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History in the Civil Engineering Curriculum at the University of Canterbury

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SUMMARY The History of Civil Engineering course for final year civil engineering students at the University of Canterbury is described. It is explained that lectures are arranged to complement project work done by the students and to coordinate with visiting speakers. Lecture topics, and sources for significant amounts of lecture material, are given. The role of a history course in an engineering curriculum, and therefore the intention in presenting the course, is explored.

The History of Civil Engineering as a topic was first introduced into the final year course for civil engineering students at the University of Canterbury by Professor H.J. Hopkins in 1969 when the course was reorganised to offer the students the choice of eight from a selection of about 16 topics. My teaching of the subject began in 1979 following the retirement of Prof. Hopkins.

Each final year topic corresponds to about 1½ hours of lecture time a week and additional laboratory or other activity time. The HCE course for example consists of 31 lectures and six afternoon sessions featuring a site visit or a lecture from a visitor with specialist knowledge in some field. The course therefore ranks as a full academic partner alongside the more traditional offerings in structural mechanics, fluid mechanics, engineering design, etc., and students who choose to take it do so in the face of the attractions of these. Numbers taking the subject since 1979 have varied between 11 and 30. (In the latter case five of the top six academic students for that year had elected to take HCE.) Meanwhile total numbers of students graduating from the final year class have varied between 70 and 90. During the year students work at three projects, each worth 15 percent of the total course mark, and sit a three hour written final exam for the remaining 55 percent.

For the first project, teams of two students are given about six weeks in which to assemble a record of an interesting old structure. The records have included notes in the categories typically asked for in engineering heritage record forms. Results have been naturally variable; depending on what the students could unearth in the course of six weeks from sources such as National Archives, libraries, museums, government departments (central and local), engineers, and informed private individuals. (One enterprising group had an interesting response to an advertisement they put in a local newspaper.) With their own notes, calculations and drawings, and correspondence etc. gleaned from various sources, some students have produced reports running to 90 pages. Since the initiation of this work three years ago (following, may I acknowledge very clearly, my attendance at the previous conference on engineering heritage at Brisbane) the emphasis has moved away from a written historical record derived from literature search and toward the preparation of a set of drawings; because this involves skills that engineering students are in the process of learning, and which are indigenous to engineering. The projects have therefore become directed more towards artefacts for which no drawings exist, or are available. Examples of work are shown in Figures 1 - 6.

The order in which lecture topics are presented is largely governed by the three projects and the timing of the lectures from the visitors. Consequently, the year begins with a set of lectures which relate to the objects likely to be encountered in the first project, and are as follows:

1 - industrial archaeology
2 - New Zealand engineering history - 2/3 lectures
3 - traditional engineering knowledge and practice at mid eighteenth century
4 - wrought iron
5 - the Britannia Bridge
6 - steel
7 - the Chicago style of tall buildings

During this project, the students are taken on a tour of the strengthening of the Christchurch Arts Centre and Christ's College, guided by the engineer responsible for this work. In addition they spend one afternoon considering architectural drawing practice, and have an afternoon lecture on New Zealand's Industrial Heritage from Mr. G.G. Thornton who has written a book with that title.

The second project, for which about six weeks' time is also allowed, is a study of the morphology of disasters. This is purely a literature research project, principal sources being the reports of commissions of enquiry. Following the largely narrative accounts resulting from more loosely written instructions of three or four years ago, the instructions for this project have been made more specifically technical:

- briefly describe the failure event in technical terms (befitting an engineer)
- prepare a chart summary of the organisational hierarchy, showing relationships of responsibility between the parties, and append notes as necessary
- identify built-in weaknesses (and strengths) in the project management
- assess their contribution to the failure of the project

Between two and three lectures (8,9) are devoted to introducing this project. First the general features of management of a major civil engineering project are discussed and the roles of various parties identified. Next, sets of parameters which govern the success or failure of a project are presented. These are principally the parameters Pugsley (1973) and Blockley (1980) have applied to the analysis of disasters. Thus a background is erected against which the organisation under study is analysed, and built-in organisational difficulties indentified and evaluated. Finally, five failures are presented in outline and each student chooses one of them to study. They are:

Tay Bridge

Quebec Bridge

Kings St. Bridge

Kaimai Tunnel (New Zealand)

Westgate Bridge

In the year of the largest class the Ronan Point and Ferrybridge disasters were added to the list to widen the choice. Emphasis is place on conciseness, technical accuracy and technical relevance in reports in this project. Students are encouraged to support judgemental comments with evidence and to consider the problem of avoiding libellous remarks.

