52-YEAR APPLICATION OF SEISMIC PROVISIONS TO MAJOR RESEARCH FACILITY

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ABSTRACT

In 1959 I was asked by the U.S. Atomic Energy Commission (AEC) to review a 1957 proposal by Stanford University to construct a $107 million Two-Mile Linear Electron Accelerator research facility. After careful review and meetings with Stanford scientists and a few members of the Board of Trustees I recommended the present site and a budget of $114 million. The west end of the facility would be 0.6 miles from the 900-mile long San Andreas fault and extend over two miles to the east. After approval by the U.S. Congress and President Eisenhower, Stanford selected the Architect-Engineer-Manager team of Aetron-Blume-Atkinson to design the facility and manage its construction, except the electron accelerator and its electronic ancillary equipment. I was appointed Technical Director responsible for all design and construction documents for the site, all structures, roads, and utilities.

After starting the designs I assisted John Blume with development of seismic design criteria for the site as the then current UBC had low seismic design provisions- basically 0.1g. We finished construction in early fall 1966.

The 1989 Loma Prieta earthquake caused only minor damage to some of the original structures although 0.29g was recorded in the accelerator housing. Many of the structures constructed after 1966 suffered damage of varying degree. They were designed in accordance with the UBC.

In 1995 I was contacted and invited to be seismic consultant to SLAC. I recommended that all structures and systems be evaluated by independent structural engineer firms. All of the original structures (1961-1966) were given high marks. Many of the newer facilities were deemed to need seismic upgrade. Those buildings have been upgraded and a few replaced by newer facilities. SLACr is valued well over two billion dollars at present.

INTRODUCTION

The group of physicists assembled by Stanford and led by Dr. Wolffgang (Pief) Panofsky were leaders in high-energy particle physics. They submitted a Scientific Proposal to the U.S. Navy Research Center in 1957. After favorable reviews by several Government agencies the project was assigned to the Atomic Energy Commission to design, construct and operate the high energy facility.

The initial proposed design of the physical facility was prepared by an engineering geologist. Two parallel tunnels separated by about 25 ft of earth were proposed. One tunnel would house the electron accelerator and the other would enclose all electrical equipment and other items needed to operate the accelerator. After review I commented that the two tunnels would not work. One tunnel would need to be entered frequently for services and maintenance work.

I recommended that there be one tunnel covered with 25 ft of compacted soil with a parallel structure on the surface.The physicists were convinced by my analysis. Several days later the AEC requested a proposal from Blume office.to make a study of possible sites within five miles of Stanford. The study was needed in six weeks. I gave the AEC Engineering Director a verbal proposal and he accepted. He authorized me to proceed - he would get me a contract shortly. I assembled a small team - we made an aerial and printed map survey. We made a brief study of five different sites and selected one as having the best overall advantages. Our report was reviewed by Stanford and within three days was accepted with a few minor changes. Our report was then submitted to the AEC.

About one week later the AEC asked me to do a detailed feasibility study, site investigation, and cost estimate of the recommended site. The local AEC had to submit the report to Washington AEC within six weeks, I gave the AEC Director a verbal six-figure cost estimate. He gave me his approval to proceed and said he would get me a written contract soon. I assembled a team of engineering geologists, a soil boring firm, an aerial photography/mapping company, an electrical/mechanical/plumbing firm, an architectural firm, and a high-energy effects consultant. We completed the report on time. The project cost estimate totaled $114 million.

I spent a solid 24 hours proof reading the report before submitting it to the AEC representatives who made a special trip from headquarters. Two days later I submitted a two page errata - a copy was sent by special handling by taking it to the San Francisco airport and have the airline pilot take it to Washibton where it was picked up by the AEC. The next day the local AEC came into my office and handed me a contract for the work.

My wife and children welcomed me back to the living.

SELECTION OF ARCHITECT-ENGINEER-MANAGER

After the AEC received approval from Congress, they awarded Preliminary Planning money for the Project. Stanford started the process for selection of an Architect-Engineer-Manager to design and manage the project except for the electron accelerator and its ancillary electronics. Stanford selected the Aetron-Blume-Atkinson team. Aetron was the architect-enineer subsidiary of Aerojet General (manufacturer of solid propellant for missiles). Blume was the firm I worked for, and Atkinson was a major west coast general contractor and one I had worked with on several large projects. I was selected as Technical Director responsible for all design and construction documents except the Stanford accelerator and its electronics.

FACILITY DESIGNS

ABAI worked closely with Stanford to establish criteria, priorities. and schedules for design and construction. We worked in a temporary office facility on campus. Stanford named the project Stanford Linear Accellerator Center (SLAC). After a few months, ABA moved into a warehouse facility in Palo Alto - about four miles from the SLAC site. and two and a half miles from my home.

