10:11:10 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 06/12/92

Active

Project #: E-20-606 Cost share #: E-20-313 Rev #: 5
Center # : 10/24-6-R6875-0A0 Center shr #: OCA file #:
Work type : RES
Contract#: BCS-8906508 Mod #: MEMO OF 5/28/92 Document : GRANT
Prime #: Contract entity: GTRC

Subprojects ? : Y CFDA: 47.041
Main project #: PE #:

Project unit: AERO ENGR Unit code: 02.010.110
Project director(s):
GOODNO B J CIVIL ENGR (404)894-2227
CRAIG J I AERO ENGR (404)-

Sponsor/division names: NATL SCIENCE FOUNDATION / GENERAL
Sponsor/division codes: 107 / 000

Award period: 900215 to 920731 (performance) 921031 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	243,288.00
Funded	0.00	243,288.00
Cost sharing amount		46,388.00

Does subcontracting plan apply ?: N

Title: ADVANCED SEISMIC DESIGN METHODS FOR PRECAST CLADDING

PROJECT ADMINISTRATION DATA

OCA contact: Mildred S. Heyser 894-4820

Sponsor technical contact

SHIH-CHI LIU
(202)357-9545

NSF
1800 G STREET, N.W.
WASHINGTON, D.C. 20550

Sponsor issuing office

DIONIE HENRY
(202)357-9626

NATIONAL SCIENCE FOUNDATION
1800 G STREET, NW
WASHIGNTON, DC 20550

Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A NSF supplemental sheet
Equipment title vests with: Sponsor GIT X

Administrative comments -
TO TRANSFER FUNDS IAO $31,036 FROM E-16-664 (SUB) TO THIS PROJECT PER MEMO FROM UMA AMIRTHARAJAH DATED 5/28/92 AND MEMO DATED 5/29/92 FROM K. ARNOLD.

2:45:34 OCA PAD VIEW - PROJECT HEADER INFORMATION 04/04/96

roject # E-20-606 Mod # MEMO OF 5/28/92 Rev # 5 SCREEN 1 OF 2
ontract # BCS-8906508 OCA File # Status T
ontract entity GTRC Prime Cont #
)PI GOODNO B J CFDA 47.041 PE #
SSN 395-46-6670 Unit CIVIL ENG Phone (404)894-2227
roject Unit AERO ENGR Unit Code 02.010.110
Spon/Div NATL SCIENCE FOUNDATION / GENERAL
Sponsor #/Division # 107 / 000
Type of document GRANT
Award period: from 900215 to 920731 (perf) 921031 (rpts)

Sponsor amount	New this change	Total to date
Contract value	$ 0.00	243,288.00
Funded	$ 0.00	243,288.00

Cost sharing # E-20-313 Cost sharing $ 46,388.00
Does subcontracting plan apply? (Y/N) N
Title -
DVANCED SEISMIC DESIGN METHODS FOR PRECAST CLADDING

1 Admin F3 Deliv F5 Mods/Revs
2 Finan F4 Terms F6 Closeout F8 Forward F12 Return

:46:05 OCA PAD - VIEW CLOSEOUT INITIATION SCREEN 04/04/96

oject # E-20-606 Center # 10/24-6-R6875-0A0
oject Director GOODNO B J Unit 02.010.110
ntract/Grant # BCS-8906508 Contract Entity GTRC
onsor 107 000 Prime Contract #
NATL SCIENCE FOUNDAT/GENERAL
tle Closeout Initiation Complete Date 920917 Project Status T
VANCED SEISMIC DESIGN METHODS FOR PRECAST CLADDING
ard Period: 900215 to 920731

oseout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other _____	N	

omment _____

F8 Next F12 Return

:46:05 OCA PAD - VIEW CLOSEOUT DISTRIBUTION SCREEN 04/04/96

oject # E-20-606 Center # 10/24-6-R6875-0A0
onsor 107 000
ATL SCIENCE FOUNDAT/GENERAL

oject director	Y
ministrative network representative	Y
RI Accounting/Grants and contracts	Y
ocurement/Supply services	Y
search property managment	Y
search security services	N
ports coordinator (OCA)	N
RC	N
oject File	Y
A/CSD	
her _____	N
_____	N

ig Notice Date 920917 Notice Date 920917 Closeout Complete Date
chive Box # Burn Date

