REPORT OF THE
PRELIMINARY IMPLEMENTATION SURVEY TEAM
FOR
JOINT STUDY PROJECT
ON
SEISMIC DESIGN OF STRUCTURES IN CHILE

APRIL 27, 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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1. GENERAL

1.1 Background

Chile and Japan, being on the Circum-Pacific Seismic Belt, have suffered devastating losses due to the past destructive earthquakes. Since the earthquake disaster results from the combined effects of natural phenomena and human activities of the society, continous efforts must be made both on academic and practical bases.

Fundamental studies on prevention and mitigation of earthquake disasters are being done by several universities in Chile, with a very important participation of the Department of Structural Engineering of the Universidad Católica de Chile, which assuredly is one of the most authorized institutes of the country. Information sustaining this assertion will be found in Section 2 of this report.

In order to interchange technical information and promote a cooperative research program between Chile and Japan, the Japan International Cooperative Agency (JICA) has sent technical missions to the Universidad Católica since 1984: the first mission from November 24 to December 18, 1984; the second one from January 11 to January 29, 1986; and the third from March 3 to March 29, 1987. The introduction of their reports, particularly that of the third mission, presented a very detailed justification of the convenience for both Japan and Chile of establishing such a cooperation program.

The first two missions tried to learn about the research in progress at the Universidad Católica de Chile and lectured on some recent developments in earthquake engineering in Japan. They also recognized the neccesity of promoting research, through a cooperative program on the following three subjects:

1) Ground motion and design spectra,
2) Reinforced masonry structures, and
3) Soil dynamics.

The third mission discussed with the people directly concerned the feasibility of a future cooperation between the two countries, so as to reach a common recognition of what in such a project would be useful for the mitigation of future earthquake disasters in both countries, as well as for mutual understanding and friendship.

Based on the third mission report, JICA decided to take a further step towards higher level cooperation in this field, and reached the conclusion that a joint study project would be appropiate to be adopted as a cooperation program. Therefore, JICA sent the preliminary implementation survey

team (herafter referred as "the Japanese team") to visit from April 15 to April 30, 1988. The purpose of the Japanese team was:

a) to discuss and define the draft of the Record of Discussion (R/D), which will be signed by JICA and the Universidad Católica to start the Joint Study Project on Seismic Design of Structures in Chile.
b) to collect additional information on the Universidad Católica and its Department of Structural Engineering for project implementation.
c) to discuss and develop a more detailed procedure for project implementation, including research framework, tentative schedule, technical training, equipment installation, etc.
d) to discuss and agree on legal aspects related to special privileges for Japanese experts, customs procedures, etc.

As a result of the discussion between the Japanese team and the Universidad Católica de Chile, the need of focusing more precisely the three proposed research subjects was recognized, and the following programs were redefined:

1. Earthquake Engineering: Evaluation of Design Seismic Forces Appropriate for the City of Santiago.
2. Structural Engineering: Seismic Behavior of Reinforced Concrete and Reinforced Masonry Structures.
3. Soil Dynamics: Dynamic Properties of Soils for Seismic Design of Structures and Foundations.

Naturally, this redefinition of the projects and preparation of the draft of R/D required considerable adjustments, that were made in close cooperation by the members of the Japanese team and the professors from the Universidad Católica involved in the project. The Japanese team highly evaluated the research programs proposed by the Universidad Católica included in this report.

1.2 Members of the Preliminary Implementation Survey Team

1. Hisahiro Hiraishi (Team Leader)
   Dr. of Engineering
   Head of Structure Division, Structural Engineering Department, Building Research Institute, Ministry of Construction.
2. Yasuo Yamada
   Dr. of Engineering

Assistant Professor, Institute of Engineering Mechanics, University of Tsukuba.

3. Tomiyoshi Ogawa
   Deputy Director, Housing Policy Division, Housing Bureau, Ministry of Construction.
4. Minoru Sasago
   O.I.C. (L.A.), Experts Assignment Department, JICA.

1.3 Schedule of the Mission's Activities

Saturday 15, Arrival in Santiago of Drs. Hisario Hiraishi and Yasuo Yamada, and Mr. Tomiyoshi Ogawa.

Discussion on Research Program (Hiraishi, Yamada and Ogawa).

Sunday 16, Discussion on Research Program with Profs. Lüders and Troncoso (Hiraishi, Yamada, and Ogawa).

Arrival in Santiago of Mr. Minoru Sasago.

Discussion on Research Program.

Monday 18, Greeting and introduction at JICA.

Courtesy call to the Director of the International Cooperation Division of Odeplan.

Courtesy call to the Counselor of Japan.

Meeting and discussion at Universidad Católica.

Welcome dinner by Dean of the College of Engineering Professor Dr. Bernardo Domínguez.

Tuesday 19, Discussion at Universidad Católica: Structural Engineering Program (Hiraishi); Soil Dynamics Program (Yamada); Administrative Aspects and R/D Draft (Ogawa and Sasago).

Discussion at Universidad Católica: Earthquake Engineering Program (Hiraishi and Yamada).

Visit to the Structural and the Geotechnical Engineering Laboratories of the Structural Engineering Department (Ogawa and Sasago).

Courtesy visit to University of Chile. Meeting and lunch. Host: Professor Joaquín Monge.

Courtesy visit to Minister of Education Dr. Juan Antonio Guzmán.

	Meeting at JICA Office (Ogawa and Sasago).
	Discussion on research implementation and report preparation at Universidad Católica (Hiraishi and Yamada)
Wednesday 20,	Arrival at Valdivia.
	Courtesy call to the Rector of Univ. Austral.
	Welcome meeting and lunch with authorities of Univ. Austral.
	Inspection of Tsunami damage in Corral.
	Informative meeting on JICA Project Universidad Austral. Faculty of Veterinary Sciences. (Sasago).
	Discussions on Structural Engineering Program (Hiraishi with Lüders); Soil Dynamics Program (Yamada with Troncoso).
Thurday 21,	Inspection of earthquake damage in Valdivia: Water Tank, Hospital.
	Inspection of earthquake damage in Llanquihue: Bridge.
	Inspection of earthquake damage in Puerto Montt: Harbour Structures.
Friday 22,	Inspection of earthquake damage in San Antonio. (Ogawa and Sasago).
	Preparation of Report (Hiraishi and Yamada).
Saturday 23,	Inspection of earthquake damage in Viña del Mar and Valparaíso.
Sunday 24,	Preparation of Report.
Monday 25,	Preparation of Report.
	Lunch with Rector of the Universidad Católica de Chile, Professor Dr. Juan de Dios Vial Correa.
	Farewell cocktail party offered by the Japanese Team.
Tuesday 26,	Preparation of Report.
	Farewell call to the Embassy of Japan and JICA office.
Wednesday 27,	Submitting Report to the Universidad Católica and JICA.
	Departure from Santiago.

2. General Description of the Universidad Católica de Chile

2.1 The Universidad Católica de Chile

a) History

The Universtiy was created in 1888 by the Catholic Church, at the time the Official Religion of the Chilean State. It was intended to offer an education in the technical professions, mainly as an alternative open to young men of the lower social classes. The original technical orientation changed in a few years, leading to an organization that differed very little from the State University, but it was responsible for the great importance that the College of Engineering has always had within the University.

Since 1923 the University has been increasingly drifting from its initial private status to one in which it is an integral part of the National University System, dependent of the Ministery of Education. Its funding comes from the State, from tuition fees, and from service sold to the community, in the same way as with the rest of the Universities. Admission to the University is through a nationwide process involving all the University System; its tuition fees are of the same level as those charged by the rest of the System. The rights of the founding institution are at present limited to the appointment of the Rector or President of the University, on nomination of the Academic Senate.

The University is a very prominent institution in Chilean public life, both through the professional activities of its graduates, a great many of them in influential positions, and through the research and extension work of its faculty, and the research services they offer. One such extension activity was the introduction of television in Chile, thirty years ago. Since then the University operates a television channel, the one with the highest ratings in the country, which in addition to entertainment, provides a yearly home-education course system (TELEDUC) which has been recently awarded funds by the Japanese Goverment.

Many innovations in the Chilean University System are traceable to this institution. For instance the process of changing from the old Spanish-american instruction based exclusively in part-time professors with no research activities, to a full-time faculty, was initiated in this country in the early '60s by the College of Engineering and the School of Business Administration of the Universidad Católica. And in a certain way, for the professional fields, it has been completely achieved only here. The same can be said of development programs for having these full-time faculty members obtain advanced degrees abroad.

b) Current State of the Universidad Católica

At present the University has in Santiago sixteen Colleges and Faculties distributed in the following four locations:

Campus Casa Central
Ave. Libertador Bernardo O'Higgins 360
Land Area: 24500 square meters
Built Area: 40500 square meters

Campus San Joaquín
Ave. Vicuña Mackenna 4860
Land Area: 759000 square meters
Built Area: 80000 square meters

Campus Oriente
Ave. José Battle y Ordoñez 3300
Land Area: 57000 square meters
Built Area: 13000 square meters

Campus Lo Contador
Ave. El Comendador 1916
Land Area: 15000 square meters
Built Area: 5200 square meters

drawings of these campuses are given in Appendix A.

The University has an academic staff of 771 full-time professors, 247 of which have doctoral degrees. In Regional Campuses in five locations south of Santiago, it has 303 professors, of which 55 have doctoral degrees.

The University has 16800 students, of which 11000 attend the four Santiago Campuses. These students are in general of the highest intellectual level. This is due to the fact that during the last ten years, the interest of high school graduates to enter this University has greatly increased. Actually, about half of the best graded students in the National Admission Test, choose to attend this University. Appendix B includes the corresponding details.

The budget of the Universidad Católica for 1988 is Chilean $ 6.002.871.000.; 63% of these funds are provided directly by the government. The budget presents balanced income and expenses. The previous figure does not include income from services. For reference consider that at present exchange rates 1 Yen = 2 Chilean $ aproximately.

2.2 The College of Engineering

a) History

The School of Engineering was founded in 1900, and during its first half-century, it followed very closely the model of its counterpart in the Universidad de Chile, actually, a typical patern in all Spanish America. However, at the end of the decade of the 50´s, it initiated a development plan devised to establish a full-time faculty devoted to research. The plan started by sending young engineers to worldwide renowned universities to obtain first a Master´s degree, then a Doctor´s degree. At present, the staff of the School of Engineering includes 72 full-time professors. More than half of the full-time professors hold Ph.D. degrees from major American universities or doctoral degrees from European institutions. Seventeen young faculty members are abroad following Ph.D. programs. In fact, the Ph.D. degree is now a requirement for promotion of faculty members.

b) Organization

The College of Engineering is formed by the School of Engineering and the School of Constructors. The latter school is oriented to the education of building contractors at a more practical level than Civil Engineers. The School of Engineering has 9 Departments as shown in the organization chart given in Appendix C. The facilities of the School of Engineering are located in the Campus San Joaquín; the buildings of the School of Engineering are shown in dark in the picture of the Campus San Joaquín included in Appendix A.

c) Student Body

The School of Engineering has 1500 undergraduate students engaged in a six-year program towards the professional degree of Civil Engineer. It should be noted that in Chile the word "Civil" is used to denote the quality or level of an engineering program, such as the word "Diplom" is used in German engineering degrees. In fact, graduates may major in a civil engineering field, or in an industrial engineering field, at their choice.

It is worthwhile mentioning that this School of Engineering, as it happens with the Universidad Católica as a whole, enjoys the best position from the point of view of the preferences shown by highschool graduates applying for admission to the Chilean University System. As it was mentioned before, the process of admission to Chilean Universities is administrated in a centralized way according to the results of a national test taken simultaneously by all applicants. During the last years, it has become apparent that there is a marked preference for engineering, and for this School of Engineering in particular. For instance, during the 1988 admission process, just completed, 30 out of the best 100 candidates of a whole of 130000 applicants to the University System, chose to study engineering, and 18 of those preferred this School of Engineering, with the other 12 almost equally divided among three other institutions. Appendix B gives more information on this point.

In addition to this undergraduate program, a three-semester Master of Science program is available; this program, initiated in 1984 as a research oriented degree, is designed to have a registration of about 100 students; at present it is operating at half its capacity.

d) Staff

As mentioned above the School of Engineering has 72 full-time professors and about the same number of part-time lecturers coming from the profession to help them in the teaching. The number of full-time academic staff of each Department is indicated in the organization chart presented in Appendix C.

All full-time professors have 44 hours/week contracts. Their working requirements in teaching, research, administration, service, and extension are variable. As an indication of the time dedicated to the various tasks, the average for the staff of the School of Engineering is given:

Teaching	33%
Reasearch	40%
Administration	15%
Services	8%
Extension	4%

e) Research

The research oriented training of the faculty members has led to a substantial research activity, as shown by the number of research projects that have been awarded after a tough competition for research funds; as of this moment, the School of Engineering through all its nine departments is developing 34 projects funded by the Research Division of the University, 15

projects funded by the National Research Agency, 12 projects funded by foreign agencies, and 9 by other national institutions. The results of this research activity are published in the form of papers and reports, that add up to a number of more than 200 per year. About 15% of these papers appear in the journal "Apuntes de Ingeniería" ("Engineering Records"), published quarterly by the School of Engineering, which is widely distributed to the Chilean research and professional community.

f) Budget of the School of Engineering

The budget of the School of Engineering in term of expenses for 1988 is given in the following table:

Salaries and Benefits		
Academic Staff	$ 296.000.000.-	
Technical and Administrative Staff	211.000.000.-	
Teaching Assistants	18.000.000.-	
Sub-Total		$ 525.000.000.-
Training of Academic Staff		52.000.000.-
Operating Expenses		27.000.000.-
TOTAL EXPENSES		$ 604.000.000.-

The previous figures do not include the operating expenses incurred in the service activity of the School of Engineering. The service activity covers quality control and applied research for industry in the private and public sectors.

2.3 The Department of Structural Engineering

a) Facilities of the Department

The Department has an office area in the Devés Hall on Campus San Joaquín. A drawing of this office area is included in Appendix A. The Department also has space in a separate building where the Laboratories of Structural Engineering and Geothecnical Engineering are. This building also has office space. Details of the space distribution of this Lab building and some pictures of the facilities are given in Appendix A.

b) Teaching and research staff

The Department has a teaching and research staff of ten full-time members, six of which have Ph.D. degrees, one a German diplom, another is at present working for a Ph.D. in the United States, and the last is a junior faculty member who will initiate graduate studies in the near future. Staff member resumes are given in Section 3.2 of this report. The academic categories of these staff members distribute as indicated in the following table. The table also includes the number of part-time lecturers that colaborate in the teaching activities but do not participate in research.