It became obvious that seismic design per UBC at about 0.1g would not be suitable for the SLAC facilities as the west end would be about 0.6 miles from the San Andreas fault. John Blume was a nationally recognized seismic researcher and structural engineer. He proposed to SLAC that he develop appropriate seismic design criteria for the site. I assisted him with site details, the types of structures to be built, the finished tolerances required, types of soils, and long term tolerances for the accelerator housing, and connecting structures.. The accellerator tube needed to be aligned to +/- 0.5 mm in 10,000 ft. We adopted Blume's recommendations and all structures were carefully designed to meet the criteria.

PROJECT SCHEDULES

It was realized that the construction would require several years to design and complete. We worked with SLAC to establish a master schedule and schedules for each project. The Critical Path Method was used for scheduling all design and constrution. Each SLAC division and ABA agreed to this procedure. Project design criteria (pre-Title I,), preliminary design (Title I,), final design (Title II), out for construction bids and actual construction(Title III), and Title IV (As built drawings). Each step had definite ABA and SLAC actions, and then SLAC approvals.

I insisted that written minutes be made of each meeting, copies sent to attendees, comments submitted within three days or minutes were final. Minutes were important to avoid arguments later. The CPM process and written minutes kept each project on schedule. Contractors had to submit CPM schedules for their projects. We had weekly meetings to briefly discuss each project and resolve any problems.

Two large research buildings were constructed in 1963-66 that are of special interest. The largest is 125 ft clear spacn, 78 ft clear height, and 200 ft long with a minimum of 24" thick walls and roof. The research to be conducted required that much of the exterior walls be removable from grade to a height of 12 or 20 ft so that the electron beam could be bent by electro-magnets to a shielded target outside the building. The removable wall panels can be moved by a large forklift. The fixed base supporting columns and walls (some are five ft thick have bundled #18 bars to enable better concrete placing. The soils consultant (Dames and Moore assigned 10,000 psf allowable soil pressure.

A smaller similar (sister) building was constructed close by. The larger building was awarded an architectural award for *Excellent Expression of Function.* .The cast-in-place walls were cast with a retardant on the forms so the surface could be washed with hi-pressure water and expose the aggregate.

SPECIAL PROJECT REQUIREMENTS

Maintaining exact alignment during operation of the accelerator was essential. There were several site factors that had to be measured. I was fortunate that the Associate Director of the Coast and Geodetic Survey had just retired. I contacted him and invited him to visit the site at our expense. He was interested and I signed him (Captain Brittain) to a three-year consulting contract.

> **Earth tides** (the moon can cause minute movements of the earth surface). For a period of three weeks Capt. Brittain and two or three assistants were on site just before sunrise to make measurements with a Theodolite. The movements were considered acceptable by SLAC.
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> Variations in the earth's **geoid** along the accelerator housing. We made changes on the construction drawings to correct for this variation..

Captain Brittain did the layout surveying for the construction contractor. As the accelerator housing.had to be built in a straight line, the drawings showed the housing as an upward curve. The bidders thought we were weird. To better balance the excavated earth we then tilted the alignment down 50 ft to the east so that the accelerator was tangent to the earth's surface only cutting into the surface 50 ft plus about 2.75 ft to allow for curvature of the earth's surface.

The possible effect of the **northerly movement** of the Pacific side of the San Andreas fault was a concern. I engaged Engineering Geology Professor Parkinson at UC Berkeley to review the problem and submit a report. He predicted several inches of northerly movement of the west end of the accelerator housing. We thus designed the supports for the accelerator tube to be adjustable horizontally if needed. To date there has been no discernible movement.

Possible **magnetic affects** on the accelerator beam of horizontal reinforcing bars in the concrete housing.. We separated the horizontal bars every 80 feet.

Cracking of concrete. To minimize cracking of concrete we retained UC Berkeley Professor Ray Davis for advice on concrete mixtures. He recommended using limestone from Kaiser Permenente quarry located about 10 miles south of SLAC. Kaiser later changed their mind and agreed to pay the extra cost of using granite rock aggregate from Half Moon Bay,CA/.

We checked the routes for concrete trucks and concluded they woul be a traffic hazard. ABA decided to construct a concrete mixing planet on site. The plant provided 130,000 cy of high quality concrete for site structures. The variation in strength was determined to be lower than any other large concrete construction project.

PLAUDITS

In September 1966 at the formal dedication of SLAC, a personal telegram from United States President Lyndon Johnson was received by Stanford University and SLAC. The telegram sent congratulations "Congratulations for completing the first major U.S. funded project within budget, on time, and works as predicted." Of interest, the proposed research projects for SLAC were successfully completed in less than 10 years. Meanwhile, new research was proposed , funded, and successfully completed.

