

COMPUTER AIDED DESIGN OF  
TWO WAY REINFORCED CONCRETE SLABS

BY

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and Computer Science, Federal University of  
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requirement for the award of Postgraduate Diploma in  
Computer Science.

DECEMBER, 1999

## DECLARATION

Aliyu Garba Abdulkadir declare that the contents of this project are a result of my own effort and have neither been copied, reproduced or pirated from any other previous work or publication and I hereby take full responsibility for any errors or misrepresentations contained here in. All contributions and references have been fully acknowledged.

CERTIFICATION

This project is certified to have fulfilled all requirements in partial fulfillment of the requirements for the award of postgraduate diploma in Computer Science and is hereby approved.

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## DEDICATION

I dedicate this work to

Baba, Dr Garba Ja Abdulkadir " Teacher"

Mama, Hajia Mairo G. Abdulkadir " Uncompromising Love"

My wife, Maryam " My other all"

My daughter, Bilkisu " Unlimited affection"

My son, Albara "Inspiration"

And lastly but not the least , Engr. Mohammed Nur Khalil who helped

to make this possible



## ACKNOWLEDGEMENT

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Course Co'ordinator MR. A.O BADMUS and all the host lecturers whose contribution I appreciate, Engr. Abu Ibrahim who shared patiently his accumulated experience of Computer aided design in Civil Engineering Practice.

And finally, I wish to thank the host of people whom have in one way or the other influenced positively to make this humble effort successful, so many that writing their names may produce an endless list.

## ABSTRACT

This work attempts to produce a software to be used in the design of reinforced concrete two way slabs as may be used for Computer Aided Design in civil engineering design office practice.

The software developed in the QUICKBASIC programming language (environment) is designed to be interactive receiving input parameters of the desired configuration from the engineer/user and an output of the designed configuration parameters results.

It is hoped that engineers will find it to be a useful tool in Reinforced Concrete design practice.

## DEFINITION OF SYMBOL

$L_x$	-	Length of Shorter Side
$L_y$	-	Length of Longer Side
$G_k$	-	Characteristic dead load
$Q_k$	-	Characteristic imposed load
$N$	-	Design ultimate load per unit area
$P_c$	-	Unit Weight of concrete
$h$	-	Thickness of slab
$T_w$	-	Ratio of longer side to shorter side
$M_s$	-	Maximum design ultimate moments
$M_{sy}$	-	Maximum design ultimate moments in the direction of long span
$N_d$	-	No of discontinuous edges
$N_s$	-	No of discontinuous short edges
$N_l$	-	No of discontinuous long edges
$\alpha_x$	-	Moment coefficients for short span of unrestrained slabs
$\alpha_y$	-	Moment coefficient for long span of unrestrained slabs
$\beta_x$	-	Moment of coefficient for short span of restrained slabs
$\beta_y$	-	Moment coefficient for long span of restrained slabs
$f_{cu}$	-	Concrete grade
$B$	-	Breadth of slab (1m of span)
$M$	-	Ultimate design moment
$f_y$	-	Steel strength of reinforcement

- D - Effective depth of slab
- A's - Area of compression reinforcement
- As - Area of tension reinforcement
- V - Design ultimate shear force
- Vpa - Average design shear stress
- Vl - Maximum allowable shear stress
- Vc - Ultimate concrete shear stress
- Fyr - Steel strength of shear reinforcement
- Asv - Area of shear reinforcement
- Sv - Spacing of shear reinforcement
- Vp - Concentrated punching load
- Vp1 - Maximum punching shear stress
- Vpa - Average punching shear stress
- Apv - Area of punching shear reinforcement
- U - First critical perimeter of area under concentrated punching load
- A - Breadth of area under concentrated punching load
- B - Length of area under concentrated punching load
- Sd - Basic span depth ratio
- Asp - Area of tension steel provided for long span
- Asr - Area of tension steel required for short span
- Acp - Area of compression steel provided for long span
- Rc - Calculate span effective depth ratio
- Ra - Actual span effective depth ratio

- W - Crack width
- Acr - Distance from the point (Crack) under consideration to the nearest reinforcing bar.
- Em - The Average strain
- Cm - Minimum cover to reinforcement
- X - Depth of neutral axis
- W1 - Strain at the crack level
- Ms - Serviceability moment
- A1 - Distance from the compressive face of the section to the point (Crack) under consideration.
- Es - Modules of elasticity steel
- Esc - Modules of elasticity of concrete
- I - Second moment of area of the section considered
- Dc - Depth to compression reinforcement
- Dt - Depth to tension reinforcement
- S - Tension steel bear spacing

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## CHAPTER 1

### 1.0 INTRODUCTION

#### 1.1 PREAMBLE

Civil Engineering design and analysis usually involves cumbersome algorithms due to the relationship between the governing variables involved in the solutions. In addition designs also involve repetitive procedures and calculations for solving similar design problems from one design problem to another and hence the process of design may be extremely tedious and time consuming.

With the arrival of the computer age it is now possible to shorten design calculations and processing time through the development of computer software and the application of such software to solve design problems. The application of computer to solve design problems is termed computer aided design.

It is worthy to note that the computer has not come to replace the process of design, the engineer as the name implies uses his ingenuity in carrying out the design and the computer serves as a useful tool in the execution of the design processes. Though the computer can be used as a design tool in the

synthesizing of the design strategy, the analytical part of reinforced concrete design is extremely numerically oriented and this is undoubtedly where the computer can be of considerable assistance to the designer.

This work presents a modest effort to develop a program aimed at simplifying the structural analysis and design of two ways slabs supported by beams or walls.

1.2

### **SYNOPSIS**

This work is concerned with a situation where the structural arrangement of the members is known. TWSLAB Calculates the stresses in the slab and compares the calculated and allowable stresses and displacement, then if certain values are greater than the allowable ones or if the allowable values are unacceptably greater than the calculated value, changes will be made in the assumed configuration of the section, it may be beneficial to repeat this cycle a number of times until an optimum section or member that satisfies all conditions is obtained.

It is therefore useful to develop a procedure (computer aided design) alternative to the complete conventional reprocessing by which the result of the modified structure can be obtained immediately.

### **1.3 PROJECT OBJECTIVES**

This computer aided design software development project is carried out with the intention of creating a tool for the design and analysis of two way slabs with the following specific and special advantages over the conventional analysis and design.

#### **1.3.1 TIME SAVING**

The use of computer makes the analysis and design to be executed within a minute fraction of the time taken for the manual approach.

#### **1.3.2 ERROR HANDLING**

All human errors are eliminated at the developmental level of the computer programme (debugging) and the computer can repeat works in a similar manner without making any mistakes, while in the manual computations the possibility of human errors is glaring.

#### **1.3.3 ACCURACY AND PRECISION**

The design requires the use of complex formulae and computations a series of approximations may be resorted to and hence an unrealistic output may result. With this computer aided design software this shortcoming is

eliminated as the complex formulae and algorithms are programmed, in addition precision is higher and an exact solution results.

#### **1.3.4 REPRODUCTION OF OUTPUT AND REVISION OR DESIGN**

It is easier with the aid of a plotter/printer and other accessories to reproduce design output since the computer provides an instant interface for reproduction of stored data.

Also revision of result is easier since the engineer does not have to go through the procedures of manual computation once more but simply reviews input parameters.

#### **1.3.5 ECONOMY**

The two way slab is a commonly occurring member of reinforcement concrete structures and hence with high repetition of this member design the computer aided design has overall economic advantage over the manual computation in terms of design materials economy for example paper, ink, etc.

#### **1.3.6 REFERENCE TO CODE OF PRACTICE**

In all areas of Engineering design guiding codes of practice are needed to provide reference, design charts, and tables which serve the purpose of standardization.

A lot of time and space will be saved where computer aided design programme is used since such data is stored in the computer memory at once and read in a matter of seconds for the design.

#### **1.3.7 OPTIMIZATION**

Testing of several of the alternative design parameters values to achieve optimization requires many trials and iterations, the use of this computer software will make these large number of iterations possible within minutes. It is thus preferred over the manual approach in order to facilitate a quick and accurate solution and testing of sufficient number of alternatives.

#### **1.3.8 OUTPUT PRESENTATION**

The output can usually be presented in different letter sizes and colours for a readable presentation as far as the necessary hardware is available.

#### **1.3.9 INFORMATION SHARING**

Information or the design output and input can be shared through networking facilities between distant consultants working on the same project.