Full Professors	6
Associate Professors	2
Assistant Professors	1
Lecturer	1
Part-time lecturers	7

All the full-time staff of the Department will be involved in the Joint Study Project. Their teaching activities spread over a large spectrum of structural and geotechnical subjects so as to cover almost all the courses required for students majoring in the different fields of civil engineering.

c) Administrative and Technical Personnel

The activities of the Department are assisted by the following non-academic staff:

Mr. Ramón Lobos	Civil Engineer
Ms. Pamela Jenkins	Civil Engineer
Mr. Alfredo Marín	Civil Engineer
Mr. Raúl Alvarez	Civil Engineer
Mr. Jorge Maturana	Laboratory Technician
Ms. Alda Goffreri	Secretary
Ms. Myriam Fredes	Secretary
Ms. Josefina Uribe	Secretary
Ms. Rosemarie Kania	Secretary
Ms. Alejandra Bravo	Librarian (part-time)
Mr. Leonardo Lizama	Assistant Technician
Mr. Nelson Martínez	Assistant Technician
Mr. Manuel Ravelo	Assistant Technician
Mr. Andrés González	Assistant Technician

Mr. Gabriel González	Assistant Technician
Mr. Geremías León	Assistant Technician
Mr. Andrés Muñoz	Bore Drilling Technician
Mr. Juan Velásquez	Bore Drilling Technician
Mr. Héctor Calderón	Janitor
Mr. Roberto Arredondo	Janitor

d) Budget of the Department

The budget of the Department for 1988 in terms of expenses is the following:

Salaries and Benefits		
Academic Staff	$ 58.800.000.-	
Technical and Administrative Staff	18.365.000.-	
Teaching Assistants	3.250.000.-	
Sub Total		$ 80.415.000.-
Training of Academic Staff		1.900.000.-
Operating Expenses		1.300.000.
TOTAL EXPENSES		$ 83.615.000.-

These figures do not include operating expenses related to service to private and public sectors that the Department gives through the Geotechnical Engineering Laboratory. Typical services of the lab are soil mechanics tests and soil exploration.

e) Students

The undergraduate students most related to the department are those majoring in the subjects of Structural Engineering, Construction Engineering, Hydraulic Engineering, and Transportation Engineering (Structural Engineering includes Geotechnical Engineering). The yearly graduation count in these majors is about 30, 60, 10 and 10 respectively. Thus, about 110 students register in each of the courses offered by the Department which are common to these majors, while about 30 take the advanced courses offered by the Department for students majoring in Structural Engineering.

In addition to the undergraduate students the Department currently has 3 graduate students working towards the Master of Science degree. As mentioned above, the graduate program has been recently created in the School of Engineering.

f) Research

In contrast with the breadth of the teaching scope of the Department, the research activity of the professors is entirely focused towards earthquake engineering, up to the point that in certain fields they have proved to be among the most prominent experts in the country. The following are main research subjects:

Problems in design-oriented modelling of buildings, especially of buildings with lateral resistance provided by structural walls, with particular interest in the significance of three-dimentional effects. Implementation of computer programs for practical applications. Comparison with observed behavior in recent earthquakes. Simplified methods for preliminary design.

Behavior and design of reinforced masonry using local materials and building techniques. Static analysis of full-scale elements. Formulation of mathematical models. Proposals at code level. Evaluation of present code implicit safety as disclosed by behavior in the March 3, 1985 earthquake.

Evaluation of earthquake requirements on structures using Chilean ground motion data. Analysis of response spectra. Derivation of design spectra. Study of energy dissipation requirements. Seismic risk in Chile.

Dynamic properties of soils, with particular emphasis in saturated sands. Cross-hole and shaking table experimentals. Formulation of a mathematical model of seismic changes in the structure of a soil. Methods for seismic design of tailing dams. Comparisons with observed behavior of tailing dams during recent earthquakes.

Finite element techniques in Geotechnical Engineering. Flow in porous media, with special interest in fast draining of dams. Formulation of the general model for a step by step analysis of earth structures and implementation of the corresponding computer program.

Rock mechanics. Development of techniques for rock sampling. Formulation of a mathematical model for analysis of the stability of rock slopes.

All research is related to externally financed projects, though a substantial support comes from the regular budget of the Department through the availability of faculty, secretarial, and auxiliary personnel working-time, and the use of facilities and equipment without charge or overhead, as well as access to free computer time in the University mainframe.

Appendix D shows the projects under way at the moment, stating researchers involved, source and funds.

As can be observed, the main source is a fund set up by the central administration of the University for granting operating money to projects, selected under a competitive proposal system, judged by referees external to the University. The School of Engineering is normally awarded a very substantial amount of this fund, and the Department gets more than a proportional share of it.

Noteworthy among the University funded projects are "Evaluation of methods used for design and analysis of earthquake-resistant reinforced concrete structures using data from the Chilean earthquake of 3 March 1985" and "Behavior of reinforced masonry buildings during the 3 March 1985 earthquake and implications for their earthquake-resistant design" that serve as a complement to the projects financed by the National Science Foundation of the United Stated, "Evaluation of methods used for design and analysis of earthquake-resistant reinforced concrete structures using data from the Chilean earthquake of March 3, 1985" and "Evaluation of design and analysis techniques for masonry structures based on the performance in the Chilean earthquake of March 3, 1985", respectively. This mechanism to provide money to enhance the participation of University professors in international projects is not only permitted, but specifically encouraged by the grant giving agency. This is important for the intended JICA cooperative program, as it could help the Chilean professors involved in securing funds for research assistants, other personnel, and expenses not financed by JICA.

g) Dissemination of Research Results

Previous projects already finished have led to a substantial number of publications in the past. For further reference, those published in the last three years are included in Appendix E.

As can be observed from the above mentioned list, a great many items correspond to papers presented in conferences. In particular, the 4th Chilean Conference on Earthquake Engineering held in April 1986 in Viña del Mar, saw a very active and distinguished participation of the Department members. The journal "Engineering Records" periodically has issues reserved for earthquake engineering that are widely distributed to the profession.

A very significant activity of the departmental faculty in which their research findings can be very conveniently trasmited to the professional community, is their deep involvement in the code generating process. Chilean codes and standards are prepared by a normalizing institution that borrows the time of technical personnel from research centers to prepare drafts that are then subjected to public discussion, and are finally approved by a panel formed by prominent specialists from the profession, and again, from the universities. The involvement through the last years of many professors of the department in one or all of these three stages has been most significant. Recently issued codes for Reinforced Masonry Design and for Minimum Load Specifications are in

a large amount the result of this effort. The involvement of the departmental faculty in the Reinforced Concrete Design Code and the draft of the Earthquake-Resistant Design of Buildings Code, now under revision, is very deep, as well as broad, as it includes practically all subjects dealt in each code.

h) Equipment Management

The laboratories of the Structural Engineering Department are housed in a 1000 square meters building, erected 13 years ago (See Appendix A). In addition, there is a very closely associated materials lab, dependent from the Construction Engineering Department. Another closely related lab, with which interchange of equipment is frequent, is the Mechanical Engineering lab, dependent from the corresponding Department.

Both laboratories of the Department have a number of modern testing systems, such as an MTS hydraulic dynamic actuator, a dynamic triaxial soil test system, a set of static hydraulic, single action actuators, several transducers for displacement and acceleration measurements, and several graphic recorders. This equipment has been in operation for a number of years, due to the care that has been used in handling it and to the availability of electronic technicians provided by the Electrical Engineering Department, on the basis of the internal transfer of maintenance funds allocated yearly in the departmental budget, or through payment from funds available as operating expenses of an on-going research project. The electronic shop is directed by a very competent electrical engineer who has under him three electronic technicians. Both NEC computers suplied by the two previous JICA missions have been serviced in a very satisfactory way by this maintenance system.

A list with the most important equipment in the laboratories of the Department is presented in Appendix F.

3. The Joint Study Project on Seismic Design of Structures in Chile

3.1 Introduction

The research programs to be developed within the frame of this project have been focused on three subjects in which the members of the faculty of the Universidad Católica are actively working. It is felt that in these areas the joint effort of the Chilean research team and of the Japanese experts will be most fruitful. The valuable equipment that the Japanese Goverment will provide shall find in this project full and effective use, even after it reaches to an end. The programs chosen are of direct interest to the Chilean community as a contribution to the reduction of earthquake hazard through a more thorough knowledge of the local seismic and geotechnical conditions, and through a better understanding of the earthquake response characteristics to be expected in buildings of the typical architectural and constructive techniques of the country. They are also of interest to the Japanese community, being on the one hand, valid topics of research in themselves, and being on the other, subjects related to the behavior of structural layouts and materials that may eventually interest Japanese constructors. The task of defining these programs and analyzing their potentialities was performed by the three Japanese Missions referenced before. In the course of their most productive visits they established tentative formulation of joint research programs with increasing detail and precision. This Preliminary Implementation Survey Team has now thoroughly restudied the proposition of the Third Japanese Mission, and has given the three programs the final presentation of the following sections.

3.2 Personnel and Facilities for the Joint Project

a) Personnel for the Project

The Chilean study team will be headed by Professor Rafael Riddell.

The members participating in each program are the following:

Earthquake Engineering Program: Rafael Riddell (Coordinator)
Jorge Vásquez
Ernesto Cruz
Michel Van Sint Jan
Carl Lüders
Juan Carlos de la Llera

Structural Engineering Program:	Carl Luders (Coordinator)
	Pedro Hidalgo
	Rodrigo Jordán
	Ernesto Cruz
Soil Dynamics Program:	Jorge Troncoso (Coordinator)
	Fernando Rodríguez
	Bernardo Domínguez
	Eduardo Varas

A short resume of each of the Chilean faculty members participating in the joint study project is presented below in alphabetical order. Data includes name, position, date of birth, academic experience, and research interests:

Ernesto Cruz, Associate Professor, born 1954, Civil Engineer Universidad Católica de Chile (1977), M.S. University of California, Berkeley (1980), Ph.D University of California, Berkeley, (1985), joined the Department in 1977. He works in simplified models for earthquake analysis and design of buildings, having developed considerable experience in software development for microcomputers and main frame systems, as well as in the handling of computers and interfacing them to other digital equipment such as data acquisition systems. He is the professor in charge of the strong motion intruments managed by the Department.

Juan Carlos de la Llera, Lecturer, born 1961, Civil Engineer Universidad Católica de Chile, (1985), joined the staff of the Departament in 1987 after two years as Research Assistant. His main interest is focused to the analysis and earthquake-resistant design of reinforced concrete buildings, having worked under Professor Riddell in the evaluation of the analysis and design methods of the high-rise buildings of Viña del Mar that experienced damage during the Chilean earthquake of March 3, 1985. He is schedule to depart in August 1989 to obtain his Ph.D. degree.

Pedro Hidalgo, Professor, born 1939, Civil Engineer Universidad Católica de Chile (1963), M.S. University of California, Berkeley (1966), Ph.D University of California, Berkeley, (1975), joined the Department in 1963. He has worked in the Earthquake Engineering Research Center of the University of California, Berkeley, first in shaking table tests of full size two-story reinforced concrete frame structures, and afterwards conducting over 40 quasi-static cyclic shear tests of reinforced masonry shear walls. He presently works in both experimental and analytical research of reinforced masonry structures, and analytical research in reinforced concrete, and since

1980 has steadily worked in the discussion of structural and earthquake-resistant design codes in the Institute of National Standards. He intends to continue with his integrated research-code implementation work in the future.

Rodrigo Jordán, Assistant Professor, born 1955, Civil Engineer Universidad Católica de Chile (1978), joined the Department in 1978. He is now working for his Ph.D. degree at the University of Texas, Austin, and his thesis subject is the development of methods to repair reinforced concrete elements damaged during earthquakes. He is schedule to return in early 1990. Prior to his departure to Austin, he worked in analytical research with Professor Hidalgo, both in reinforced masonry and reinforced concrete.

Carl Lüders, Professor, born 1937, Civil Engineer Universidad Católica de Chile (1964), Diplom Ingenieur; Technische Hochschule, Darmstadt, West-Germany (1967), joined the Department in 1963. He has been in charge of the Structural Engineering Laboratory since 1968 and has a vast experimental experience on both in-situ and laboratory tests. His work has covered both academic research and tests performed for construction companies and structural engineers through the Office of Research Services. Lately, he became the chairman of the code commitee of the reinforced concrete Chilean code. His research activity has focused on the seismic behavior of reinforced masonry walls, where he has carried out more than 40 quasi-static cyclic shear tests. He plans to continue with this work, including the study of methods to repair such walls damaged during earthquakes; he also intends to conduct tests on reinforced concrete elements to validate some of the new code provisions.

Rafael Riddell, Professor, born 1946, Civil Engineer Universidad Católica de Chile (1970), M.S. University of Illinois, Urbana-Champaign, (1976), Ph.D University of Illinois, Urbana-Champaign, (1979), joined the Department in 1970. He has served as Director of the Office of Research Services of the College of Engineering for four years, and he is presently the Head of the Department. He has been active in the area of seismic risk and design spectra for the last nine years since he wrote his Ph.D. thesis under Professor Newmark. He has been recently involved in the definition of the design earthquake spectra and seismic zoning for the new Chilean code under study. He is also interested in seismic behavior and earthquake resistant design of reinforced concrete buildings.

Fernando Rodríguez, Professor, born 1944, Civil Engineer Universidad Católica de Chile (1967), Doctor of Engineering, Politechnical University of Madrid, Spain, (1977), joined the

Department in 1977. He is presently the Head of the Geotechnical Engineering Laboratory in charge of the laboratory and in situ soil tests and soil mechanics studies for private contractors and mining companies. His research activity is focused on the numerical methods (finite elements) to solve a number of practical problems, such us the earthquake response of earth dams, the design forces for the lining of tunnels, the design of concrete slabs resting on a soil base, etc.

Jorge Troncoso, Professor, born 1937, Civil Engineer Universidad Católica de Chile (1962), M.S. University of Illinois, Urbana-Champaign, (1966), Ph.D University of Illinois, Urbana-Champaign, (1975), joined the Department in 1967. He has been working in Geotechnical Engineering since 1963 participating in research and consulting projects mainly related to earthquake geotechnical engineering and applications to civil and mining engineering. His main accomplishments are the development of wave propagation tests for in-situ determination of soil shear modulus and damping ratio as functions of strain, the analyses of seismic behavior of earth structures and tailings dams, the study of liquefaction of silty sands and related effects of aging and seismic history, and the solution of complex problems of design and construction of deep excavations, slope stability and foundations on soft ground.