F7 Previous
F12 Return

E-20-606
NSF #1

Georgia Institute of Technology

A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
ATLANTA, GEORGIA 30332

SCHOOL OF
CIVIL ENGINEERING

TELEX: 542507 GTRC OCA ATL

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(404) 894-2227
FAX (404)894-2278
BITNET: BGOODNO@GTRI01
INTERNET: BG6@PRISM.GATECH.EDU

November 5, 1990

Dr. Henry J. Lagorio
Earthquake Hazards Mitigation
NATIONAL SCIENCE FOUNDATION
1800 G Street, NW
Washington, D.C. 20550

Dear Dr. Lagorio:

I have taken the liberty of sending you the enclosed copy of our First Year Progress Report on NSF Grant BCS-8906508 entitled *Advanced Seismic Design Methods for Precast Cladding.*

We have tried to adhere to the new requirements described in NSF Notices 107 and 110. We will be happy to submit this report on the preprinted forms to be supplied by NSF, once they are available, but wanted to provide you with our report in the meantime in case you have any questions or comments.

Please feel free to contact me if you need additional information on our first year research activities.

Sincerely,

Barry J. Goodno
Professor

cc: Dr. J. I. Craig
encl.

FIRST YEAR PROGRESS REPORT

NSF Grant BCS-8906508
ADVANCED SEISMIC DESIGN METHODS FOR PRECAST CLADDING
February 15, 1990 - February 14, 1991

by

Professors Barry J. Goodno and James I. Craig
Co-Principal Investigators
Schools of Civil and Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332-0355

October 31, 1990

PI/PD NAME AND ADDRESS

Dr. Barry J. Goodno, Co-PI, PD
School of Civil Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332-0355
FAX (404)894-2278

Dr. James I. Craig, Co-PI
School of Aerospace Engineering
Georgia Institute of Technology
Atlanta, Georgia 30332-0150

PART I - PROJECT IDENTIFICATION INFORMATION

1. Program Official/Org.: Dr. Shih-Chi Liu and Dr. Henry J. Lagorio, NSF

2. Program Name: Earthquake Hazards Mitigation

3. Award Dates: Year 1 - February 15, 1990 to July 31, 1991 (including 6 month unfunded flexibility period)

4. Institution and Address: Georgia Institute of Technology
Atlanta, Georgia 30332-0355

5. Award Number: NSF Grant BCS-8906508

6. Project Title: ADVANCED SEISMIC DESIGN METHODS FOR PRECAST CLADDING

PART II - SUMMARY OF COMPLETED PROJECT: YEAR 1 OF 2

The first year of this investigation has been concerned with the possible use of architectural precast cladding as a passive control system designed to limit the seismic response of building structures. Building facades are often dismissed as nonstructural and are not normally assumed to interact with either frame or wall-panel building construction. However,

architectural precast panels constitute an important part of the precast industry and these panels are widely used on precast as well as steel and reinforced concrete frame buildings. The focus of the research has been the possible use of precast panels and their attachments to the structure as part of an integrated building cladding system which provides both increased lateral stiffness and damping for the structure as a whole. Analytical models have been formulated for promising advanced connection designs that offer improved energy dissipation, ductility and failure characteristics and modes compared to present precast cladding systems. Plans have been made for laboratory testing of selected connection designs. Results of the completed 2-year project are expected to include an improved understanding of behavior of heavy cladding systems on modern buildings during earthquakes and the development of both conceptual models and test results for particular integrated cladding designs.

PART III - TECHNICAL INFORMATION

SUMMARY OF RESEARCH ACCOMPLISHMENTS DURING YEAR 1 (OF 2)

(A) EDUCATIONAL IMPACT

A number of graduate students have been directly involved in the research program being carried out under the grant. They are listed below along with the program of study:

1. Loai F. El-Gazairly, Ph.D., Civil Engineering, expected 1991
2. Jean-Paul Pinelli, Ph.D., Civil Engineering, expected 1991
3. Michael W. Wolz, MSCE, Civil Engineering, expected 1991
4. Cheng-Chieh Hsu, MSCE, Civil Engineering, expected 1991
5. Joo-Woo Kim, Ph.D., Civil Engineering, expected 1993
6. George P. Wheatley, MSCE, Civil Engineering, expected 1991
7. W. Brandon Winzurk, MSCE, Civil Engineering, expected 1991

Each of these students have been heavily involved in the grant research, and the first four have co-authored several of the publications listed below.

