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"Memoirs of an Experimental Stress Analysis Engineer: 1945-1980"

by John B. Mantle

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Abstract

Research and teaching have always been integral to John Mantle's professional career, as have the Universities of Saskatchewan and Regina and their administration. But he has also done his share of engineering practice. Although this paper is mainly concerned with specific aspects and projects of his research in experimental stress analysis using photoelastic techniques, it includes a variety of other background 'noises' often heard by the engineering educators of his time, as well as notes on his travels and generous mention of his colleagues and students. The text has been illustrated by a number of figures, supplemented by a bibliography that helps to sum up his career and achievements.

About the Author

John Bertram Mantle was born in 1919. He graduated from high school in Saskatoon in 1937. The award of a bursary enabled him to attend the College of Engineering of the University of Saskatchewan, from which he graduated with great distinction in mechanical engineering in 1941. The following year he worked with CGE in Peterborough, after which he was commissioned as an engineering officer in the RCAF. Going back to the College in Saskatoon as an instructor in the fall of 1945, he began several years of varied teaching, research and professional experience during which he obtained an MSc from the University of Illinois and was appointed an assistant professor of mechanical engineering in the College. He was promoted to full professor in 1956 and two years later became Head of the ME Department. In 1967 he transferred to the Regina Campus of the University (later the University of Regina) as Dean of Engineering and remained there until his retirement in 1980, to Creston, British Columbia. He also served as Chairman of the National Committee of Deans of Engineering, President of the Association of Professional Engineers of Saskatchewan, and Vice-President Western Region of the Engineering Institute of Canada. He received the Distinguished Service Medal of APES in 1979.

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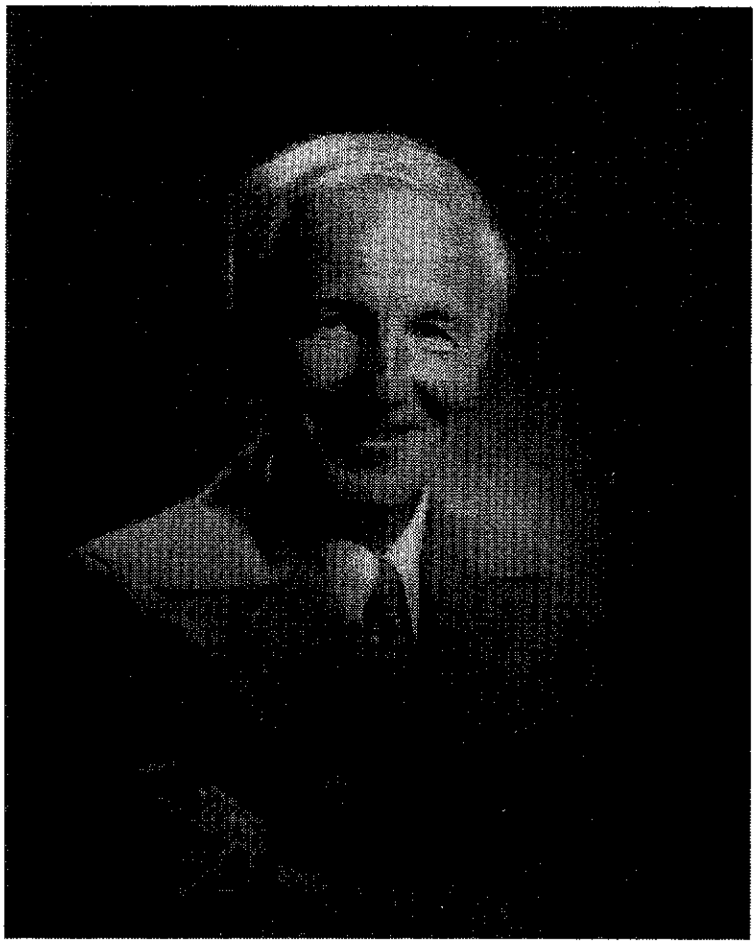

John Bertram Mantle

Introduction

As an engineering educator, I have always had a strong sense of the value of passing on knowledge to those who are to follow. But in thinking over my years of endeavour, there was a thread that always went along with my main occupation of teaching. Even within this thread of experimental stress analysis, it mostly involved directing and encouraging others, be they students or colleagues, to solve a problem. Further, I always felt that a project was never complete until it was satisfactorily written down and made known to as wide an audience as possible. Generally, the vehicle for this was meetings of the Society for Experimental Stress Analysis (SESA) and its Proceedings, or the publications of the Engineering Institute of Canada (EIC). So I am happy now to be writing my 'memoirs' for the Institute.(1)

University of Illinois and Theoretical and Applied Mechanics

My favourite subjects in the course work in the undergraduate program in mechanical engineering at the University of Saskatchewan were applied mechanics and machine design. As a result, during my first year of teaching at this University several of my colleagues suggested that a good specialty for me to get into would be theoretical and applied mechanics. The University of Illinois, during the immediate post-war years, was offering summer course work in this field, so I packed my bags and headed to Champaign-Urbana as soon as my winter assignment was completed. Within the Department of Theoretical and Applied Mechanics I took classes in mechanical vibrations, advanced mechanics and materials, as well as laboratory work in photoelasticity, electrical resistance strain gauges, mechanical strain gauges and the fatigue of metals.