Michel Van Sint Jan, Associate Professor, born 1945, Civil Engineer Universidad Católica de Chile (1971), M.S. University of Illinois, Urbana-Champaign, (1975), Ph.D University of Illinois, Urbana-Champaign, (1982), joined the Department in 1971. He develops his research activity in the field of rock mechanics, with particular interest in the practical problems that face the mining companies in Chile. However, his strong background in geology and soil mechanics has permitted him to get involved in earthquake zonation problems and to initiate a research activity in soil-structure interaction that is much needed by the professors of the Department that work in the structural problems. In particular, he is working in the type of models and soil properties needed to study the influence of soil in the earthquake response of structures.

Jorge Vásquez, Professor, born 1938, Civil Engineer Universidad Católica de Chile (1963), M.S. University of California, Berkeley (1965), Ph.D University of California, Berkeley, (1972), joined the Department in 1963. He has worked during the last few years in modelling of buildings for earthquake design, with particular concern for the problem of torsion and three-dimensional compatibility. He has recently implemented a very flexible structural modelling computer program that can be used as and aid in teaching as a means to study irregular structures difficult to model and as a modular system to develop new research programs.

Also in the project will participate the following faculty members of other Departments of the School of Engineering:

Bernardo Domínguez, Professor, born 1943, Civil Engineer Universidad Católica de Chile (1967), Doctor of Engineering, Institute National Politechnique de Toulouse, France (1977). He is presently the Dean of the College of Engineering. His research activity is focused on soil transportation, sedimentation and deposition by hydraulic methods, in the Hydraulics Engineering Department.

Eduardo Varas, Professor, born 1941, Civil Engineer Universidad Católica de Chile (1965), Ph.D. Stanford University (1976). His research activity is focused on hydrology, in the Hydraulic Engineering Department, and he has participated in research projects on soil dynamics with water seepage through soils and pore water pressure measurements in oil deposits.

b) Facilities

The facilities of the Department have been described in Section 2.3.a) of this report. The equipment requested for this project will be installed in the Laboratory building of the Department. Site accelerographs will be housed in special instrument shelters located in restricted access areas.

3.3 Earthquake Engineering Program

a) Subject

Evaluation of Design Seismic Forces Appropriate for the City of Santiago.

b) Objective

The purpose of the proposed research is to contribute to the definition of earthquake design requirements that reflect the characteristics of the motion that can be expected for different areas in the City of Santiago, from the point of view of both the ground motion and the structural response of the typical buildings of the city.

To attain this general objective it is necessary to pursue the following specific objectives: a) to obtain a thorough knowledge of the ground motion in sites of different soil conditions, and b) to assess the characteristics of the response of the buildings typical of the Santiago area. To achieve these goals, this program includes the installation of strong motion accelerographs and the use of microtremor measuring techniques.

The program will provide instrumental backing to the work of researchers from other institutions that have been trying to produce zonation specifications from geomorphological considerations and interpretation of the observed geographical distribution of damage. The results obtained will be of interest to practicing engineers designing important buildings in the city, the Ministry of Housing, the Ministry of Construction, and the National Code Writing Agency. After completion of the program, the Chilean team will continue to give the same use to the equipment.

The microtremor studies of a significant number of buildings in Santiago will also provide a test of the validity of the structural models in use for the design of such buildings. A data bank of natural periods, damping coefficients and mode shapes will be created, for use after the occurrance of a moderate or large scale earthquake.

c) Procedure

The first activity of the program will be the selection of the specific locations where the accelerographs are to be installed. This sites will be chosen within five areas in a city that is fairly extended through a valley with widely different soils, and for which there is up to the present no strong motion acceleration record. The preselected areas are:

1. **Central Area.**
   Alluvial deposit of very dense coarse gravel, with up to 20 cm-diameter cobbles. Depth to water table, about 55 m. At about 250 m from the porposed instrument site Santa Lucía hill emerges as an "island hill" and raises some 60 m above the alluvial plain which sorrounds it. The geological conditions of this site are characteristic of a large part of the city where the majority of the tall buildings are located.
2. **Renca.**
   Layers of saturated compressible silts and clays of medium plasticity, (N = 8 to 10; Su = 0.5 kgf/cm^2 interbedded with lenses of sand and sandy gravel. Depth to the water table, about 1 m. Depth to rock, about 200 m. This is an area of steady growth of construction of industrial facilities and low income housing projects.
3. **East Ñuñoa.**
   Dense and firm silt of medium compressibility interbedded with 5 to 10 cm-thick layers of dense silty gravel and sands. Unsaturated soil. Thickness of the stratum, more than 20 m. Depth to water table, more than 90 m. Depth to rock, estimated 100 m. This is an area of new development of low and middle rise buildings.

4. **Santa María de Manquehue.**
   Fine-grained solils (sils, silty sands and clays of low platicity) in layers of rapidly decreasing depth at the foot of mountains. This is an area of expensive individual residential units and of clean industries and research institutions facilities.
5. **Maipú.**
   Soil of volcanic origin, defies USCS classification. Made up of cuiders, ashes and pumice. Firm and brittle; unsaturated. More than 20m thick. This is a highly industrialized area and its becoming a densely populated low and middle income residential area.

The five sites are indicated on the Geological Map of Santiago included in Appendix G.

The next step of the program will be the actual installation of the accelerographs in bases and shelters that will be prepared previously.

Each site will subjected to a thorough sub-soil exploration, considering at least a 30m bore drilling, testing of samples, and detailed microtremor studies. The instruments will allow to determine the differences of the spectral characteristics, both on normal response spectra and also on Fourier Amplitude and Phase spectra of motions registered in different soils.

Following the ground motion study, microtremor studies of the response of a number of buildings in the City of Santiago will be performed. Most of these buildings will have the typical Chilean structural layout, characterized by heavy use of structural walls. This type of construction is rather unique for tall buildings, and there is little information about their actual earthquake response, so that the validity of the structural models in use has not been adequately verified. The performance of these buildings during the recent earthquake was quite satisfactory from the safety point of view, but the structural damage was in no way negligeable, with considerable wall cracking and destruction of lintels.

The results of microtremor measurements will be compared with analytical results using different structural models. They will also be classified and adequately documented so as to serve for comparisons with microtremor measurements to be performed after a medium or large scale earthquake.

As a part of the program, software for the analysis of recorded information, both from the strong motion equipment, end the microtremor devices will be prepared in a way that they can be routinely used in the future.

d) List of equipment requested

The equipment requested is the following:

Digital strong motion accelerographs for 5 sites	1 set
Recording and play-back unit	1 set
Micro tremor measurment	1 set

The use that will be given to the accelerographs has been described above. The play-back unit is necessary to read the tapes produced by the instruments and convert the information to a computer readable format.

e) Chilean Research Team

The faculty members participating in this program will be Professors R. Riddell, J. Vásquez, M. Van Sint Jan, E. Cruz and J.C. de la Llera. Professor R. Riddell will serve as coordinator.

3.4 Structural Engineering Program

a) Subject:

Seismic Behavior of Reinforced Concrete and Reinforced Masonry Structures.

b) Objective

The main objective of this program is to study the experimental seismic behavior of reinforced masonry and reinforced concrete shear walls and to develop better models to predict their strength and deformation capacity. Since almost all the buildings that are constructed in Chile use shear walls as earthquake-resistant elements, this knowledge will permit to improve the earthquake-resistant design of such buildings. The research conducted in other earthquake countries is primarily oriented to frame-type structures, which are unusual in Chilean construction; consequently, Chilean researchers cannot apply all of the results obtained elsewhere and are being forced to carry out the experimental and analytical research for this type of buildings. Moreover, the structural behavior observed during the damaging earthquakes that struck central Chile and Mexico City in 1985 and San Salvador in 1986 showed that shear wall-type buildings have many advantages over the frame-type buildings from the seismic behavior point of view.

c) Procedure

The work that will be developed during this program will include part of the tests that belong to the ongoing experimental research program at the Structural Engineering Department. However, the last series of tests will make use of the new equipment supplied by JICA.

The test program that is indicated below is restricted to reinforced masonry walls constructed with clay brick units. The parameters included in this study are the aspect ratio of the wall, the amount of horizontal reinforcement, the axial compression load and the type of grouting. The experimental work is scheduled as follows:

First and second years : Seven tests with aspect ratio M/Vd equal to 1.00, horizontal reinforcement ratios of 0.0006 and 0.0012, axial compressive stress of 0.025 MPa and 0.5 MPa.

The new equipment is expected to arive and get into service during the final months of the second year of this program.

Third year : Seven tests with aspects ratios of 1.00, 0.60 and 0.35, and selected values of the other parameters. The new equipment should be used to run some of these tests.

The results that will be obtained during this program and afterwards from the test of reinforced concrete elements, will be transferred to the engineering practice through propositions to the Institute of National Standards to improve the earthquake-resistant design codes on reinforced masonry and reinforced concrete structures. Concerning this aspect, it is appropriate to note that Prof. Hidalgo has worked since 1980 as a part-time member of this institute and presently is a member of a four-men committee that has to coordinate the work of five research committees and write the draft of the new Chilean code "Earthquake-Resistant Design of Buildings". Prof. Lüders has also served as member of several code committees and presently is the chairman of the code committee "Design of Reinforced Concrete Structures".

d) List of Equipment Requested

At present, the Structural Engineering Laboratory only has equipment to carry out experimental research on reinforced masonry walls, using a quasi-static type of test. The support of JICA to this program will permit the transfer of the Japanese technology in on-line data acquisition systems connected to microcomputers that process the information and perform the data reduction. This would improve considerably the facilities available at the University to carry out experimental research on the seismic behavior of structural components. Moreover, the availability of a computer-controlled actuator system will make possible to control and study in a better way the

behavior of the walls between the ultimate strength and collapse of the specimen. Particularly, it will permit to have constant axial compression stresses on the specimens during the shear quasi-static tests.

Appendix H shows how the equipment requested will be assembled in the laboratory with the other equipment that is already available. The requested list of the equipment follows:

1.	Actuator system (±50 ton, ±200 mm): actuator servo-controller load cell electric oil pump unit (220 volts, 50 Herz).	1 set
2.	D/A converter for microcomputer, 12 bits, 2 channels.	1 set
3.	A/D converter for microcomputer, 12 bits, 8 channels.	1 set
4.	Scanning box, 50 channels.	1 set
5.	Loading Frame.	1 set

e) Chilean research team

The faculty participants in this project will be Professors C. Lüders, P. Hidalgo, R. Jordán and E. Cruz. Professor C. Lüders will serve as coordinator.

3.5 Soil Dynamics Program

a) Subject

Dynamic Properties of Soils for Seismic Design of Structures and Foundations

b) Objectives

The main objectives of this program are to investigate fundamental dynamic properties of soils, such as cyclic stregth and liquefaction potential, in relation with seismic design of structures and foundations. These studies take into consideration important special effects such as aging and seismic history, and using the experiences derived from recent earthquakes as the one of March 3, 1985.

The investigation shall concentrate in soils which represent high risks of failures to structures supported on them or to structures built with these soils. These failures may be related to a decrease of bearing capacity, liquefaction or high displacements.

The results of this investigation should permit to improve the methods of design of foundations and structures in seismic zones.

c) Procedure

Deposits of soils of high risk of liquefaction or of critical behavior shall be studied in detail to determine their cyclic strength and their compressibility. These studies will be applied in the evaluation of seismic behavior of structures and in the design of structures and foundations.

First, three or five appropiate soil deposits shall be selected for in-depth study. Selection shall be based upon the following criteria:

1. High liquefaction or seismic failure potential.
2. Deposits shall have well documented soil properties or well documented seismic behavior.
3. Deposits shall be located in a zone of high seismic activity.
4. Deposits shall be located inside a zone with a radius of about 150 km from Santiago.
5. Deposits shall be composed by soils of different properties.

Second, piezo-cone resistance tests shall be conducted at each site in a number of points sufficient of determine shear strength characteristics as a function of depth and as a function of age. At this stage correlatives shall be established between in-situ properties and piezo-cone resistance, and between piezo-cone resistance and mechanical and index properties measured in laboratory.

Third, laboratory tests shall be performed, in addition to those already available, in undisturbed samples and in compacted samples using cyclic triaxial equipment, to obtain a complete profile of soil dynamic properties of each selected site.

Fourth, in-situ equipment shall be installed in one of the selected sites to record pore water pressures during occurrence of earthquakes. To this purpose, four dynamic piezometers shall be installed in different points to verify real pore water pressure variations in the different soils of the deposit. Two accelerometers shall be installed one with the purposes of on the surface of the deposit and one at the bottom, recording the accelerations, assessing amplification effects and estimating seismic stresses which cause the pore water pressure variations.

Fifth, analytical studies shall be performed to interpret the results of the investigation.

d) List of Equipment Requested

1. Piezo-cone penetrometer
2. In-situ seismic pore water pressure recording equipment
3. Cyclic triaxial cell

e) Chilean Research Team

The faculty members participating in this program will be Professor J. Troncoso, F. Rodríguez, B. Domínguez and E. Varas. Professor J. Troncoso will serve as coordinator. Civil Engineer R. Lobos, Engineer of the Soil Mechanics Laboratory, shall cooperate in Laboraty and in-situ testing of soils.

3.6 Tentative Implementation Program

a) Experts from Japan to Chile

Both long term and short term Japanese experts will be dispatched to Chile to work in the project together with the Chilean study team at the Universidad Católica de Chile.

Experts in equipment will also be sent to install the equipment, perform the necessary adjustments to leave the equipment in operating conditions, and provide all information necessary for maintenance and service.

b) Training of Chilean Personnel in Japan

Academic staff members of the Structural Engineering Department will visit Japan for exchange of scientific information, technical discussion on joint study matters, and/or seminar presentation. The aproximate schedule and duration of visits is the following:

Professor	Beggining of visit	Duration of visit
Ernesto Cruz	March 1, 1989	40 days
Jorge Troncoso	September 1, 1989	30 days
Carl Luders	March 1, 1990	60 days
Rafael Riddell	April 20, 1990	30 days
Pedro Hidalgo	March 1, 1991	40 days
Jorge Vásquez	April 1, 1991	40 days

c) Equipment

The time of arrival of the requested equipment is indicated in the Tentative Schedule on page 38 of this report. The equipment for each program shall arrive prior to the arrival of the long term experts in each project.

d) Reports

It is expected that the joint study will produce several technical publications. Regardless of publications on specific research findings, two global reports will be issued reporting the work done in the project. A mid term report will be issued 2 years after the beggining of the project.t A final report will be issued at the end of the project in 1991.

e) Budget

The Universidad Católica de Chile will provide as counterpart the cost of the time dedicated to the project by the academic and non-academic personnel, as well as operating expenses, and cost of installation of equipment in the laboratories and in the field.

