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## Expert Systems Technology

EDA (Educational Design Assistant)

Quintec-Prolog Quintec-Flex

.UNIX

SUN Workstation

### ABSTRACT

*Computers have been introduced as an element into the teaching environment for a long time now. Until recently, computers have been used for relatively routine calculations such as: report writing, spreadsheets, drafting, and simple simulations. Very rarely are computers used to help teach and visualize fundamental concepts, or to explore the alternative solutions of a design project. Today the most interesting and exciting branch in computer applications is expert systems technology. Expert system technology can play a great role in enhancing the processes of teaching and learning in engineering education.*

*This paper addresses the impact of Expert Systems (ES) technology in providing the necessary support for developing earthquake engineering computer-aided education. An introduction to ES technology is briefly presented. Then, the benefits from the application of ES in engineering education are outlined. A theoretical strategy is proposed for developing ES prototypes for engineering education purposes. An educational prototype ES for teaching earthquake resistant design of buildings is briefly presented. The prototype was developed using a SUN SPARCstation under the UNIX operating system, and using Quintec-Prolog, Quintec-Flex, and FORTRAN 77 as programming environment. The paper concludes with a summary and recommendations on future impact of artificial intelligence and ES technologies on computer-aided engineering education.*

simulation

spreadsheets

self-learning

.interactive learning

WWW

expert systems

.creativity

intuition

simulations

"What-If design scenarios"

( )

design problems

WWW

expert systems

artificial intelligence

statics

multimedia

.structural analysis and design

dynamics

student-interface

.[Siekmann, 1990]

Intelligent tutoring system "

Computer-Aided Instruction

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Areiti, 1990,

Student-Interface

[Henry, 1994]

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[Vanegas, 1993] Vanegas

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[Wriggers et al, 1990]

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theory of elasticity

finite element method

.matrix algebra

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[Pudlowski, 1990] Pudlowski

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Internet

Intranet

Expert Systems Technology

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[Waterman, 1986 &amp; Mockler, 1992] Expert systems

Intuition

,Rules of thumb

Judgement

Expertise

ill-structured problems

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heuristic solutions

.[Shortliffe, 1976]

.conventional programs

Engineering Education Application

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FEM

.learning by doing

symbolic reasoning

symbolic processing

.detailed design

conceptual design

**EDA** (Educational Design Assistant)

clauses

facts

production rules

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.data structure

frames

Quintec-Flex Quintec-Prolog [Quintec System, 1989]