I chose to do a thesis on stress analysis of curved beams using the photoelastic technique. This involved machining various two-dimensional models from a plastic material (about 1/4 inch thick). These models were placed in a polarized light field and, while under appropriate loads, the resulting patterns of 'fringes' were photographed and evaluated for the locations and magnitudes of the maximum stresses. A typical fringe pattern is shown in **Figure 1 which, with the other eight, appears at the end of this paper.** This work resulted in my first published paper, in the Proceedings of the Society for Experimental Stress Analysis. The paper was co-authored by my supervisor, Professor T.J. Dolan.(2) Most of this material later found its way into the classic Handbook of Stress Concentration Factors by Peterson and Wahl.(3)

The classes and thesis project at the University of Illinois produced for me a Master of Science degree in theoretical and applied mechanics and launched me, over the years, into numerous projects in this field. These were done on a part-time basis while continuing my university teaching career.

University of Saskatchewan, Saskatoon

The College of Engineering at Saskatoon had seen some work done with photoelasticity before my arrival there, even as a student. For example in 1932-33, Dean C.J. Mackenzie (who later taught me hydraulics for part of a year, before he was called to head the National Research Council in 1939), in designing the Broadway Bridge in Saskatoon, had one of his graduate students - Zusse Levinton - make use of the technique to analyze temperature stresses in the bridge. One of the plastic models had been retained by Dr. N.B. Hutcheon, my undergraduate machine design professor, and I well recall looking at it in awe during my student days. Indeed, a bit later I included a photo of it in a general paper that I did for the Saskatchewan Engineer entitled, "Photoelasticity: the Rainbow Stress Analysis Technique."(4) Dr.

Hutcheon had himself done some photoelastic work at University College, London, England, in the famous early-beginnings laboratory of E.G. Coker, a Professor of Civil and Mechanical Engineering, and and L.N.G. Filon, a Professor of Applied Mathematics and Mechanics. Later he gave me his copy of their masterful book on photoelasticity, published in 1931.(5) This text, along with the two volumes by the American, M.M. Frocht of the Illinois Institute of Technology, became my chief sources of basic theory information and help with experimental technique over the years.(6)(7) Frocht's <u>Volume I</u> was devoted to two-dimensional work, while <u>Volume II</u> introduced three-dimensional aspects. The photographic work in these two books was superb and a great inspiration to a budding experimental stress analysis engineer.

Under Dr. Hutcheon's guidance the college had purchased some equipment to start an experimental stress analysis laboratory. This included a commercial 4 inch field polariscope, some mechanical strain gauges, a Beggs' deformeter kit and several R.R. Moore rotating beam fatigue machines.

When I finished my MSc project, I was assigned some space, given a small budget to develop a laboratory and asked to put on a class in experimental stress analysis for postgraduate students in mechanical and civil engineering and engineering physics. After devising a straining frame and camera to go with the polariscope, we eventually added selsyn operated 12 inch diameter elements for the polariscope, photometer read-out gear for interpreting fringe order and a special oven for three-dimensional photoelastic modelling. Also, in time, equipment for dynamic stress analysis using electrical resistance strain gauges was added. Through the years, this laboratory proved very satisfactory for education purposes, producing numerous undergraduate projects, 18 MSc research problems, and one PhD research thesis. Furthermore, several 'outside' projects (for PFRA, Sask Power, de Havilland Aircraft and several orthopaedic surgeons) were undertaken and my own personal research problems pursued. Many of these latter were financed by grants-in-aid of research from the National Research Council, the Saskatchewan Research Council and the Defence Research Board of Canada.

National Research Council, Structures Laboratory

In the summer of 1948 it was arranged that I should be 'seconded' to the Structures Laboratory of the NRC's Division of Mechanical Engineering in Ottawa to do experimental stress analysis. This Laboratory had some photoelasticity equipment and a basic laboratory, but no one to work in it. The idea was for me to train some of their people and to build up a laboratory that could be adapted quickly to solve practical problems. As a result of this summer's work, a Laboratory Note was prepared for NRC describing their photoelastic apparatus and its adjustment, detailing methods for the preparation and loading of models, as well as techniques for the determination of stresses.(8) Also included were recommendations for further study, and a bibliography of recent papers on both two- (55 items) and three-dimensional (30 items) photoelasticity. Of special concern to us at the time was the problem of time-edge stresses, which distort model fringe patterns leading to inaccuracies, and how best to utilize brittle lacquers on models to indicate the principal stress directions. Both of these problems led to personal research projects for me.

PFRA Projects

In the early 1950s there was considerable interest in building - in Saskatchewan and Alberta - large earth-filled dams for irrigation purposes. The Prairie Farm Rehabilitation Administration (PFRA) of the Canada Department of Agriculture was considering a very large one on the South Saskatchewan River, in Saskatchewan, and a smaller one, the Waterton, on the St. Mary's-Milk River in Alberta. In both of these, the design engineers were faced with the decision either to tunnel around the site or to excavate along the river bank for the construction of large concrete conduits that would divert the stream flow during the period of dam building. In the case of the conduits, the theoretical stress analysis was difficult because of the indeterminate nature of the structure and the variety of possible loadings. We, at the University, were asked to undertake an experimental analysis for the South Saskatchewan and, a couple of years later, for the St. Mary's-Milk River.

Our experimental findings for the Saskatchewan conduits were detailed in six preliminary reports in 1952 and ten supplementary reports from 1953 to 1958, which were then published as a single paper in the SESA Proceedings under the title "A Photoelastic Study of Multibarrel Conduits."(9) My co-worker for this project was Banchidhar Pant, a bright young engineer from the Indian Central Power Research Station at Poona who just happened to be looking for such a problem for credit for his MSc degree in the University of Saskatchewan's Department of Civil Engineering.

