.

BRIEF DISCUSSION OF RELEVANT LITERATURE

Many authors have set their goal to improve the SI process and have developed computer programmes to use complex probability distribution methods to test theoretical models. A significant progression in SI risk management was the emergence of a Computer Aided Simulation for Project Appraisal and Review programme (CASPAR) developed by Willmer (1988). Peacock (1990) concluded that in order to reduce risk during substructure work "preplanning site investigative work in a logical sequence, and improving the communication system between the principle parties was vital to achieve a qualitative report, capable of meeting designers requirements" (p.57). Despite Weltman and Head's (1983, p14) ground investigation model, Berkeley (et. al., 1991) called for further research for techniques that could assist project managers assess and pre-empt potential sources of risk. In order to achieve this goal, it is necessary to identify the factors that bring about discrepancies in current SI information, and the problems that result from inadequate SI procedures.

RESEARCH SURVEY

A questionnaire survey was carried out targeting 1,000 construction organizations, six hundred specifically to design-and-build organizations, two hundred to ground engineering practices and two hundred to site investigative organizations. The data identified key issues and prime causes of dissatisfaction with current site and ground investigative procedures.

The response rate totalled 47.4% and was unexpectedly high for a construction industry survey (Black, C. et.al. 2000.; and Boddy, D. et.al., 2000). The pilot survey, carried out in 1997 had an equally high response rate, indicating that the survey subject was particularly sensitive for those concerned. A significant addition to the completion and return of the questionnaires was the time and investment made by those who had provided additional data, records and case study information to assist this research.

The opening section of the questionnaire response drew attention to the extra-ordinarily high response rate. In addition to the actual completed questionnaires, further information was provided on blank questionnaire forms and attached correspondence from managing directors, project managers, engineers, and other construction professionals eager to ensure their contribution was included in this research. In total a further 41 documents were received. These documents, although only representing 4% of the population, provided invaluable data for further analysis. Information included case study data, detailed project cost estimating schedules, site progress programmes that identified project overruns, and project reports from site diary inputs. Further information was gathered as a direct result of using 'trigger' and 'open' questions in the design of the questionnaire.

During the literature search a particular issue was raised by both Rys (1983) and Peacock (1990). These works, a survey for the Brunel University examining the effects of instigating procedures on SI projects, and the University of Manchester (UMIST) survey that identified SI procedures and risk analysis, both established the major consumers instigating SI services. This work, via the questionnaire survey, identified the percentage of those instigators of SI work in 2001 (Table 1.).

An immediate consistency and regularity can be seen regarding the percentage of SI consumers; a quarter of the workload reported was from Government or Authority sources. It was established from the University of Brighton survey, that in addition to the 25% of SI work commissioned by Government or Authority, from the private consultant 38% of SI consumers, 20% was sanctioned as a result of working on projects related to or contracted by Government or Authority. This economic strength supports the need for Government to lead the public sector towards 'best practice' as recognized by eminent authors such as Latham (1994) and Egan (1998).

There is evidence of an increasing commitment by Government to improve the agenda of the UK construction industry. The Government commissioned the aforementioned reports, and it is hoped that The Homes Bill, currently going through Parliament, will include a SI agenda in the Home Condition Report proposal. Such commitment will endorse action already being taken by the National House Building Council (NHBC) and other building insurers, in an effort to register pre-construction planning, SI procedures and provide proof of 'best practice' during the development of projects.

Table 1: Comparative survey of SI Consumers and Instigators of SI work

	Private Consultant	Developer / Contractor	Manuf. / Commerce	Government Auth.
Brunel University Survey 1983 Sample Frame	45%	25%	12%	18%
UMIST Survey 1987 SI Consumer	36%	27%	11%	26%
University of Brighton Survey 2001 SI Consumers	38%	24%	13%	25%

A small proportion of questions were designed to establish the organizations stature, turnover, experience, types and sizes of contracts undertaken and type of construction service provided. The data from these questions established a true reflection of general issues and concerns from the industry and ensured a representative survey sample. The information gained from initial enquiries was later checked using published data and company accounts to verify information.

The global research programme aimed at reducing risk associated with uncertain ground conditions, has been developed with small to medium sized contractors in mind, although the research programme is not mutually exclusive to that group. Research identified that 48% of the sample had an approximate turnover of under £5 million, with 19% between £20-50 million. Over 40% of single contracts ranged between £1-5 million, whilst 15% undertook contracts of £10-50 million.

It was clear from the survey that 78% of the D&B contractors used outside structural or geotechnical consultants for both temporary and permanent design work. From these, 95% stated that they would only appoint such a specialist after the contract has been awarded to them. Having committed to a fixed contract sum, it begs the question, is ‘best practice’ and therefore ‘best value’ achieved from geotechnical specialists when such an important appointment is made following the commitment to an outline planning design? It is worthy to note Kerzner’s (1994) view that “in order to reduce risk in the design process, the design must reflect a sound design policy and be based upon proper engineering discipline and practice in order to integrate factors that influence the production, operation and support of a projects life cycle” (p.897).

