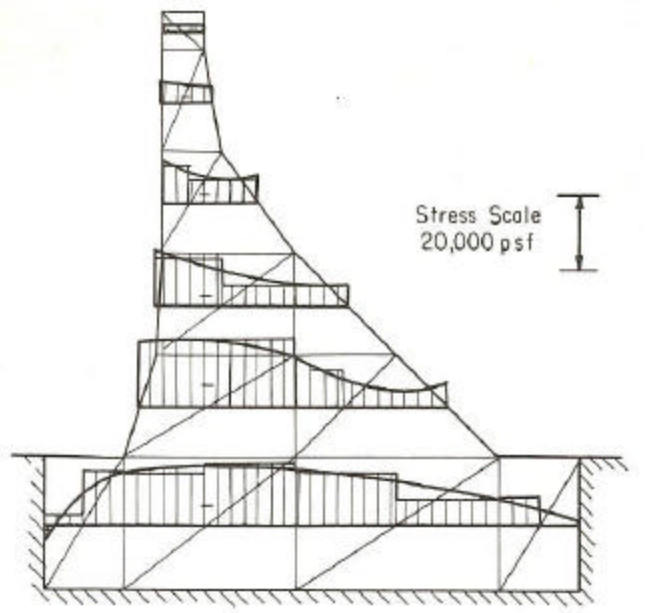
January 10, 2014

2nd ASCE Conference on Electronic Computation
Pittsburgh, PA - September 8-10, 1960

Ray Clough was on Sabbatical leave in Trondheim, Norway during the 1956-57 academic year. This is where he read Argyris'and other papers and decided to solve problems in ***Continuum Mechanics*** by the ***Finite Element Method*** which was similar to his previously summer research at Boeing which was termed the ***Direct Stiffness Method***. After his return to Berkeley in the Fall Semester of 1957 he indicated, in writing, he was inviting students to conduct research on the finite element analysis of membranes, plates and shells. Therefore, Ray and his students started using the Finite Element Method three years prior to the publication of the first Finite Element Paper at the 2nd ASCE Conference in September 1960.

The major reason for the delay in any significant research publications, prior to 1960, was the lack of modern computer equipment on the Berkeley Campus. In 1957 the only Electronic Digital Computer in the College of Engineering was a used IBM 701 based on vacuum tube technology. It had a maximum of 4,096 locations of 16 bits memory. The computer only had the ability to solve 40 simultaneous equations. Ari Adini, also a student of Ray's, used the IBM 701 and an existing equation solver to work the examples in Clough's 1960 paper given at the ASCE conference in Pittsburgh. However, the element and global stiffness matrices were calculated by hand. Therefore, the analysis of the gravity dam shown to the right was not impressive due to the very coarse mesh. However, Ray pointed out the new IBM 704, (recently installed on campus) was significantly faster with 4,096 locations of 32 bit high-speed memory and a 32 bit floating-point CPU that would allow fine mesh problems of this type to be solved in a few minutes.



21.—NORMAL STRESSES DUE TO DEAD LOAD ON

Ed Wilson's MS Degree was completed in 1958, working under the superposition of Ray. He wrote a semi-automated two-dimensional stress program, based on the force method, for the IBM 701 using rectangular plane elements and produced a very limited capacity program. However, Ed did master the art of programming in machine language called SAP (Symbolic Assemble Program).

Therefore, in fall of 1959 when the IBM 704 was installed, Ed was ready to produce a practical, nonlinear, structural analysis program in a very short period of time. It was a general purpose two-dimensional frame program that included both nonlinear axial and bending deformations.

Loading was applied incrementally and a new tangent stiffness matrix was formed after each load increment.

In addition, hand calculations were not required since the x and y location of the number joints and the location and properties of the members were the basic input data in addition to the joint loads. Therefore, it could easily solve any two-dimensional frame or truss structures.

Also, after the joint equilibrium equations were solved for the displacement the element forces were automatically calculated. The user was only required to plot the displacements and member forces as a function of the load increment as shown in the figure to the right.