The structural conditions of the design were rather involved. The cross-section on one-half of the conduit was to contain two circular barrels 25 feet in diameter, with possibly three different thicknesses of concrete at the crown and invert. The top loading was to be for the full weight of the overburden (200 feet), with the horizontal side thrust taken as zero, one-third and two-thirds of the vertical load. As well, the hydrostatic pressure inside the barrels was assumed to be equal to a head of 185 feet of water.

The photoelastic model to simulate this structure was a two-dimensional one approximately 3 inches by 1 1/2 inches by 1/4 inch thick. Loading was applied by screws through photoelastic disc gauges and rubber pads for top and side loading. A rather unique rubber pressure tubing arrangement was devised to represent hydrostatic loading. A view of the loading arrangement for earth pressure is given in **Figure 2**, with a typical resulting photoelastic fringe pattern shown in **Figure 3**. I understand that when the dam was finally built the tunnel option was used for diverting the river but, nevertheless, I had a good feeling about this particular project!

Some of these results were carried over to the St. Mary's-Milk River conduit design, including supplementary analyses using Beggs' deformeter. We also did some analytical work using electrical resistance strain gauges placed in 6 feet diameter steel culverts under earth loading. Most of this work was carried out in our laboratory by PFRA engineers under my direction, all of the results being given to the PFRA design team through four preliminary reports during 1954-55.

It should be noted that, as a result of doing these two projects in our laboratory, we were able to acquire a considerable amount of equipment for experimental stress analysis work at the University that would not have been possible otherwise.

Reinforced Stress Raisers

My first experience with 'frozen stresses' was with Gerry Weckman's MSc experimental work in 1950. His problem involved a flat plate in tension, having a circular hole in it, and a reinforcing ring attached to one side only, as shown in the drawing in **Figure 4**. This arrangement causes an unsymmetrical distribution of stress through the thickness, so some sort of three-dimensional analysis is needed to get at the maximum stresses. In the stress-freezing procedure, the model is made from certain plastics that are bi-phase, one phase softening at a critical temperature. The model, with forces applied, is heated up with the temperature held for a while and then gradually cooled to room temperature. The stresses are 'frozen' into the model and it may be machined or sliced to permit analysis of the stress distribution through the model. The procedure was followed, in this case with several different cross-sectional shapes of reinforcing rings being attached to the plate by an adhesive. The findings were presented at the Spring Meeting of SESA in Milwaukee, Wisconsin, and appeared in print in that Society's Proceedings.(10)

This problem was tackled in much greater detail in 1964-65 by a PhD student, K. Lingaiah, with an analytical study directed by my former student and colleague, Walter North, and with experimental work under my direction. Several more reinforcing ring cross-sections were used, including some with a fillet. In the photoelastic models the rings were machined integrally with the plate rather than being attached by adhesive. The frozen stress and slicing (by difference) technique was used to get at the stress distributions. The significant parts of the research were presented at the 1966 SESA Spring Meeting in Detroit and appeared in the following issue of Experimental Mechanics.(11) The theoretical part was presented separately at the 5th U.S. National Congress on Applied Mechanics in Minneapolis that same year, with the results published in the Proceedings of the Eleventh Congress of the Indian Society of Theoretical and Applied Mechanics.(12) Later Dr. Lingaiah included some of the material in his own book on stress-concentrations.

Time-Edge Effect and Other Researches

One of my pet 'bug-a-boos' with regard to photoelastic stress analysis models was the problem of the 'time-edge' effect. This results in distortion of the fringe pattern, often at the most critical point, and introduces inaccuracies in the analysis. One summer (1957) I decided to see what I could do about extending knowledge of this phenomenon. My findings are contained in a paper published in the Transactions of the EIC.(13) They confirmed that the effect was due to moisture migration and that the defect can be arrested by the storage of freshly cut models under certain relative humidity and low temperature conditions. The state of moisture content through a 1/4 inch thick plate of photoelastic material after storage for some years at room temperature was shown to be parabolic in nature.

I also reported on my time-edge research efforts in a paper in the Engineering Journal a couple of years later, along with some other interesting studies.(14) With respect to photoelasticity, one thing discussed was the 'photostress' technique and 'photostress gauge' in which a layer of sensitive plastic is adhered to the actual structure (steel, iron, concrete, etc.) and polarized light is reflected from the structure's surface after passing through the plastic. The reflected polarized light, before and after loading, can be observed and the stresses measured. Also, some of the newer three-dimensional photoelastic materials were discussed. In addition, a description was given of some of our experiences with dynamic loading stress analysis using the metal film electrical resistance strain gauge and high speed cameras. Of special interest to me were the studies involving pressure in shotgun barrels, as carried out by my former student and colleague, Ron George. In the Journal publication of this particular paper I note useful written 'discussion' from C.M. Hovey (University of Manitoba) and John Foreman (University of Western Ontario).

Fatigue of Metals Research

My interest in metal fatigue began at the University of Illinois where one part of our experimental laboratory was devoted to the topic. I was intrigued to find how nicely my test specimens, on a rotating beam fatigue machine, broke after thousands of cycles to fit an S-N curve we were working up. Then, in 1948, my favourite fiction writer - Nevil Shute - came out with his book, No Highway, in which a research scientist realized with horror that a part of the plane in which he was crossing the Athantic was about to reach its fatigue limit! As a result, several of my MSc students did projects in this field during 1958-1962, with financial assistance from the National Research Council and the Defence Research Board of Canada.

