REFERENCES

1. T. Vien, "SITECAD," (Pilot Project for The World Bank, Washington, D.C., 1985).

2. E. Dluhosch and T. Vien, "MASONRY COMPUTE," (International Masonry Institute, Washington, D.C., 1985 - present).

3. T. Vien, "Investigation of an Integrated Computer System for Architectural Design," (S.M.Arch.S. Thesis, Massachusetts Institute of Technology, Cambridge, 1985).

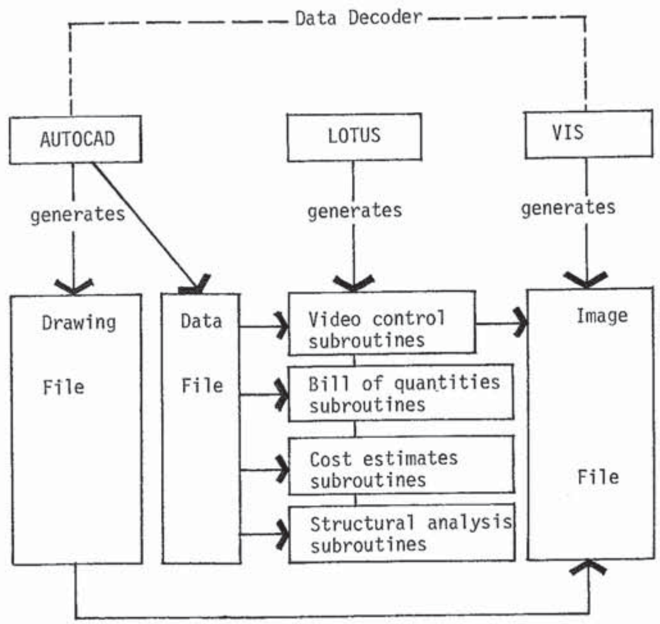

Fig. 1 Representation of the overall interface conditions.

CADD for Steel and Reinforced Concrete Buildings and Structures

T. Furuya

CHIYODA Chemical Engineering
and Construction Co., Ltd.
P.O. Box 10, Tsurumi, Yokohama, JAPAN

KEYWORDS

Computer-aided Frame Analysis, Design, Deflection Control, Plotting, Drawing, Graphics.

ABSTRACT

CHIYODA has developed a CADD (Computer-Aided Design and Drafting) system named IFADS and is currently using it for the design of many steel and reinforced concrete buildings and structures. IFADS (Integrated Frame Analysis and Design System) consists of the following subsystems; (1) frame analysis (2 and/or 3 dimensoinal); (2) code check and/or member design using the latest codes of AIJS (Architectural Institute of Japan-Steel), AISC (American Institute of Steel Construction) and ACI (American Concrete Institute); (3) plotting for visual checks of the input data and for stress diagrams; (4) automatic drawing (framing plan and elevation, and member schedule using graphics); and (5) material take-off. IFADS also has the capabilities to design composite structures of steel and reinforced concrete, to automatically control deflection of steel members and to design reinforced concrete shear walls and slabs. Large savings in manpower and costs, assurance of quality and standardization has been achieved by using IFADS.

CADD pour des Bâtiments et des Structures en Acier et en Bèton Armé

T. Furuya

CHIYODA Chemical Engineering
and Construction Co., Ltd.
P.O. Box 10, Tsurumi, Yokohama, JAPAN

MOTS CIEFS

Analyse et Dessin par Computer, Ossature, Selection des Bars, Contrôle de Fléche, Tracement, Graphics.

SOMMAIRE

CHIYODA a developpé un system de CADD (Computer-Aided Design and Drafting) nommé IFADS, et il l'utilise generalement au dessin de la charpente des bâtiments et des structures differentes, en acier et en bèton armé. IFADS (Integrated Frame Analysis and Design System) se compose de sous-systèmes suivants: (1) analyse d'ossature de deux ou trois dimensions; (2) selection ou justification des bars d'ossature conformément à les codes de AIJ (Architectural Institute of Japan) en acier, AISC (American Institute of Steel Construction), et ACI (American Concrete Institute); (3) tracement à permettre un contrôle visual des données et des sollicitations calculées; (4) dessin automatique (plan et elevation d'ossature, et liste des bars) par l'utilisation de computer-graphics; et (5) compte de matériau. IFADS est aussi capable de dessiner des structures composeés en acier et bèton armé, de contrôller des fleches des pièces en acier, et de dessiner des dalles et des murs en bèton armé sujets à la sollicitation de cisaillement. On a pu éparger de temps et dépense, assurer la meilleure qualité, et accomplier une standardisation, par l'utilisation du IFADS.