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**EDA**

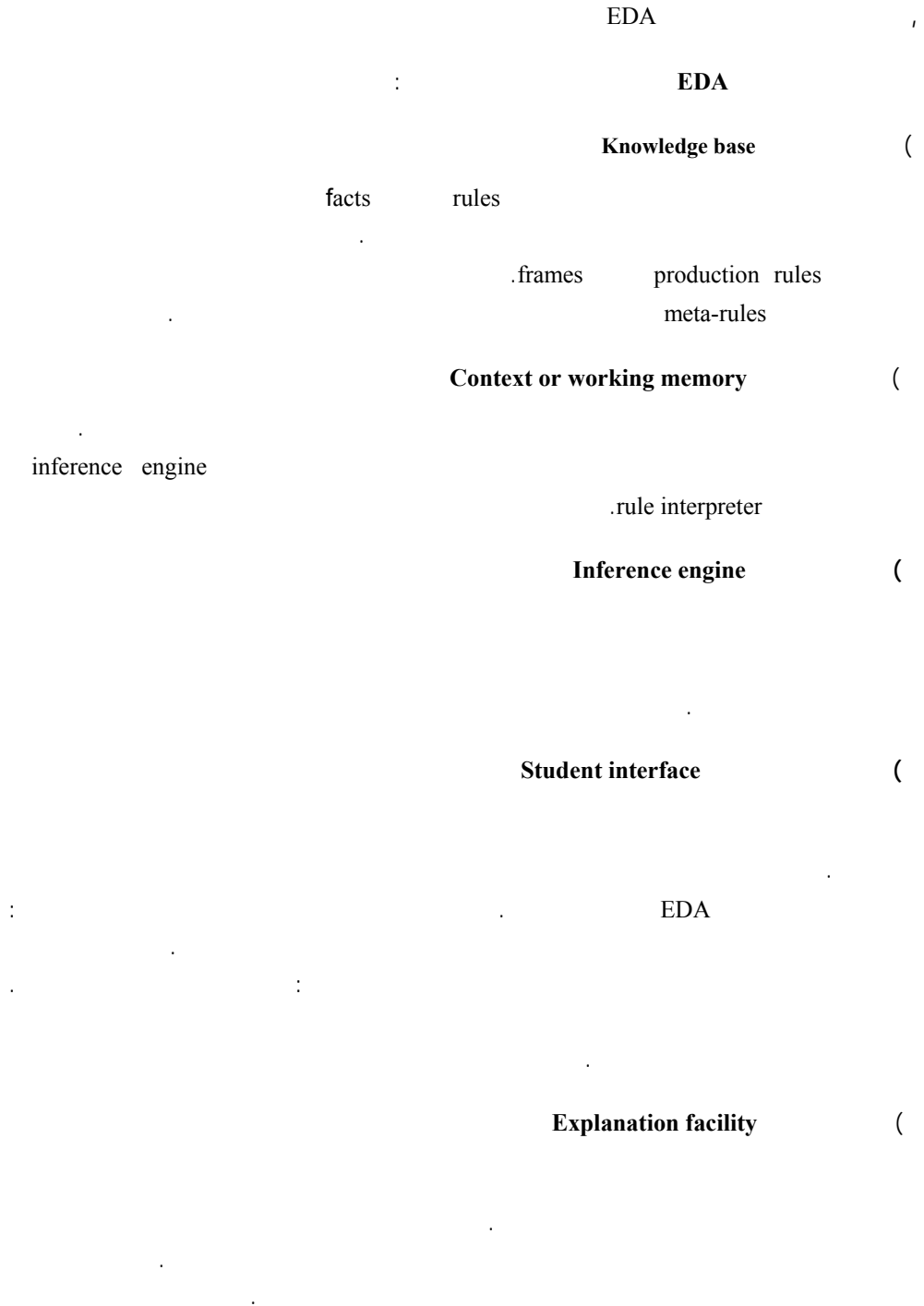
.FORTRAN 77

.UBC [Uniform Building Code, 1991]

UBC

[Kannan & Powell, 1975] DRAIN-2D

elastic & inelastic analysis



**Knowledge acquisition facility**

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**Knowledge acquisition**

bottle-neck "

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knowledge engineer

:[Hart, 1985]

Eurocode 8 [Comite Euro-International du Beton, 1987] CEB UBC-91

.[Penelis &amp; Kappos, 1997, Booth, 1994]

interview technique

engineering judgement

**Student-interface menus**

EDA

menus

( ) :

: **HELP**: **GEOMETRY CHECK**: **CODE LOADS**

: ANALYSIS

.DRAIN-2D

: DISPLAY

: RESTART

: FILES

: UNIX

: EXIT

.Unix

EDA

EDA

menus

DRAIN-2D

DRAIN-2D

EDA

Unix Pipes

DRAIN-2D

**Student-Interface**

student-interface ( )

( )

student model

conceptual student model



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student ( )  
system model

student model  
.student-interface  
( )