## CHAPTER 2

### 2.0 SYSTEM ANALYSIS

### 2.1 SYSTEM REQUIREMENTS

Developing a computer aided system necessitates the acquisition of suitable hardware and software, training in their implementation and the development of new design skills in their use. For the purpose of running these computer aided design programme successfully the following minimum computer system requirements are envisaged.

#### 2.1.2 SOFTWARE

To achieve versatility in usage an enhanced version of BASIC referred to as QUICK BASIC (QBASIC) is chosen as the programming language for the purpose of these design.

Basic is an acronym for beginners all purpose symbolic instruction code. It is a high level programming language whose methods of coding syntax is simplified for whatever class of user.

One important characteristic of Basic is its availability in all Disk operating Systems DOS, QBasic is available in DOS 6.0, 6.1 and 6.2. Hence these version of DOS is necessarily required, a display unit i.e monitor and a keyboard for data entry are required since the design processing is aimed at



being on-line interactive. Any other peripherals to the system may be added to suit user convenience.

## 2.2 DATA SOURCE AND INPUT

The limit state method of design of the British Standard code of practice BS 8110 of 1985 is used for the standardization of these computer aided design program. The code will also serve as the reference from which standard design data is extracted.

The programme is designed in such a way that all the constant standard code parameters needed for the design are represented as constraints, also similar constraints form the basis of the formulae and expressions that evolve the design.

On the other hand as the programme runs it will prompt the Engineer or designer to input the variables forming the necessary design input and these will be furnished via the keyboard the processing technique is thus invariably interactive processing.

## 2.3 OUTPUT FORM

Basically the expected output form of each design will be a tabular presentation of values of the variables that define the designed element.

For the purpose of the project design drawings have not been considered as design output since these may require complex graphics programming exceeding the capabilities of Q-Basic, but it is worthy to note that there are today available graphics design packages with such capabilities, foremost amongst these packages is AUTOCAD a draughting tool very suitable for engineering drawings.

The input of the computer aided design programme can easily be transformed into standard design drawing presentations via these packages.

## **2.4 LIMITING FACTORS FOR COMPUTER AIDED DESIGN SYSTEMS IN NIGERIA.**

Several factors militate against computer aided design systems in Nigeria and these humble effort is no exception, the following factors apply.

### **2.4.1 COMPUTER APPRECIATION**

Lack of adequate training on computer appreciation for professional applicability. The majority of Nigeria Engineers are yet to appreciate even the basic operation of a computer and hence are yet to become computer aided designers.

## CHAPTER 3

### 3.0.0 STRUCTURAL ANALYSIS AND DESIGN

#### 3.1.0 DESIGN STRATEGY AND ASSUMPTIONS

The Limit state design method of the British Standard Code of Practice BS 8110 of 1985 is adapted for all designs in this project. BS 8110 defines the aim of design thus “The aim of design is the achievement of an acceptable probability that the structure being designed will perform satisfactorily during their intended life”

Bending, shear and punching shear are considered for the ultimate limit state design while deflection and cracking is considered for the serviceability limit state design.

The slab is assumed to be rectangular and supported on beams or walls on its edges such as is found in buildings etc.

#### 3.2.0 SLAB DIMENSION

A two way slab is defined by

$$L_x/L_y \leq 2$$

#### 3.3.0 ULTIMATE LIMIT STATE ANALYSIS

##### 3.3.1 LOADS

$$G_k = L_x \cdot L_y \cdot d \cdot P_c \dots\dots\dots 1.0$$

#### **2.4.2 NON - AVAILABILITY OF BASIC TOOLS**

Many Nigerian institutions in both the private and public sectors are yet to be fully computerised and therefore the basic computer aided design programming tools, hardware, software and literature are not readily available to engineers.

#### **2.4.3 COST**

The high cost of computer training, hardware, working software literature and prewritten packages is another factor reflecting from Nigerias poor economic state.

The total design ultimate load per unit area  $N$  is given by

$$N = 1.4G_k + 1.6Q_k \dots\dots\dots 1.1$$

**3.3.2 BENDING**

There are two cases to be considered depending on support conditions as follows

**3.3.2.1 SIMPLY SUPPORTED SLAB WITHOUT ADEQUATE PROVISION TO RESIST TORTION AT THE CORNERS (CORNERS ARE FREE TO LIFT)**

The maximum design moments per unit width are given by the following equations.

$$M_{sx} = \alpha_{sx} \cdot N \cdot L_x^2 \dots\dots\dots 1.2$$

$$M_{sy} = \alpha_{sy} \cdot N \cdot L_x^2 \dots\dots\dots 1.3$$

Where the moment coefficient  $\alpha_{sx}$  and  $\alpha_{sy}$  are given by

$$\alpha_{sx} = (L_y/L_x)^4 / 8[1+(L_y/L_x)^4] \dots\dots\dots 1.4$$

$$\alpha_{sy} = (L_y/L_x)^2 / 8[1+(L_y/L_x)^4] \dots\dots\dots 1.5$$

**3.2.2.2 SLABS RESTRAINED AT ONE OR MORE EDGES WITH ADEQUATE PROVISION TO RESIST TORTION**

$$M_{sx} = B_{sx} \cdot N \cdot L_x^2 \dots\dots\dots 1.6$$

$$M_{sy} = B_{sy} \cdot N \cdot Lx^2 \dots\dots\dots 1.7$$

The values for the moment coefficient  $B_{sx}$  and  $B_{sy}$  for the four different positions of maximum and minimum moments are given below.

- (i) Coefficient  $B_y$  for positive midspan moment for strips spanning  $L_y$

$$B_y = (24 + 2Nd + 1.5Nd^2) / 1000 \dots\dots\dots 1.8$$

Where

$$0 < Nd < 4$$

- (i) Coefficient  $B_1$  and  $B_2$  for negative support moment for strips spanning  $L_y$

$$B_1 = B_2 = 0 \quad , \text{ for discontinuous edges} \dots\dots\dots 1.9$$

$$B_1 = B_2 = 4/3 \cdot B_y \quad , \text{ for continuous edges} \dots\dots\dots 2.0$$

- (ii) Coefficient  $B_x$  for positive midspan moment for strip spanning  $L_x$

$$B_x = Y / [ (1 + K_3) + (1 + K_4) ]^2 \dots\dots\dots 2.1$$

Where

$$Y = 2/9 [ 3 - i/18 \cdot L_y/L_x \{ i/(B_y + K_1 \cdot B_y) + i/(B_y + B_y) \} ] \dots\dots 2.2$$

$$K_1 = K_2 = K_3 = K_4 = 0, \text{ for discontinuous edges} \dots\dots\dots 2.3$$

$$K_1 = K_2 = K_3 = K_4 = 4/3, \text{ for continuous edges} \dots\dots\dots 2.4$$

$$B_3 = B_4 = 0, \text{ for discontinuous edges} \dots\dots\dots 2.5$$

$$B_3 = B_4 = 4/3 \cdot B_x, \text{ for continuous edges} \dots\dots\dots 2.6$$

### 3.3.2.3 SECTION DESIGN FOR BENDING

The following formulae and procedure provide the areas of reinforcement required to resist flexure

$$K = 0.156 \dots\dots\dots 2.7$$

$$K = M/bd^2 \cdot F_{cu} \dots\dots\dots 2.8$$

Case (I) if  $K < K$  then compression reinforcement is not required

$$Z = d \{ 0.5 + (0.25 - K/0.9) \} \dots\dots\dots 2.9$$

Where  $Z < 0.95d$

$$X = (d - z) \cdot 0.45 \dots\dots\dots 3.0$$

$$A_s = M / 0.85 \cdot F_y \cdot Z \dots\dots\dots 3.1$$

Case (ii) if  $K > K'$  then compression reinforcement is required

$$Z = d \{ 0.5 + (0.25 - K/0.0) \} \dots\dots\dots 3.2$$

$$X = (d - Z) \cdot 0.45 \dots\dots\dots 3.3$$

$$A'_s = (K - K') F_{cu} b d^2 / 0.87 f_y (d - d') \dots\dots\dots 3.4$$

$$A_s = (K \cdot F_{cu} \cdot B d / 0.877 \cdot F_y \cdot Z) + A_s \dots\dots\dots 3.5$$

### 3.3.3 SHEAR

The average design shear stress  $V_p$  at any section is given by the equation

$$V_a = V / bvd \dots\dots\dots 3.6$$

$$B_v = 1000$$

And this is bounded by the limits thus

Let Max shear stress =  $V_1$

$$V_1 < 0.8 F_{cu} \text{ or } 5 \text{ N/mm}^2 \text{ (the lesser)}$$

The design shear stress that can be resisted by the slab is given by



$$V_c = 0.79 (1000 A_s/bd)^{1/3} \cdot (400/d)^{1/4} \cdot 1/1.25 \dots \dots \dots 3.7$$

Where

$$0.15 < 100 A_s/bd < 3$$

$$d < 400$$

Shear reinforcement is provided in accordance to type of case as follows:

Case (I) if  $d < 200$

Then shear reinforcement is not required.