INTRODUCTION

CHIYODA has developed a CADD (Computer-Aided Design and Drafting) system named IFADS (Integrated Frame Analysis and Design System) and is currently using it for the design of many steel and reinforced concrete buildings and structures.

IFADS consists of the following subsystems;

(1) Pre-Processor for input data check.
(2) 2 and/or 3 dimensional elastic static and dynamic frame analysis.
(3) Code check and/or member design in accordance with the latest codes of AIJS (Architectural Institute of Japan-Steel), AISC (American Institute of Steel Construction) and ACI (American Concrete Institute), and material take-off of steels, re-bars, concretes and forms.
(4) Plotting for visual checks of the input data and for stresses.
(5) Automatic drawing of the frame plane and elevation, and member schedule using graphics system which are currently being developed.

IFADS also has the capabilities to design composite structures of steel and reinforced concrete, to automatically control deflections of steel members and to design reinforced concrete shear walls and slabs. IFADS macro flow chart is shown in Fig. 1.

1. IFADS GOALS OF DEVELOPMENT

IFADS has been developed to achieve the following goals:

(1) Manhour and cost savings for design, drawing and material take off.
(2) Improvement of accuracy of calculations and assurance of design quality.
(3) Minimum weight design by case studies.
(4) Reduction of design period.
(5) Standardization of output forms and drawings.

2. IFADS FEATURES

IFADS has the following features:

(1) Arbitarily structures such as octagonal buildings can be designed. IFADS can design only straight members. However, a curved member can be designed adding internal node joints and replacing the curve with a series of straight members.
(2) Composite structures of steel and reinforced concrete can be designed.
(3) Design can be done in accordance with either American or Japanese design code.
(4) Autoamtic data generation of self weights of members and panels (slabs and walls), and unbraced lengths and effective length factors of steel members can be done.

(5) Loads and combinations of loads up to 50 can be designed for.
(6) A girder which is connected to several subbeams can be designed as one member.
(7) Member equating (resizing of members for reasons such as easing of construction) for selected steel members and continuation of re-bars for adjacent reinforced concrete members and panels can be assigned.
(8) Material take-off of steels, re-bars, concretes and forms can be done automatically.
(9) Easy input by free format and by a command structured language.
(10) Visual input data check by plotting. Structural and loading data are checked by diagrams of isometric or plane views of frames.

3. STIFFINESS ANALYSIS AND DYNAMIC ANALYSIS

ICES STRUDL-II (developed by the Massachusetts Institute of Technology and improved on by IBM) is used for stiffness analysis and dynamic analysis. Modified Gaussian elimination method is used for stiffness analysis, and Householder tridiagonalization method or iteration method is used for solution of eigenvalues and eighevectors. It has an algorithm to reduce the band width of the stiffness matrix. Forces, displacements, deflections, reactions, eigenvalues, eigenvectors, dynamic participation factors and so on, are output.

4. DESIGN OF STEEL STRUCTURES

Code check and/or member selection in accordance with the AIJS-1970 and AISC-1978 codes are available now. In the case of code check, stiffness analysis is executed only one time using input member dimensions. In the case of member selection, stiffness analysis is executed twice, 1st time using input member dimensions and the second time using automatically selected new member dimensions. Axial, flexure and combined (axial and flexure) members can be designed.

In addition to code check, property (cross-sectional area, depth, width) constraints and deflection constraints under given loads can also be checked. Input data such as unbraced lengths of compression flange, unbraced lengths and effective length factors are generated automatically.

Member properties such as the cross-sectional area, moment of inertia, section modulus, depth of section, flange width of section, radius of gyration, flange thickness, and web thickness, etc., of JIS (Japan Industrual Standard) and ASTM material are stored on disk. Connections of column-grider, girder-subbeam and column bases are standardized in relation to the dimensions of each member. Code check or design results such as profile of steel members, critical load number and the location, name of the most sever formula and the checked value, section forces, allowable stresses, critical deflection and so on, are output. An example of output data is shown in Fig. 2.

5. DESIGN OF REINFORCED CONCRETE STRUCTURES

Design in accordance with ACI 318-77 and ACI318-83 is now available. Normal, moderate (special provision for seismic design described in ACI 318-83 chapter A.9) or seismic (described in ACI 318-77 Appendix A) design methods can be used. Flexure and combined (axial and bending) members and panels (oneway and twoway slabs, bearing walls and blastproof walls) can be designed.