computer system

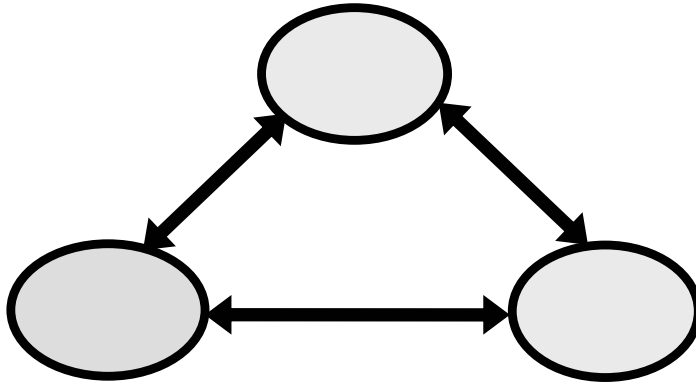
EDA  
coupled walls

A

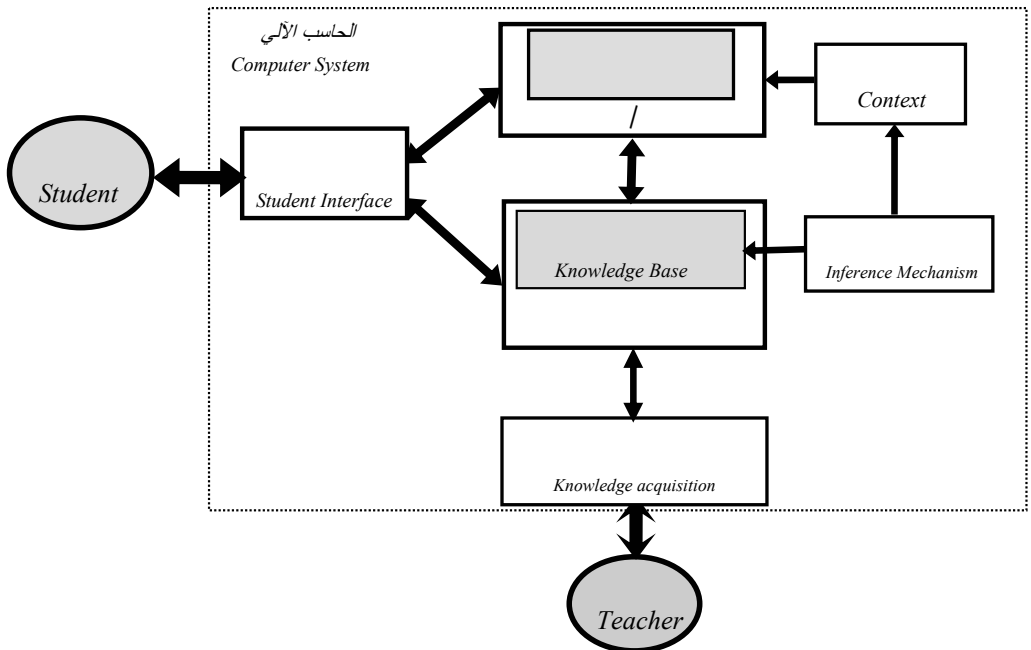
EDA

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EDA

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RESTART
FILES
UNIX
EXIT

MENU

SELECT ANY OPTION

HELP

GEOMETRY

CODE LOADS

ANALYSIS

DIPLAY

SDA

SCIENTIFIC DESIGN  
INSTITUTE  
1994

PLAN

ELEVATION

DESIGN DATA INFORMATION

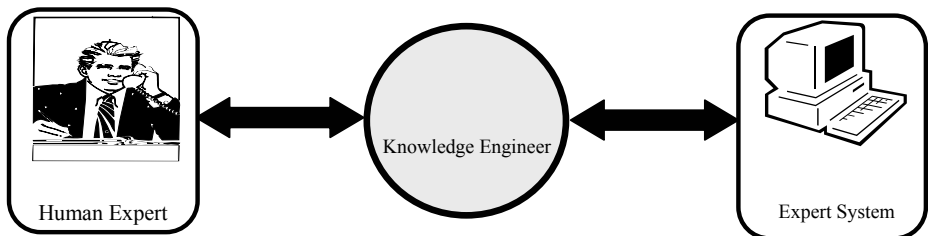
Type of building: Office building  
 Zone: California (Zone 4), Number of Floors: 10  
 Story height: 2.75 m, Ground height: 3.50 m  
 Columns: 0.4X0.4 m, Walls thickness: 0.4 m  
 Slab thickness: 0.20 m, Dead load: 5 kN/m<sup>2</sup>, Live load: 2.5 kN/m<sup>2</sup>