This research established that 33% of contractors, 19% of SI organizations and 32% of consulting structural and ground engineering organizations stated that the use of D&B procurement system is rapidly increasing in the UK construction industry. A Client needing to have one point of responsibility, that is willing to take all of the design and construction risk seems to be one of the main reasons for the spiral increase.

Using case study documentation, this research has established that from a sample of design-and-build contracts totalling a contract sum of £39,943,000 just £156,200 was spent on SI work. These figures indicate that only 0.004% of the contract sum has been allocated to this vital process. If percentage recommendations where adhered to, offered by Rowe (Clayton *et al.*, 1982) for an adequate site investigation, the average percentage of cost would be 1.1% of the contract sum. Using this survey’s project data the SI cost should equate to £439,373 Further research identified that 57% of contractors used in this survey had experienced difficulties in the ground working phases on site, solely as a result of inadequate site investigative work, resulting in huge losses in time, expense and negative media exposure. This situation was endorsed by consulting ground-engineering organizations that reported that 48% had been required to advise construction companies who had experienced unforeseen problems during sub-structure operations.

The total cost of failure is not quantifiable, yet, reason prevails, when 213 cases from 1000 questionnaires cite inadequate SI information as being the sole reason why organizations have taken action to redeem monies, the time to improve the SI process must be now.

Perhaps the most worrying aspect for the construction industry is its apparent apathy to recognize and face this continuing problem. Out of a total of 474 questionnaires returned completed, only three organizations reported having used any form of risk assessment in connection with identifying risk associated with uncertain ground conditions. Only 23% of contractors had attempted any form of risk assessment and of these 98% were in accordance with The Construction (Design and Management) Regulations (CDM, 1994).

This survey endeavoured to establish who within construction organizations evaluated, and finally decided upon the adequacy and acceptability of available SI information. It appeared from the survey that although 89% of SI organizations recommended the decision should be made by the engineering design team, in fact, contractors indicated that 67% of the decisions were made by managing directors, with little or no engineering background. Only 12% cited project managers and 2% structural engineers, as being involved in the decision making process.

DISCUSSION OF RESULTS

Peacock and Whyte (1992), concluded from their research that "the client financing the works may not be aware of the economic risk associated with uncertain ground conditions – nor the benefits of carrying out risk management techniques". Despite there being advanced risk analysis programmes available to assist clients in identifying risk and uncertainty in construction works, the problem lies not in the state of the art, but in the application of the art, and in the commitment by construction professionals to use such resources.

Although procurement systems have not been a major focus within this research study, their significance upon site and ground investigation ownership and responsibility should not be overlooked. According to Franks (1994, p.5), the major difference between the four most common forms of building contract approaches, with regard to the supply of site investigation information, may be seen by comparing a 'traditional' system (using standard form of building contract with quantities) against a 'design build' system. Ultimately, the client under a 'traditional' contract is charged with supplying information required for the builder. Under a JCT Standard Form of Building Contract with Contractor's Design (CD 81), the design-and-build firm takes the role of both the contractor and the design leader and as such becomes responsible for the supply and flow of information.

With the introduction of The Construction (Design and Management) Regulations (CDM, 1994), irrespective of which procurement route has been chosen by the client for the development of their project, under regulation 11. (2) "every client shall ensure that all information which is relevant to the function of the planning supervisor, has been ascertained by making enquiries which is reasonable for a person in his position to make" (p.7). In particular, the planning supervisor is required to ensure, so far as is reasonably practicable, that the designers are aware of all information and ground conditions so as to avoid foreseeable risk.

This research identified the need to establish 'one single point of responsibility' regarding the acceptance of, or request for further SI information. By focusing the

work on contractors having been awarded building contracts under design-and-built conditions the contractor becomes the sole beneficiary of financing further SI work, or paying the price for proceeding with inadequate design information.

This research has identified that a key factor missing from existing SI procedure has been the inability to feed back information during the site investigation. This feedback system relies upon the experience of the supervisor, and their ability to recognize and recommend whether further investigation work should be carried out. It is important that this review process should enable designers and the project team to make changes and for those changes to be reflected in the investigation, so avoiding re-visits and duplication of work. It is difficult to see, however, how consulting geotechnical engineers can be involved in the development of, or changes to the design proposals if they are not appointed early in the project life-cycle, as identified by this research.

Hunt, Dryer and Driscoll (1991), noted that "It is not necessarily clear at the outset what scope of investigation is required; there should always be a degree of flexibility in the approach to designing the investigation". A flexible approach was considered to be of paramount importance, according to Robb (1982), who suggested, "when contemplating an investigation the work should be able to be varied in light of the results as they become available" (p.24). Despite this recognition, this research has established that flexible SI work has been stifled as a result of inadequate funding and a lack of commitment.