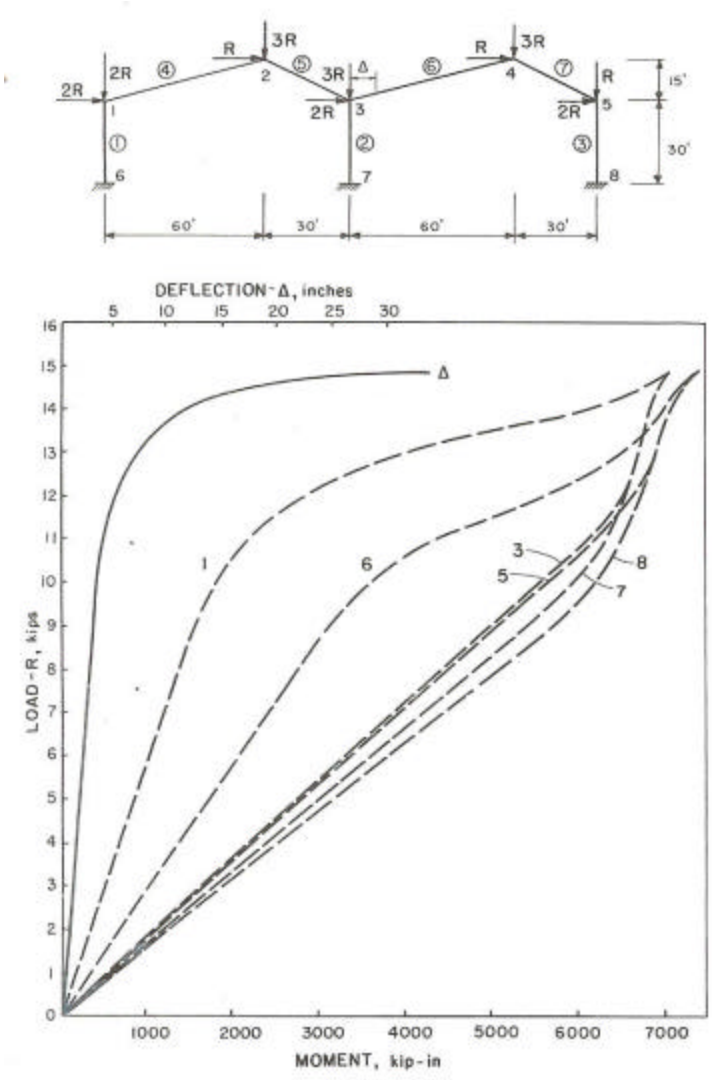


FIG. 6.—ANALYSIS OF RIGID FRAME BENT

After writing the report on this small research project entitled "Matrix Analysis of Non-Linear Structures", Ray suggested that Ed submit the paper for presentation at the Pittsburgh conference. Needless to say, Ed was surprised that it was accepted. After all, this was his very first paper.

Ray and Ed traveled to Pittsburgh (shared a room to save money) to present our papers. Attending an ASCE national conference was a very significant experience for Ed and was an unique opportunity to meet many important researchers in the field of structural analysis. Over 300 engineers had registered to hear 35 researchers present how they used electronic computers to solve many different types of problems in the broad field of civil engineering.

Ray and Ed presented papers on how to solve different classes of structural analysis problems. However, most of the papers reported how a specific problem was solved using a digital computer.

Prior to the conference, Ray and Ed had started the development of a general purpose program for the two-dimensional plane stress (or strain) problems based on the triangular finite element. In order to increase the capacity, on a computer with limited amount of high-speed memory, the stiffness matrix was formed in a compacted form and then solved by an improved Gauss-Seidel iteration method. Therefore, it was then possible to solve large practical problems with the IBM 704.

Within a few weeks after the completion of the program, Dr Roy Carlson, a consultant for the US Army Corp of Engineer, approached Ray concerning the analysis of Norfork dam. It was a great opportunity for Ray and Ed to show the structural engineering profession the power of the finite element method. See the following link:

http://edwilson.org/History/The%20First%20Automated%20Finite%20Element%20Program.pdf

After this early success in writing computer programs that could be used by professional structural engineers to design or retrofit of real structures, Ed found in really enjoyed programming. Even when he had a "bug" in a program it was fun to solve the puzzle. After over 50 years he still enjoys writing finite elements programs that are compact, efficient and satisfy the fundamental physical equations of the behavior of solid and fluid mechanics.