Shortly after the SLAC dedication, I was visited by two Colonels from U.S. Airforce Tullahoma, Tennessee. They questioned me for several hours about all details of the design, scheduling, cost control, and construction of SLAC. They were under pressure from their commanders to design and build a major wind tunnel at Tullahoma within budget, schedule, andt hat it would work.

EARTHQUAKE EXPERIENCE AT SLAC

The 1989 Loma Prieta earthquake (R=7.9) was recorded in the accelerator housing at 0.29g. There was only minor damage to structures at the site. The original 1961-1966 structures had no structural damage but some minor non-structural damage. The structures constructed after 1966 (in accord with UBC) suffered some structural and non-sructural damage. The damage was repaired and a few minor structures were replaced by newer structures.

In 1995 I was contacted and invited to be seismic consultant to SLAC. I recommended that all structures and systems be evaluated by independent structural engineer firms. All of the original structures (1961-1966) were given high marks. Many of the newer facilities were deemed to need seismic upgrade. These buildings have been upgraded and a few replaced by newer facilities.

I drafted Seismic Design Criteria for the SLAC site for structures and non-structures. I was asked to review designs for seismic resistance and constructibility. About three years ago I reviewed the structural design for a $350 million new research facility.

Currently there are few projects except facilities for priority research. SLACr is valued at well over two billion dollars.

There are several photos attached. Thank you for listening.

Roland Sharpe

JSCA Honorary Member
ASCE Distinguished Member
SEAOC College of Fellows

EERI Honorary Member
SEAONC Honorary Member
Honorary Fellow Member- Association of Consulting Engineers India