The first one was Lou Torfason, whose assignment was to design, and have running, a multi-specimen flat sheet fatigue machine. It eventually was capable of holding 16 reversed bending cantilever test pieces of the type used by the U.S. Bureau of Standards, and it was possible to operate them at up to four different stress levels. Alan Doige used this machine to study the effect of surface finish on the fatigue life of an aluminum alloy. We measured the surface finish rather precisely with a newly acquired Taylor-Hobson Talysurf recorder. This was followed up by Ron George doing a study of the effect of the edge preparation of specimens. Some had machined square edges, others machined smooth, some machined semicircular, others punched square and, finally, some were punched and smoothened. Altogether, some 300 testpieces were broken and S-N curves drawn up for the five different types of edge preparation. These results, including a description of the machine, were written up and submitted to the Americal Society for Testing and Materials for possible publication. The paper was accepted and appeared in Materials Research and Standards, with a lively 'discussion' appearing in a later issue.(15)

Several other problems in metal fatigue were tackled using the R.R. Moore rotating beam machines adapted to give multi-stress level loadings. The normal machine has the load applied by suspending dead-weights through two bearing housings. The load was made to fluctuate as desired by means of a multi-level cam, acting on a follower, with a calibrated spring through a lever arm acting on the dead-weights. Art Opseth, using this equipment, studied the effect of certain periods of fluctuating understress (damage) on the fatigue life of mild steel. This was followed by John Shewchuk looking into the effect of other stress cycles on the life of this metal, and comparing his results with Miner's theory for cumulative damage. Most of these results, along with some comparison studies for different fatigue machines done by my colleague, John Whelan, were put together in a paper that was published in the EIC Transactions in February 1964.(16)

Diamond-Head Buttress Dam Project

Probably the most challenging project that I participated in was helping with the design of the diamond-head buttresses for the earth fill dam of the Squaw Rapids Power Development on the North

Saskatchewan River. The dam was being built for the Saskatchewan Power Corporation, with Crippen-Wright Engineering of Vancouver responsible for design. The main portion was to be of the earth fill type with concrete spillway and three buttresses, acting as independent units, constructed at each side of the spillway to provide a transition to the river banks. Each buttress was to be roughly triangular in section and about 100 feet high, 50 feet wide and 100 feet long. The two buttresses adjacent to the spillway were to contain a circular stairwell and two horizontal galleries, as shown in the drawing of **Figure 5.** The problem was to evaluate expected stresses in the buttresses, especially in the region of the stairwell and galleries, under various back-fill and hydrostatic pressures.

I was asked to carry out a photoelastic stress analysis of the proposed design. It was decided to use the three-dimensional stress-freezing and slicing procedure, using machine cut pieces glued together. To simulate the loading, special clamps (Negator or isotonic springs) were adapted to act as force applicators. The model in its rig of clamp-holding devices looked rather 'hairy' out of the stress freezing oven, but the arrangement worked admirably! (**Figure 6**) The results were put together in a report by myself and my capable assistant (C.R. Jones of Crippen-Wright) and later in a paper in the September 1961 issue of the Engineering Journal.(17) Very helpful 'discussion' pieces were included, coming from W.B. Rice of Queen's, W.O. Richmond of the University of British Columbia and I.W. Smith of the University of Toronto.

Hydrostatically Loaded Cylinder Studies

Arising from our work on the PFRA conduits, described above, came W.P.T. North's MSc project on single barrel conduits under hydrostatic loading. This was assisted by a grant-in-aid of research from the National Research Council and resulted in a paper in the Experimental Mechanics Proceedings.(18) This was tackled as a two-dimensional problem. Of special interest here was the use of a fixture embodying a rubber pressure disc and helical spring to apply known internal pressures to the models. Calibration was done using a thick cylinder photoelastic model and the corresponding theory. The three-dimensional stress-freezing and slicing technique was utilized to confirm uniform loading through the thickness of the model. Several outside boundary shapes were used, varying from square through to octagonal to circular. Separation of the principal stresses along critical sections was done with the aid of Southwell's 'relaxation' procedure. This process took many hours using the hand calculator, and would have been so much simpler using today's computer techniques!

Travels to Distant Laboratories

As I began presenting papers at meetings of the Society for Experimental Stress Analysis, I tried to visit photoelasticity laboratories in the host city areas and also to make special trips to other cities around the world with noted facilities and workers.

From the meetings, I recall most interesting visits to the Illinois Institute of Technology (M.M. Frocht and A.J. Durelli), Columbia University (R.D. Mindlin), Westinghouse (M.M. Levin), Northwestern (M. Hetenyi), and the Massachusetts Institute of Technology (W.M. Murray - a Canadian). In Canada there was considerable experimental stress analysis activity: the Universities of Toronto (I.W. Smith), British Columbia (W.O. Richmond) and Waterloo (J.T. Pindera) all stood out. I also obtained good information from visits to the Universities of Minnesota, Pennsylvania and California.

One summer, 1955, I took a short course on electrical resistance strain gauges and instrumentation put on by Peter K. Stein at MIT. It was most informative and gave me an opportunity to meet with Frank Tatnall, Given Brewer, Bill Bean and other strain gauge 'fathers'. (It is worth noting in parentheses that Peter Stein is still - in 1996 - giving his courses, from his home base in Phoenix, Arizona.)