Re-bar tables according to JIS, ASTM and BS (bar size, nominal diameter, normal area, nominal mass) are stored on disk. Required number and size of re-bars, design moments, moment capacity and so on, are output. An example of output data is shown in Fig. 2.

6. DRAWINGS (UNDER DEVELOPMENT)

Drawings of framing plans and elevations, and member schedules are drawn automatically on a graphic display screen using structural data (joint coordinates, member incidences, member angles, name of rows for frames, etc.), design data (member name and profile, etc.), and design results (member dimensions). Those sections which have not been stored in the computer such as stairs, handrails, openings in the walls and slabs and so on, are drawn manually on a graphic display screen. Approximate 70% of necessary drawings is expected to be made automatically by IFADS. An example of drawings is shown in Fig. 3.

7. IFADS MILESTONES

MIT ICES STRUDL delivered to CHIYODA	1972
Formation of IFADS development group	Oct. 1979
IFADS Static, Dynamic Analysis and Plotting System released	Dec. 1981
IFADS AISC Design Code System released	Mar. 1982
IFADS AIJS Design Code System released	June 1982
IFADS ACI Design Code System released	Sept.1985

8. CONCLUSION

Large savings in manhours and costs (approximately 70%), improvement of accuracy of calculations and assurance of design quality, minimum weight design by case studies, reduction of design period, standardization of output forms and drawings have been achieved by IFADS. IFADS has been utilized an average of 470 computer runs per a month during the last 3 years by civil and structural engineers.

