THE ENGINEERING COUNCIL OF SOUTH AFRICA

CASE STUDIES ARISING FROM CONTRAVENTION OF ECSA's RULES OF CONDUCT FOR REGISTERED PERSONS.

PUBLISHED BY ECSA TO MINIMISE THE RISK OF RECURRENCE

Case Study No. 2012/4 : Collapse of a structure arising from faulty welding of steelwork

THE PROJECT

Large scale additions to an existing shopping centre involving major structural engineering elements.

BACKGROUND TO THE CASE

The owners of a shopping centre appointed a firm of consulting engineers to provide the structural engineering services required in proposed additions to an existing shopping centre and a senior Professional Engineer in the firm was designated to take charge of the assignment.

The new structure included a steel lattice girder beam spanning 34m over an open area, supporting the ceiling and roof of this part of the building. After the beam had been erected a welded connection in the lattice beam failed, causing the beam to collapse and resulting in injuries and fatalities to persons below. A lengthy enquiry took place under the auspices of the Department of Labour at which the design engineer and the structural steelwork subcontractor's engineer were key witnesses. Subsequent to this ECSA instituted its own investigation into these engineers who were both registered with ECSA. The questions of responsibility for design and responsibility for correct workmanship regarding the welded connection which failed received much attention Eventually the designer was found by ECSA to have contravened certain Rules of Conduct and was charged. A settlement agreement was arrived at in terms of which the engineer pleaded guilty to the charges and was subjected to a fine of R20 000.

DETAILS OFTHE PROBLEM

The Client/Consultant agreement provided *inter alia* for "design and commissioning" of structural engineering services, involving reinforced concrete foundations and structures and a steel roof structure. The agreement noted that the firm would not be responsible for "design elements on equipment supplied and installed by others" and was required to "approve the structural designs of other consultants."

It was established that the reason for the failure of the lattice beam was the failure of a welded joint between a diagonal member and the top chord of the lattice beam, at the end where it was supported on a concrete column. The welded joint was unable to withstand the forces exerted on it and the welds failed, chiefly because the preparation of steelwork for the welding (e.g. chamfering) had not been done correctly and the welding itself was hence suspect.

Also relevant is the fact that the joint was not welded *in situ,* with the beam on the ground. The steelwork subcontractor had proposed using a 20 ton crane to lift the completed lattice into position, but this was ruled out. The lattice was accordingly supported on scaffolding and the welding of the joint had subsequently to be done "up in the air."

The Department of Labour enquiry was held in terms of the Occupational Health and Safety Act and placed considerable emphasis on the culpability of the beam designer and steelwork subcontractor in terms of the Act, against the background of their respective obligations in the contract.

It was acknowledged in the investigation that structural welding is a specialised activity, requiring execution by a competent (or coded) person The inspection and approval of the welding likewise needs a person with the requisite competence and experience. It was acknowledged that this was beyond the competence of the average structural engineer.

The responsibility of the design engineer in the monitoring (often termed "supervision") of construction includes inspections by the engineer to verify the contractor's workmanship and materials comply with the contract specification. In the project the owner limited the engineer to approximately 4 hours per fortnight, to visit site for inspections and site meetings. Consequently it was necessary for the Engineer to rely on, and to stipulate, that the contractor and subcontractors should be responsible for carrying out their own inspections of their work, to fulfil their obligations to produce work which complied in all respects with contract specifications and requirements. This applied particularly to the welding of the lattice beam members and joints, where the necessary competence and expertise resided with the contractor and subcontractors.

Equally, it was incumbent on the design engineer to ensure the contractor and subcontractors were furnished with all information and details necessary for the manufacture, erection or fabrication of all elements needed for the Works. In the case of structural steelwork this included comprehensive "general arrangement" drawings made by the engineer, sufficient for the steelwork subcontractor to prepare "shop" drawings which included all details for fabrication or manufacture, both in the shop and on the site. Clearly it was also incumbent on the design engineer to check and approve the shop drawings to ensure the design intent and requirements were clearly stated and could be fully complied with by the subcontractor.

It was determined that the design required all welds to be full penetration welds, although this requirement appeared not to have been clearly stated to the subcontractor. Examination of numerous welds in the joints of the collapsed beam revealed that weld preparation (e.g. chamfering of the edges of steel members) had not been done. It was also evident that weld gaps which were too wide were filled by first welding in round bars. Also, the welding of the joint which failed was complicated by the joint being too close to the

support column. The subcontractor's engineer, who bore responsibility for his company's workmanship and materials to be compliant, inspected the welding when done, for visual defects. He was unable to verify the number of weld runs, since these were now covered and he had to rely on assurance from his welding foreman, who was able to inspect the work during welding. It was evident the subcontractor had concerns about the lattice beam welding, because he suggested at site meetings the addition of gusset plates at the joints, but this was not acted upon.

In consideration of the role of the design engineer in the construction monitoring stage, with a view to identifying faults or actions contributing to the cause of the collapse it was firstly accepted that the design of the structure was not at fault. It had to be accepted that the frequency of inspections or verifications done by the engineer were limited by the owners limiting the time to be spent on these duties. The engineer did however have concerns regarding the welded lattice beams being erected in sections with joints being welded high off the ground. A load test on this part of the structure was requested, as the engineer considered "the scope of site welding adds an unknown element to the design process that should be checked for consistency" The Owners refused to accede to this request, because of extra time and costs involved. It is conceivable that a load test could have indicated the deficiencies in the construction of the lattice beam and a collapse could have been averted.