Case (ii) If  $v_a < v_c$

Then shear reinforcement is not required

Case (iii) If  $v_c < v_a < v_c + 0.4$

Then provide shear reinforcement given by the equation

$$A_{sv} = 0.4b \cdot S_v / 0.87 F_{yv} \dots \dots \dots 3.8$$

Case (iv) if  $v_a > v_c + 0.4$

Then provide shear reinforcement given by the equation

$$A_{sv} = b (v - v_c) \cdot S_v / 0.87 F_y \cdot v \dots \dots \dots 3.9$$

### 3.3.4 PUNCHING SHEAR (SHEAR UNDER CONCENTRATED LOADS)

The design shear stress at the critical perimeter,  $1.5d$  from the face of the loaded area is given by the equation.

$$v_{pa} = V_p / \{ 2(a + b) + 8(1.5d) \} \dots\dots\dots 4.0$$

There are two cases

Case (i) If  $v_{pa} < v_c$

Then no shear reinforcement is required

Case (ii) if  $v_{pa} > v_c$  and  $h > 200\text{mm}$

Then shear reinforcement can be provided by

$$A_{pv} = (v_{pa} - v_c) \cdot u \cdot d / 0.87 \cdot f_{yv} \dots\dots\dots 4.1$$

Where

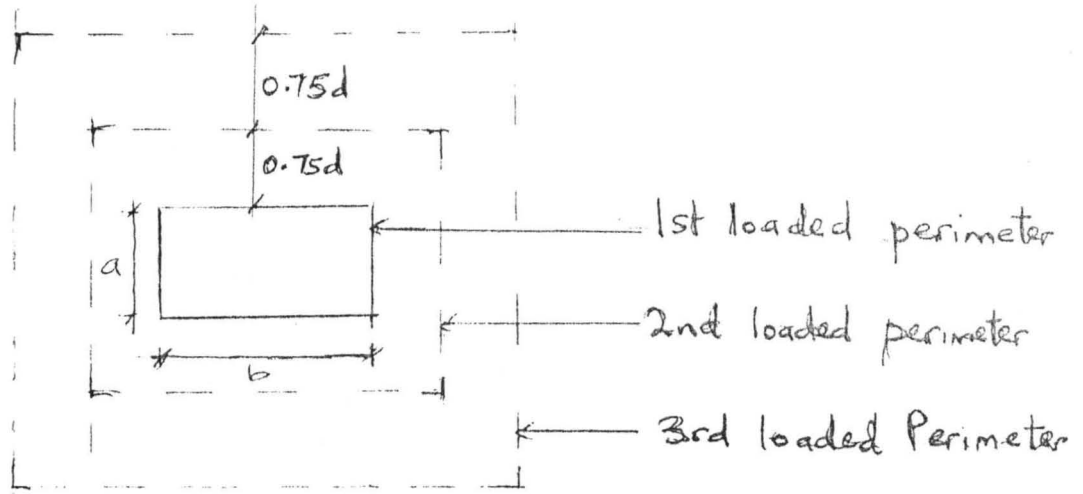
$$(v_{pa} - v_c) > 0.4 \text{ N/mm}$$

$$u = \{ 2(a + b) + 8(1.5d) \} \dots\dots\dots 4.2$$

If reinforcement is required the procedure is repeated for the next critical

perimeter at  $0.75d$  out from the first perimeter that is  $u$  is increased by

$4(0.75d)$  until  $v_{pa} < v_c$ , see fig 1.



PUNCHING SHEAR LOADED PERIMETER

FIG 1

The max shear stress is calculated from  $V_{max} = v_p / [2(a + b)]d_p$  and should not exceed  $0.8 f_{cu}$  or  $5N/mm^2$  whichever is the lesser.

### 3.40 SERVICEABILITY LIMIT STATE ANALYSIS

Once the slab has been designed at the ultimate limit state the serviceability requirements for deflection and cracking under service loads are then considered.

#### 3.4.1 DEFLECTION

In all normal cases the deflections of the slab will not be excessive if the ratio of its span to effective depth ratio is not greater than the calculated limiting values.

Basic span depth,  $SD = 20$  and if span  $> 10m$  then  $SD = 2 \times 10/L_y$

$$R_c = SD \cdot F_1 \cdot F_2 \cdot F_3 \dots \dots \dots 4.3$$

Where,

$$F_1 = 0.55 + (4.77 - f_s) / 120 ( 0.9 + M/ bd^2) \dots \dots \dots 4.4$$

And,

$$F1 \leq 2$$

$$F_s = (5f_y \cdot A_{sr} / 8 A_{sp}) * 1/B_p \dots\dots\dots 4.5$$

Also

$$F2 = 1 + (1000A_{cp}/bd) / (3 + 100A_{cp}/bd) \dots\dots\dots 4.6$$

And,

For factor F3 there are two cases depending on the slab span L

Case (i)  $L < 10m$

$$F3 = 1$$

Case (ii)  $L > 10m$

$$F3 = 10/L$$

Now the actual span depth ratio

$$R_a = L/d \dots\dots\dots 4.7$$

Section is O. K. if  $R_a < R_c$

### 3.4.2. CRACKING

BS 8110 Part 2 of 1985 stipulates that the calculated design surface crack width should not exceed 0.3mm. The equation below is used to calculate the value of the design surface crack width.

$$W = (3 A_{cr} \cdot E_m) / 1 + 2 [(A_{cr} - C_m) / (h - x)]$$

But for the bottom surface  $A_{cr} = C_m$  therefore  $w = 3(A_{cr} \cdot E_m)$ .....4.8

Where,

$$E_m = E_1 - \{ [ b (h - x) \cdot (A - X)] / E_s \cdot A_s \cdot (d - x) \}$$
.....4.9

For case.  $\mu = 1000$  and  $A_1 = h$

$$E_m = E_1 - (h - x)^2 / 3 E_s \cdot A_s (d - x)$$
.....5.0

$$E_1 = M_s \cdot (d - x) \cdot m / E_s \cdot I$$
.....5.1

$$M = E_s / E_c$$
.....5.2

$$E_c = 20 + 0.2 F_{cu}$$

$$I = [ 1/3 ( b \cdot x^3 ) ] + [ (m - 1) \cdot A_s \cdot (x - d)^2 ] + [ m \cdot A_s \cdot (d - x)^2 ]$$
.....5.3

$$X = - \{ [ (m - 1) A_s + m \cdot A_s ] + - \{ [ (m - 1) A_s + m \cdot A_s^2 ]$$