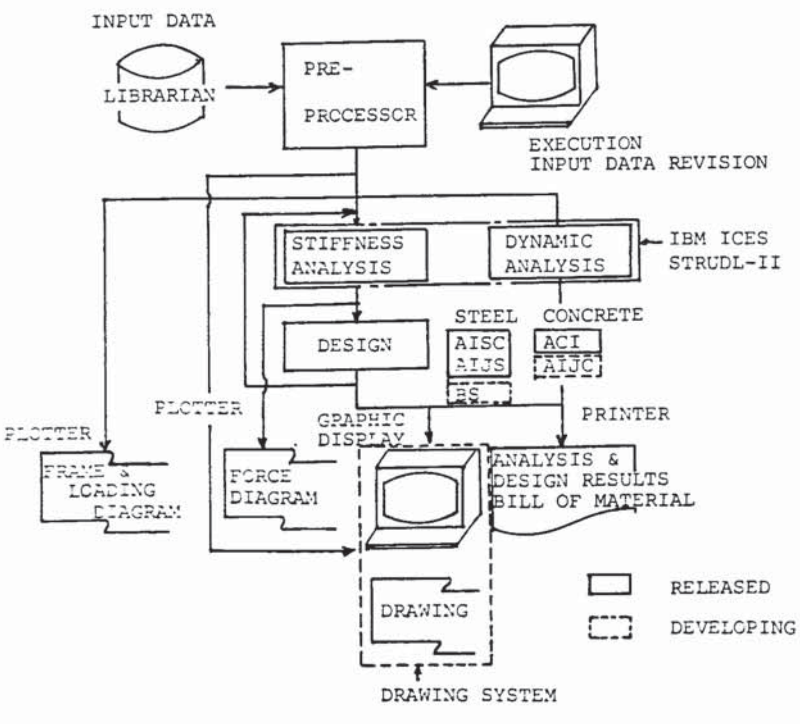

Fig. 1 IFADS macro flow chart


```
************************ D E S I G N   R E S U L T S ********************** UNIT: CM MTON      REP-ID: IFADS-09-03  PAGE-  2
        << S T E E L   M E M B E R   D E S I G N   ( A I S C ) >>           AXIS: LOCAL         JOB-ID: STEEL-01     DATE: OCT. 3.85

/----MEMBER ID----/===================================================CODE CHECK======================================================/CONSTRAIN
                 /          /CRITICAL/-CONTROL CHECK-/---------SECTION FORCE--------/------ALLOWABLE STRESS,CB,QA,QS---------/  CHECK
 NO.   CLASS      SECTION  LOAD NO. PRIMARY   RATIO(P)  FX         FY        FZ     FAT  FBT(Y)  FBT(Z)   CB     FV(Y)  QA   RESULT
NAME   CHECKED BY RESULT   LOCATION SECONDARY RATIO(S) TORSION     MY        MZ     FAC  FBC(Y)  FBC(Z) FBC'(Z)  FV(Z)  QS

    5  GIRDER     HM244          9  PAR1.6.2  0.60      0.5        1.4       0.0   1.44   1.00    1.44   1.00    0.96  1.00  NONE
2GX1   COMBINED   PASSED    300.00  PAR1.6.2  0.46      0.0        0.0     430.2   1.10   1.00    1.44   ---     0.96  1.00

    6  GIRDER     HM244          9  PAR1.6.2  0.60      0.5        1.4       0.0   1.44   1.00    1.44   1.00    0.96  1.00  NONE
2GX1   COMBINED   PASSED    300.00  PAR1.6.2  0.46      0.0        0.0     430.2   1.10   1.00    1.44   ---     0.96  1.00

    7  GIRDER     HM194          9  SLENDRSS  0.69     -0.1        0.0       0.0   1.44   1.00    1.44   1.00    0.96  1.00  NONE
2GY1   COMBINED   PASSED    250.00  FM1.6-2   0.41      0.0        0.0     130.6   0.56   1.00    1.17   ---     0.96  1.00

    8  GIRDER     HM194          9  SLENDRSS  0.69     -0.1        0.0       0.0   1.44   1.00    1.44   1.00    0.96  1.00  NONE
2GY1   COMBINED   PASSED    250.00  FM1.6-2   0.41      0.0        0.0     130.6   0.56   1.00    1.17   ---     0.96  1.00

    9  SUBBEAM    HM244          8  MOM.YZ-C  0.58      0.0        0.0       0.0   ---    1.00    1.44   1.00    0.96  1.00  NONE
2B1    FLEXURE    PASSED    250.00  MOM.YZ-C  0.55      0.0        0.0     388.8   ---    1.00    1.33   ---     0.96  1.00

    1  COLUMN     HW125         12  FM1.6-2   0.81     -2.7        0.4       0.0   1.92   2.40    1.92   1.75    1.28  1.00  NONE
1C1    COMBINED   PASSED    400.00  SLENDRSS  0.76      0.1        0.0    -174.8   0.63   2.40    1.92   ---     1.28  1.00

    2  COLUMN     HW125         12  FM1.6-2   0.81     -2.7        0.4       0.0   1.92   2.40    1.92   1.75    1.28  1.00  NONE
1C1    COMBINED   PASSED    400.00  SLENDRSS  0.76     -0.1        0.0    -174.8   0.63   2.40    1.92   ---     1.28  1.00

    3  COLUMN     HW125         13  FM1.6-2   0.81     -2.7       -0.4       0.0   1.92   2.40    1.92   1.75    1.28  1.00  NONE
1C1    COMBINED   PASSED    400.00  SLENDRSS  0.76     -0.1        0.0     174.8   0.63   2.40    1.92   ---     1.28  1.00

    4  COLUMN     HW125         13  FM1.6-2   0.81     -2.7       -0.4       0.0   1.92   2.40    1.92   1.75    1.28  1.00  NONE
1C1    COMBINED   PASSED    400.00  SLENDRSS  0.76      0.1        0.0     174.8   0.63   2.40    1.92   ---     1.28  1.00

   10  BRACE      L130X9        11  SLENDRSS  0.94      0.4        0.1       0.0   1.92   ---     ---     ---     ---   1.00  NONE
1V1    AXIAL      PASSED    721.11  TENSION   0.01      0.0        0.0       0.0   0.18   ---     ---     ---     ---   0.96

   11  BRACE      L130X9        10  SLENDRSS  0.94      0.4        0.1       0.0   1.92   ---     ---     ---     ---   1.00  NONE
1V1    AXIAL      PASSED    721.11  TENSION   0.01      0.0        0.0       0.0   0.18   ---     ---     ---     ---   0.96

   12  BRACE      L130X9        11  SLENDRSS  0.94      0.4        0.1       0.0   1.92   ---     ---     ---     ---   1.00  NONE
1V1    AXIAL      PASSED    721.11  TENSION   0.01      0.0        0.0       0.0   0.18   ---     ---     ---     ---   0.96

   13  BRACE      L130X9        10  SLENDRSS  0.94      0.4        0.1       0.0   1.92   ---     ---     ---     ---   1.00  NONE
1V1    AXIAL      PASSED    721.11  TENSION   0.01      0.0        0.0       0.0   0.18   ---     ---     ---     ---   0.96