3.7 Working Conditions of Japanese Experts

a) Office

Each long term Japanese expert will be given one office room similar to those ordinarely occupied by faculty members. Short term experts will receive one office room. The offices will be located either at Devés Hall or at the Department Laboratory Building, depending of the nature of the expert's activities.

b) Phone

Experts will have a telephone extension at their desks and, as is the case with faculty, they will not be charged for local calls.

c) Secretary and typist

The Department clerical personnel will work for the experts on the same basis as for faculty members. This will, of course, include typing of letters or documents in Spanish or English.

d) Car

Transportation of short term experts to and from their hotel or residence to the University Campus will be provided by the Departament's personnel in private or institutional cars.

4. DRAFT OF RECORD OF DISCUSSIONS

To implement the joint project explained above, the Japanese team and the Department of Structural Engineering of the Universidad Católica agreed on the draft of the Record of Discussions starting on the next page.

RECORD OF DISCUSSIONS

THE RECORD OF DISCUSSIONS BETWEEN THE JAPANESE IMPLEMENTATION SURVEY TEAM AND THE AUTHORITIES CONCERNED OF THE GOVERNMENT OF THE REPUBLIC OF CHILE ON THE JAPANESE TECHNICAL COOPERATION FOR THE JOINT STUDY PROJECT ON SEISMIC DESIGN OF STRUCTURES IN CHILE

The Japanese Implementation Survey Team (hereafter referred to as "the Team") organized by the Japan International Cooperation Agency (hereafter referred as "JICA") and headed by _____, visited the Republic of Chile from ____ to ____ for the purpose of working out the details of the technical cooperation program concerning the Joint Study Project on Seismic Design of Structures (hereafter referred to as "the Project").

During its stay in Chile, the Team exchanged views and had a series of discussions with the Chilean authorities concerned in respect of the desirable measures to be taken by both Governments for the successful implementation of the Project.

As a result of the discussions, the Team and the Chilean authorities concerned agreed to recommend to their respective Governments the matters referred to in the Document attached hereto, based on "ACUERDO SOBRE COOPERACION TECNICA ENTRE EL GOBIERNO DEL JAPON Y EL GOBIERNO DE LA REPUBLICA DE CHILE" (the Agreement on Technical Cooperation between the Government of Japan and the Government of the Republic of Chile) signed at Santiago on July 28, 1978.

Santiago, Chile, _____1988

_____	_____
(name)	(name)
Head of Japanese Implementation Survey Team	Rector of Universidad Católica de Chile
Japan International Cooperation Agency Japan	The Republic of Chile

_____

Witness: Government Official
Ministry of Education
The Republic of Chile

THE ATTACHED DOCUMENT

I. COOPERATION BETWEEN BOTH GOVERNMENTS

1. The Government of Japan and the Government of the Republic of Chile will cooperate with each other in implementing the Project, for the systematic studies, development and improvement of the scientific techniques against earthquake disasters in Chile.

2. The Project will be implemented in accordance with the Master Plan which is given in ANNEX I.

3. General conditions of cooperation between both governments in implementing the Project will be based on the Agreement on Technical Cooperation between the Government of Japan and the Government of the Republic of Chile.

II. DISPATCH OF JAPANESE EXPERTS

1. In accordance with the laws and regulations in force in Japan, the Government of Japan will take necessary measures through JICA to provide at its own expense the services of the Japanese experts as listed in ANNEX II through the normal procedures under the Technical Cooperation Scheme of the Government of Japan.

2. The Japanese experts referred to in 1 above will be granted in the Republic of Chile the privileges, exemptions and benefits no less favourable than those granted to experts of third countries or/of international organizations performing similar missions in the Republic of Chile.

III. PROVISION OF MACHINERY AND EQUIPMENT

1. In accordance with the laws and regulations in force in Japan, the Government of Japan will take necessary measures through JICA to provide at its own expense such machinery, equipment and other materials necessary for the implementation of the Project as listed in ANNEX III, through the normal procedures under the Technical Cooperation Scheme of the Government of Japan.

2. The articles referred to in 1 above will become the property of the Government of the Republic of Chile upon being delivered C.I.F. to the Chilean authorities concerned at the ports and/or airports of disembarkation, and will be utilized exclusively for the implementation of the Project in consultation with Japanese experts referred to in ANNEX II.

IV. TRAINING OF CHILEAN PERSONNEL IN JAPAN

1. In accordance with the laws and regulations in force in Japan, the Government of Japan will take necessary measures through JICA to receive at its own expense Chilean personnel connected with the Project for technical training in Japan through the normal procedures under the Technical Cooperation Scheme of the Government of Japan.

2. The Government of the Republic of Chile will take necessary measures to ensure that the knowledge and experience acquired by the personnel from technical training in Japan will be utilized effectively for the implementation of the Project.

V. LOCAL EXPENSES

The budget to meet the local expenses necessary for the implementation of the Project will be provided to the Japanese expert by JICA in accordance with the laws and regulations in force in Japan and will be managed by the Japanese expert designated by JICA.

VI. DATA OWNERSHIP AND PUBLICATION

The data accumulated through the Project will be jointly owned by the participatin organizations (JICA, Japanese Ministry of Construction and Universidad Católica). When the reports or documentations concerning the Project are compiled and published, it is to be mentioned that the Project has been implemented by JICA and Universidad Católica as the Technical Cooperation Project between the Government of Japan and the Government of the Republic of Chile.

VII. MEASURES TO BE TAKEN BY THE GOVERNMENT OF CHILE THROUGH THE AUTHORITIES CONCERNED

1. In accordance with the laws and regulations in force in the Republic of Chile the Government of the Republic of Chile will take necessary measures through the authorities concerned to provide at its own expense:

(1) Services of the Chilean counterpart personnel and administrative personnel;

(2) Supply or replacement of machinery, equipment, instrument, vehicles, tools, spare parts and any other materials necessary for the implementation of the Project other than those provided through JICA under III above;

(3) Transportation means for official trips of Japanese experts within the Republic of Chile;

(4) Facilities necessary for the maintenance and protection of machinery, instruments, and tools listed in ANNEX III.

2. In accordance with the laws and regulations in force in the Republic of Chile, the Government of the Republic of Chile will take necessary measures through the authorities concerned to meet:

(1) Expenses necessary for the transportation within the Republic of Chile of the articles referred to in III above as well as for the installation, operation and maintenance thereof;

(2) Customs duties, internal taxes and any other charges, imposed in the Republic of Chile on the articles referred to in III above;

(3) All local expenses necessary for the implementation of the Project other than those provided through JICA under V above.

VIII. ADMINISTRATION OF THE PROJECT

The leader of the Japanese Study Team and the leader of the Chilean Study Team will collaboratively assume the overall responsibility for the implementation of the Project.

Resident Representative of JICA in Chile will undertake the role of advice and coordination for the successful implementation of the Project.

IX. MUTUAL CONSULTATION

There will be mutual consultation between the two Governments on any major issues arising from, or in connection with this Attached Document.

X. TERM OF COOPERATION

The duration of the technical cooperation for the Project under this Attached Document will be three (3) years from December 1, 1988 to November 30, 1991

ANNEX	I	MASTER PLAN
ANNEX	II	PROJECT TEAM AND PARTICIPATING ORGANIZATION
ANNEX	III	LIST OF ARTICLES
ANNEX	IV	TENTATIVE IMPLEMENTATION SCHEDULE

ANNEX I. MASTER PLAN

1. Background and Objective

Chile, situated on the Circum-Pacific Seismic Belt like Japan, has suffered tremendous damage due to the past destructive earthquakes, therefore, it is a top priority for Chile to take measures against future disasters.

For the purpose of developing this field, the fundamental studies on prevention and mitigation of earthquake disasters have been done by several institutions in Chile, and since 1960 the Japanese Government has been carrying out technical cooperation in this field, receiving more than 30 Chilean trainees into Japan. Moreover, in order to offer lectures at seminars and supply equipment with instructions on them, since 1984 the Japanese Government has sent to the Universidad Católica three missions of short-term experts in the field of Earthquake Engineering and Soil Dynamics: the first from November 24 to December 18, 1984 (3 experts); the second from January 11 to 29, 1986 (3 experts); and the third from March 3 to 29, 1987.

Through these cooperations, both Chilean and Japanese researchers have realized that it is quite fruitful for them, not only from the academic viewpoint but also from its practical effects on the administrative measures, to exchange information and experiences concerning various problems of Earthquake Engineering. Considering the abundant academic knowledge and strong research potentialities of the group at the Universidad Católica which are not fully developed because of the lack of equipments etc., both sides have come to realize that it is extremely useful to advance Joint Study further, extending the scale of cooperation.

Based on the above mentioned backgrounds, this Joint Study Project aims at the systematic studies, development and improvement of the scientific techniques against earthquake disasters in Chile.

2. Study framework

The Project will cover the following study items:

(1) Earthquake Enginering: Evaluation of Design Seismic Forces Appropriate for the City of Santiago.

(2) Structural Engineering: Seismic Behavior of Reinforced Concrete and Reinforced Masonry Structures.

(3) Soil Dynamics: Dynamic Properties of Soils for Seismic Design of Structures and Foundations.

ANNEX II. PROJECT TEAMS AND PARTICIPATING ORGANIZATIONS

The Project will be jointly implementated by the Japanese Study and the Chilean Study Team. Each Team consists of the following experts:

1. The Japanese Study Team

Team Leader:

Researchers/Experts in the field of:
- Earthquake Engineering
- Structural Engineering
- Soil Dynamics

2. The Chilean Study Team

Team Leader: Rafael Riddell

Researchers/Experts in the field of:

- Earthquake Engineering:	Rafael Riddell (Coordinator)
	Jorge Vásquez
	Ernesto Cruz
	Michel Van Sint Jan
	Carl Lüders
	Juan Carlos de la Llera
- Structural Engineering:	Carl Lüders (Coordinator)
	Pedro Hidalgo
	Rodrigo Jordán
	Ernesto Cruz
- Soil Dynamics:	Jorge Troncoso (Coordinator)
	Fernando Rodríguez
	Bernardo Domínguez
	Eduardo Varas

ANNEX III. LIST OF ARTICLES

	ITEM	
1.	Observation of Ground Motion	
	(1) Digital Strong Motion Accelerographs for 5 sites:	1 set
	(2) Recording and Play-back unit:	1 set
	(3) Micro Tremor Measurement:	1 set
2.	Structural Testing	
	(1) Actuator System (±50 ton, ±200 mm):	1 set
	actuator	
	servo-controller	
	load cell	
	electric oil pump unit (220 volts, 50 Herz).	
	(2) D/A Converter for microcomputer, 12 bits, 2 channels.	1 set
	(3) A/D Converter for microcomputer, 12 bits, 8 channels.	1 set
	(4) Scanning Box, 50 channels.	1 set
	(5) Loading Frame.	1 set
3.	Soil Testing	
	(1) Piezo-Cone Penetrometer:	1 unit
	(2) In-situ Seismic Pore Water Pressure Recording Equipment	1 set
	(3) Cyclic Triaxial Cell:	1 unit

ANNEX IV. TENTATIVE IMPLEMENTATION SCHEDULE

ITEM	1988 1 3 5 7 9 11	1989 1 3 5 7 9 11	1990 1 3 5 7 9 11	1991 1 3 5 7 9 11
1. Assigment of Japanese experts				
1) Long-term Experts				
(1) Earthquake Engineering		xxxxxxxxxxxxxxxx		
(2) Structural Engineering			xxxx	xxxxxxxxxxx
(3) Soil Dynamics			xxxxxx	
2) Short-term Experts (Earch for 1 month)				
(1) Earthquake Engineering		x	x	x
(2) Structural Engineering		x	x	x
(3) Soil Dynamics		x	x	x
(4) Equipment Experts	x		x x	
2. Provisions of Machinery/Equipment				
(1) Earthquake Engineering	x			
(2) Structural Engineering			x	
(3) Soil Dynamics			x	
3. Training of Chilean personnel in Japan		x x	xx	xx
4. Seminars at Universidad Católica		x	x	x
5. Reporting and Joint Chilean/Japanese meeting	Δ		O	Ô

Δ: Joint meeting O: Interim report Ô: Final Report

5. CONCLUDING REMARKS

The Japanese team and its counterpart in the University Católica discussed on the Joint Study Project on Seismic Design of Structures in Chile to agree with the detailed procedure for the project implementation and define the draft of the Record of Discussion (R/D).

The project, which is scheduled from December 1988 to November 1991, will cover the following three subjects:

1. Earthquake Engineering: Evaluation of Design Seismic Forces Appropiate for the City of Santiago.
2. Structural Engineering: Seismic Behavior of Reinforced Concrete and Reinforced Masonry Structures.
3. Soil Dynamics: Dynamic-Properties of Soils for Seismic Design of Structures and Foundations.

In order to implement the project smoothly and effectively, the following types of cooperation will be provided through JICA under the scheme of the technical cooperation of the Government of Japan and through measures taken by the Universidad Católica and other Chilean authorities concerned.

a) Dispatch of Japanese Research Experts to Chile

Both long term and short term Japanese research experts will be dispatched to Chile to work in the project together with the Chilean study team at the Universidad Católica de Chile.

b) Provision of Machinery and Equipment

Instrumentation for laboratory tests and field observations is indispensable for the project implementation. Adding to the existing machinery and equipment in the Universidad Católica, some machinery and equipment necessary for the project implementation will be provided through JICA.

c) Dispatch of Chilean Researchers to Japan

Chilean researchers will stay at the Building Research Institute of Ministry of Construction and other institutions in Japan for several months to exchange scientific information and make

technical discussions on the joint study project.

Based on the ability studies stated in Chapter 2 of this report, the detail of the project, which includes tentative implementation procedure, is proposed in Chapter 3. Also, following these conclusions, the draft of the Record of Discussion (R/D) is proposed in Chapter 4.

It should be noted here that there are some points regarding the project implementation discussed between the Japanese team and its counterpart in the Universidad Católica. These points are summarized as follows:

1. Both the Japanese team and its counterpart in the Universidad Católica understand that the list of machinary and equipment which will be provided through JICA for the project are essential to carry out this Joint Study Project. The Japanese team has promised its Chilean counterpart to make its maximum effort to recommend JICA to follow the list, understarding that the listed machinary and equipment are highly crucial to the project implementation.

2. Both the Japanese team and its counterpart in the Universidad Católica understand that the number and schedule of Chilean researches who will visit Japan to collect information necessary for the project is a tentative one. However, the Japanese team has promised its Chilean counterpart to make the maximum effort to recommentdJICA to follow the proposed plan.

3. Both the Japanese team and its counterpart in the Universidad Católica understand that there is a need of short term experts in equipment installation but the schedule of such experts remains tentative because installation procedure of machinery needs to be analyzed more in Japan.