$$..... + 2b [(m-1) \cdot A_s \cdot D + m \cdot A_s \cdot d] \} / b$$
.....5.4

## CHAPTER 4

### 4.0 PROGRAMMING

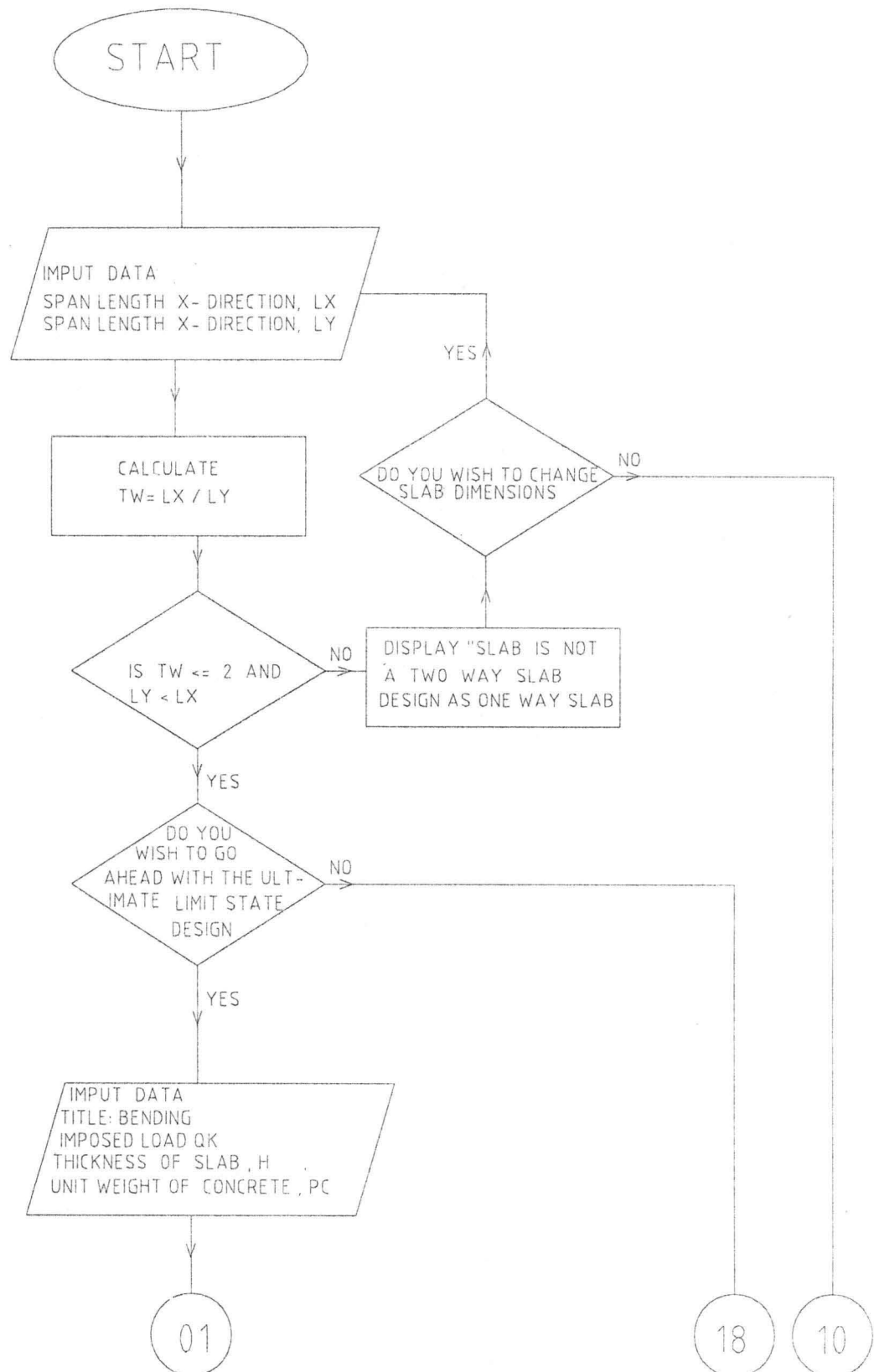
#### 4.1 PROBLEM DEFINITION AND ANALYSIS

The program TWSLAB is intended to assist the engineer in designing and checking for any one or more of the design parameters bending ,shear, punching shear, deflection and cracking and hence as the flow chart clearly depicts each one of the design parameters is programmed for separately while the program interactively prompts the user to select one or more of these parameters as it runs for the design.

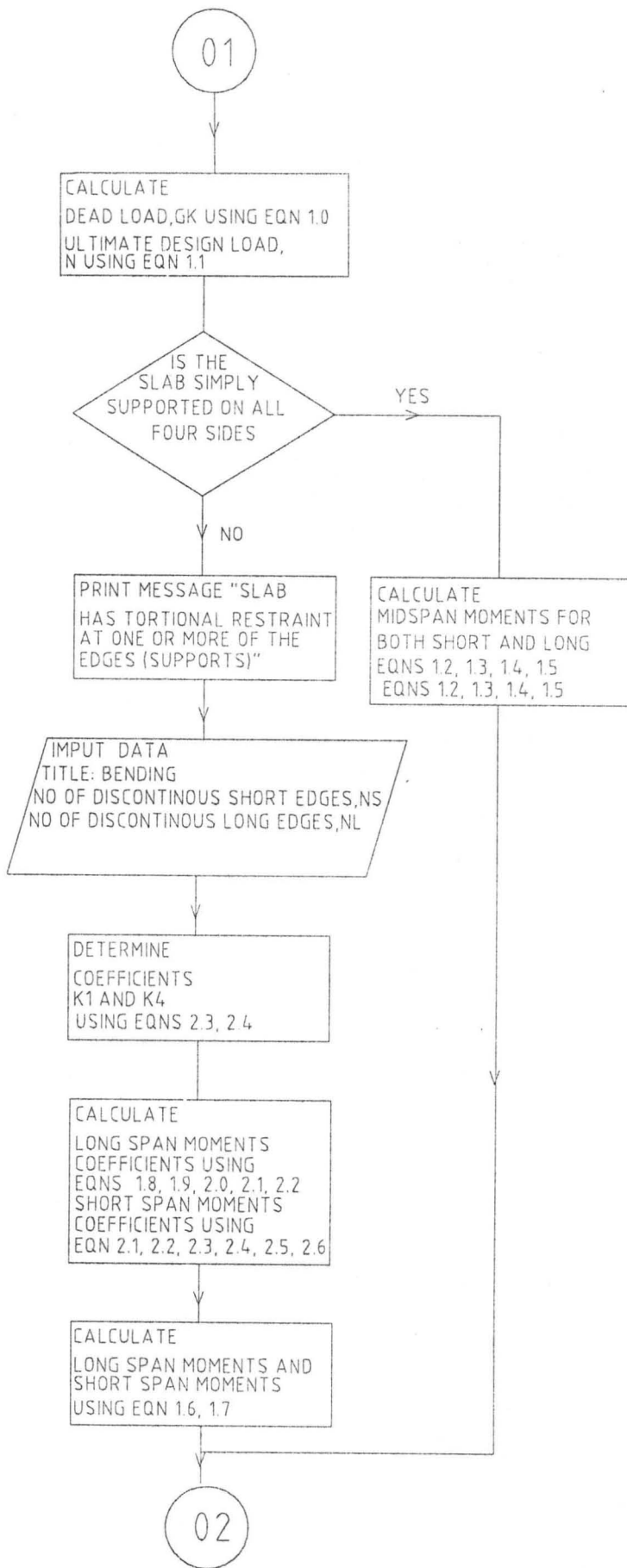
This implies that one could check one , two , three , four or more of these design aspects for the particular case of design one wishes to work upon.