        *****************************************
        *
        *  TOTAL NUMBER OF FAILED MEMBER :    0  *
        *
        *****************************************


******************* D E S I G N   R E S U L T S ************************ UNIT: CM MTON      REP-ID: IFADS-09-07  PAGE-  2
<< R C   C O M B I N E D   M E M B E R   D E S I G N   ( A C I ) >>     AXIS: LOCAL         JOB-ID: A9999III     DATE: DEC.24.85

/----MEMBER ID-----/ DESIGN /LOCATION/----------------MAIN BAR--------------------/---------TIE------------/LD-DIR./ NEUTRAL AXIS  /
 NO.  NAME/CLASS     CODE                PT(%)   NO. SIZE   NSY  NSZ    F      G       VU    SIZE PITCH    (K)     (KY)     (KZ)

   1   1C1        ACI(NOR)   START   1.00     8-D16     3    3    0.71   0.71     2.53   D10 @ 17.0  0.438    0.49     1.18
       COLUMN     COMBINED   END     1.00     8-D16     3    3    0.71   0.71     2.53   D10 @ 17.0  0.558    0.58     0.98

       / STRENGTH / DIMENSION /LOCATION/LD-NO/----AXIAL FORCE----/-----SPECIFIC MOMENT----/LOCAL/-----DESIGN MOMENT-----/CAPACITY/
                                                   PU        PN      MUT    MNT  MNT/MUT  AXIS    MU0   M.FAC    MU       MN

       FCP= 0.210  B  =  40.00  START    7     -22.64    -22.70    457   1083   2.37    (Y)    -166   1.10    -183     -434
       FY = 4.200  H  =  40.00                                                           (Z)     380   1.10     418      992
       COP-S=0.765 L  = 400.00  END      7     -14.45    -14.53    658   1051   1.60    (Y)     291   1.10     321      512
       COP-E=0.814                                                                       (Z)    -522   1.10    -575     -917


/----MEMBER ID-----/ DESIGN /LOCATION/----------------MAIN BAR--------------------/---------TIE------------/LD-DIR./ NEUTRAL AXIS  /
 NO.  NAME/CLASS     CODE                PT(%)   NO. SIZE   NSY  NSZ    F      G       VU    SIZE PITCH    (K)     (KY)     (KZ)

   4   1C1        ACI(NOR)   START   1.00     8-D16     3    3    0.71   0.71     1.73   D10 @ 17.0  0.459    1.10     0.44
       COLUMN     COMBINED   END     1.00     8-D16     3    3    0.71   0.71     1.73   D10 @ 17.0  0.896    0.63     0.71

       / STRENGTH / DIMENSION /LOCATION/LD-NO/----AXIAL FORCE----/-----SPECIFIC MOMENT----/LOCAL/-----DESIGN MOMENT-----/CAPACITY/
                                                   PU        PN      MUT    MNT  MNT/MUT  AXIS    MU0   M.FAC    MU       MN

       FCP= 0.210  B  =  40.00  START   11     -14.48    -14.42    294   1047   3.57    (Y)     243   1.10     267      952
       FY = 4.200  H  =  40.00                                                           (Z)     111   1.10     123      437
       COP-S=0.814 L  = 400.00  END      7     -11.56    -11.32    469   1033   2.20    (Y)    -285   1.10    -313     -689
       COP-E=0.831                                                                       (Z)    -318   1.10    -350     -769


/----MEMBER ID-----/ DESIGN /LOCATION/----------------MAIN BAR--------------------/---------TIE------------/LD-DIR./ NEUTRAL AXIS  /
 NO.  NAME/CLASS     CODE                PT(%)   NO. SIZE   NSY  NSZ    F      G       VU    SIZE PITCH    (K)     (KY)     (KZ)

   2   1C2        ACI(NOR)   START   1.00     8-D16     3    3    0.71   0.71     1.81   D10 @ 17.0  0.306    1.49     0.43
       COLUMN     COMBINED   END     1.00     8-D16     3    3    0.71   0.71     1.81   D10 @ 17.0  0.442    1.23     0.56

       / STRENGTH / DIMENSION /LOCATION/LD-NO/----AXIAL FORCE----/-----SPECIFIC MOMENT----/LOCAL/-----DESIGN MOMENT-----/CAPACITY/
                                                   PU        PN      MUT    MNT  MNT/MUT  AXIS    MU0   M.FAC    MU       MN

       FCP= 0.210  B  =  40.00  START   10     -24.55    -24.57    303   1096   3.61    (Y)    -264   1.10    -290    -1048
       FY = 4.200  H  =  40.00                                                           (Z)     -81   1.10     -89     -321
       COP-S=0.754 L  = 400.00  END      7     -32.35    -32.35    402   1091   2.71    (Y)     334   1.10     368      998
       COP-E=0.707                                                                       (Z)     148   1.10     163      441
```