Inappropriate SI information has been identified as the main contributing factor to the difficulties experienced during sub-structure work. Case studies highlighted instances where general feasibility SI reports were eventually used for the bases to design complex foundation systems. The inadequacy of the SI information drove the designers to incorporate huge factors of safety and for contractors to recognize the potential risk and increase the tender sum to reflect the possibility of future problems. It has been noted that by providing a 'footprint' of the proposed development, SI work can be specifically designed to provide accurate field data, thus reducing unnecessary and expensive investigative work.

The questionnaires and case studies have identified concerns and issues from both those issuing and receiving site and ground investigation reports. These issues centred on the lack of uniformity between reporting and the difficulty experienced when trying to find key information. Executive summary sheets commonly used to highlight key areas of the SI were criticized by practitioners as not easily identifying the information most needed. However, SI organizations noted cases where entire projects had been designed on little more than the information contained in the executive summary. The detailed information that should have been used within the main body of the report had been overlooked. To date there is not a universally recognized 'pro-forma' or standard recording schedule for presenting site investigative documentation. From the researcher's experience and study, each investigation organization appeared to have developed their own way of delivering their desk and field research findings.

Therefore, the summary of factors that bring about discrepancies and problems in SI information listed can be categorized into three:

Contractors

- tendering is an expensive process and often inadequate information is 'made do with' in an effort to cut tendering overheads;
- lack of uniformity in reporting methods and procedures of SI information;

- limited time to study the SI information, and those tendering the overall project do not fully understand SI reports, and;
- inappropriate specification of SI work by those with limited experience or expertise to carry out such a function;

Consulting Ground Engineers

- tendering SI work stifles a flexible approach to investigative work and does not promote 'best practice' or value;
- insufficient funds are provided to enable designers adequate design information;
- SI consumers need educating about the benefits of carrying out a thorough SI;
- SI work must be specific to the requirement of the brief, all to often inappropriate SI information intended for basic feasibility purposes becomes the only information available for the final design of the project;
- adequate time must be allowed for the planning and execution of a thorough SI exercise, and;
- failure to appoint consultants early in the projects life cycle. Early consultation and design appraisal is paramount to the success of a project.

SI Organizations

- failure to consult or appoint geotechnical / environmental specialists to the design team early in the projects development;
- tendering against a 'shopping list of SI exercises' rather that a tailored brief;
- inadequate planning and specification of the SI process;
- inflexible approaches are adopted from the outset, and the failure to ensure that a senior, experienced engineer is present on site to modify and request further investigative work, and;
- insufficient budg*et al.*located to ensure an adequate and holistic SI.

CONCLUSION

The methodology used in this research has served as an appropriate means to collect the necessary data required to substantiate the paper's aim.

The work used a responsive evaluation study to identify construction professionals' dissatisfaction with present site and ground investigation procedures, and the problems they faced as a result of using inadequate information. If practitioners' attention could be focussed on addressing such issues, the current process of site and ground investigation practice can be improved.

Most of the issues raised by construction professionals responding to the questionnaire survey originate from failure to carry out rudimentary SI principles, established and presented in the first International Conference of Soil Mechanics at Harvard University, Cambridge, Massachusetts, in 1936. Typically these principles were identified as a result of a series of major construction failures following the prolific worldwide boom of civil engineering projects at the turn of the century.

The importance of carrying out a thorough desk and site reconnaissance survey, ensuring adequate funding, appointing specialist geotechnical expertise, and facilitating a flexible working environment meet with absolute agreement, yet, as this research has established 98% of the SI organizations stated that insufficient funds were allocated to SI work. Only 0.004% of contract sums are being spent on SI work, instead of the recommended 1.1% offered by Rowe (Clayton *et al.*, 1982) for an

adequate site investigation. The scale of the problem is such that 57% of contractors used in this survey had experienced difficulties in the ground working phases on site, solely as a result of inadequate site investigative work, resulting in huge losses in time, expense and negative media exposure.

The UK construction industry is informed by possibly the world's most comprehensive research and development network, the BRE are but one 'expert' source. However, it is essential that basic principles of SI work and pre-construction planning are better understood before the benefits of 'concurrent engineering', 'lean thinking', 'best practice' and the introduction of a 'generic design and construction process protocol' can be realized.

This paper provides evidence to support requests for adequate funding for SI work. It further establishes the link between difficulties experienced by contractors as a direct consequence of unforeseen ground conditions and incorrectly specified and funded SI. The paper further offers hope that future research and development of SI procedures may reduce risk associated with uncertain ground conditions. Further research and development of SI procedures is currently being undertaken by the authors.

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