(B) PUBLICATIONS RESULTING FROM OR ASSOCIATED WITH GRANT

1. Goodno, B. J., and Craig, J. I., "Historical Overview of Studies on the Contribution of Cladding to Lateral Resistance of Buildings," Proceedings, The International Symposium on Architectural Precast Cladding - Its Contribution to Lateral Resistance of Buildings, organized by the Precast/Prestressed Concrete Institute, held in Chicago, Illinois, November 8-9, 1989, pp. 36-47.

2. Pinelli, Jean-Paul, Craig, J. I., and Goodno, B. J., "Development and Experimental Calibration of Selected Dynamic Models for Precast Cladding Connections," Proceedings, The Fourth U.S. National Conference on Earthquake Engineering, held in Palm Springs, California, on May 20-24, 1990, Vol. 2, pp. 147-156.

3. El-Gazairly, Loai F., Goodno, B. J., and Craig, J. I., "Analytical Investigation of Advanced Connections for Precast Cladding on Buildings," Proceedings, The Fourth U.S. National Conference on Earthquake Engineering, held in Palm Springs, California, on May 20-24, 1990, Vol. 2, pp. 441-450.

4. Pinelli, Jean-Paul, Craig, J. I., and Goodno, B. J., "Development of Advanced Concepts for Precast Cladding," Proceedings, ATC-29 Seminar: Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures, held in Irvine, California, on October 3-4, 1990, pp. 26.1-26.11.

5. Wolz, M. W., Hsu, C., and Goodno, B. J., "Nonlinear Interaction Between Building Structural Systems and Nonstructural Cladding Components," Proceedings, ATC-29 Seminar: Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures, held in Irvine, California, on October 3-4, 1990, pp. 25.1-25.12.

6. Goodno, B. J., El-Gazairly, L. F. and Wolz, M. W., "Nonlinear Dynamic Analysis of Buildings with Advanced Cladding Connections," to appear in Proceedings, Seventh Conference on Computing in Civil Engineering and Symposium on Data Bases, to be held in Washington, D. C., May 6-8, 1991.

7. Pinelli, Jean-Paul, Craig, J. I. and Goodno, B. J., "Development and Calibration of Nonlinear Dynamic Models for Precast Cladding Connections in Seismic Design," to appear in Proceedings, Seventh Conference on Computing in Civil Engineering and Symposium on Data Bases, to be held in Washington, D. C., May 6-8, 1991.

(C) PUBLICATIONS INDIRECTLY RELATED TO GRANT ACTIVITIES

1. El-Gazairly, Loai F., and Goodno, B. J., "Dynamic Analysis of a Highrise Building Damaged in the Mexico Earthquake Including Cladding-Structure Interaction," Proceedings, The International Symposium on Architectural Precast Cladding - Its Contribution to Lateral Resistance of Buildings, organized by the Precast/Prestressed Concrete Institute, held in Chicago, Illinois, November 8-9, 1989, pp. 257-286.

2. Pinelli, J-P. and J. I. Craig, "Experimental Studies of the Performance of Mexican Precast Cladding Connections," Proceedings, The International Symposium on Architectural Precast Cladding - Its Contribution to Lateral Resistance of Buildings, organized by the Precast/Prestressed Concrete Institute, held in Chicago, Illinois, November 8-9, 1989, pp. 159-173.

3. Goodno, B. J., "Cladding Performance: Some Lessons from Two Recent Major

Earthquakes," presented at The International Symposium on Architectural Precast Cladding - Its Contribution to Lateral Resistance of Buildings, organized by the Precast/Prestressed Concrete Institute, held in Chicago, Illinois, November 8-9, 1989.