## 4.20 FLOWCHART

The flowchart of the program TWSLAB is as follows





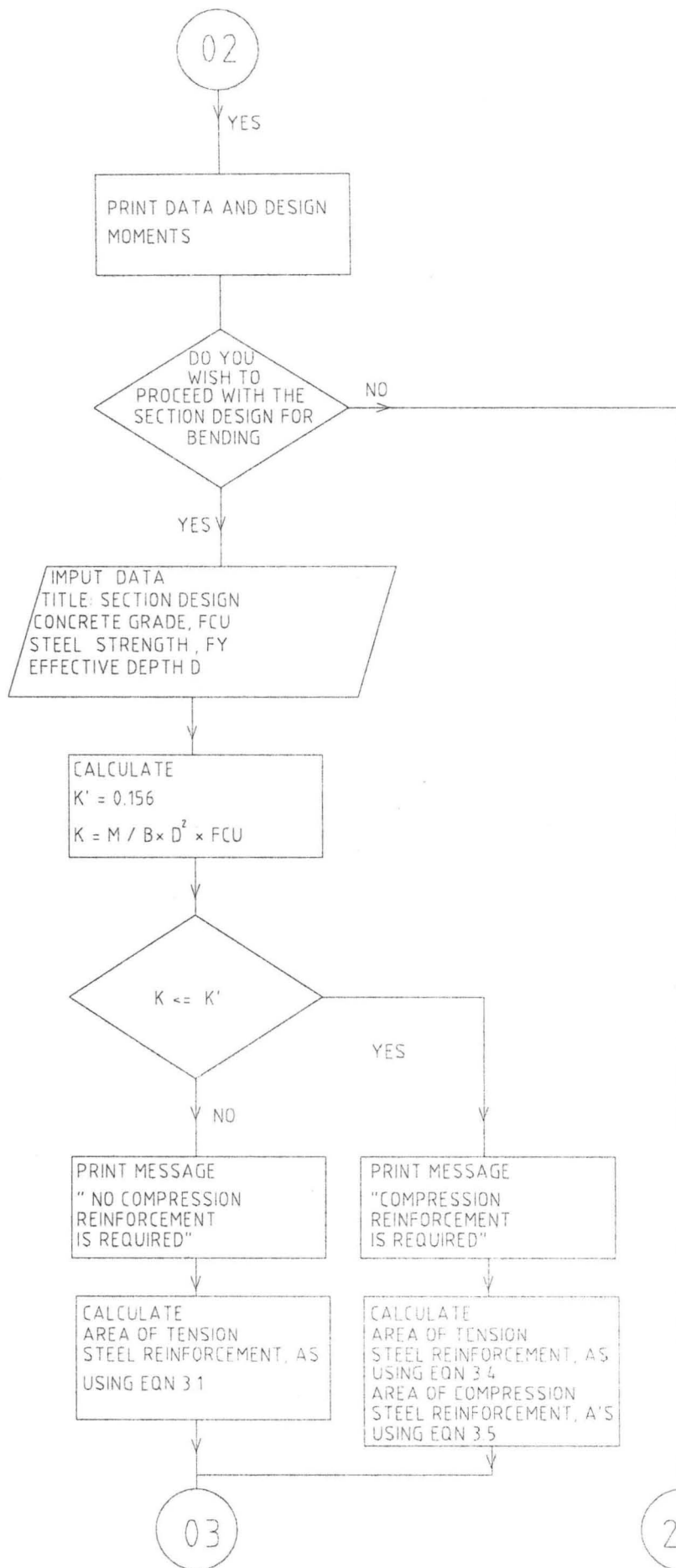


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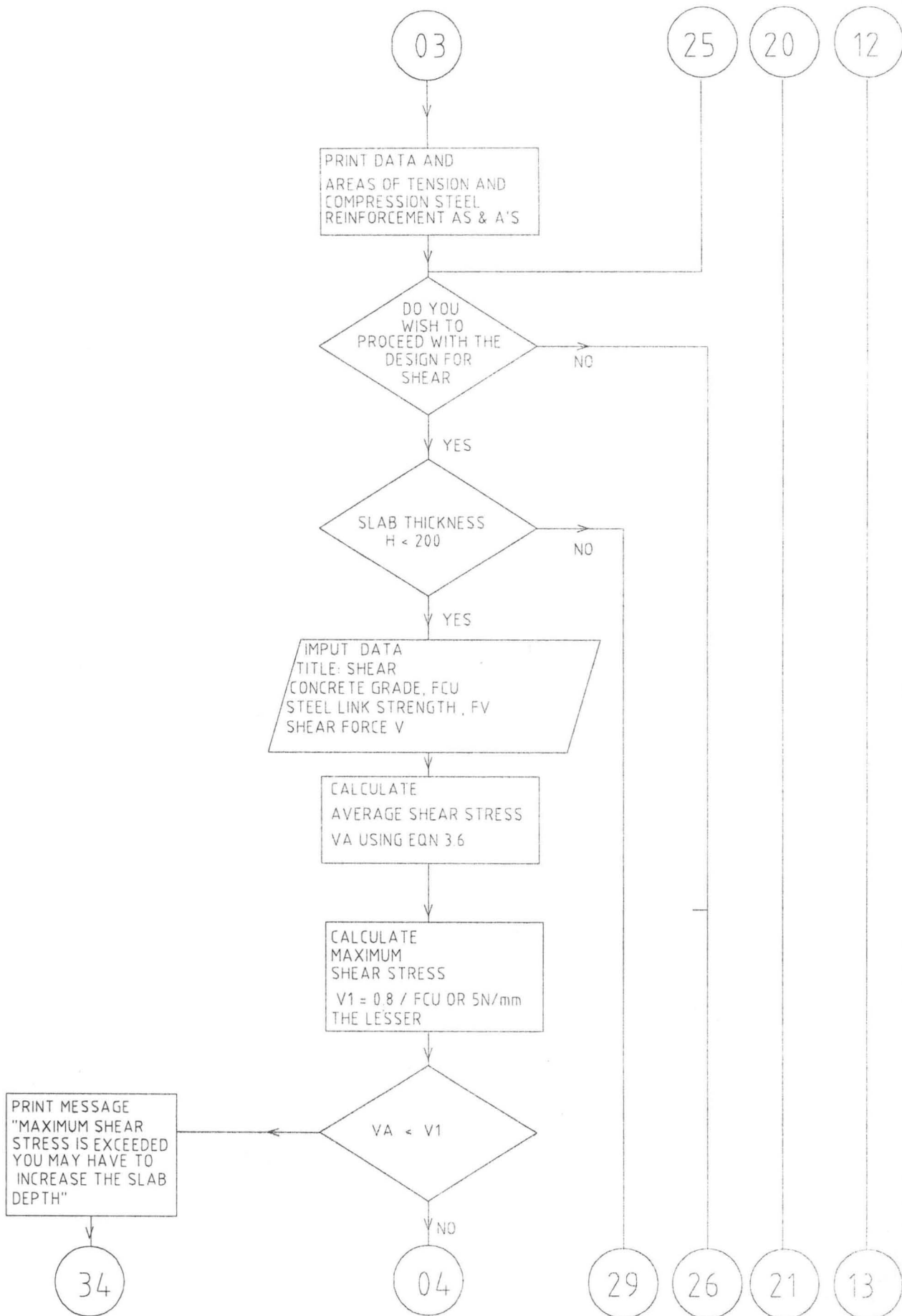
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