One of the most satisfying aspects of teaching the course is the support provided by colleagues. The Head of Department, Professor R. Park, has himself written two serious articles which are used intensively. One is a chapter on the development of reinforced concrete in a book published in tribute to Pugsley on the occasion of his 80th birthday. The other is a comprehensive account of the development of present seismic code regulations in New Zealand, delivered as an annual address to the New Zealand Concrete Society. Other members of the faculty very generously give lectures on topics they have researched particularly. In 1984, in preparation for them there was a lecture on

10 - the development of the concept of Cauchy stress

Following that, guest lectures were given on:

11 - hydraulics and fluid mechanics (2 lectures)

12 - the catenary contest

13 - slope stability

14 - Karl Terzaghi

Other lectures have been given in previous years.

The third project, an essay on the engineering contribution of a famous person (engineer, architect, mathematician, artist, ...) is also a book research and is given little introduction beyond a simple list of names for whom the University libraries have suitable reference material, usually a book on the life of.... Students generally get from this the feeling of dedication, determination and energy exhibited by famous builders, particularly in overcoming difficulties in their struggles with the forces of nature. In order to limit the size of the written work in this project, and to allow them to experience examination conditions, the students are asked to present themselves at the assigned time and write unaided for one hour on their topic.

A highlight just after the middle of the year has been the set of afternoon lectures given by:

Professor H.J. Hopkins: The development of arches and vaults.

Professor H.J. Simpson (School of Fine Arts): Roots of modern architecture/The Crystal Palace/Gothic architecture.

Professor P.G. Lowe (Dept. of Civil Engineering, University of Auckland): Engineering text books and engineering education. (Prof. Lowe is a dedicated collector and has a comprehensive library of old engineering texts, all the more remarkable for being in New Zealand.)

The sequence of lectures which is used to prepare for these visitors consists of:

15 - Greek science

16 - Roman engineering

17 - Gothic architecture

18 - the Renaissance

19 - the effect of structure on architecture

20 - the beginnings of technical education in the English Renaissance

21 - technical education in Europe

22 - technical education in Britain

The project on disasters (which is returned to the students at about this point in the course) is concluded with a lecture:

23 - remedial work following various failures

Some earlier themes are continued and others introduced in a final set of lectures:

24 - the London County Council (General Powers) Act, 1909, and the Steel Structures Research Committee, 1929-1936

25 - structural steel design regulations since 1936

26 - reinforced concrete construction and code developments

27 - limit states design and the direction of present code developments

28 - a structural mechanics topic (column, beam)

29 - public health in Eighteenth Century London and the Royal Commission of 1899-1916

30 - development of codes for seismic design

The final examination is set as a fourth project. About ten topics (with exclusions of the form: 'prepare topic 5A OR 5B') are presented to the class in August following the completion of the third project. Students are asked to prepare two of the topics for a final three hour examination. On average the answers are about 1700 words in length for each of the two essays.

Since the students are judged on their written work and drawings the usual literacy and technical proficiency criteria for these are applied. In addition, in the language of their written work the students are asked to be technically correct and reflect understanding of technology at a level appropriate for first year engineers. They should not make statements without supporting evidence. They should be able to develop a coherent line of explanation, and show appreciation of the main line of development of whatever technology they are discussing, not being drawn off to give undue weight to insignificant developments. As far as possible they should in their writing show identification with their subject and avoid using the language of their sources.

A number of sources have been consulted for the preparation of lectures. As a general comment it can be remarked that in order of merit original papers are the most fruitful sources (often supplemented by lengthy discussion, in the case of articles in the Proc. I.C.E. for example), followed by articles in journals on the history of technology or science, monographs on specific topics, and general histories of engineering. Two major history of technology journals of note are the History of Technology series of occasional publications and the Transactions of the Newcomen Society. In addition, useful information is found in industrial archaeology journals and in sporadic articles on history topics in engineering journals. To date the following sources have provided significant material for the lectures:

1.
I.E.A. Engineering Heritage Record Form

2.
Furkert, F.W. (1953) Early N.Z. Engineers, Wellington, Reed.
Lloyd-Pritchard, M. (1970) An Economic History of N.Z. to 1939, Auckland, Collins.
Noonan, R.J. (1975) By Design, Wellington, N.Z. Govt. Printer.
O'Regan, R. (1980) Te Ara Tika, Wellington, Crown Leasehold Association.