(D) SUMMARY OF RESEARCH ACTIVITIES IN YEAR 1

The research carried out during Year 1 of the proposed 2 year program has led directly to 2 publications/presentations at national conferences, 4 at national specialists meetings and one survey paper on experimental research in this field. In addition, several other papers related to the current work were also presented. The principal investigators have been active participants in and contributors to ongoing professional activities on the West Coast, at the National Center for Earthquake Engineering Research, and in the Southeast.

The Year 1 research has largely proceeded according to the plan outlined in the revised proposal submitted to the NSF in September 1989. The research has been organized into several primary tasks, each of which is being pursued by one or more graduate research assistants and all of which are coordinated by the co-PI's. Each of the tasks are summarized below:

Task 1: *Development of a three dimensional nonlinear structural model for a multistory reinforced concrete structure.* The objective of this task is to accurately model the dynamic behavior of a case study building that has been damaged in a major earthquake. Initial attempts were directed at development of nonlinear cladding-connection elements to be incorporated into IDARC (Inelastic Damage Analysis of Reinforced Concrete structures, NCEER). However, critical problems were encountered in the accurate representation of three dimensional effects (due to unsymmetric planform) in the case study building. To remedy this shortcoming of IDARC, Task 1 was modified to focus first on the development of three dimensional analysis capabilities to the IDARC program (referred to here as IDARC-3D). The strategy has been to initially develop a basic 3-D analysis approach without consideration of certain local interaction effects such as biaxial bending of columns. Code modifications of the basic IDARC to create IDARC-3D have been completed and testing is underway. Cladding elements will then be added and IDARC-3D will then be used to evaluate the performance of the case study building to determine how effective the program is in predicting the observed damage. Finally, the use of advanced connection models to moderate damage will be studied.

Task 2: *Development of a two dimensional building model for a steel frame building with nonlinear cladding-connection elements.* To complement the case-specific approach of Task 1, a more general study of the effectiveness of cladding with advanced connections on the response of steel frame structures is underway. The basis for the model is DRAIN-2D with specially developed nonlinear connection models that are based on laboratory observations (both previous and current). The NCEER 3-bay, 6 story test building is being modeled, and preliminary results confirm the accuracy of the DRAIN-2D model on the basis of shake table results and NCEER analysis. This structure was

chosen for several important reasons. First, there are extensive analysis and test results available for the structure without any cladding. Second, the original analysis and test work was to study active mass dampers and tendon tensioning as means for controlling structural response, and these results should provide a good comparison for the relative effectiveness of advanced ductile cladding connections in also controlling earthquake response. Finally, the advanced cladding analysis for this structure could lead to future laboratory testing of a fully clad model using candidate advanced connection designs.

Task 3: *Development of a general three dimensional steel frame building model incorporating nonlinear cladding-connection elements.* This task is directed at establishing a reference nonlinear 3-D building model for steel frame structures. A model for the NCEER test frame (see Task 2) is currently under development using ANSYS, a general purpose frame and finite element analysis program with nonlinear modeling capabilities. Preliminary results for the linear elastic response have been confirmed against other models, and initial nonlinear response results are in general agreement with the DRAIN-2D results from Task 2.

Task 4: *Development of an experimental program to design, test and evaluate advanced cladding connections and to formulate analytical models to represent measured response.* A key part of the research program is the use of actual test data to model advanced cladding connection designs. This requires the development of laboratory test facilities and the execution of a focused test program. Conceptual studies were initially undertaken for a laboratory connection test fixture and based on these results a detailed design program is currently being completed. The design provides for testing connection systems up to 10" in effective length at interstory drift levels up to 4" with or without gravity loading present. It is expected that the facility will be completed by 1 January 1991 and that testing will begin in Year 2 of the research program. Both empirical and lumped parameter mechanical models for the insert and connection elements (suitable for Task 1-3 use) have been developed and the insert models calibrated on the basis of earlier insert tests (part of a previous research program - see Ref. (C)2 above). Finally, three different advanced connection elements have been identified and are being studied in more detail. These are: (a) a ductile steel loop (based on an earlier u- strip connection design), (b) an eccentric torsion element, and (c) an "enhanced" ductile rod design. It is expected that prototype models of each type will be fabricated for testing during Year 2.