4. The Universidad Católica understands that it may be necessary for a Goverment official concerned to sign the R/D as a witness when the R/D is signed by both the Head of the Japanese Implementation Survey Team of JICA and the Rector of Universidad Católica de Chile. However, the current form of signing the draft is tentative, and if necessary, the Universidad Católica will consult with the resident representative of JICA in Chile to figure out the final form of signing the R/D.

5. If there are any additional changes in the draft made in Japan, the final draft of the R/D will be sent to the Universidad Católica 3 weeks prior to the arrival of the Japanese Implementation Survey Team of JICA so as to make legal procedure in the University easier.

Finally, the Japanese team is very grateful to the Rector of the Universidad Católica de Chile, to the Dean of the College of Engineering, and to the professors of the Structural Engineering Department for providing assistance to the Japanese team to complete this report.

APPENDIX A

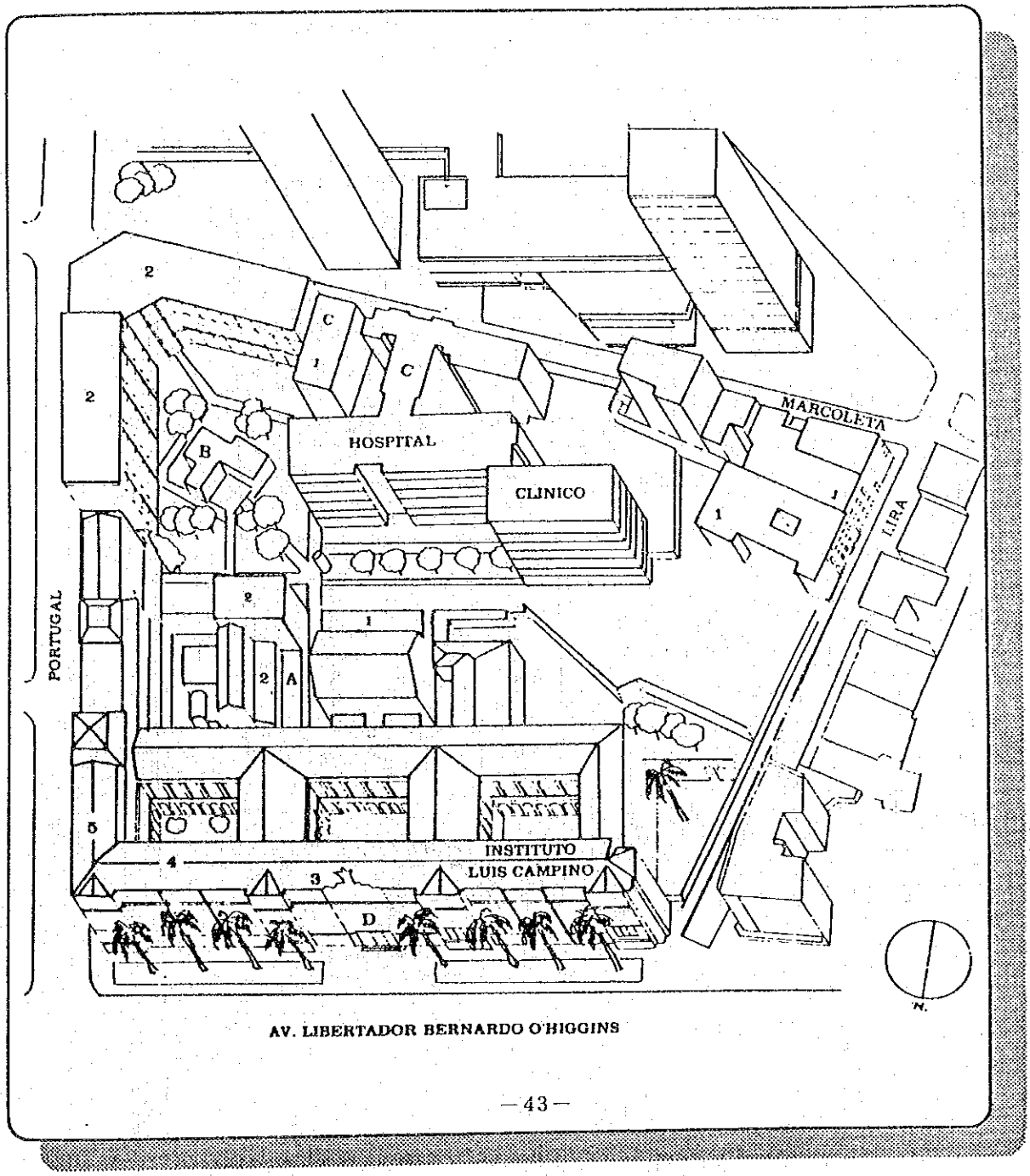
FACILITIES OF THE UNIVERSIDAD CATOLICA DE CHILE

Campus Casa Central

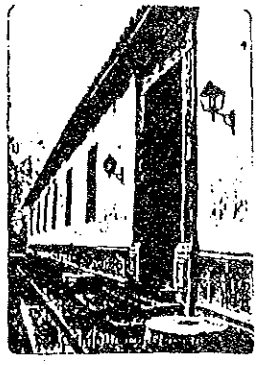
1. Esc. Medicina (Facultad de Medicina)
2. Facultad de Ciencias Biológicas
3. Rectoría
4. Inst Ciencia Política
5. Esc. de Administración (ESAE)

Sup. terreno : 24.500 m2
Sup. Construida : 40.500 m2

A. BIBLIOTECA B. CASINO C. SERVICIOS MEDICOS D. CAPILLA



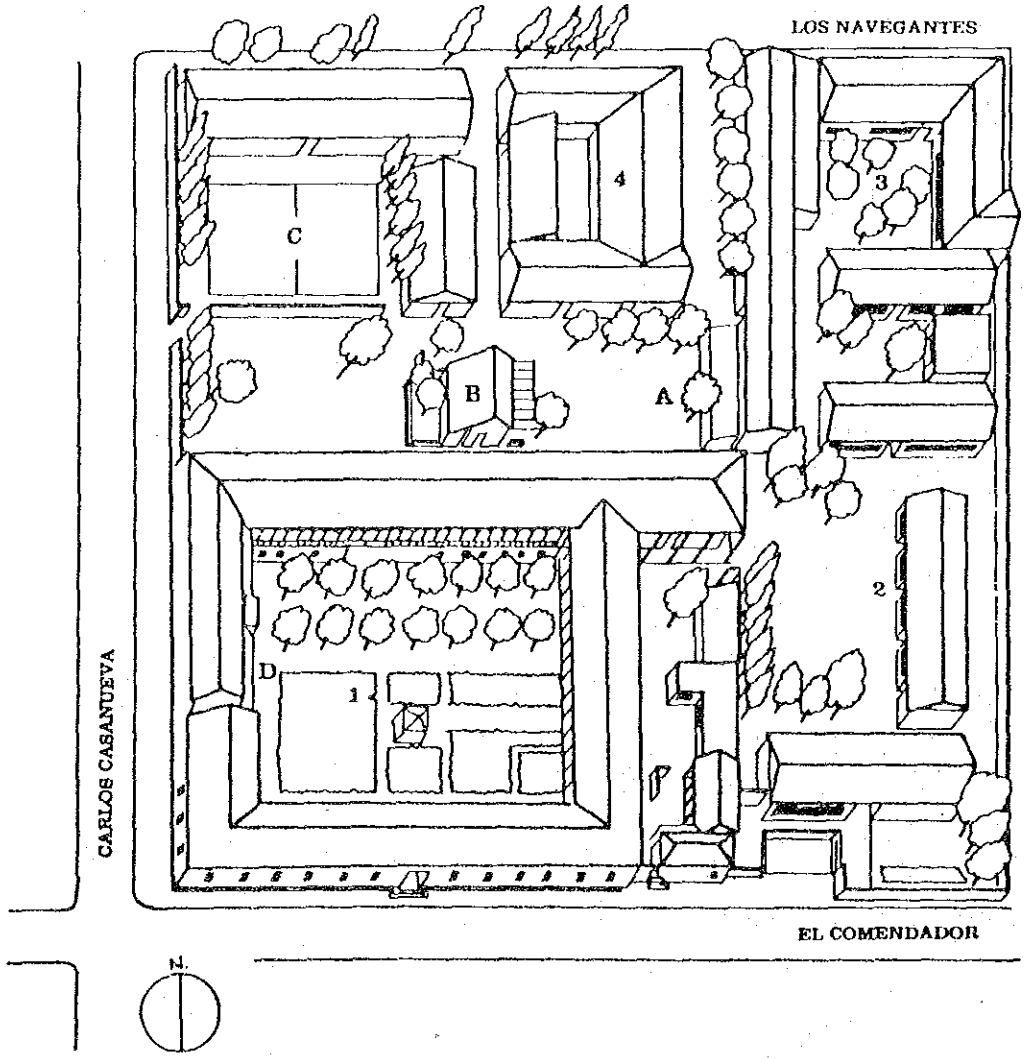
Campus Lo Contador



1. Escuela de Arquitectura
2. Escuela de Arte
3. Escuela de Diseño
4. Instituto de Estudios Urbanos

Sup. terreno : 15.000 m2
Sup. construida : 5.200 m2

A. BIBLIOTECA B. CASINO C. DEPORTES D. CAPILLA



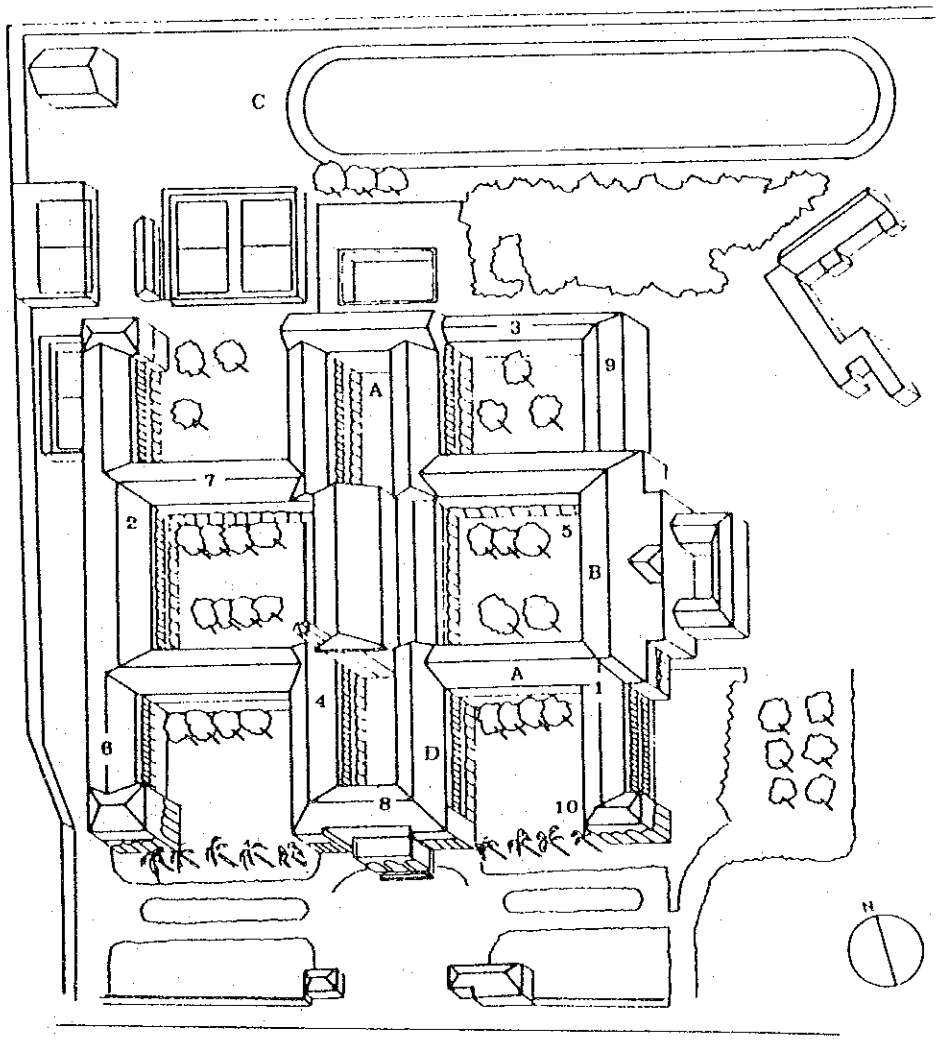
Campus Oriente


Campus Oriente

1. Fac. de Derecho
2. Fac. de Educación
3. Esc. de Periodismo
4. Inst. de Filosofía
5. Esc. de Teatro
6. Inst. de Letras
7. Fac. de Teología
8. Depto. de Estética
9. Instituto de Música
10. Inst. de Historia

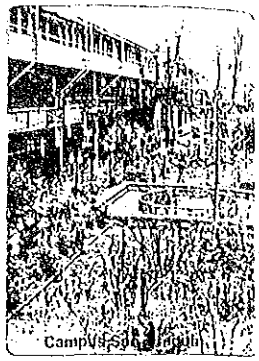
Sup. Terreno : 57.000 m2
Sup. Construída : 13.000 m2