ECSA's investigation into the conduct of the professional engineers involved (the design engineer and steelwork subcontractor's engineer) was carried out subsequent to the Department of Labour investigation, and centred around possible contravention of ECSA's Rules of Conduct. As regards the subcontractor's engineer, who acted as manager for the steelwork contract, it was evident and accepted he was responsible for doing his own inspections of the welding and responsible for rectification of defects. It was noted that since he relied upon the results of inspections and reports from his welder and foreman on the welded joints, he could not himself be held negligent but might be in contravention of ECSA's Rules of Conduct if the reports were misleading or false. A legal opinion sought by ECSA on this aspect came to the conclusion that since the issue of determination centred around the arranging and checking the welding work to SABS 1200H, the contractor subject to its obligations need not be an engineer – meaning that ECSA did not have jurisdiction in respect of the engineer's conduct. There was therefore no *prima facie* evidence the subcontractor's engineer transgressed ECSA's Rules of Conduct.

Turning to the engineer responsible for design and construction monitoring, the role was considered in detail by an expert who concluded there were numerous shortcomings in the project, such as:

a) The issues that led to the collapse of the lattice beam could be ascribed to errors and omissions in the original engineering drawings and also on the subcontractor's shop drawings
b) The quality and level of information on these drawings was not up to a normal professional standard expected for the project
c) As a result of this and of inadequate checking of shop drawings against original engineering drawings, the design intent of the engineer had not been carried through to a shop detail level and the shop drawings conflicted with the details of the engineer

d) The lattice beam members had significant eccentricities as fabricated (e.g. difference between member centrelines and centroidal axes, causing secondary bending moments) which were not taken into account.
e) Important and heavily loaded connections are normally specified by the engineer on the engineering drawings, including weld specifications and test requirements, but these were lacking. The joint which failed was a particularly critical item.
f) This was aggravated by the lattice beam having to be assembled in sections and welded together – no design details were provided by the engineer for construction joints – this detail was left to the contractor
g) The number and nature of critical connections were such a non-destructive testing programme such as X-rays should have been specified, but this was not done.
h) From a structural safety viewpoint the engineer is obliged to provide sufficient supervision to ensure that the structure as built is safe for public use. This assurance comes with the engineer signing the structural certificate of the local authority.

As a result ECSA concluded there was *prima facie* evidence the engineer had contravened ECSA's Rules of Conduct as follows:

3(1) (a) (did not discharge duties with skill, efficiency, professionalism, knowledge, competence, due care and diligence)

3(1)(c) (failed to engage and adhere to acceptable practices).

3(3)(a) (did not at all times have due regard and priority for public health, safety and interest)

3(5)(c) (did not provide work or services of quality and scope and to a level which is commensurate with accepted standards and practices in the profession.) .

The engineer pleaded guilty to the charges. He entered into a plea bargain process with ECSA, pleading guilty in particular to Rule of Conduct 3(5)(c) and accepting the imposition of a fine by ECSA in the amount of R20 000. A settlement agreement was signed and presented to an ECSA Tribunal for ratification.

WHAT LESSONS CAN BE LEARNED ?

Lessons to be learned are considered under various headings:-

By the design engineer:

1. Ensure that the contractor and subcontractors are fully aware of their responsibility to deliver the required standards of materials and workmanship – notwithstanding the extent of the engineer's inspections, testing, and approvals which may be applied.

2. Ensure the design of the structure is checked in terms of the engineer 's Quality Management System. This includes the design of important joints and connections.

3. The detailed requirements for welding must be prescribed by the engineer, e.g. preparation, types of weld, welding materials equipment and procedures including dimensions and details.

4. If reliance is to be placed on the contractor for specialised inspections and tests to be done by the contractor's own competent personnel, the engineer should specify his requirements in detail

5. The engineer's drawings must provide all information necessary for the contractor to produce shop drawings for fabrication without having to make assumptions which are pertinent to the design. General arrangement drawings should show centroidal axes and centrelines of structural members

6. Shop drawings must be thoroughly checked by the engineer for compliance with the original engineering drawings and must contain all details relevant to fabrication and erection, without having to design or detail on site during construction.

7. Insist on testing being done on the structure or elements of the structure as applicable, to give the engineer assurance of structural safety

8. Ensure that the engineer as designer understands and fulfils his obligations in terms of the Construction Regulations, including:
    a) Providing design information to client and contractor
    b) Informing the contractor of dangers/hazards in the design
    c) Providing details of site investigations, structure loading, plus methods and sequence of construction
    d) Carrying out inspections to ensure design compliance
    e) Stopping any contractor not working to the design
    f) Conducting a final inspection with a completion certificate provided

By the Contractor/subcontractor:

9. Be aware that the constructing parties carry full responsibility for their materials and workmanship meeting requirements, including rectification of defects, irrespective of the extent of construction monitoring being exercised by the engineer

10. Understand that this responsibility carries the obligation of self-checking by the constructing parties of their own work, as dictated by risks of defects or the safety of the constructed article and have reports available for the record of the engineer. This applies particularly to specialist work where the contractor's staff have the specialist skills to do the work and/or carry out the inspections or tests

11. Ensure shop and fabrication drawings are complete for their purpose and accord with the engineering drawings. No fabrication or erection should take place before the relevant drawings have been approved by the engineer

12. Ensure compliance with the Construction Regulations, including provision of Health and Safety Plans, appointment of Construction Safety Officer and Construction Supervisor and keeping a Consolidated Health and Safety file on site

By the Employer:

13. Ensure inspections of the structure at specified intervals (Regulation 9(4))

14. Be aware of the Employer's vicarious liability for all persons on site (OHS Act Sectn. 37)

15. Provide an overall Health and Safety Specification and ensure he Principal Contractor's OHS programme is implemented

16. Do not prevent or restrict the Engineer's construction monitoring activities, inspections or tests, where these are necessary to provide assurance as to the safety of the structure.

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