SLAC LOOKING WEST


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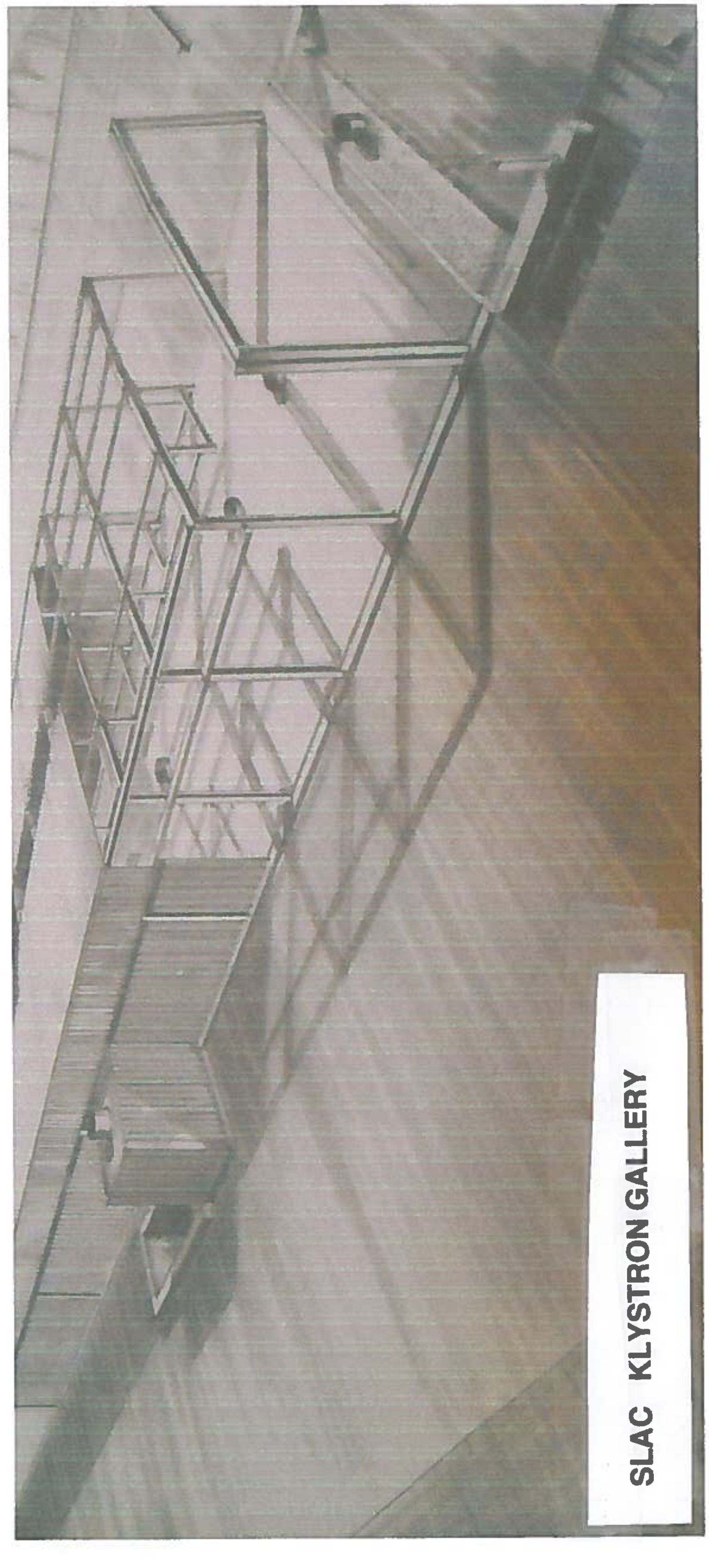
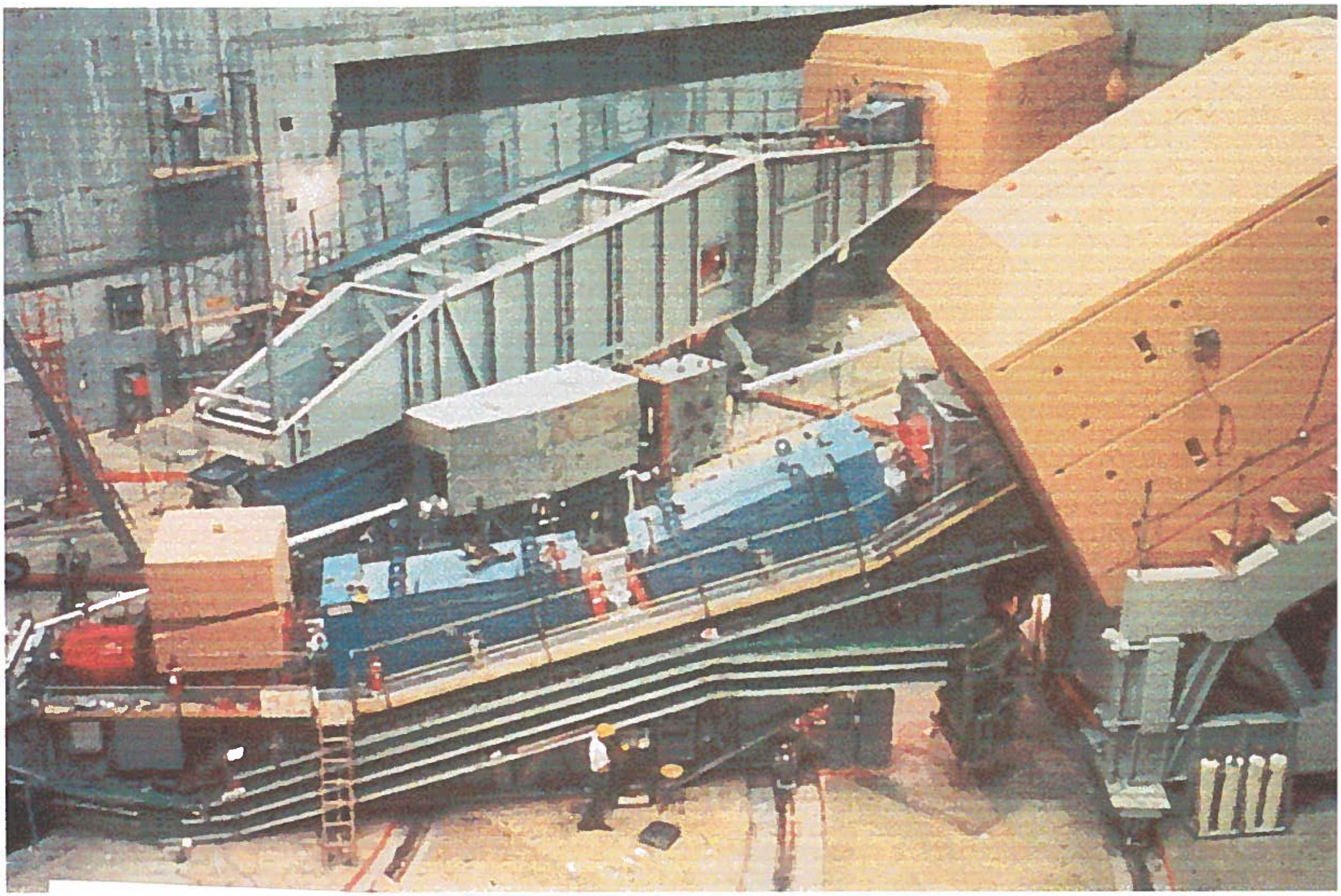
SLAC ACCELERATOR HOUSING


SLAC KLYSTRON GALLERY



ESA - SPECTROMETER - NOBEL PRIZE WINNER AT SIDE