Another summer, 1961, I was able to make an extended visit to the United Kingdom to see current activities there. I visited with G. Robertson at Dundee Tech. and Dr. Phillips at the National Engineering Laboratory at East Kilbride, H. Fessler at Nottingham University, Dr. Meyer at Sheffield University, Dr. Biggs at Cambridge, and also spent useful time at Rolls Royce in Derby and at the University of Manchester. I was fortunate to find considerable activity at Coker and Filon's famous laboratory at University College, London. H.T. Jessup, who in 1957 updated the pioneering photoelasticity text, and Ian Allyson, who became President of SEM in 1986, were both hard at work there.

In 1964-65 I was able to take a sabbatical leave in the Mechanical Engineering Department of the University of Melbourne, Australia. While headquartered there, I did some teaching and was the chief organizer for a short course in photoelasticity put on for the benefit of engineers in industry and government departments. For this I produced a handbook on photoelastic stress analysis and, working with the Department of Civil Engineering, presented the course to some 30 participants.(19) Later that year I was asked to do the same course for the University of Western Australia in Perth and the University of Queensland in Brisbane, and was able to do so. As well, I presented seminars on our own experiences to groups at the University of Adelaide in South Australia and the University of Sydney, and visited workers at the University of New South Wales, Monash University and the University of Tasmania.

All in all, this was a most satisfactory year and encouraged me to return to Australia ten years later for another sabbatical. This time I was Visiting Professor in Mechanical Engineering at the University of Queensland. While there, I worked along with Tom Leahy, who was an authority on a reusable rock stress meter. His work was sponsored by Mt. Isa Mines and, as a result, I was able to visit that 'outback' area, go down into a very warm mine and conduct some tests with Tom's meter.

Other travels were done by my reading of the literature and, through this medium, learning of the pioneering work of Foppl and Kuske in Germany, Favre in France, Brown and Hickson in Britain and Tuzi in Japan.

Blade Root Project

One problem that we tackled was suggested by de Havilland Aircraft of Canada and was in support of their design of the 'Canadian Hydrofoil Ship'. The particular part involved was the attachment of the propeller blades to the hub, which was to have counterbored holes. This resulted in stress concentrations arising at the fillet radius of the counterbore that could govern the fatigue life of the structure. Bolt preloading further complicated the problem.

One of my MSc students, Bill Shabbits, undertook a three-dimensional photoelastic stress analysis using the stress freezing and slicing procedure. This involved using a casting material (an epoxy resin) not previously used by us. The model of the blade root, full-scale to the design, was fabricated by casting three pieces, machining each of them and then attaching them together with a special adhesive. Plugs to simulate the hold-down bolts were made from the same plastic, and force applied through a lever system. **Figure 7** shows a drawing of the assembled model in its loading rig. To get at the principal stresses, it was necessary to take several diametral slices around the hold-down bolt area, then take sub-slices (and finally 'cores' as a check) and examine these photoelastically. A blown-up fringe pattern at a critical section is shown in **Figure 8**. Most of the interesting findings with regard to this project were given at a meeting of the Canadian Society for Mechanical Engineering and then reported in the <u>Engineering Journal</u> in July 1971.(20)

Bio-Medical Engineering Cases

Through the years it has been a considerable source of personal satisfaction to find that my knowledge of experimental stress analysis could be of benefit to members of the medical profession as they sought to reduce human suffering. While at the University of Saskatchewan, I did bio-medical engineering work with both an opthalmologist and an orthopaedic surgeon, and when at the

Universities of Regina and Queensland with other orthopaedic surgeons.

The opthalmological work at Saskatoon involved devising a simple testing machine for determining the strength of sutures of various materials. These materials were to dissolve in the course of a few days, so they were immersed in special liquids during the test.

In the case of the Saskatoon surgeon, the joint under study was the upper femur ball and socket. When 'grandma' fell and fractured her hip at the femur neck, the normal repair involved a 'Smith-Peterson' nail being impacted along the neck of the femur. The question was: Where was the best location, axially, to prevent subsequent re-fracturing? One of my graduate students, Paul Krawczk, undertook a three-dimensional stress freezing and slicing photoelastic analysis to solve the problem. A full-scale casting was made and, while in the oven, loads were applied to simulate body forces. Then the model was sliced and stresses evaluated. This was repeated several times with a simulated pin introduced in different positions through the neck. Analysing the stresses from these told us which position of the pin would give the most favourable stress distribution.

At the University of Queensland, Dr. R. Cooke was worried about the human upper femur as well. He and other surgeons were repairing broken hips using the 'Charnley' prosthesis to replace the ball, along with a plastic cup for the socket. These two pieces were anchored to the good parts with an acrylic cement, as shown in Figure 9. They had become alarmed to find that marked deterioration of the bone-cement interface was taking place after a very few years, resulting in excessive patient distress. I was encouraged to try to duplicate this breakdown under laboratory conditions. Part of the program was to simulate body forces acting on a test specimen of bone cement while under an assumed body environment. A simple stressing rig was devised using a calibrating steel ring with anvils and 'go' and 'no go' gauges, to maintain a given small compressive force on the test piece. The design procedure used was one often employed by industrial engineers called the 'IDEALS approach' and our work was written up as a case study in a book by Dr. Gerald Nadler of the University of Wisconsin.(21)