A. BIBLIOTECAS B. CASINO C. COMPLEJO DEPORTIVO D. CAPILLA



J. BATTLE Y ORDOÑEZ

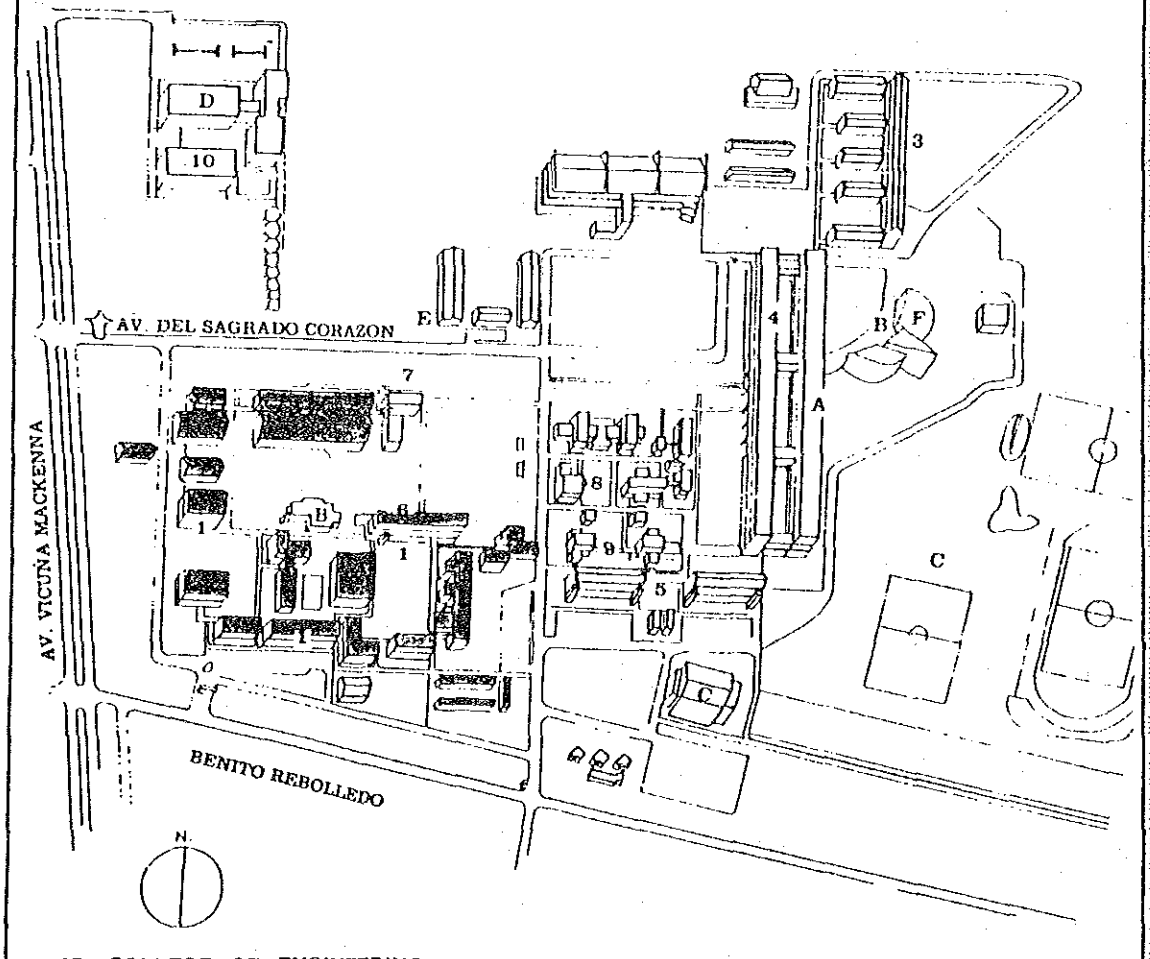
Campus San Joaquín



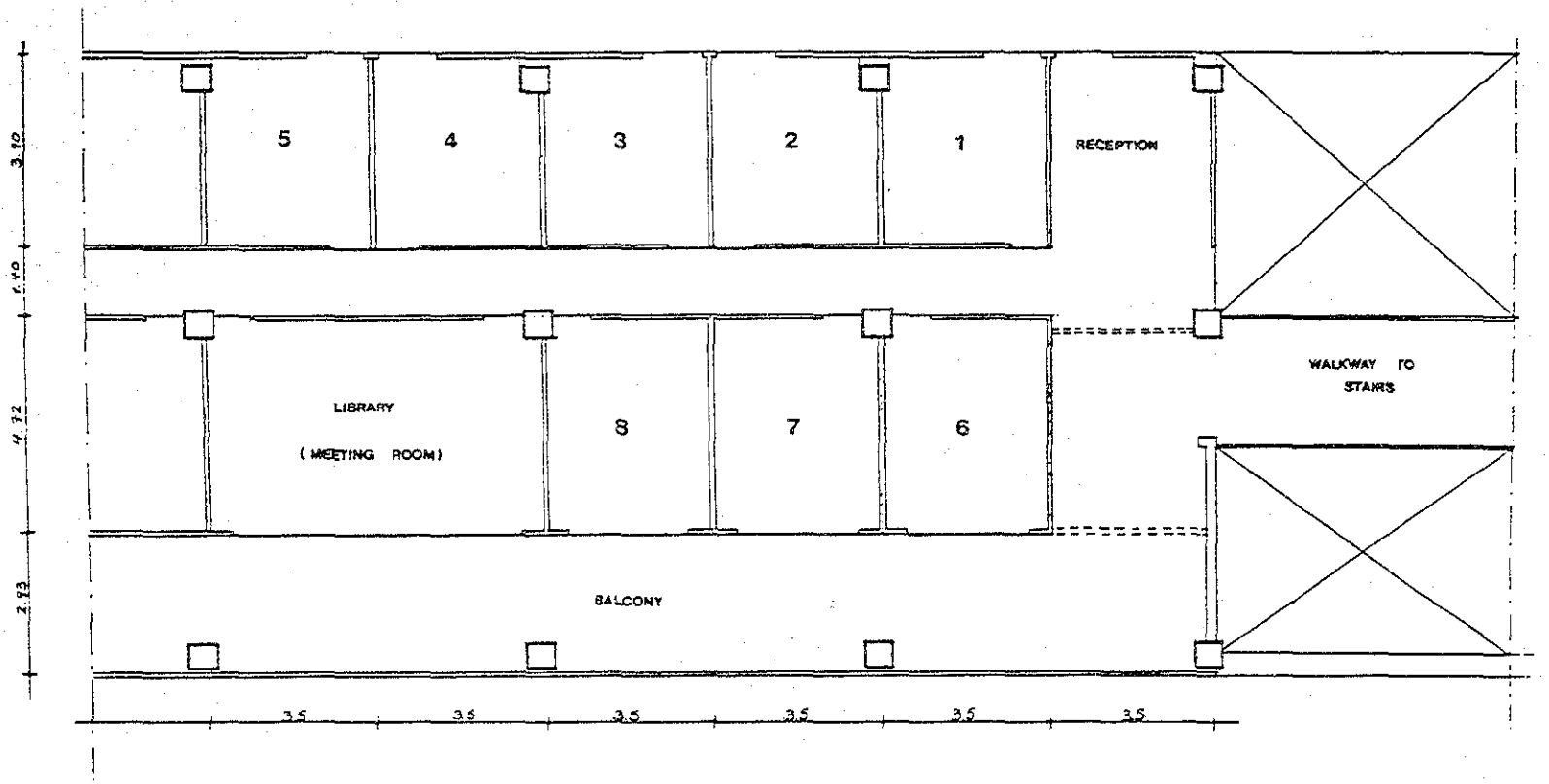
1. Esc. de Ingeniería
2. Esc. de Construcción Civil
3. Fac. de Agronomía
4. Fac. de Ciencias Sociales
5. Fac. de Cs. Económ. y Adm.
6. Fac. de Matemática
7. Instit. de Geografía
8. Fac. de Química
9. Fac. de Física
10. Esc. de Enfermería

Sup. terreno : 759.000 m2
Sup. construida : 80.000 m2

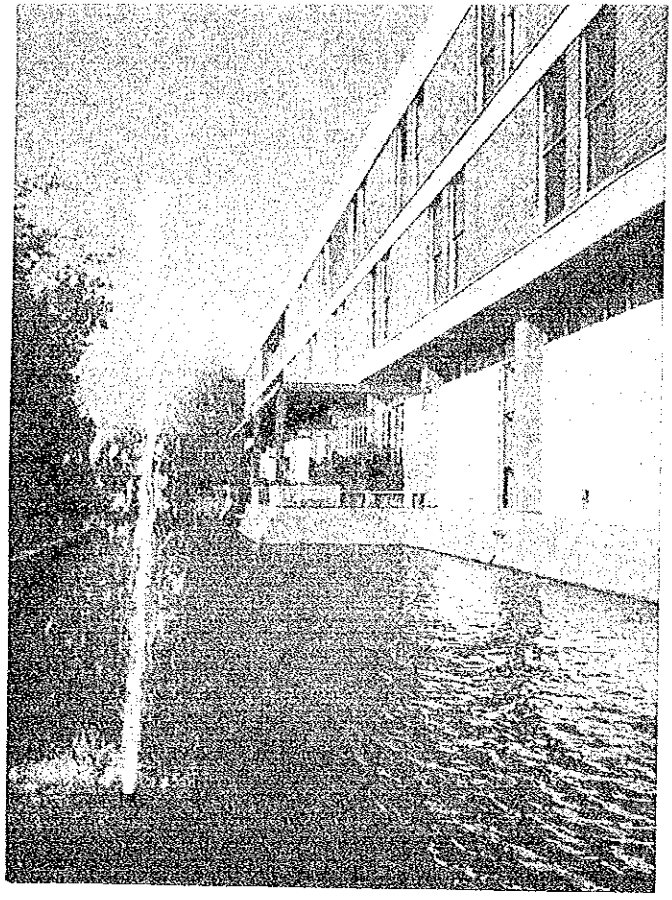
A. BIBLIOTECA B. CASINO C. COMPLEJO DEPORTIVO D. CENTRO DE DIAGNOSTICO
E. CAPILLA F. AULAS HELEN LEE LASSEN



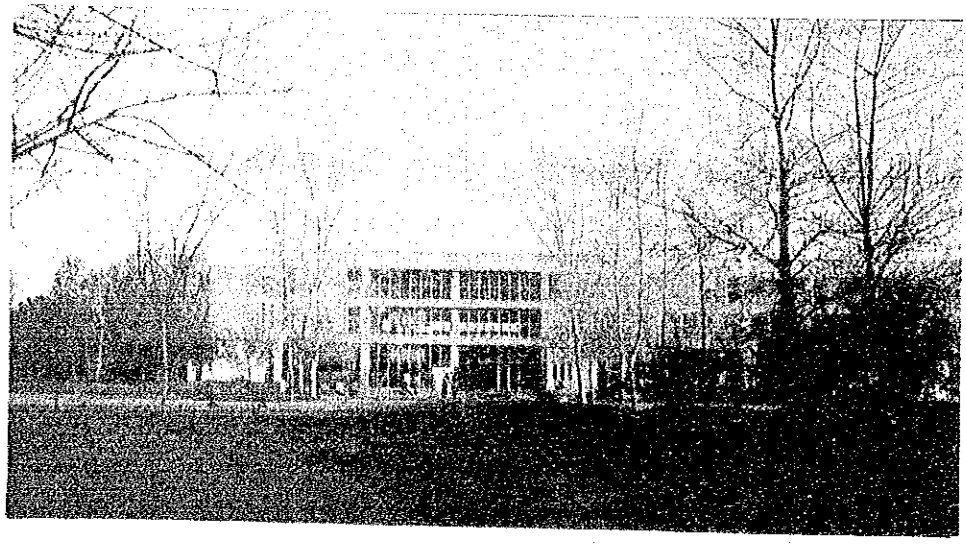
■ COLLEGE OF ENGINEERING

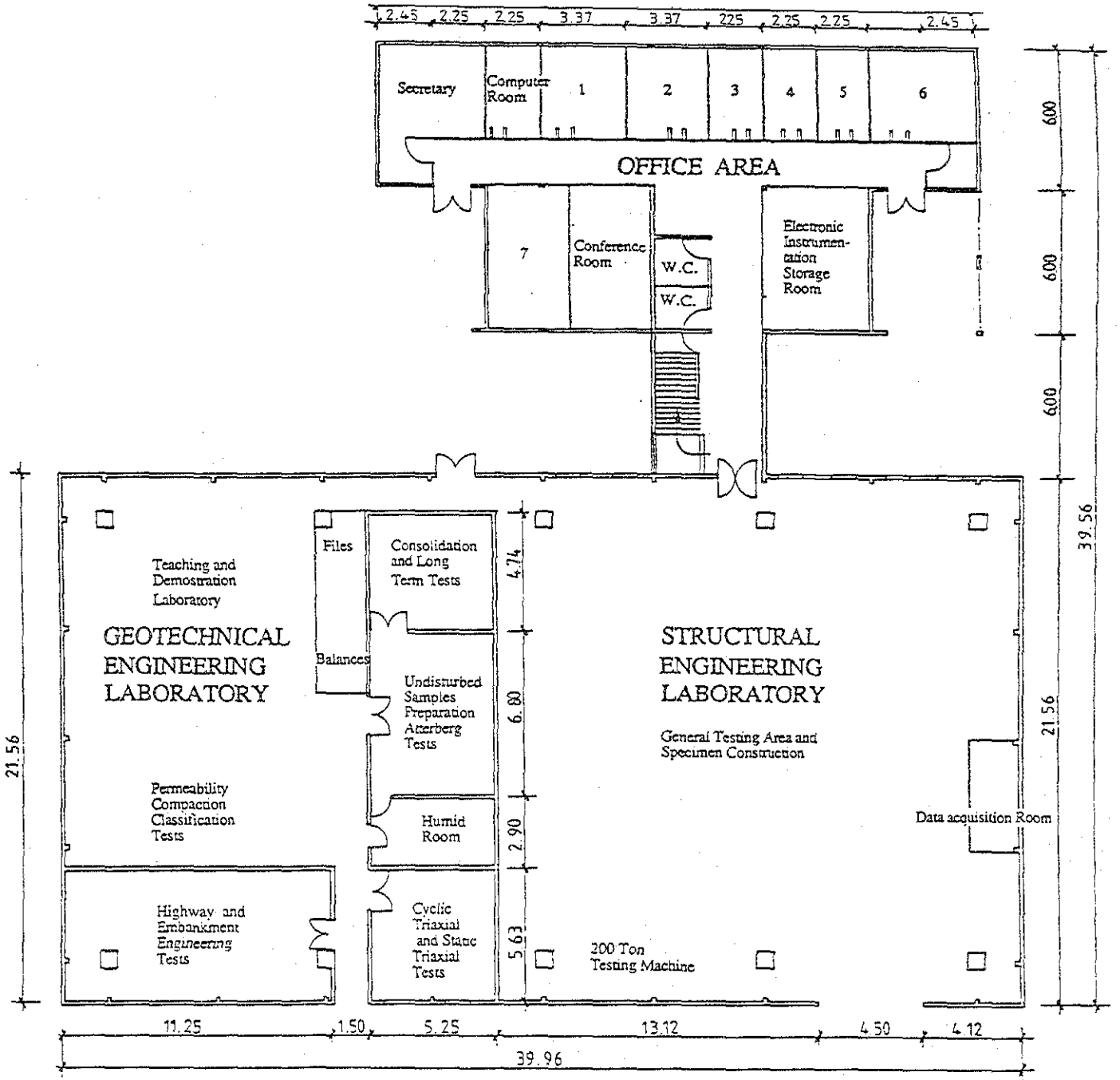


DEPARTMENT OFFICE AREA (DEVES HALL)