3.
Smeaton, J. (1837) Reports of the late John Smeaton, 2d. ed., London, M. Taylor.
Cresy, E. (1861) Encyclopaedia of Civil Engineering, London, Longman Green.
Ruddock, T. (1979) Arch Builders and their Bridges, Cambridge, C.U.P.
Heyman, J. (1982) The Masonry Arch, Chichester, E. Horwood.

4.
Rhead, R.L. (1941) Metallurgy, London, Longman Green.
Gale, W.K.V. (1964) Wrought Iron - A Valediction, Trans. Newc. Soc., vol. 36, pp 1-12.
Sutherland, R.J.M. (1964) The Introduction of Structural Wrought Iron, Trans. Newc. Soc., vol. 36, pp 67-84.
Gale, W.K.V. (1967) The British Iron and Steel Industry, Newton Abbot, David and Charles.

5.
Cresy, Encyclopaedia of Civil Engineering.
Rosenberg, N. and Vincenti, W.G. (1978) The Britannia Bridge, Cambridge Mass., MIT Press.

6.
Gale, The British Iron and Steel Industry.

7.
Shankland, E.C. (1897) Steel Skeleton Construction in Chicago, Proc. I.C.E., vol. 128, pp 1-27.
Condit, C.W. (1968) American Building, Chicago, U. of Chicago Press.

8.
Wearne, S.H. (1973) Principles of Engineering Organisation, London, E. Arnold.
Pugsley, A. (1973) The Prediction of Proneness to Structural Accidents, The Struct. Engr., vol. 51, pp 195-196.
Smith, D.W. (1976) Bridge Failures, Proc. I.C.E., Pt. 1, vol. 60, pp 367-382.
Sibley, P.G. and Walker, A.C. (1978) Structural Accidents and their Causes, Proc. I.C.E., Pt.1, vol. 62, pp 191-208.
Blockley, D.I. (1980) The Nature of Structural Design and Safety, Chichester, E. Horwood.

9.
Reports of Commissions of Enquiry into:
Tay Bridge
Quebec Bridge
Kings Bridge
Kaimai Tunnel
West Gate Bridge

10.
Truesdell, C. (1968) Essays in the History of Mechanics, Berlin, Springer.

12.
Truesdell, C. (1960) The Rational Mechanics, in L. Euleri Opera Omnia, ed. Speiser, A. et al., vol. 10/11, series 2.

13.
Heyman, J. (1972) Coulomb's Memoir on Statics, Cambridge, C.U.P.

14.
Terzaghi, K. (1960) From Theory to Practice in Soil Mechanics, N.Y., Wiley.

15.
Archimedes (1963) Works, N.Y., Dover.

16.
Vitruvius Pollio (1960) Vitruvius: The Ten Books on Architecture, N.Y., Dover.
Chevallier, R. (1976) Roman Roads, London, Batsford.

17.
Villard de Honnecourt (1959) The Sketchbook of Villard de Honnecourt, Bloomington, Indiana Univ.
Mark, R. (1972) The Structural Analysis of Gothic Cathedrals, Sci. Am., vol. 227, no. 5, pp 90-99.
Mark, R. (1982) Experiments in Gothic Architecture, Cambridge, Mass., MIT Press.

18.
Gille, B. (1966) The Renaissance Engineers, London, Lund Humphries.
Truesdell, Essays in the History of Mechanics.

19.
Torroja M, E. (1958) Philosophy of Structures, Berkeley, U. of Calif. Press.
Collins, P. (1965) Changing Ideals in Modern Architecture, London, Faber.
Kepes, G. ed. (1965) Structure in Art and Science, London, Studio Vista.
Nervi, P.L. (1966) Aesthetics and Technology in Building, Cambridge, Mass., Harvard U. Press.

20.
Bacon, F. (1859) The Works of Francis Bacon, popular edition, Boston, Houghton Mifflin.
Stimson, D. (1949) Scientists and Amateurs: A History of the Royal Society, London, Sigma.
Ward, J. (1967) The Lives of the Professors of Gresham College, N.Y., Johnson Reprint.