At Regina I worked with Dr. A.P. Pieron and Harold Berwald, our machinist, to develop a device to improve the process of applying traction to the spine of a patient suffering from spondylolisthesis (otherwise known as slipped discs). We were able to 'invent' an apparatus which, according to the surgeon, worked very well with several of his patients. The key to it was the incorporation of the same isotonic spring (Negator clamps) that we had used previously to put compressive forces on the faces of the photoelastic models for the diamond-head buttress dam discussed above. The apparatus formed the basis of an application for patent protection and for a paper submitted by Dr. Pieron to the Canadian Orthopaedic Society in January 1977.(22)

Conclusions and Acknowledgements

I ended my working career with 13 years as an administrator at the University of Regina, but was able to do a bit of research and teaching in experimental stress analysis. I had a small photoelastic laboratory with a large field polariscope, a fancy 'stress freezing' oven and commercial 'photostress' equipment. Postgraduate students were not available, but some summer students worked on photoelastic model casting techniques and the time-edge effect. On retirement, I was able to pass my 'know-how' on stress analysis on to a small group of engineers from the Saskatchewan Power Corporation and to colleagues at the University.

I am grateful to the University of Regina for permitting me to work with Dr. Pieron and to have that wonderful second sabbatical year at the University of Queensland. I am indebted to the University of Saskatchewan for allowing me to use the Mechanical Engineering Department's facilities for working with the PFRA and other 'outsiders' and for enabling me to have my first sabbatical in Melbourne. And then I must remember with gratitude Professor T.J. Dolan and Dr. N.B. Hutcheon, who undoubtedly launched me into the fascinating field of photoelasticity and a very satisfactory part-time career in experimental stress analysis.

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Notes and References

(1) Since 1984 SESA has been known as the Society for Experimental Mechanics (SEM). In 1966 this organization awarded me a Gold Certificate in recognition of 50 years of continuous membership. The EIC, which I joined as a Student in 1941, honored me in 1970 with election as a Fellow of the Institute.

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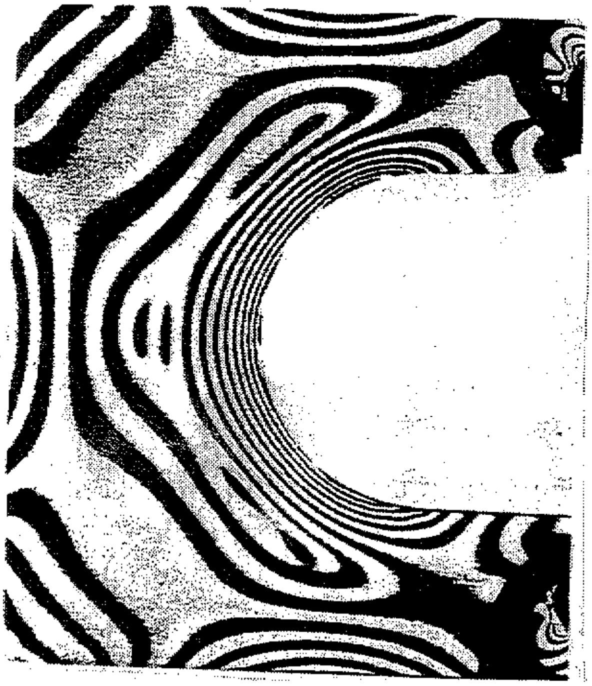