PART IV - SUMMARY DATA ON PROJECT PERSONNEL

(see attached form)

PART IV — FINAL PROJECT REPORT — SUMMARY DATA ON PROJECT PERSONNEL

(To be submitted to cognizant Program Officer upon completion of project)

The data requested below are important for the development of a statistical profile on the personnel supported by Federal grants. The information on this part is solicited in response to Public Law 99-383 and 42 USC 1885C. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. You should submit a single copy of this part with each final project report. However, submission of the requested information is not mandatory and is not a precondition of future award(s). Check the "Decline to Provide Information" box below if you do not wish to provide the information.

Please enter the numbers of individuals supported under this grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

	Senior Staff		Post-Doctorals		Graduate Students		Under-Graduates		Other Participants[1]	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
A. Total, U.S. Citizens	2				3					
B. Total, Permanent Residents										
U.S. Citizens or Permanent Residents[2]:										
American Indian or Alaskan Native ...										
Asian ...										
Black, Not of Hispanic Origin ...										
Hispanic ...										
Pacific Islander ...										
White, Not of Hispanic Origin ...	2				3					
C. Total, Other Non-U.S. Citizens					5					
Specify Country 1. Egypt					1					
2. France					1					
3. Taiwan; 4. Korea					2					
D. Total, All participants (A + B + C)	2				7					
Disabled[3]										

☐ Decline to Provide Information: Check box if you do not wish to provide this information (you are still required to return this page along with Parts I-III).

[1]Category includes, for example, college and precollege teachers, conference and workshop participants.

[2]Use the category that best describes the ethnic/racial status for all U.S. Citizens and Non-citizens with Permanent Residency. *(If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)*

[3]A person having a physical or mental impairment that substantially limits one or more major life activities; who has a record of such impairment; or who is regarded as having such impairment. *(Disabled individuals also should be counted under the appropriate ethnic/racial group unless they are classified as "Other Non-U.S. Citizens.")*

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintain cultural identification through tribal affiliation or community recognition.

ASIAN: A person having origins in any of the original peoples of East Asia, Southeast Asia and the Indian subcontinent. This area includes, for example, China, India, Indonesia, Japan, Korea and Vietnam.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

PACIFIC ISLANDER: A person having origins in any of the original peoples of Hawaii; the U.S. Pacific Territories of Guam, American Samoa, or the Northern Marianas; the U.S. Trust Territory of Palau; the islands of Micronesia or Melanesia; or the Philippines.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa, or the Middle East.

THIS PART WILL BE PHYSICALLY SEPARATED FROM THE FINAL PROJECT REPORT AND USED AS A COMPUTER SOURCE DOCUMENT. DO NOT DUPLICATE IT ON THE REVERSE OF ANY OTHER PART OF THE FINAL REPORT.

OMB Number 3145-0058

NATIONAL SCIENCE FOUNDATION
1800 G STREET, NW
WASHINGTON, DC 20550

PI/PD Name and Address

Barry J. Goodno
Sch of Civil Engr.
GA Tech Res Corp - GIT
Atlanta GA 30332

NATIONAL SCIENCE FOUNDATION
FINAL PROJECT REPORT

PART I - PROJECT IDENTIFICATION INFORMATION

1. Program Official/Org. Shih-Chi Liu - ECS

2. Program Name EARTHQUAKE HAZARD MITIGATION PROGRAM

3. Award Dates (MM/YY) From: 02/90 To: 07/92

4. Institution and Address
GA Tech Res Corp - GIT
Administration Building
Atlanta GA 30332

5. Award Number 8906508

6. Project Title
Advanced Seismic Design Methods for Precast Cladding

This Packet Contains
NSF Form 98A
And 1 Return Envelope

FINAL PROJECT REPORT

ADVANCED SEISMIC DESIGN METHODS FOR PRECAST CLADDING
NSF Award Number 8906508

February 1990 - July 1992

Professors Barry J. Goodno and James I. Craig
Co-Principal Investigators
Georgia Institute of Technology
Atlanta, Georgia 30332-0355

Part II - SUMMARY OF COMPLETED PROJECT

Architectural precast cladding systems can provide significant additional lateral stiffness to buildings thereby altering their dynamic properties and seismic response compared to that of the bare frame alone. However, the precast facade is often dismissed as nonstructural and is not normally considered in the building design process to offer lateral stiffening to the building as a whole. Nevertheless, architectural precast panels have been shown to interact to a substantial degree during past earthquakes, altering the response predicted by bare frame models of the structure.