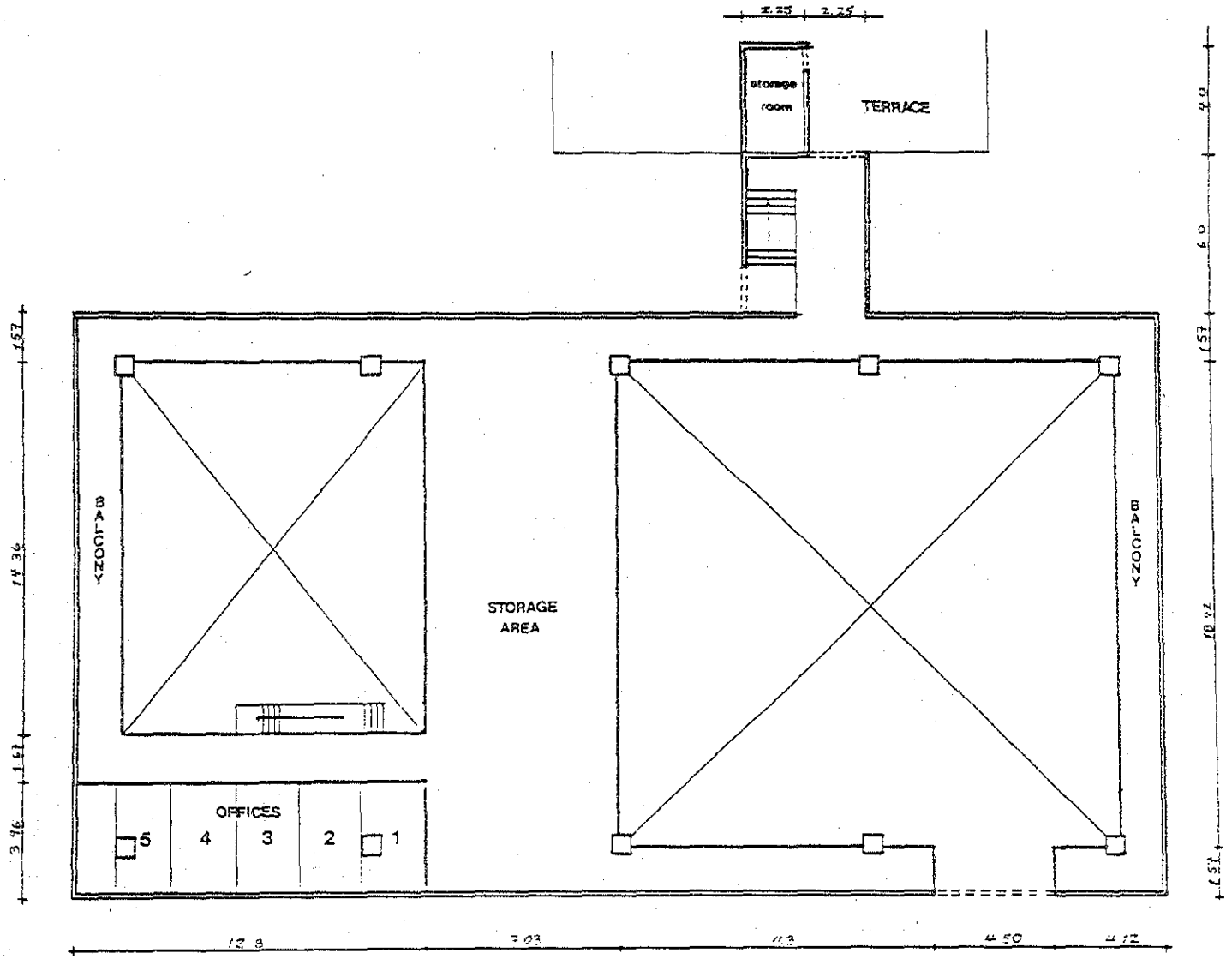


DEVES HALL

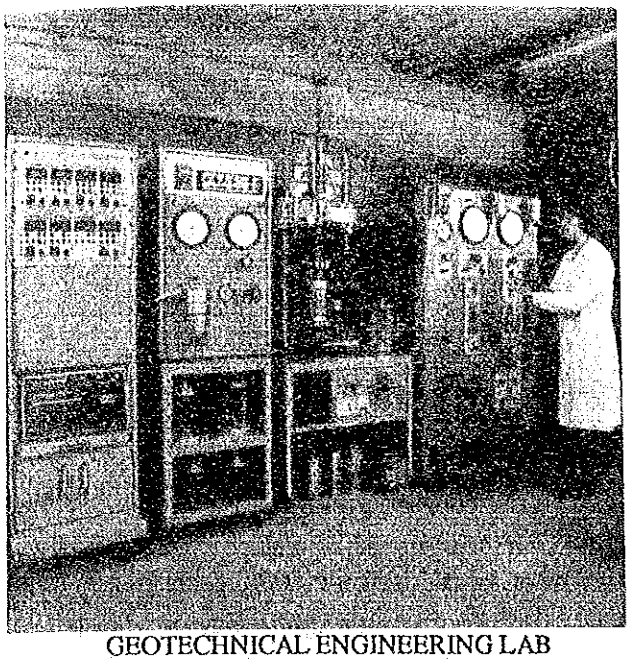




DEPARTMENT LABORATORY LAYOUT (FIRST FLOOR)

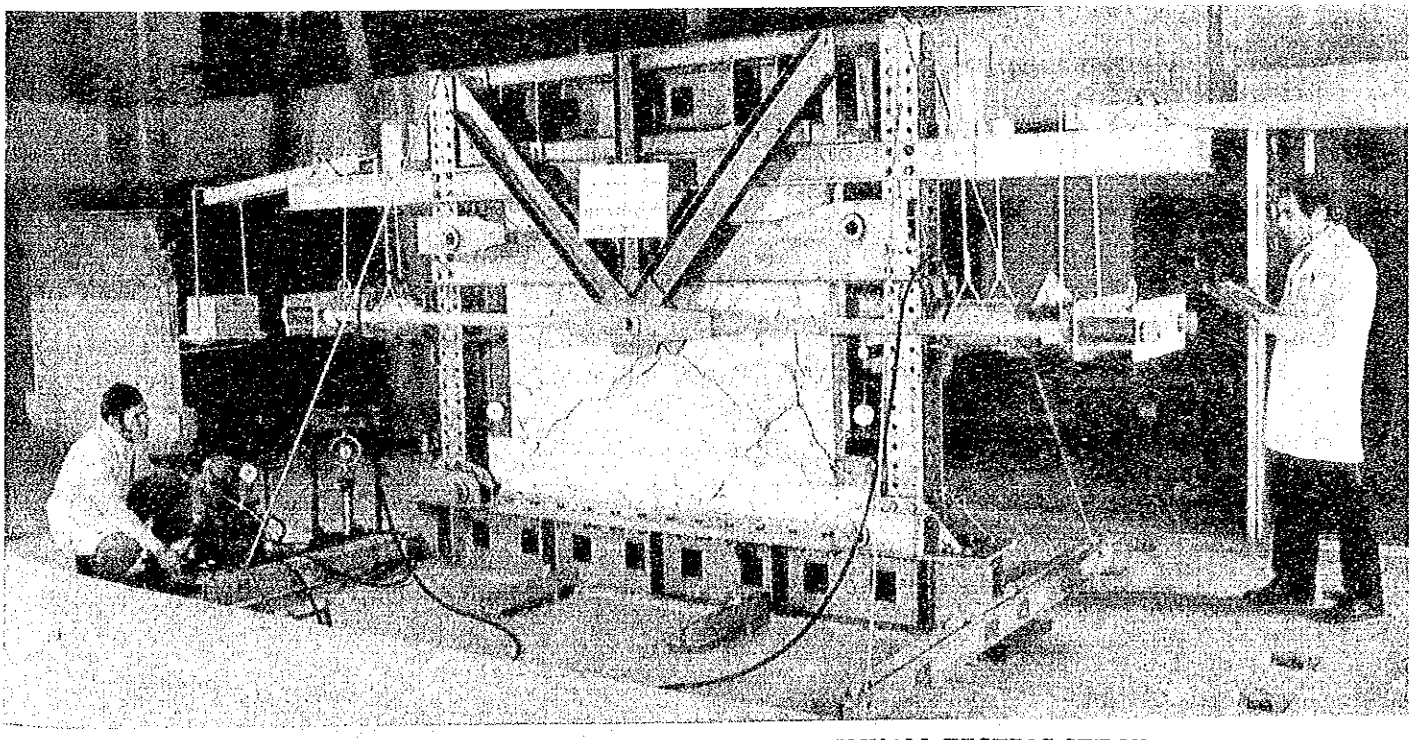


DEPARTMENT LABORATORY LAYOUT (SECOND FLOOR)



GEOTECHNICAL ENGINEERING LAB
CYCLIC TRIAXIAL TESTING
MACHINE

STRUCTURAL ENGINEERING LAB
200 TONS TESTING MACHINE



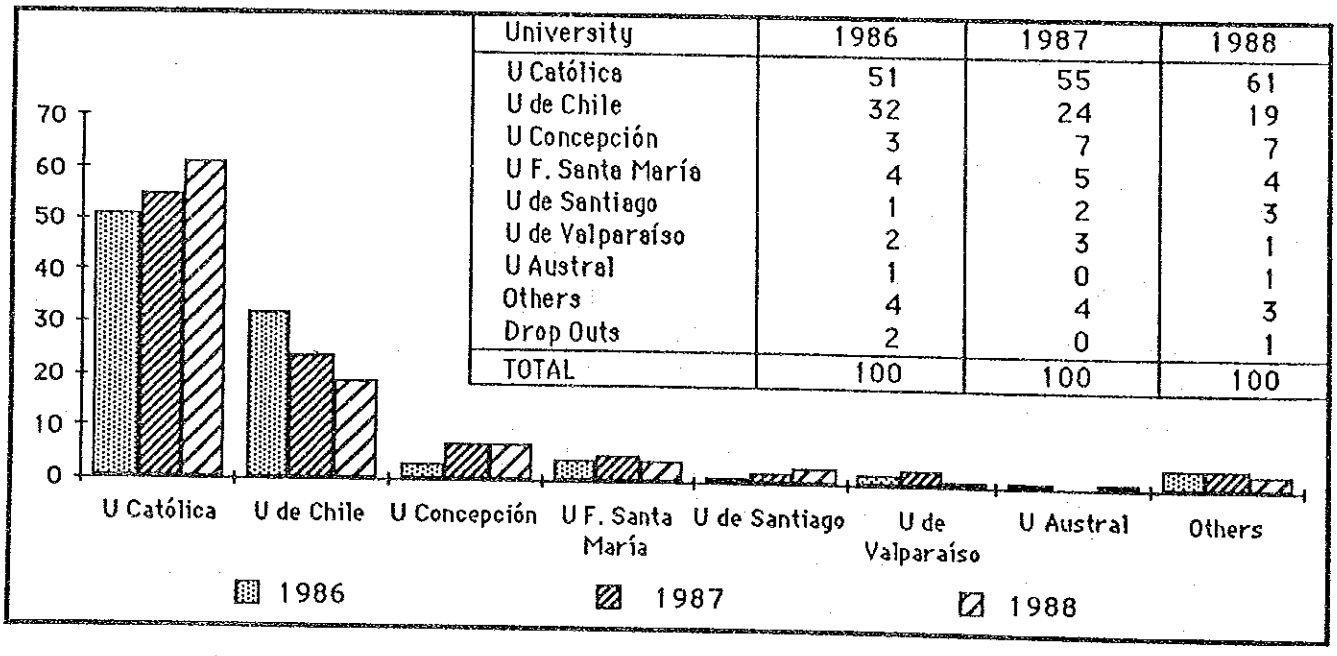
STRUCTURAL ENGINEERING LAB. MASONRY WALL TESTING SET-UP

APPENDIX B

ADMISSION TO THE NATIONAL UNIVERSITY SYSTEM FOR THE YEARS 1986, 1987, AND 1988

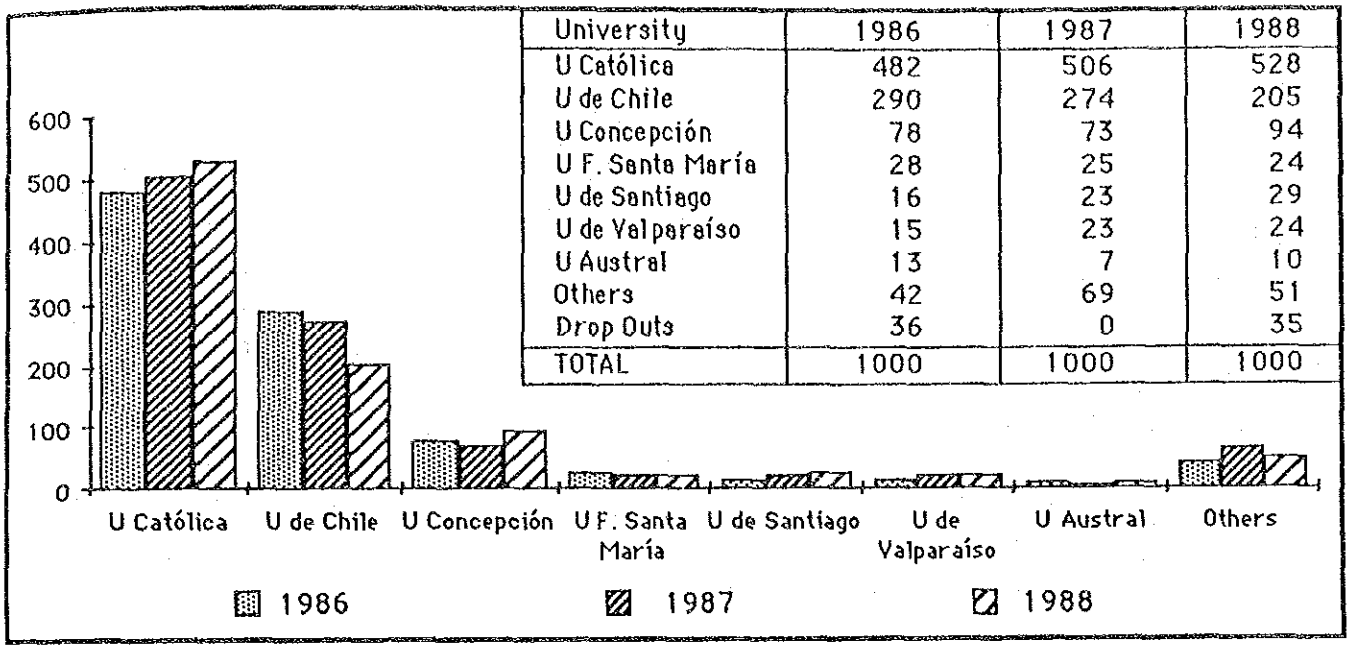
Some information of the preferences of applicants to the National University Sistem compared with their grade in the nationwide test are presented. The test, called Academic Aptitude Test, and taylored after a well known US test, is taken yearly by about 130.000 high school graduates. In the admission process, the preferences of the applicants are satisfied in the order of their grading in the test.