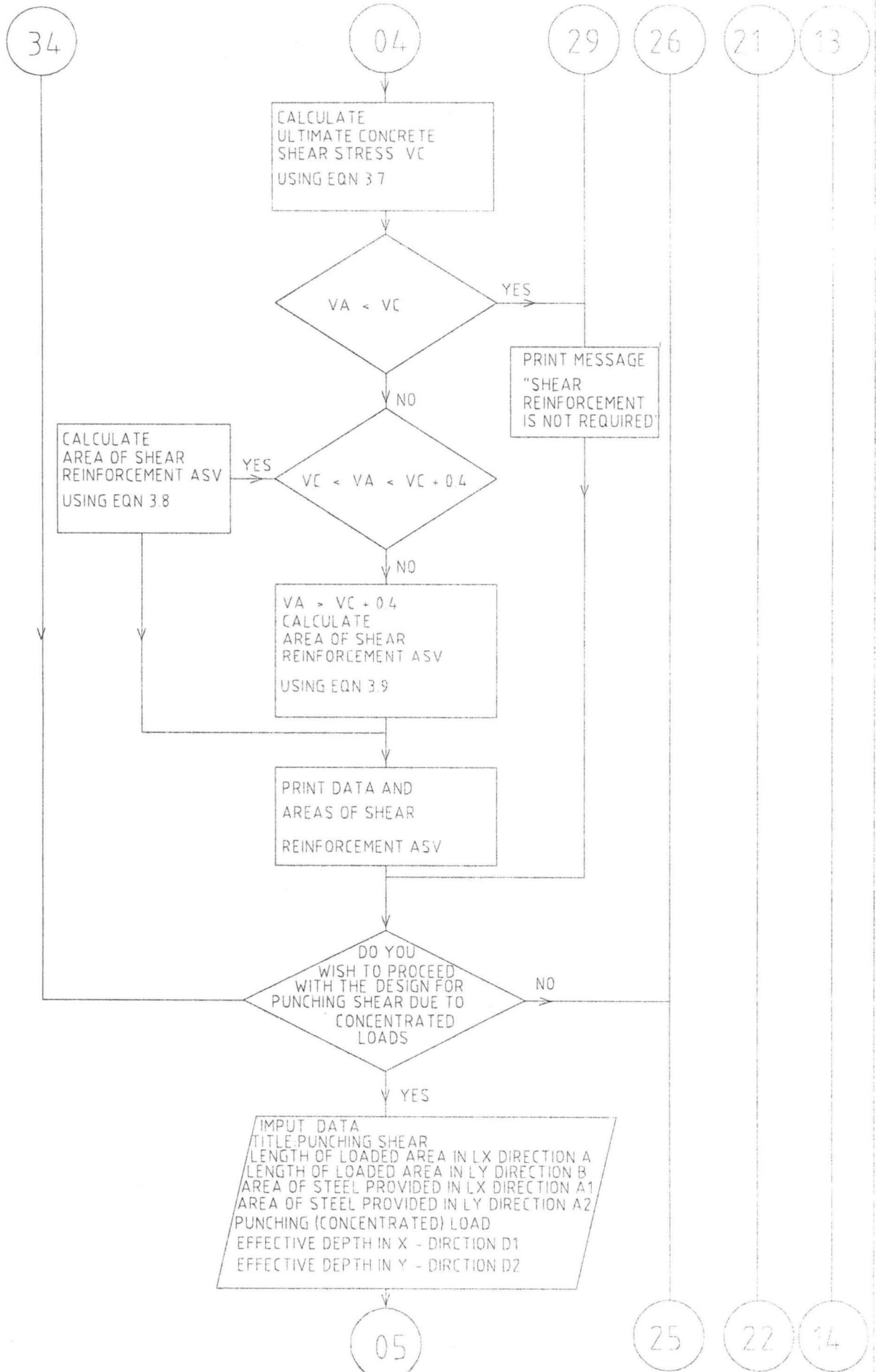
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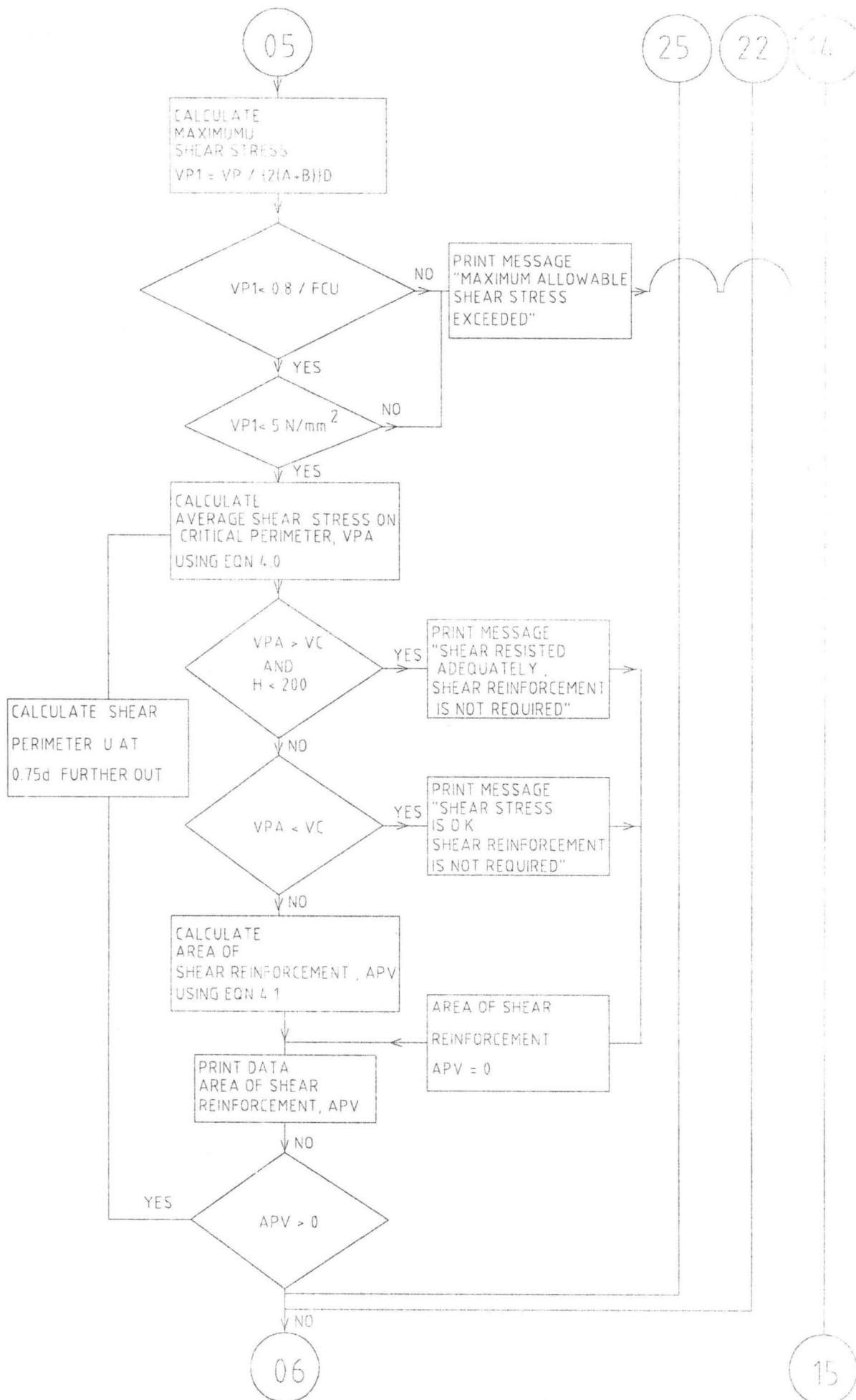
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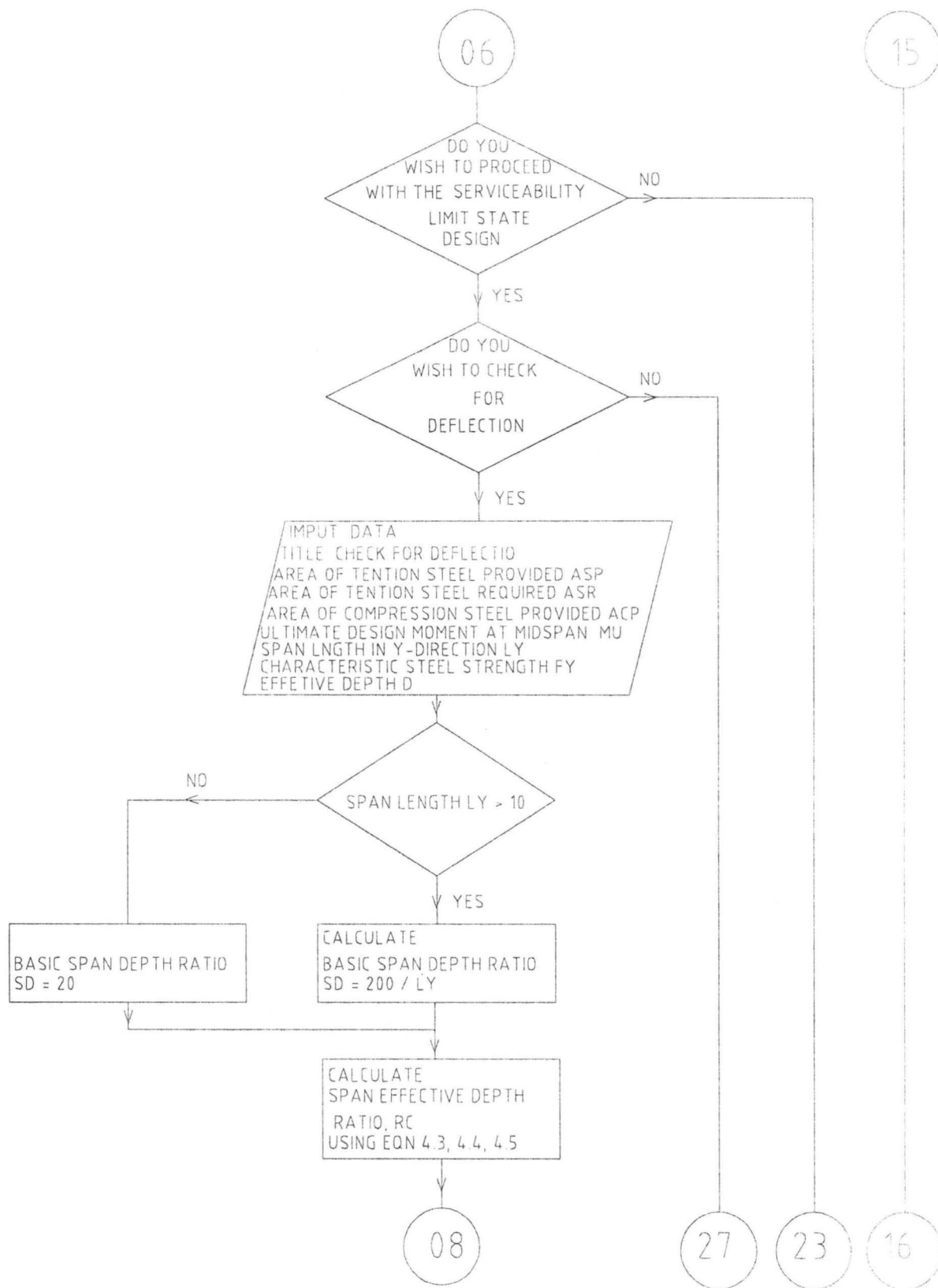
20