21.
Booker, P.J. (1962) Gaspard Monge, Trans. Newc. Soc., vol. 34, pp 15-36.
Emmerson, G.S. (1975) Engineering Education, Newton Abbot, David and Charles.

22.
Tudsberry, J.H.T. (1918) Record of the Origin and Progress of the Institution, London, I.C.E.
Pendred, L. St. L. (1947) British Engineering Societies, London, Longman Green.
Kronick, D.A. (1961) A History of Scientific and Technical Periodicals, N.Y., Scarecrow Press.
Emmerson, Engineering Education.

23.
Inglis, W. (1888) The Construction of the Tay Viaduct, Dundee, Proc. I.C.E., vol. 94, pp 99-115.

Burren, W.H. and Day, H.B. (1968) Kings Bridge, Melbourne, Restoration Works, J.I.E.A., vol. 40, pp 279-286.
Department of the Environment (1971) Gt. Britain Committee of Enquiry into the Design and Erection of Steel Box Girder Bridges, London, HMSO.
Wolfram, H.G. and Toakley, A.R. (1974) Design Modifications to West Gate Bridge, I.E.A. Civil Eng. Trans., vol. 16, no. 2, pp 143-150.

24.
D.S.I.R. (1931) First Report of the Steel Structures Research Committee, London, HMSO.
- Second (1934)
- Final (1936)

25.
Codes of Practice: BS 449, AISC (1959) (1965) (1969), NZSS 1900, AS 1250, NZS 3404.

26.
Newlon, H. ed (1976) A Selection of Historic American Papers on Concrete, Detroit, A.C.I.
Park, R. (1983) Concrete Structures, in Engineering Structures, ed. Bulson, P.S. et al., Bristol, U. of Bristol Press.

27.
Adams, P.F. (1979) Limit States Design in Structural Steel, Willowdale, Ont., Can. Inst. Steel Constr.

28.
Ayrton, W.E. and Perry, J. (1886) On Struts, The Engineer, vol. 62, pp 464-465.
Godfrey, G.B. (1962) The Allowable Stresses in Axially-Loaded Steel Struts, The Struct. Engr., vol. 40, pp 97-112.
Timoshenko, S. (1953) History of the Strength of Materials, N.Y., McGraw-Hill.

29.
Bazalguette, J.W. (1865) The Main Drainage of London, Proc. I.C.E., vol. 24, pp 280-314.
Royal Commission on the Treating and Dispensing of Sewage (1899-1916) Reports, Papers of the House of Commons, 1900-1949,
Binnie, G.M. (1981) Early Victorian Water Engineers, London, Telford.

30.
N.Z. Building Regulations Committee (1931) Report, A.J.H.R., H-21.
Park, R. (1981) Review of Code Developments for Earthquake Resistant Design of Concrete Structures in N.Z., Bull. of N.Z. Nat. Soc. for Earthq. Engng., vol. 14, no. 4, pp 177-208.

As a general text for students taking the course Professor Hopkins' book, A Span of Bridges, is recommended; and is purchased by a majority of the students.

Upon reflection it is clear that history should be only a small part of an engineering education, alongside the mass of scientific and technical data that students today are asked to assimilate. We recognise that Smeaton took a classical path in his education when in 1755, with note book and diary, he toured the Low Countries observing harbours, bridges, canals, mills and etc. on the way. There is a clear line of association back to the note book of Villard de Honnecourt. In his time the education of engineers, in their earlier manifestation as masons, was entirely based upon a study of the subject as handed down by practising masters. From about Smeaton's time, however, the education of engineers in France was being changed. It was being formalised to encompass new scientific approaches to traditional problems such as bridge building, and new problems such as the design of canal locks. Since then the encroachment of scientific attitudes into engineering education has continued, to the point where the historical approach has in the main been completely ousted.

It seems, however, that the study of history in the ordinary sense addresses a fundamentally human need, which is a wish to feel associated with a background of past experience. The reason need not be specific. In a restricted sense all engineers are natural historians. Faced with any particular problem there never has been an engineer who was not interested in an earlier solution to that problem or one like it; whether it succeeded or failed being equally revealing to him. It also happens that in a large proportion of their activities engineers perform on the basis of their personal experience. So that, for example, certain solutions having been satisfactory are then repeated, and may even become the basis for a "style". Some of the more notable engineers have developed clear personal styles: Maillart, for example, in bridge engineering. This is a very observable example, but each of us has peculiarities in the way in which we perform much smaller everyday engineering tasks, and there is a large component of experience involved in this.