Earthquake Record

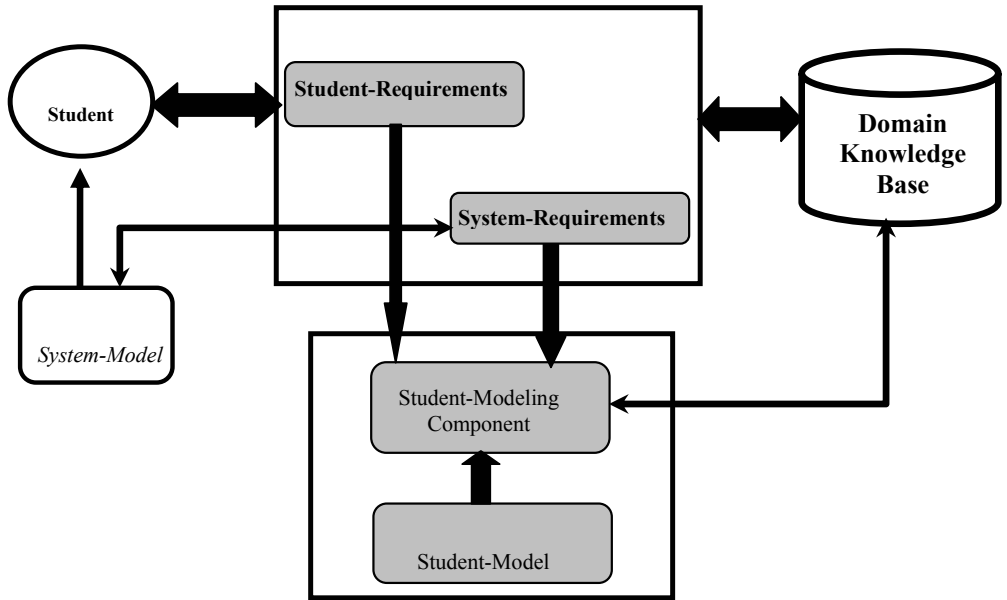
EL-CENTRO 1940

CONTINUE

EDA :

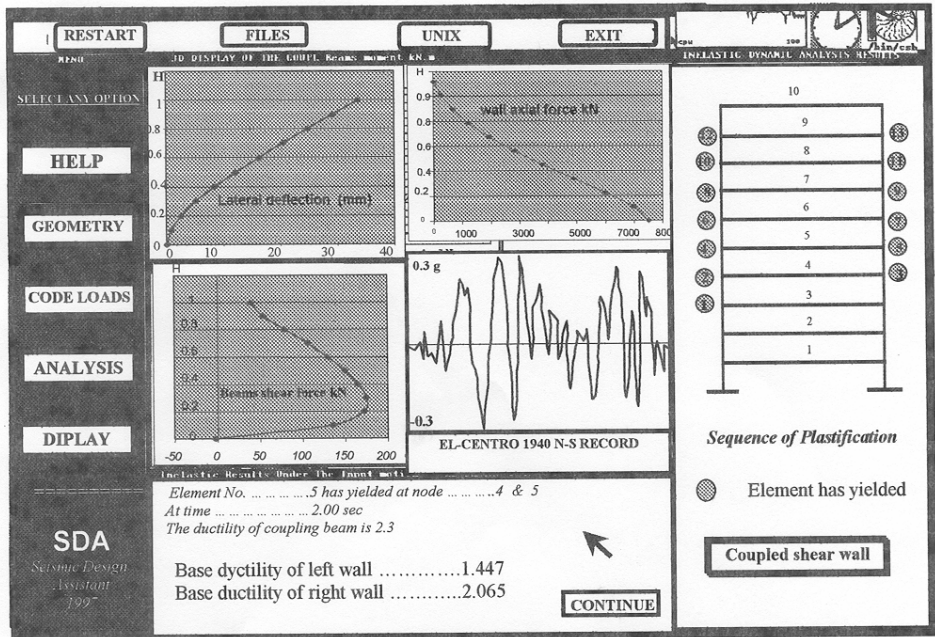


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Student Modeling Module

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EDA

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## Appendix A

### Example of Consultation

#### Design steps

In this section the consultation process between the student and the system is described as the student engage in the learning process of the problem. The plan of the building and design data information are shown in Fig. 3.

#### Part 1:

Estimation of the code static base shear force and lateral static forces (based on the UBC 91 code).