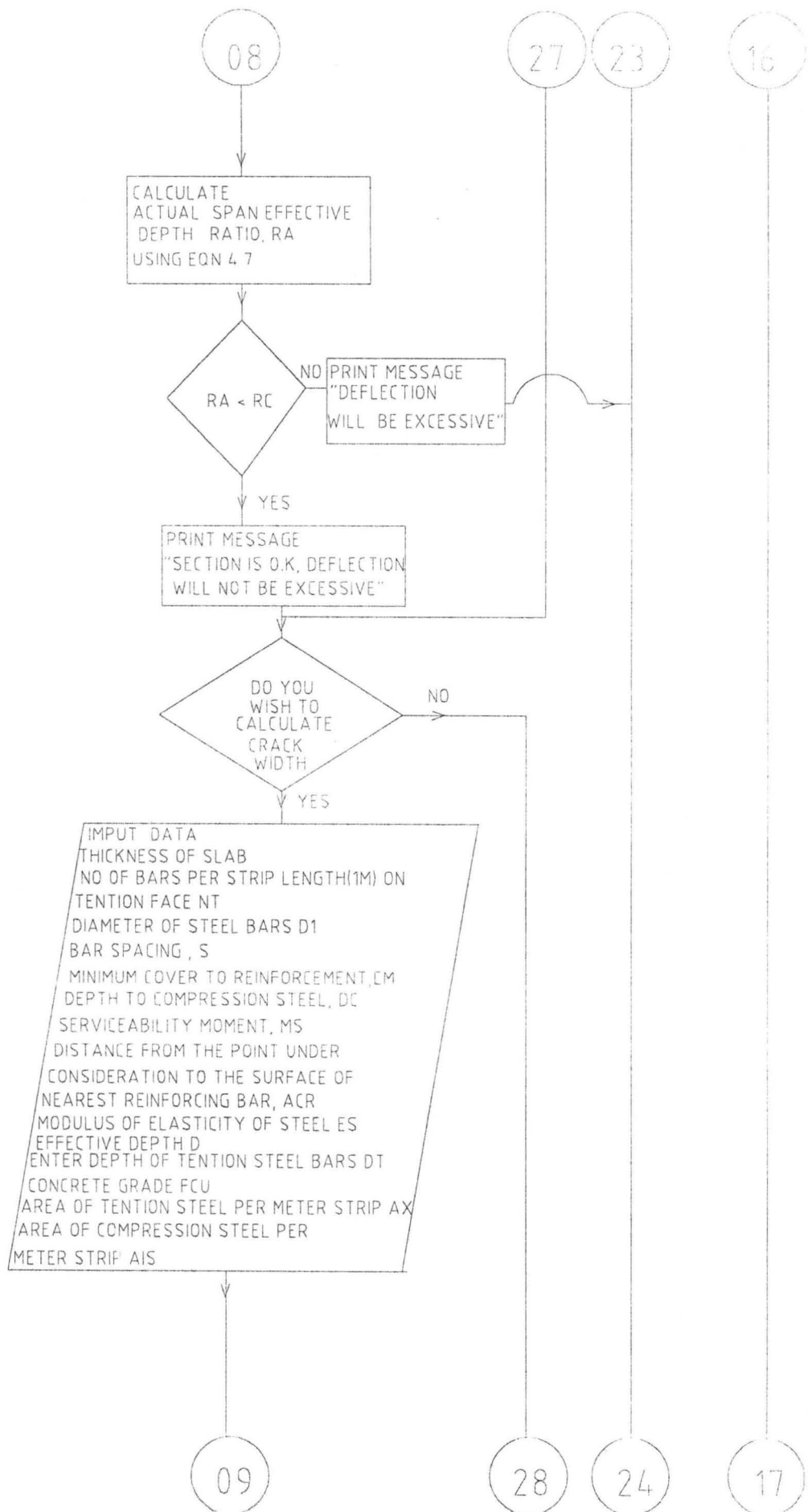
12

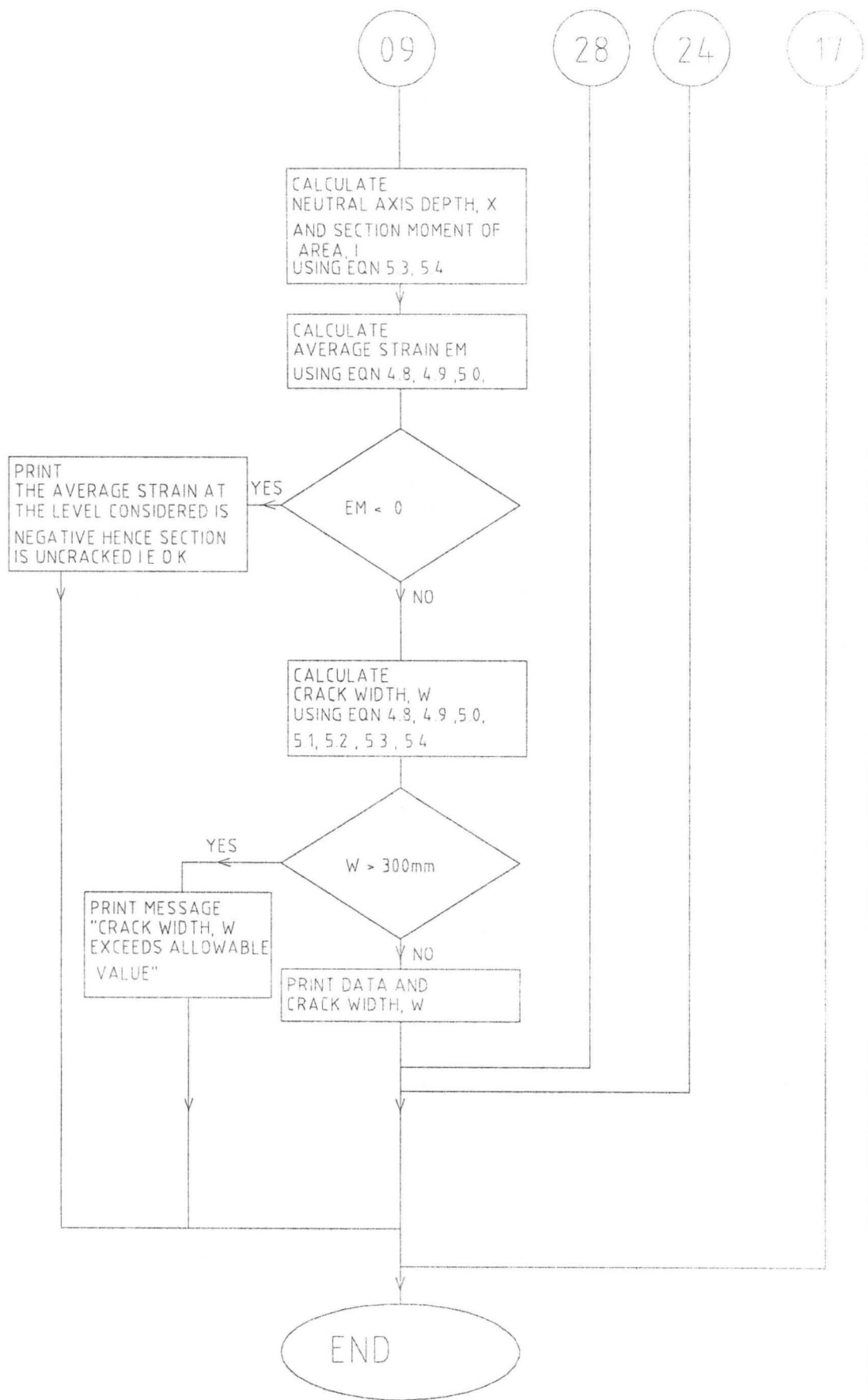














### 4.3. TEST DATA PREPARATION, RUNNING & DEBUGGING

In order to test the program data was prepared of realistic possible design applications extracted from solved (designed) examples of design problems from the book published by two renowned engineers.

#### **W. H. MOSLEY & J. H. BUNGEY**

Titled "Reinforced Concrete Design" 1992 of the department of Civil Engineering University of Liverpool.