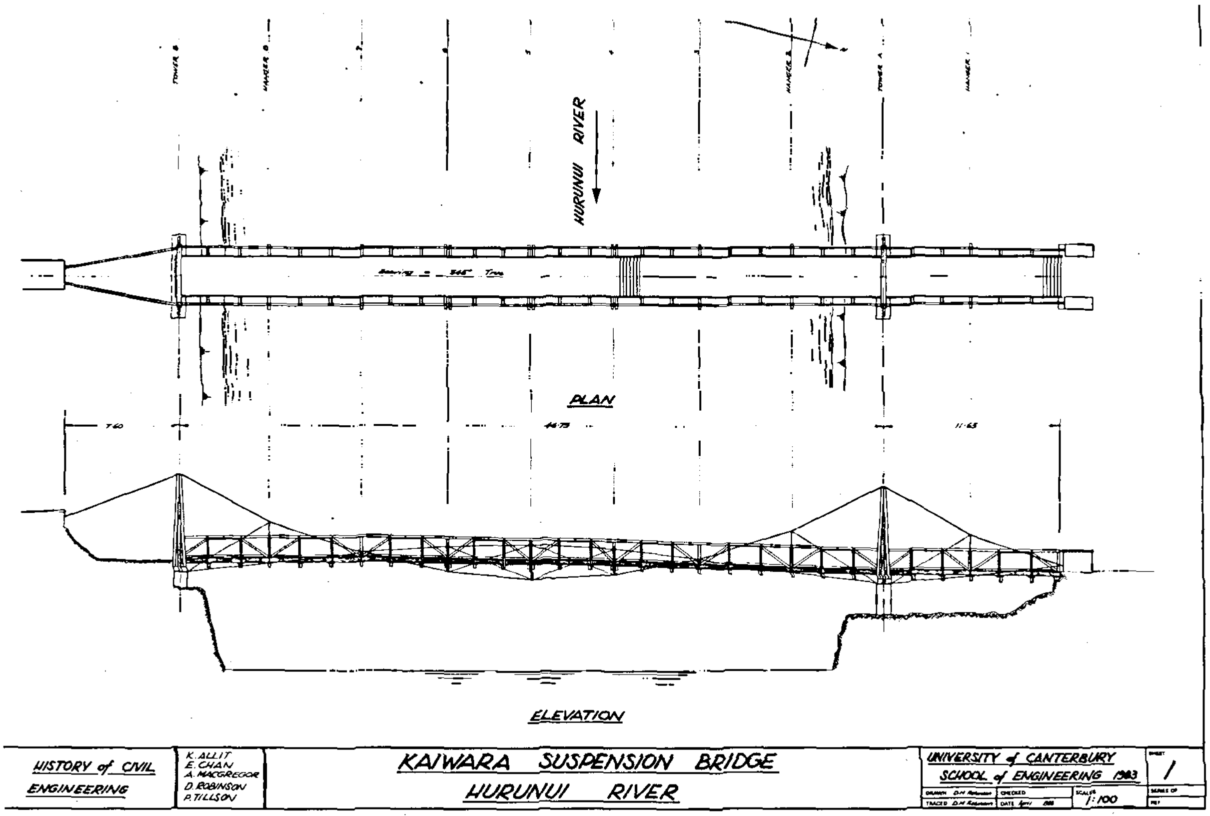
I am arguing, therefore, for the place of History in an engineering syllabus as a conscious effort to broaden the student's background as a basis on which he can develop his own approach to his work. He can for example observe the degree of commitment that some engineers have been required to give, the importance of attention to details, the importance and difficulty of maintaining communication lines between parties on a large project and the benefits that can accrue from being willing to acknowledge new technology, even against popular opinion. In a more immediate context, study of recent history can arm him for meaningful dialogue with older engineers he will work under in the first years of his career.