The present research has explored the possible use of precast panels and their attachments to the structure as part of an integrated building cladding system which provides both increased lateral stiffness and damping for the structure as a whole. Analytical models were developed for the cladding panels and their flexible attachments, and laboratory tests were conducted to establish the hysteretic behavior of promising advanced connection designs offering improved energy dissipation, ductility and failure characteristics/modes compared to present precast cladding systems.

Cladding connection models were calibrated on the basis of the lab tests, then applied to computer models of two prototype structures: a six story test frame previously used in passive and active control experiments, and a 12 story reinforced concrete building damaged in the 1985 Mexico Earthquake. Seismic evaluation of these two structures, both with and without the advanced cladding connection systems, showed that energy dissipating connections can contribute to reduced response of the building as a whole.

Results from these studies have led to new conceptual models for flexible, ductile cladding connection systems and to an improved understanding of the behavior of heavy cladding systems on modern buildings during earthquakes. The results have also begun to explain the relative roles of the additional structural stiffening versus the added damping provided by "properly" engineered ductile connection systems. The implications of these findings for future design studies has also been identified.

Part III - TECHNICAL INFORMATION

a. **Publications Resulting From Award**

a1. *Papers in Referred Journals*

1. Pinelli, J.-P., Craig, J. I., and Goodno, B. J., "Passive Control of Building Response Using Energy Dissipating Cladding Connections," to appear in Earthquake Spectra, Earthquake Engineering Research Institute, V. 9, N. 3, August 1993.

2. Pinelli, J-P., Moor, C., Craig, J. I., and Goodno, B. J., "Experimental Testing of Ductile Cladding Connections for Building Facades," to appear in The International Journal of the Structural Design of Tall Buildings, John Wiley and Sons, Inc., London, August 1993.

3. Goodno, B. J., and Craig, J. I., "Modeling of Advanced Precast Cladding Connections for Seismic Design," to appear in Building Research and Information, Chapman and Hall Ltd, London, 1993 (see also Proceedings, International Symposium on Building Technology and Earthquake Hazard Mitigation, held in Kunming, China, on March 25-29, 1991, pp. 99-114).

a2. *Papers Appearing in Published Conference Proceedings*

1. El-Gazairly, Loai F., Goodno, B. J., and Craig, J. I., "Analytical Investigation of Advanced Connections for Precast Cladding on Buildings," Proceedings, The Fourth U.S. National Conference on Earthquake Engineering, held in Palm Springs, California, on May 20-24, 1990, Vol. 2, pp. 441-450.

2. Pinelli, Jean-Paul, Craig, J. I., and Goodno, B. J., "Development and Experimental Calibration of Selected Dynamic Models for Precast Cladding Connections," Proceedings, The Fourth U.S. National Conference on Earthquake Engineering, held in Palm Springs, California, on May 20-24, 1990, Vol. 2, pp. 147-156.

3. Pinelli, Jean-Paul, Craig, J. I., and Goodno, B. J., "Development of Advanced Concepts for Precast Cladding," Proceedings, ATC-29 Seminar: Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures, held in Irvine, California, on October 3-4, 1990, pp. 26.1-26.11.

4. Wolz, M. W., Hsu, C., and Goodno, B. J., "Nonlinear Interaction Between Building Structural Systems and Nonstructural Cladding Components,"

Proceedings, ATC-29 Seminar: Seismic Design and Performance of Equipment and Nonstructural Elements in Buildings and Industrial Structures, held in Irvine, California, on October 3-4, 1990, pp. 25.1-25.12.

5. Wolz, M. W., Hsu, C., El-Gazairly, L. F., Goodno, B. J., and Craig, J. I., "Nonlinear Dynamic Analysis of Buildings with Advanced Cladding Connections," Proceedings, ASCE Seventh Conference on Computing in Civil Engineering and Symposium on Data Bases, Washington, D. C., May 6-8, 1991, pp. 729-738.