Figure 1:
A Typical Photoelastic Pattern of a Curved Beam

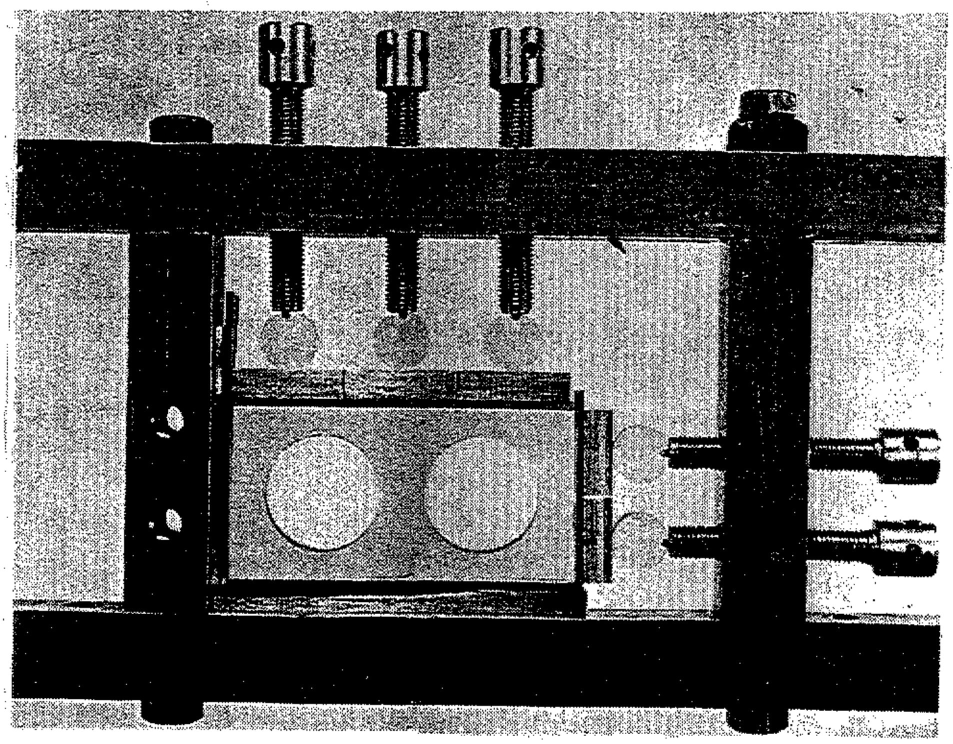


Figure 2:
Loading Arrangement for Earth Pressure on a Conduit Model

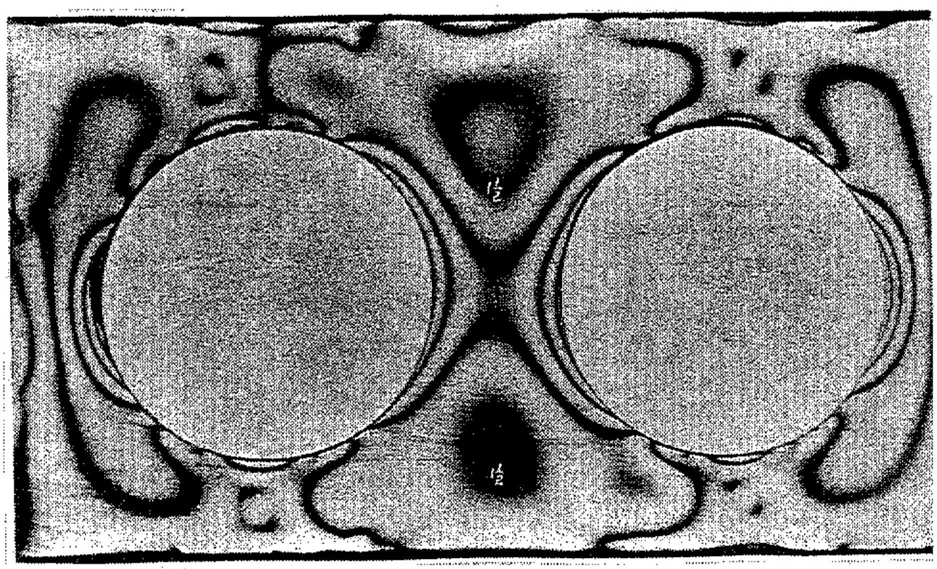
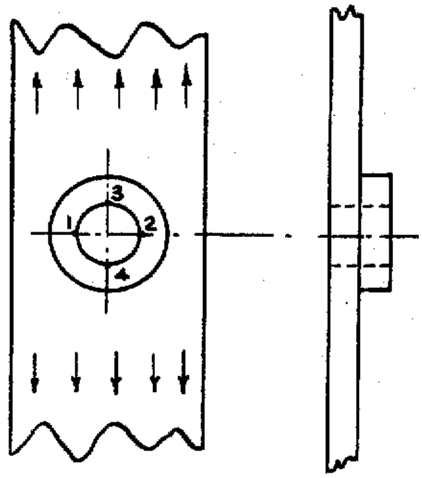


Figure 3:
A Typical Photoelastic Pattern from a Conduit Model

Figure 4:
A Reinforced Stress Raiser with Critical Points



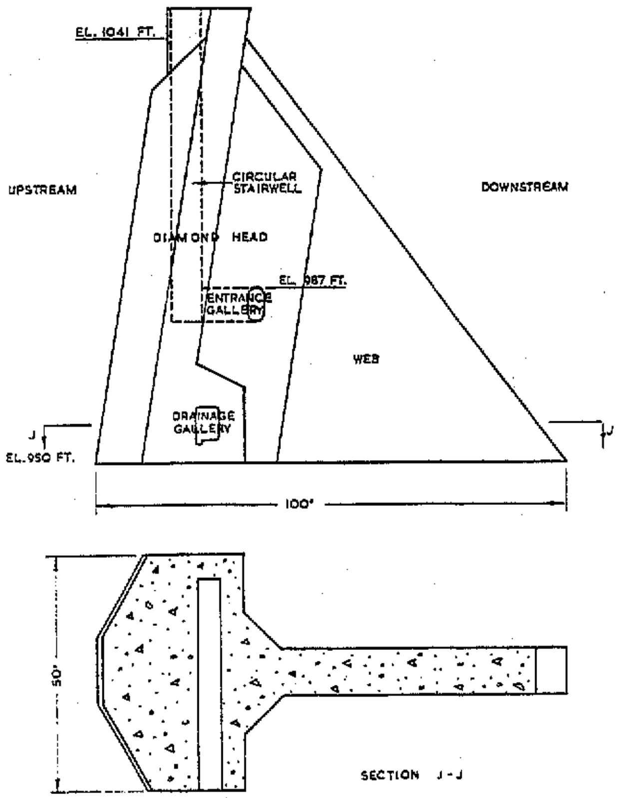
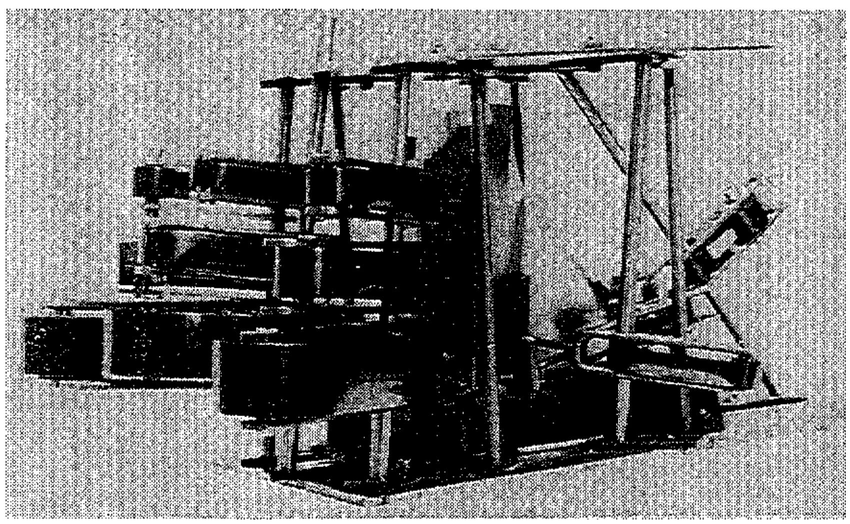