Fig. 2 An example of output data

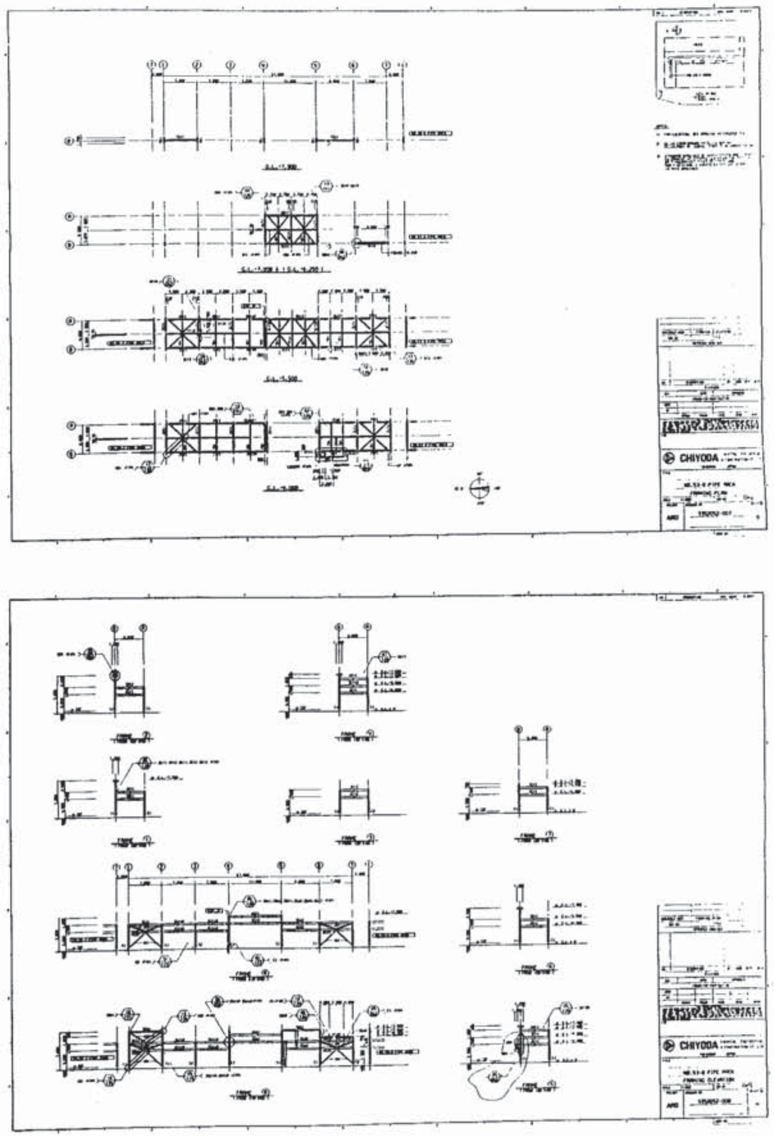

Fig. 3 An example of drawings

Knowledge-Based Building Design

J.S. Gero, A.D. Radford,
M.A. Rosenman, R.D. Coyne,
B. Balachandran, C. Mackenzie

Architectural Computing Unit
Department of Architectural Science
University of Sydney
NSW 2006 Australia

KEYWORDS

Knowledge Engineering, Building Design, Computer-Aided Design.

SUMMARY

Building design is unquestionably a knowledge-based activity, yet few existing computer-aided design systems make any explicit representation or explanation of the knowledge they assume and embody. This paper presents work towards the development of a new generation of knowledge-based computer design tools which is being carried out in the University of Sydney, Australia. It describes the philosophy of knowledge accessibility which underlies the work and its practical demonstration in diagnostic and generative expert systems, in the induction of knowledge from observed examples, and in the development of grammars of design based on production systems. It is suggested that a rigorous knowledge-based approach provides a theoretical basis for extending the role of computer-aided design into the core areas of professional design activity.

The examples used to illustrate the discussion will come from current work on expert systems for building regulations and passive solar energy design, on planning for the design of building layouts and for ithe assembly of building components, and on the induction of production rule representations of knowledge about window design from data on window performance.