6. Pinelli, Jean-Paul, Craig, J. I. and Goodno, B. J., "Development of Nonlinear Dynamic Models for Precast Cladding Connections in Seismic Design," Proceedings, ASCE Seventh Conference on Computing in Civil Engineering and Symposium on Data Bases, Washington, D. C., May 6-8, 1991, pp. 739-748.

7. Craig, J. I. and Goodno, B. J., Wolz, M. W., and Pinelli, Jean-Paul, "Analytical and Experimental Evaluation of Advanced Cladding Systems for Buildings," Proceedings, Second Conference on Tall Buildings in Seismic Regions, 55th Regional Conference, held on May 16-17, 1991, in Los Angeles, California, pp. 99-108.

8. Pinelli, Jean-Paul, Craig, J. I. and Goodno, B. J., "Hysteretic Connection Models for Load Resisting Cladding Panels in Seismic Zones," Proceedings, International Conference on Buildings with Load Bearing Concrete Walls in Seismic Zones, sponsored by the French Association for Earthquake Engineering, held June 13-14, 1991, in Paris, France, pp. 98-109.

9. Goodno, B. J., and Craig, J. I., "Modeling of Advanced Precast Cladding Connections for Seismic Design," Proceedings, International Symposium on Building Technology and Earthquake Hazard Mitigation, held in Kunming, China, on March 25-29, 1991, pp. 99-114. (see also a1.-3 above)

10. Goodno, B. J., Craig, J. I., and Hsu C., "Experimental Studies and Analytical Evaluation of Ductile Cladding Connections," Proceedings, Pacific Conference on Earthquake Engineering, Auckland, New Zealand, November 20-23, 1991, V. 2, pp. 43-54.

11. El-Gazairly, L., Goodno, B. J, and Craig, J. I., "Nonlinear Dynamic Analysis of RC Structures with Precast Cladding Using GT-IDARC," Proceedings, ASCE 8th Computing in Civil Engineering Conference, Dallas, Texas, June 7-9, 1992, pp. 896-904.

12. Goodno, B. J., and Craig, J. I., "Use of Advanced Cladding Systems for Passive Control of Building Response in Earthquakes," Proceedings, 10th World Conference on Earthquake Engineering, Madrid, Spain, July 19-24, 1992, V. 7, pp. 4195-4200.

13. Craig, J. I., Goodno, B. J., Pinelli, J-P., and Moor, C., "Modelling and Evaluation of Ductile Cladding Connection Systems for Seismic Response Attenuation in Buildings," Proceedings, 10th World Conference on Earthquake Engineering, Madrid, Spain, July 19-24, 1992, V. 7, pp. 4183-4188.

a3. *Presentations Without Proceedings*

1. Goodno, B. J. and Craig, J. I., "Performance of Precast Concrete Cladding in Recent Earthquakes," Invited Presentation, presented by B. Goodno at the ACI Spring Convention, Boston, Massachusetts, March 17-21, 1991.

2. Goodno, B. J. and Craig, J. I., "The Effect of Precast Concrete Cladding on the Lateral Load Response of Buildings," Invited Presentation, presented by B. Goodno at the ACI Fall Convention, Session on Lateral Drift of Concrete Buildings, Dallas, Texas, November 10-15, 1991.

3. Goodno, B. J., "Research Needs: Nonstructural Systems and Components," NSF East-Coast Regional Workshop on Architectural Research Needs in Earthquake Hazard Mitigation, held at the Graduate School of Design, Harvard University, Cambridge, MA, January 9-10, 1992.

b. **Data on Scientific Collaborators**

Dr. Barry J. Goodno, Professor, School of Civil Engineering, Georgia Institute of Technology, Co-Principal Investigator, Project Director

Dr. James I. Craig, Professor, School of Aerospace Engineering, Georgia Institute of Technology, Co-Principal Investigator

Mr. Loai El-Gazairly, Graduate Research Assistant, School of Civil Engineering (Ph.D. Candidate, expected completion in December 1992)

- modification of GT-IDARC; supercomputer analyses of Mexico Case Study Building

Mr. Jean-Paul Pinelli, Graduate Research Assistant, School of Civil Engineering (Ph.D. Candidate, expected completion in December 1992)

- development of laboratory test fixture for cladding connection testing; acquisition and analysis of experimental data