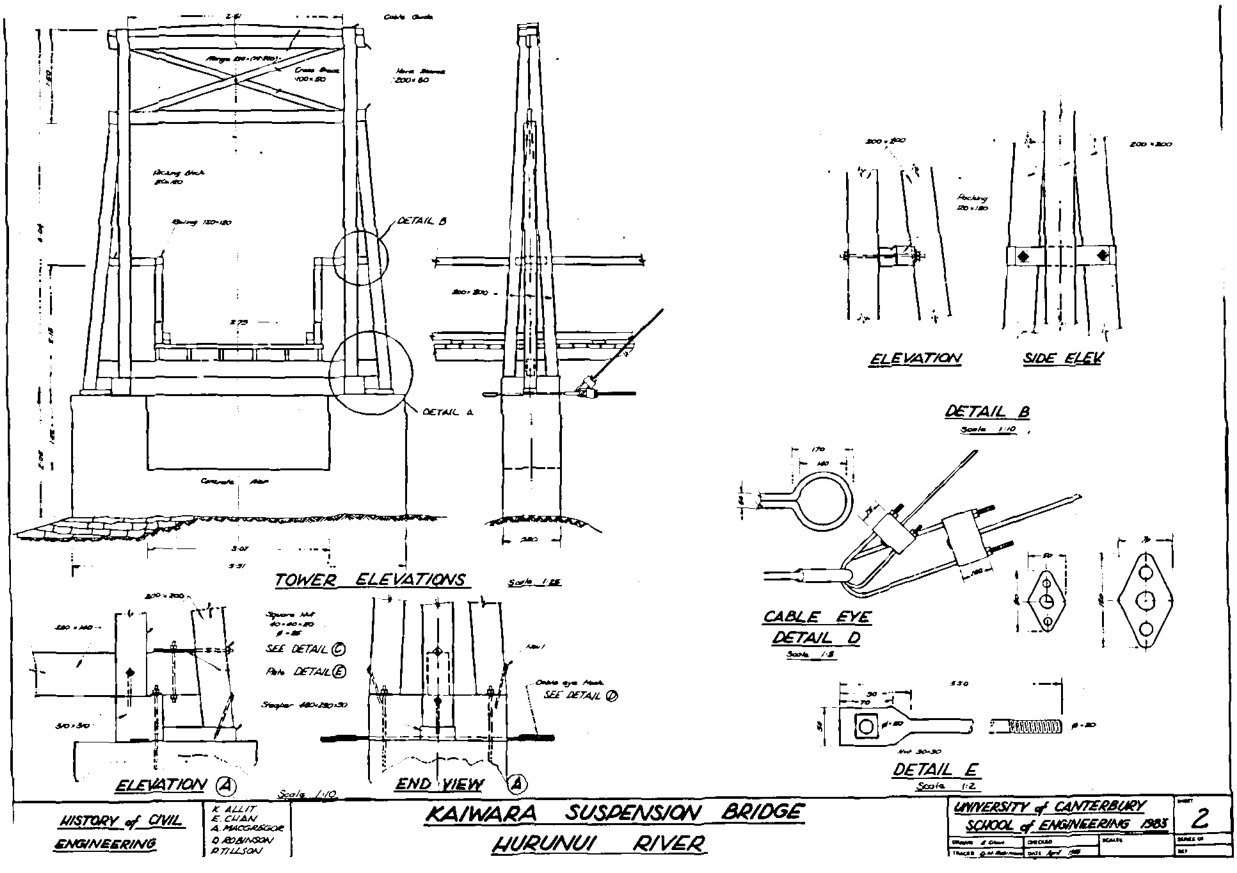
The division between history and science is fundamental. In science the result of progress is to reduce the content of many particularisations down to a refined body of theory that is as general as possible. In history progress is measured in the opposite way. The topics of history are particular events; and the more accretions of particular knowledge that can be found about an event the more it is felt to be understood. In fact it would only be completely understood if every aspect of it were known - which suggests an infinitude of knowledge impossible to achieve. This division also separates the areas of usefulness to engineering education of the two approaches. Scientific analysis is needed for the broad design, but the built object in the real world will embody some details that defy analysis and yet are crucial. These are clearly the proper subject matter for a historical study.

To end on a lighter note consider the Christchurch based chemical and process engineer whose design for a series of successful steam boilers arose from careful research into earlier solutions to heat transfer problems which had fallen into the background and been forgotten in contemporary practice. That he was acting within the mainstream of technological development is made clear by the following remark about the Japanese company Matsushita, which trades under the name "National":

> "Their concept of research and development is to analyse competing products and figure out how to do it better."

(from: Pascale, R.T. and Athos, A.G. (1981) The Art of Japanese Management, N.Y., Simon and Schuster.)