Figure 5:
A Unit of the Diamond-Head Buttress Dam

Figure 6:
A Diamond-Head Buttress Dam Model in its Loading Rig



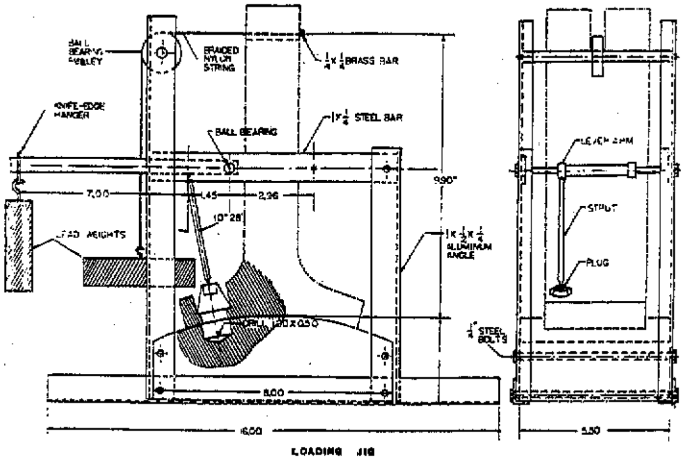


Figure 7:
The Assembled Photoelastic Model of a Blade Root in its Loading Rig

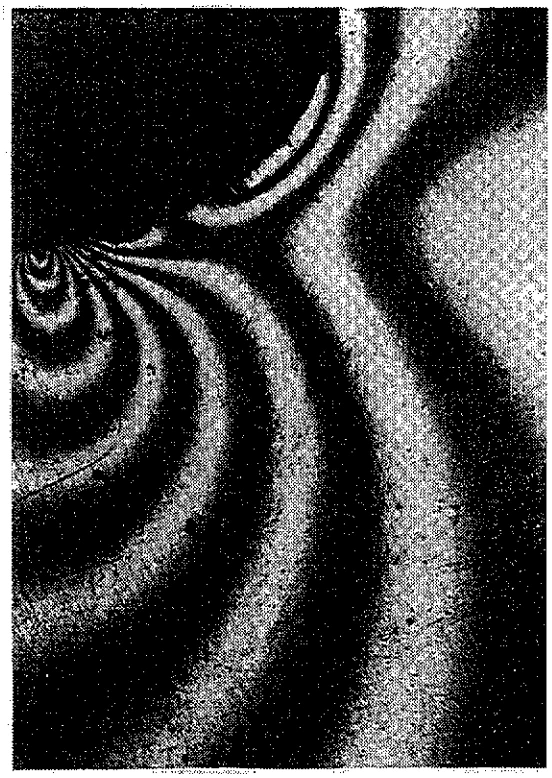


Figure 8:
A Typical Photoelastic Pattern for the Blade Root Critical Point

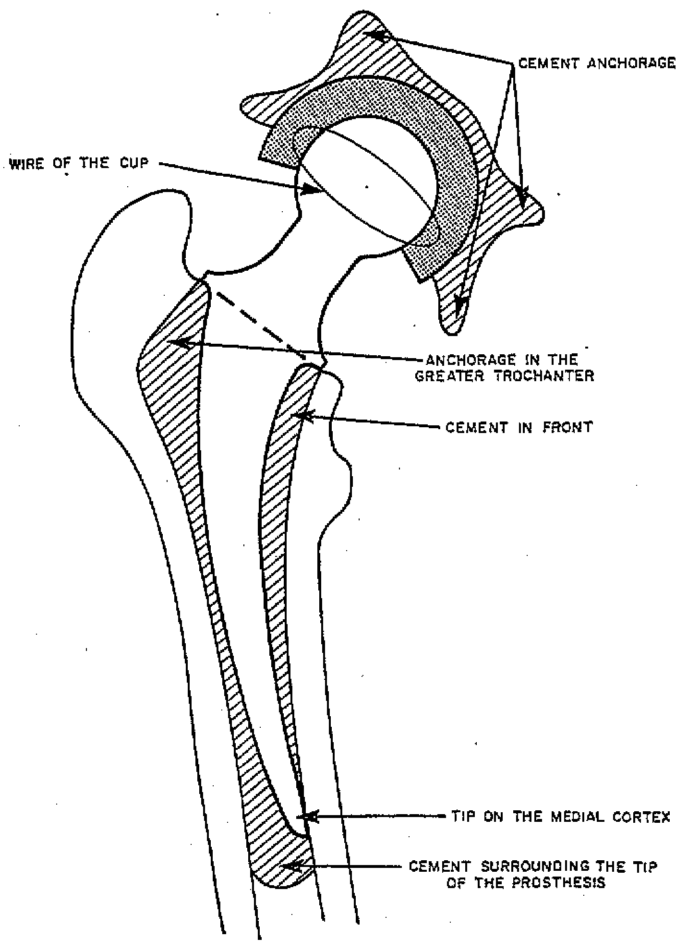


Figure 9:
A Total Human Hip Prosthesis with Bone Cement