**Student:** *Chooses the [CODE LOADS] option from the Master menu (see Fig. 3). The [CODE LOADS] option is divided into three sub-options: [Help], [Evaluate Base Shear Force], [Distribute Lateral Static Forces], and [EXIT]. The student clicks on the [Evaluate Base Shear Force] sub-option.*

**System:** *informs the student about the start of the evaluation of the seismic factors (Z,I,K,T,C,S and W) based on the UBC 91 code. Also it asks the student if he would like to see the explanation for each step.*

**Student:** *clicks on the [YES] option.*

**System:** *asks the student if the building is horizontally and vertically regular (a sub-menu is displayed to the student showing different options: [YES], [NO], or [DO NOT KNOW].*

**Student:** *replies with [YES].*

**System:** *asks about the zone area where the building to be constructed, a sub-menu is displayed to the student showing the zones number and an option called [Show Seismic Map of the USA] for showing the USA zones map.*

**Student:** *identifies the zone area of California and return back to the zones number sub-menu and clicks on the [Zone No. 4] option.*

**System:** *displays the zone factor  $Z=1.00$  and asks the student about the type of occupancy by displaying a menu which includes: [Hospital & Medical Facilities], [Fire & Police Station], [Municipal Government & Communication Centres] and [All Others].*

**Student:** *clicks on the [All Others] option.*

**System:** *displays the value of the importance factor  $I = 1.00$ . And asks the student about the type of arrangement by displaying a menu: [All building framing systems except as classified below], [Buildings with box system], [Buildings with a dual bracing system], [Building with a ductile moment-resisting space frame], [Elevated tank plus full content], and [Structures other than building].*

**Student:** *clicks on the [Building with Box system].*

**System:** *displays the force factor  $K=1.33$ . And asks the student about the building height  $H_s = ?$*

**Student:** enters 28.25 m.

**System:** advises the student that the building shall have ductile moment-resisting space frames capable of resisting not less than 25% of the required seismic forces for the structure as a whole. The system then asks the student about the external dimensions ( $L_x$ ,  $L_y$ ) of the building in Both directions.

**Student:** enters  $L_x = 45.75$  m and  $L_y = 14$  m.

**System:** asks if the profile type of the soil is known, and displays some profile types: [Rock or other Soil Exhibiting Rockfile Characteristics], [Stable Deposit of Sand, Gravels and Stiff Clays], [Soft to Medium-Stiff Clays and Sands] and [Unknown] options.

**Student:** replies by clicking the [Unknown] option.

**System:** explains that in case of  $T_s$  is unknown and the profile type of soil is also unknown the site factor can be taken equal to:  $S_x = S_y = 1.5$ , and also computes the following values: The period of the period in both directions and  $CS_x = 0.116$  and  $CS_y = 0.088$  (Where  $C = \frac{1}{\sqrt{T}}$ ). The system then asks the student about the distance between two frames or walls in both directions (X and Y directions).

**Student:** enters 7.625 m for X direction and 6.71 m for Y direction.

**System:** asks about the estimated values of dead load  $G_k$  and live load  $Q_k$  in kN/m<sup>2</sup>.

**Student:** enters 5 kN/m<sup>2</sup> for  $G_k$  and 2.5 kN/m<sup>2</sup> for  $Q_k$ .

**System:** asks about the total floor number  $NF = ?$

**Student:** inputs  $NF = 10$ .

**System:** displays to the student the computed base shear factors and the values of base static shear force for both direction of the building:

$$V_x = 7213 \text{ kN / per frame or coupled wall}$$

$$V_y = 2076 \text{ kN / per frame or coupled wall.}$$

Also at this stage, the system informs the student that the structure period  $T_s$  is bigger than 0.7 s and less than 3.6 s, the top force should be estimated as follows:

$$F_{tx} = 0.07T_s V_x = 263.36 \text{ kN in X direction}$$

$$F_{ty} = 0.07T_s V_y = 132.21 \text{ kN in Y direction.}$$

The system asks the student about the story and ground heights of the building ( $H_x = ?$ ,  $H_g = ?$ ).

