
CONNECTIONS

The EERI Oral History Series

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Edward L. Wilson

Ed Wilson

Hi Jürgen,

*This will bring back old
memories - subspace
and SAP IV, Thank you.*

Ed

The Evolution of SAP, NONSAP, and TABS Programs, 1972–1979

The local structural engineers were not ready to conduct three-dimensional structural analysis of buildings.

The First Version of SAP

Wilson: When the first version of SAP was released in 1970, only a few large companies, such as Bechtel and General Electric, liked it since it replaced my old ASOLID program that I had developed at Aerojet and had a dynamic analysis option. Also, the local structural engineers were not ready to conduct three-dimensional structural analysis of buildings since they were very happy to continue to use the two-dimensional programs FRMSTC and FRM-DYN. I must admit, the data input for the SAP program, which required the x, y, and z coordinates of all joints, was far more complicated than the frame programs, which only required the elevation of each floor and the location of the column lines.

In addition, since each element was developed by a different

student, the SAP documentations were not consistent. Also, the calculations of the mode shapes and frequencies used the approximate Ritz method. Therefore, the SAP program needed additional development work.

It took me a year, working part time, to clean up the program and the user's manual. Also, I removed the dynamic options since it was based on the use of Ritz Vectors, which most engineers did not understand. This static version of SAP was named SOLID SAP. In 1972, ninety-five percent of the structural engineers only did static analysis.

Contributions of Jürgen Bathe

Wilson: In November 1971, one of my very best graduate students, Klaus-Jürgen Bathe, completed his PhD degree thesis on "The Structural Eigenvalue Problem." His contribution was the development of a new numerical method and FORTRAN software for the calculation of the exact mode shapes and frequencies of very large mathematical models of structural systems. He had named the numerical approach the "Subspace Iteration Method." Both Ray Clough and I had been looking for a student since I joined the faculty in 1965, to create a numerical method to accurately calculate the mode shapes and frequencies for large structures subjected to earthquake loading. We had suggested this topic to several other students, however, all had failed. Jürgen Bathe solved the problem in less than one year. Also, Professor Parlett from the Mathematics Department, who was on his thesis committee, agreed the Subspace Iteration Method was a significant contribution to the field of applied mathematics.

I immediately suggested Jürgen publish his dissertation as a report in our Structural Engineering and Structural Mechanics group, the SESM series of reports with blue and yellow covers,⁵⁴ including the FORTRAN listing in the appendix. Therefore, his new Subspace Iteration Method was immediately made available to all members of the engineering profession throughout the world.

Jürgen was supported by a scholarship during the time he was working on his research. After he filed his dissertation, I requested he be appointed as an assistant research engineer to be funded from my various donor accounts to improve the dynamic analysis capabilities for the SAP program. Also, many structural engineering companies hired him as a consultant to help them implement his software in their proprietary programs.

Engineering Analysis Corporation was a Berkeley software corporation that was formed by Fred Peterson and two other employees who had worked with me at Aerojet. They had developed a relatively simple three-dimensional static analysis program called EASE, which was offered by Control Data Corporation on its CDC computers worldwide on a royalty basis. EASE had a competitor called STAR-DYN, which had dynamic analysis capability. Therefore, Fred hired Jürgen as a consultant to add dynamic capability to EASE. However, one of Fred's partners, with a degree in computer science, was in charge of making

54 K. J. Bathe, "Solution Methods for Large Generalized Eigenvalue Problems in Structural Engineering," Report UC-SESM 71-20, Department of Civil Engineering, University of California, Berkeley, November 1971.

the modifications in EASE; therefore, Jürgen and Fred made modifications to SOLID-SAP, which was a clean static version of SAP. The new program produced by Jürgen and Fred was SAP IV,⁵⁵ completed in June of 1973. In my opinion, the program and documentation was a work of art and a very significant advancement in the field of computational mechanics. Jürgen had put his heart, soul, and many nights at computer centers into the effort to produce the first large-capacity linear dynamic structural analysis computer program.

Reitherman: In the acknowledgements of the SAP IV report,⁵⁶ one sees 28 companies or agencies credited with making contributions to support the work, including big name consulting engineering firms like Agbabian Associates, Dames and Moore, Martin Associates, Pregnoff Matheu Beebe, and big corporations like Fluor, General Electric, Lockheed, and Bechtel.

Wilson: NSF basically paid just for the printing and distribution of the report. However, I was informed that later on in making budget requests to Congress, NSF referred to SAP as one of their successful projects.