Figures 1 & 2 Suspension bridge over the Hurunui River at Ethelton, 100 km north of Christchurch

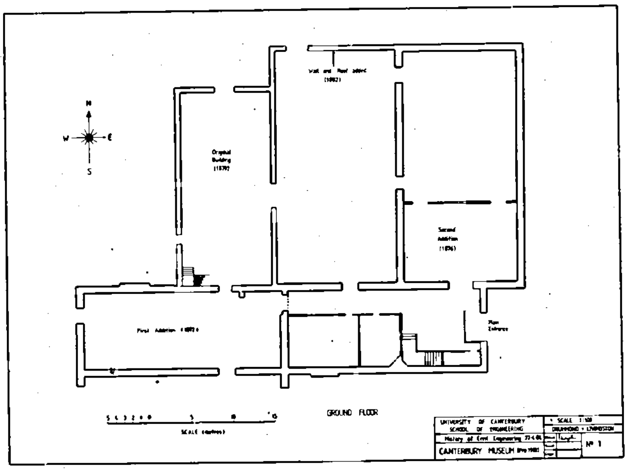
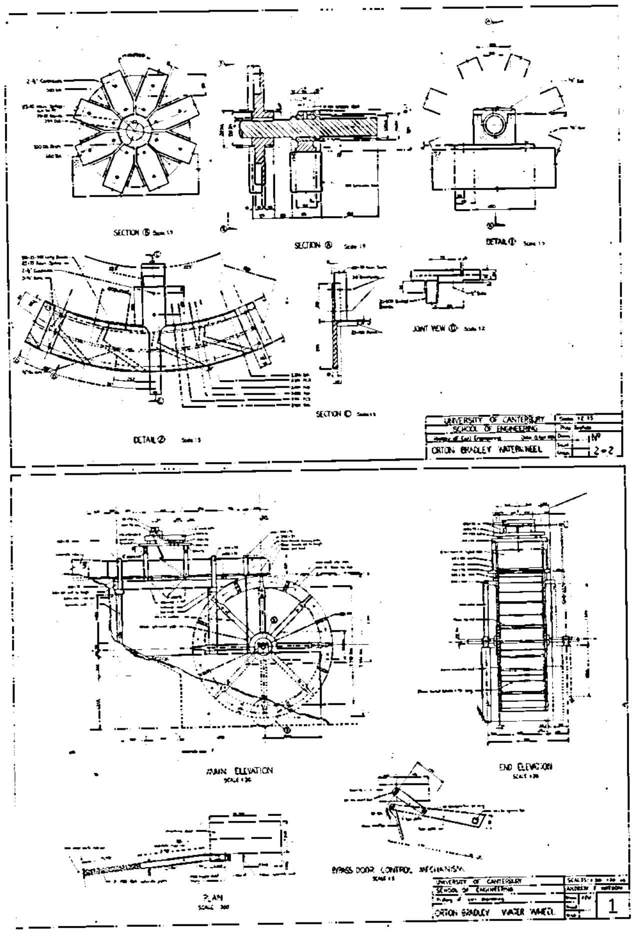


Figure 3 Ground floor plan of the Canterbury Museum, Christchurch



Figures 4 & 5 Water wheel at the Orton Bradley Estate on the southern shore of Lyttelton Harbour

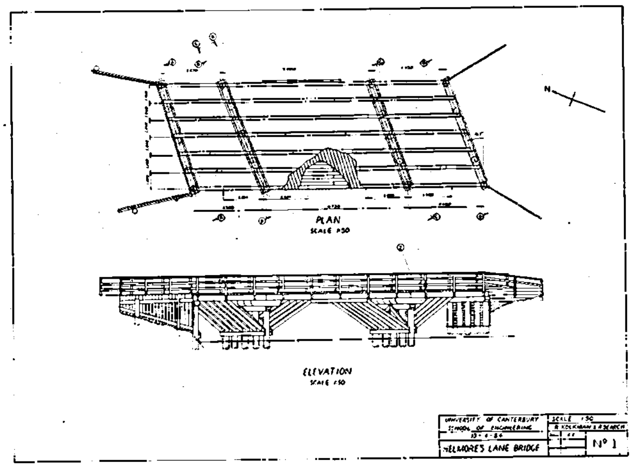


Figure 6 Helmore's Lane Bridge over the Avon River in Hagley Park, Christchurch