Figure 1 shows the preference of university, regardless of field, of the 100 top applicants, indicating for each university the number of preferences. Figure 2 is analogous, except that it considers the top 1000 applicants. Figure 3 shows the preference of university of those applicants out of the top 100 who chose to study engineering. Again, the number of preferences for each university is indicated. Figure 4 is analogous, except that it refers to the students within the top 1000 applicants.



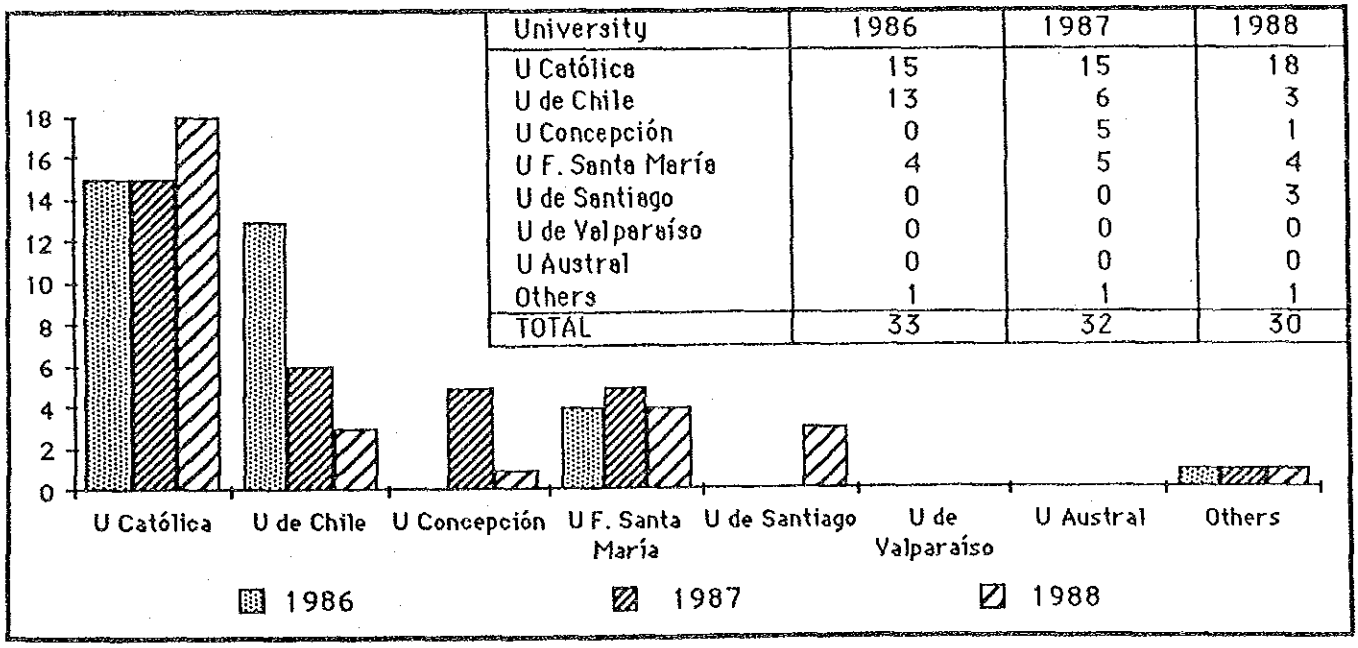
University	1986	1987	1988
U Católica	51	55	61
U de Chile	32	24	19
U Concepción	3	7	7
U F. Santa María	4	5	4
U de Santiago	1	2	3
U de Valparaíso	2	3	1
U Austral	1	0	1
Others	4	4	3
Drop Outs	2	0	1
TOTAL	100	100	100

Figure 1: Preferences of the 100 top applicants to the National University System



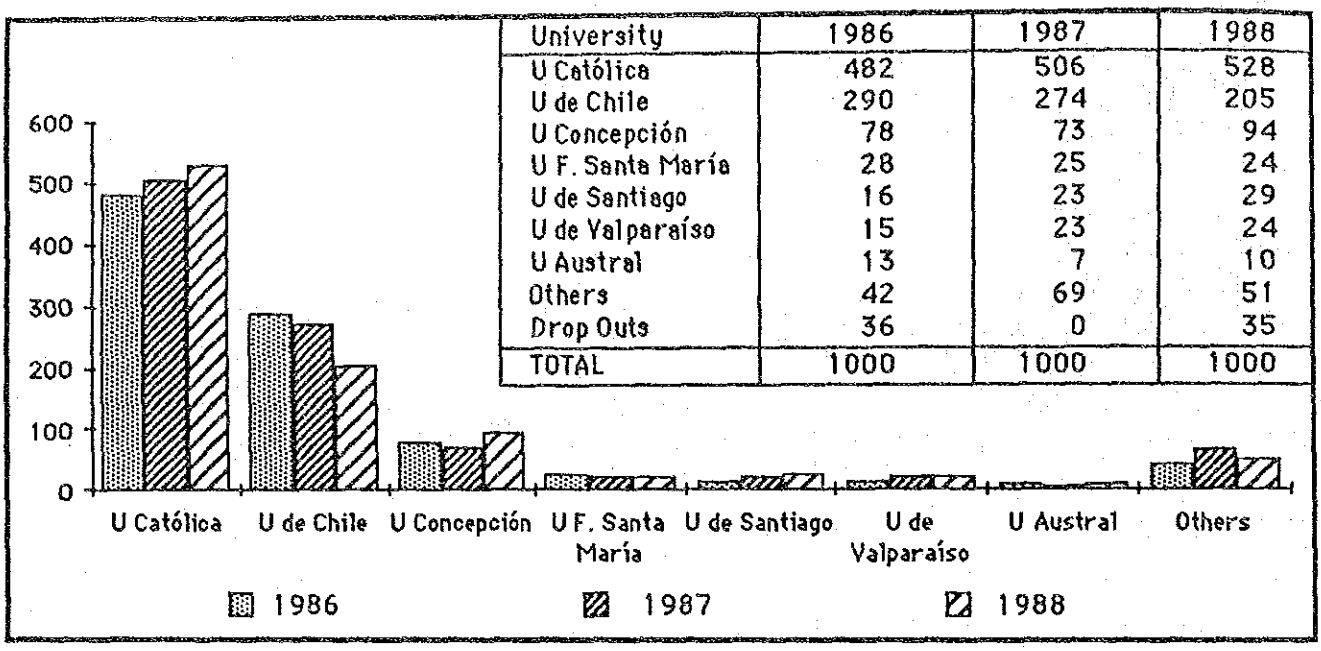
University	1986	1987	1988
U Católica	482	506	528
U de Chile	290	274	205
U Concepción	78	73	94
U F. Santa María	28	25	24
U de Santiago	16	23	29
U de Valparaíso	15	23	24
U Austral	13	7	10
Others	42	69	51
Drop Outs	36	0	35
TOTAL	1000	1000	1000

Figure 2: Preferences of the 1000 top applicants to the National University System



University	1986	1987	1988
U Católica	15	15	18
U de Chile	13	6	3
U Concepción	0	5	1
U F. Santa María	4	5	4
U de Santiago	0	0	3
U de Valparaíso	0	0	0
U Austral	0	0	0
Others	1	1	1
TOTAL	33	32	30

Figure 3: Preferences of the applicants to Engineering amongst the 100 top in the National University System



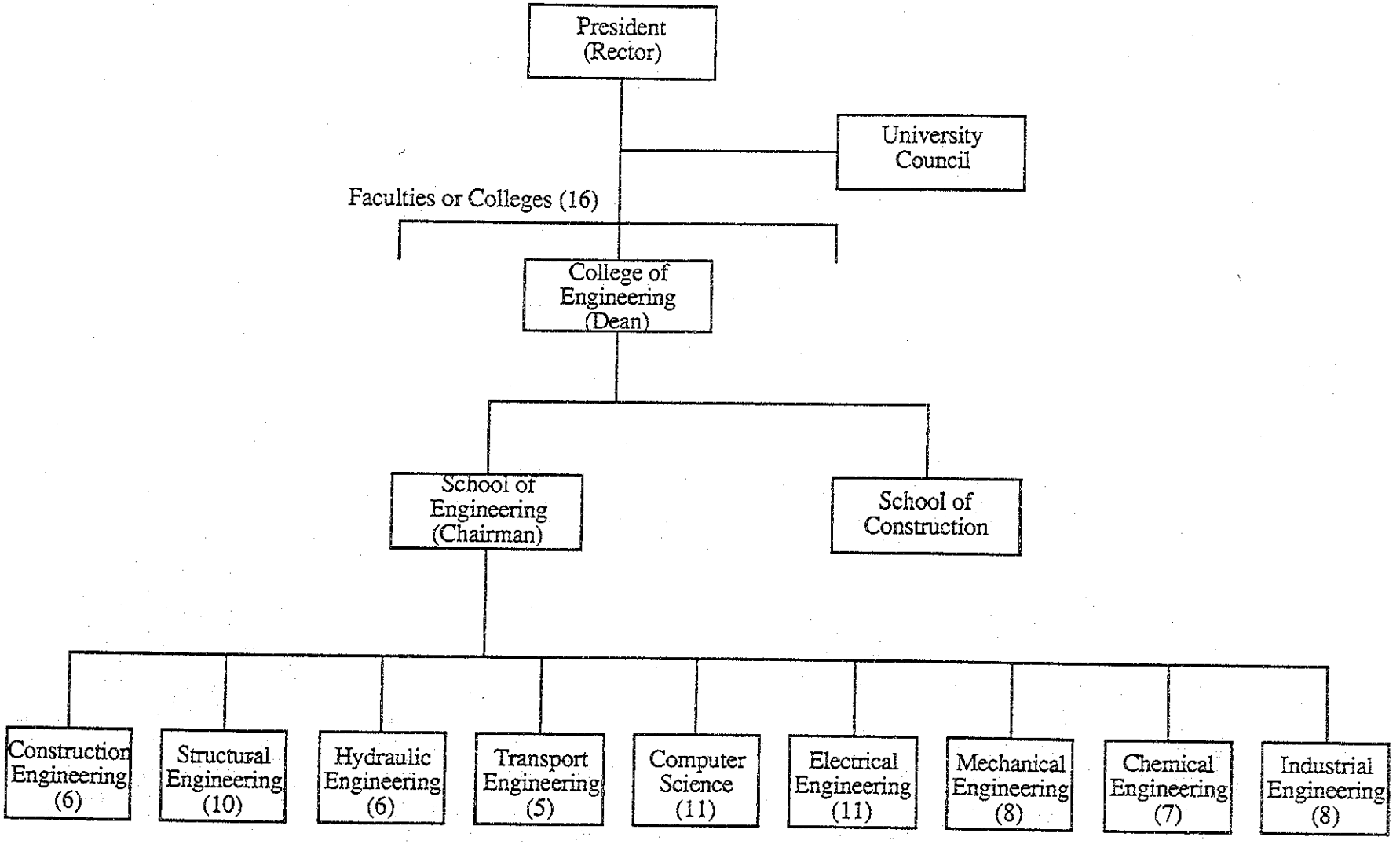
University	1986	1987	1988
U Católica	482	506	528
U de Chile	290	274	205
U Concepción	78	73	94
U F. Santa María	28	25	24
U de Santiago	16	23	29
U de Valparaíso	15	23	24
U Austral	13	7	10
Others	42	69	51
Drop Outs	36	0	35
TOTAL	1000	1000	1000

Figure 4: Preferences of the applicants to Engineering amongst the 1000 top in the National University System

APPENDIX C

ORGANIZATION CHART OF THE UNIVERSIDAD CATOLICA DE CHILE

ORGANIZATION CHART FOR UNIVERSIDAD CATOLICA



Figures in parenthesis indicate total number of full-time professors

APPENDIX D

RESEARCH PROJECTS FUNDED FOR 1987

A. SPONSORED BY RESEARCH DIVISION OF THE UNIVERSITY

1. Shear stress and strain paths in joints.
   Professors: M. Van Sint Jan
   F. Rodríguez Roa
   Amount: $ 325.000/year

2. Critical state in seismic response of tailing sands.
   Professors: J. Troncoso
   C. Lüders
   Amount: $ 616.000/year

3. Earthquake analysis of small earth dams.
   Professors: F. Rodríguez Roa
   M. Van Sint Jan
   Amount: $ 387.000/year

4. Evaluation of methods used for design and analysis of earthquake-resistant reinforced concrete structures using data from the Chilean earthquake of 3 March 1985.
   Professors: R. Riddell
   J. Vásquez
   Amount: $ 652.000/year

5. Derivation of mathematical models to predict the sesmic behavior of reinforced masonry shear walls.
   Professors: C. Lüders
   P. Hidalgo
   Amount: $ 858.000/year

6. Behavior of reinforced masonry buildings during the 3 March 1985 earthquake and implications for their earthquake-resistant design.
   Professors: P. Hidalgo
   E. Cruz
   Amount: $ 400.000/year

7. Seismic safety of buildings designed including a torsional code-specified component.
Professors: J. Vásquez, R.Riddell Amount: $ 315.000/year

B. SPONSORED BY GOVERNMENTAL NATIONAL RESEARCH AGENCY

1. Calibration of simplified analysis parameters for typical characteristics of Chilean buildings.
Professors: E. Cruz Amount: $1.532.000/year
P. Hidalgo

2. Asessment of code base shear level for the 3 March 1985 earthquake in Santiago using damage observed in reinforced masonry buildings.
Professors: P. Hidalgo Amount: $1.547.000/year
E. Cruz

3. Specification of a torsional component for earthquake-code design of building.
Professors: J. Vásquez Amount: $ 966.000/year
R. Riddell

4. Evaluation of effective ground motion parameters for the derivation of earthquake-design spectra.
Professors: R. Riddell Amount: $ 960.000/year
J. Vásquez

C. SPONSORED BY U.S. NATIONAL SCIENCE FOUNDATION

1. Evaluation of methods used for design and analysis of earthquake-resistant reinforced concrete structures using data from the Chilean earthquake of March 3, 1985.
Professors: R. Riddell Amount: $3.650.000/year (*)
J. Vásquez

2. Evaluation of design and analysis techniques for masonry structures based on the performance in the Chilean earthquake of March 3, 1985.

Professors: P. Hidalgo
E. Cruz

Amount: $ 800.000/year (*)

(*) Partial budget corresponding to funds for use by Chilean participants.

3. Building configuration and seismic performance, the Chilean Earthquake of March 3, 1985.

Professors: R. Riddell
J. Vásquez

Amount: $ 500.000/year (*)

(*) Partial budget corresponding to funds for use by Chilean participants.