Mr. Cheng-Chieh Hsu, Graduate Research Assistant, School of Civil Engineering (Ph.D. Candidate, expected completion in December 1993)

(MSCE Thesis, "Integrated Analyses of a Cladding-Frame System with Nonlinear Panel-to-Structure Connections," School of Civil Engineering, Georgia Institute of Technology, May 1991)

- modification of DRAIN-2D to incorporate cladding composite connection element; nonlinear dynamic analyses of six story test structure

Mr. Joo-Woo Kim, Graduate Research Assistant, School of Civil Engineering (Ph.D. Candidate, expected completion in June 1994)

- addition of base isolation model to DRAIN-2D for nonlinear dynamic analyses of combined passive control systems

Mr. Christian Moor, MSCE Thesis, "Analytical and Experimental Evaluation of Advanced Cladding Connections," School of Civil Engineering, Georgia Institute of Technology, March 1992

Mr. Michael Wolz, MSCE Thesis, "Nonlinear Interaction Between Building Structural Systems and Nonstructural Cladding," School of Civil Engineering, Georgia Institute of Technology, January 1991

c. **Software Development/Enhancement**

1. GT-IDARC: significant upgrade of IDARC (NCEER) for 3D nonlinear dynamic analysis of RC buildings including effects of cladding and foundation-structure interaction; substantial computer time required for nonlinear dynamic analysis (eg., 15-24 hours of CPU time on Cray Y-MP/832 for 12 story Mexico case study building; see ref. a2.-11 cited above)

2. Cladding connection elements for DRAIN-2D: addition of 3-parameter hysteretic spring and lumped parameter spring-slip-gap models; used for evaluation of cladding effect on nonlinear dynamic analyses of six story test structure

3. Optimal lumped parameter model parameter identification: for evaluation of hysteresis test data for cladding connection specimens

PART IV — FINAL PROJECT REPORT — SUMMARY DATA ON PROJECT PERSONNEL

(To be submitted to cognizant Program Officer upon completion of project)

The data requested below are important for the development of a statistical profile on the personnel supported by Federal grants. The information on this part is solicited in response to Public Law 99-383 and 42 USC 1885C. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. You should submit a single copy of this part with each final project report. However, submission of the requested information is not mandatory and is not a precondition of future award(s). Check the "Decline to Provide Information" box below if you do not wish to provide the information.

Please enter the numbers of individuals supported under this grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

	Senior Staff		Post-Doctorals		Graduate Students		Under-Graduates		Other Participants[1]	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
A. Total, U.S. Citizens	2				1					
B. Total, Permanent Residents										
U.S. Citizens or Permanent Residents[2]:										
American Indian or Alaskan Native										
Asian										
Black, Not of Hispanic Origin										
Hispanic					1					
Pacific Islander										
White, Not of Hispanic Origin										
C. Total, Other Non-U.S. Citizens										
Specify Country										
1. China					1					
2. Korea					1					
3. Egypt					1					
D. Total, All participants (A + B + C)										
Disabled[3]										

☐ Decline to Provide Information: Check box if you do not wish to provide this information (you are still required to return this page along with Parts I-III).

[1]Category includes, for example, college and precollege teachers, conference and workshop participants.

[2]Use the category that best describes the ethnic/racial status for all U.S. Citizens and Non-citizens with Permanent Residency. *(If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)*

[3]A person having a physical or mental impairment that substantially limits one or more major life activities; who has a record of such impairment; or who is regarded as having such impairment. *(Disabled individuals also should be counted under the appropriate ethnic/racial group unless they are classified as "Other Non-U.S. Citizens.")*

AMERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America, and who maintain cultural identification through tribal affiliation or community recognition.

ASIAN: A person having origins in any of the original peoples of East Asia, Southeast Asia and the Indian subcontinent. This area includes, for example, China, India, Indonesia, Japan, Korea and Vietnam.

BLACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

HISPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

PACIFIC ISLANDER: A person having origins in any of the original peoples of Hawaii; the U.S. Pacific Territories of Guam, American Samoa, or the Northern Marianas; the U.S. Trust Territory of Palau; the islands of Micronesia or Melanesia; or the Philippines.

WHITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa, or the Middle East.