**Student:** enters  $H_s = 2.75$  m and  $H_g = 3.5$  m.

## **Part 2: Elastic analysis of the coupled shear wall using the Laminar method.**

**System:** *informs the student about the interface to the FORTRAN program LATERAL.F to compute the lateral static forces at each floor level in both direction of the building. The output result from LATERAL.F program is displayed to the student and is stored in a file called LATERAL.OUT for further use.*

*The system explains to the student that the static lateral forces found in this stage are to be used as input load data to analyze the coupled shear wall. Then it asks the student about the type of box system with displaying a menu containing the following box systems: [Frames and Shear Walls] and [Braced Frames].*

**Student:** *clicks on the [Frames and Shear Walls] option.*

**System:** *asks about any existence of coupled shear walls in the building?*

**Student:** *replies with [YES].*

**System:** *asks for which coupled shear wall to design, a menu is displayed: [Coupled wall lying in X dir, or Coupled wall lying in Y dir.].*

**Student:** *clicks on the [Explain] option.*

**System:** *explains that for estimating the tributary area for dead and live loads.*

**Student:** *clicks on the [Coupled wall lying in Y dir.] option.*

**System:** *asks about the position of coupled wall: [Edge Coupled Wall, Internal Coupled wall].*

**Student:** *chooses [Internal Coupled wall] option.*

**System:** *asks the following information: number of bays in X and Y dir., max width of the bay in X and Y dir., clear span, depth, and width of the coupling beams. A passive graphical explanation is also associated with question.*

**Student:** *enters 6 & 7.625 m for X direction and 3 & 6.71 m for Y direction.*

*$L_b = 1.83$  m,  $H_b = 0.5$  m and  $W_b = 0.356$  m.*

**System:** *Asks about the general conditions of the coupled walls by displaying the following menu: [Walls without flanges at its end], [Wall with wide flanges at its ends], [Wall with narrow flanges at its ends], [Wall with one of its end connected to a transversal flange], and [See more details].*

**Student:** *clicks on the [Walls without flanges at its ends] option.*

**System:** *asks the following information: walls height, width, and thickness, and story height.*

**Student:** *inputs  $H_w=56$  m,  $W_d1=6.71$  m,  $W_d2=6.71$  m,  $W_t=0.356$  m,  $H_s = 2.75$  m, and  $NF = 10$ .*

**System:** *The 2D geometry of the coupled wall is displayed to the student to visualise it and check for any data errors.*

*The system will execute the FORTRAN program LAMINAR.FOR. The system then informs the student about the termination of the running of the program and displays graphically the analysis results: lateral deflection, shear forces in beams and walls, axial forces and moments in walls, and elastic drift at each floor level as shown in Fig. 6.*

*The steel reinforcement for coupling beams and walls is estimated using the Capacity Design Procedure. The student has the choice to choose the preferred bar diameter for beams and walls. The system displays graphically the steel configuration used in beams and walls (see Fig. 7).*



RESTART FILES UNIX EXIT

MENU  
SELECT ANY OPTION

HELP

GEOMETRY

CODE LOADS

ANALYSIS

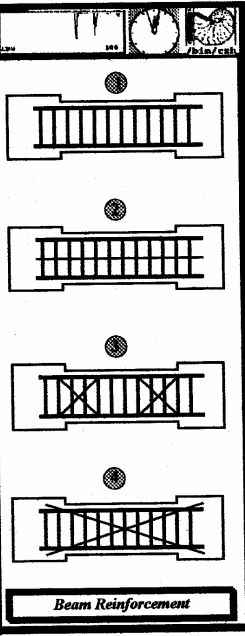
DIPLAY

SDA  
SEISMIC DESIGN ANALYSIS

**TYPICAL REINFORCEMENT USED IN COUPLING BEAMS**

- 1. Conventionally Reinforced Beams**  
*It is a beam with longitudinal reinforcement with transverse hoops, they perform well at low nominal shear demands.*
- 2. Additional Longitudinal Reinforcement**  
*This type improve the sliding shear capacity of beams.*
- 3. Bent steel near joint**  
*This type generally is 45 degree bent steel and is beneficial because it spread the hinging region away from the wall.*
- 4. Diagonally Reinforced Coupling Beams**

CONTINUE



The above is an explanation concerning different detailing techniques used in coupling beams to resist seismic forces. The configuration of the reinforcement is displayed graphically as shown in right hand side.

Beam Reinforcement

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