K. J. Bathe, E. L. Wilson, and F. E. Peterson, "SAP IV—A Structural Analysis Program for Static and Dynamic Response of Linear Systems," Earthquake Engineering Research Center Report No. 73-11, University of California, Berkeley, June 1973.

⁵⁵ Klaus-Jürgen Bathe, Edward L. Wilson, and Fred E. Peterson, "SAP IV: A Structural Analysis Program for Static and Dynamic Response of Linear Systems," U.C. Berkeley EERC Report 73-11, June 1973.

During this period, it was apparent Jürgen loved his research and consulting work at Berkeley. For example, in 1970 I had developed a program for the nonlinear analysis of a rocket launch site concrete closure for the U.S. Army Corps of Engineers branch located at Vicksburg, Mississippi, where they had a large blast load simulator. The nonlinear analysis program produced very good agreement with the experimental results. I had submitted a final report and the project was complete. However, I was having difficulty completing a paper on the new time integration method. I wanted to show mathematical proof that my method would converge and had failed to do so. I finally gave it to Jürgen and asked for his help. In less than a week, he walked into my office with a smile on his face. He not only added a simple proof that I could understand, he added a discussion on the limitations of the method. The paper was ready for publication.⁵⁷ Eventually, the method was called the Wilson Theta Method and was used extensively in other programs in the world since that time. However, within a few years, Jürgen and other researchers developed more accurate methods.

The Development of the NONSAP Program

Wilson: In late 1972, the Bureau of Mines (BOM), near Denver, contacted me to develop a complex nonlinear analysis computer program to simulate the behavior of mine structures as they were excavated, reinforced, and

⁵⁷ E. L. Wilson, I. Farhoomand, and K. J. Bathe, "Nonlinear Dynamic Analysis of Complex Structures," Earthquake Engineering and Structural Dynamics, Vol. 1, pp. 283-291, 1973.

expanded during the sequence of operations of the mining area. Clearly, it was a multiyear project that required many man-years of time and a large staff to respond to the requests of the sponsors. Normally, I would have told them such a project could not be developed by inexperienced graduate students while they were doing their own research for a doctor's degree at the university. Then, I thought, if Jürgen was willing to be project engineer, I believed it would be possible to develop a very good, general purpose, nonlinear, dynamic analysis program that would be able to solve many different types of structures.

I talked to Jürgen to check if he was willing to accept the project engineer position, with the authority to hire the staff he needed. I made it clear to him I had other projects and had accepted the position as the chairman of SESM. Therefore, I would have a minimum amount of time to help him. Jürgen agreed to accept the responsibility of being project engineer. Then, Jürgen and I had a meeting with the BOM in Denver and they agreed with our proposal. He hired two post-doctorate engineers and, in approximately one year, produced the program NONSAP.⁵⁸ At that point in time, we became colleagues and life long friends.

I met Stephen Crandall at a 1974 summer course at Union College in New York, where I gave lectures on the finite element method. A few weeks later, Steve called me and asked whom

I would recommend to be hired by MIT to teach and conduct research in the FEM area. Of course, I suggested Klaus-Jürgen Bathe. They hired him, and Jürgen has been there ever since. We were able to transfer the BOM project to MIT where he developed the powerful linear and nonlinear computer program ADINA. Jürgen has earned a very significant international reputation as a researcher and educator in mechanical, civil, and bio engineering.

After Jürgen moved to MIT, we continued to work together. He completed a book in 2008 on our work together.⁵⁹ In addition, we gave several two-day courses in Paris, Tokyo, and other places on the capability of SAP IV and ADINA. Most recently (2006), we were keynote speakers at a NATO Workshop on “*Extreme Man-Made and Natural Hazards in Dynamics of Structures*” in Opatija, Croatia. He has written a very interesting book about his life. We both had hard physical work when we were young—he in a gold mine in South Africa and I on a dairy ranch in California. Also, we are very satisfied that our research and computer programs have been used to solve real engineering problems. And we both want to use the title of Jürgen's book, *To Enrich Life*.

The TABS Program

Wilson: As I mentioned, in 1970 after SAP was released, the structural engineers who were conducting earthquake analysis of buildings continued to use the old two-dimensional frame programs. Sometime in 1971, John A.

58 Klaus-Jürgen Bathe, Edward Wilson, and Robert Iding, “NONSAP: Static and Dynamic Response of Nonlinear Systems,” Department of Civil Engineering, University of California, Berkeley, 1974.

59 Klaus-Jürgen Bathe and Edward L. Wilson, *Numerical Methods in Finite Element Analysis*, Prentice-Hall, Englewood Cliffs, NJ, 1976.