It is worthy of note that this publication is recommended by most University in Britain and in Nigeria, for use by both trainee and field engineers and takes into cognizance fully the recommendations of BS 8110 (British Standard Code of Practice).

While test running these program several errors were encountered mostly syntax errors and were corrected, this was made less difficult since Qbasic automatically highlights and warns over syntax errors, when running.

Subsequently result of designing with this programme and that of manual calculations from the publication mentioned above were tabulated and these tabulated results cover all aspects of design within the limits of this program.

## CHAPTER 5

### 5.0 CONCLUSION AND RECOMMENDATIONS

#### 5.1 BENEFITS

The following benefits accrue from the use of TWSLAB programme for the design of slabs supported on walls or beams.

First fast and speedy calculations shortening effectively design time procedure.

Secondly greater precision is achieved as the computer approximates to a higher number of decimal points compared to the manual design. This precision accounts for the small differences that can be seen from the comparison of result of using TWSLAB and the manual design procedure.

There is also the fact that the results can be printed out directly from the computer system, enhancing better presentations.

Lastly but most important, results from the use of TWSLAB compared favourable with the results of manual calculations. Confirming it as a realistic tool for computer aided design.

## 5.1 LIMITATIONS

Despite the immense benefits derived from the TWSLAB program, there are a number of factors that limit its power for design.

Though results from TWSLAB give numerical values of design parameters i.e moments, areas of reinforcement, etc the final presentation to be used on site to actualise the design are the design drawings; this program does not provide for draughting (create drawings or sketches) and hence either the drawings are produced manually or a draughting software is required.

Also in practice and in the majority of cases the design of slabs is carried out together with other members of the overall structure (houses etc) i.e beams, columns, pad footings etc. But this program is limited only to the design of slabs, it has limited use in the realisation of an overall design in a desired structural project.

Finally it must be mentioned that TWSLAB is limited to design of two way slabs supported by beams or walls and does not deal with one way slabs and flat slabs even though these are less common.

### 5.3 A WINDOW INTO THE FUTURE

The future of computer aided design has never been brighter and presently software for CAD are produced by specialist firms all over the world covering almost every aspect of civil engineering. The TWSLAB is a modest effort created for a limited purpose and needs to be further enhanced to encompass other structural members if it is to be competitive.

The future requires the computer aided design programmer/engineer to work towards the creation of a more versatile software complete with draughting and visual graphical presentation capabilities if it is to be of any relevance as we advance fast into the computer millemium.

## APPENDIX A

### PROGRAM LISTING

```
1000 CLS
1001 PRINT "=====
1002 PRINT "YOU ARE WELCOME TO THIS PROGRAM CALLED TWSLAB"
1005 PRINT "IT WAS WRITTEN IN PARTIAL FULLFILLMENT OF THE REQUIREMENT "
1010 PRINT " FOR THE AWARD OF POSTGRADUATE DIPLOMA IN COMPUTER "
1015 PRINT "SCIENCE BY THE FEDERAL UNIVERSITY OF TECHNOLOGY MINNA"
1020 PRINT "THE PROGRAM IS A QUICKBASIC(QBASIC) PROGRAM FOR THE DESIGN "
1025 PRINT "OF ALL TYPES OF TWO-WAY SLABS IN ACCORDANCE TO THE BRITISH"
1028 PRINT "STANDARD CODE OF PRACTICE BS 8110 of 1985"
1030 PRINT "FOR FURTHER INFORMATION CONTACT ENGR ALIYU GARBA ABDULKADIR"
1031 PRINT "=====
1032 PRINT ""
1035 PRINT "DO YOU WANT TO CONTINUE"
1040 INPUT "TYPE Y AND PRESS ENTER ", DS
1045 IF (DS = "Y") THEN GOTO 1055
1050 IF (DS = "y") THEN GOTO 1055
1053 GOTO 2395
1055 PRINT ""
1060 PRINT ""
1070 PRINT "ENTER SPAN LENGTH IN x - DIRECTION - METRES"
1075 INPUT LX
1080 PRINT "ENTER SPAN LENGTH IN y - DIRECTION - METRES"
1085 INPUT LY
1086 PRINT ""
1090 IF (LY < LX) THEN GOTO 1091 ELSE GOTO 1093
1091 PRINT "SPAN LENGTH IN y-DIRECTION MUST BE LONGER THAN IN x-DIRECTION"
```

```

1092 GOTO 1070
1093 IF (LY < 2 * LX) THEN GOTO 1096
1094 PRINT "SLAB IS NOT A TWO WAY SLAB, DESIGN AS ONE WAY SLAB"
1095 GOTO 2395
1096 PRINT ""
1097 PRINT "NOTE THAT IN DESIGN CALCULATIONS A STRIP OF SLAB OF WIDTH 1m"
1098 PRINT "IS CONSIDERED IN ANY DIRECTION"
1099 PRINT ""
1100 PRINT "DO YOU WISH TO PROCEED WITH ULTIMATE LIMIT STATE DESIGN"
1105 INPUT "TYPE y AND PRESS ENTER ", A$
1110 IF (A$ = "Y") THEN GOTO 1117
1115 IF (A$ = "y") THEN GOTO 1117
1116 GOTO 2395
1117 PRINT ""
1120 PRINT "ENTER CHARACTERISTIC DEAD LOAD GK, - KN/Sqr.m"
1125 INPUT GK
1130 PRINT "ENTER CHARACTERISTIC LIVE LOAD QK , - KN/Sqr.m "
1135 INPUT QK
1136 PRINT ""
1137 PRINT ""
1140 N = (1.4 * GK) + (1.6 * QK)
1145 PRINT "TITLE :BENDING"
1146 PRINT "======"
1147 PRINT ""
1150 PRINT "IS THE SLAB SIMPLY SUPPORTED ON ALL FOUR SIDES"
1155 INPUT "TYPE Y AND PRESS ENTER ", B$
1160 IF (B$ = "Y") GOTO 1175
1165 IF (B$ = "y") GOTO 1175
1170 GOTO 1234
1175 SX = ((LY / LX) ^ 4) / (8 * (1 + ((LY / LX) ^ 4)))

```

```
1180 SY = ((LY / LX) ^ 2) / (8 * (1 + ((LY / LX) ^ 4)))
1185 MSX = SX * N * (LX ^ 2)
1190 MSY = SY * N * (LX ^ 2)
1191 PRINT ""
1192 PRINT ""
1195 PRINT "SPAN LENGTH IN X - DIRECTION = "; LX; "METRES"
1200 PRINT "SPAN LENGTH IN Y - DIRECTION = "; LY; "METRES"
1205 PRINT "CHARACTERISTIC DEAD LOAD = "; GK; "KN / m2"
1210 PRINT "CHARACTERISTIC LIVE LOAD = "; QK; "KN / m2 "
1215 PRINT "ULTIMATED DESIGN LOAD = "; N; "KN / m2"
1220 PRINT "MID SPAN MOMENT IN DIRECTION OF LX= "; MSX; "KN-m/m"
1225 PRINT "MID SPAN MOMENT IN DIRECTION OF LY= "; MSY; "KN-m/m"
1230 GOTO 1376
1234 PRINT ""
1235 PRINT "SLAB HAS TORSIONAL RESTRAINT(IS CONTINUOUS)"
1236 PRINT "AT ONE OR MORE OF THE EDGES (SUPPORTS)"
1237 PRINT ""
1240 PRINT "ENTER NUMBER OF DISCONTIOUS SHORT EDGES (0,1 or 2)"
1245 INPUT NS
1250 PRINT "ENTER NUMBER OF DISCONTIOUS LONG EDGES (0,1 or 2)"
1255 INPUT NL
1260 ND = NS + NL
1261 K1 = 4 / 3
1262 K2 = 4 / 3
1263 K3 = 4 / 3
1264 K4 = 4 / 3
1270 IF NS = 1 THEN K2 = 0
1275 IF NS = 2 THEN K1 = 0
1276 IF NS = 2 THEN K2 = 0
1280 IF NL = 1 THEN K4 = 0
```

```

1285 IF NL = 2 THEN K3 = 0
1286 IF NL = 2 THEN K4 = 0
1290 BY = (24 + (2 * ND) + (1.5 * (ND ^ 2))) / 1000
1295 y = (2 / 9) * (3 - (SQR(18 * (LY / LX)) * (SQR(BY + K1 * BY) + SQR(BY + K2 * BY))))
1300 BX = y / ((SQR(1 + K3) + SQR(1 + K4)) ^ 2)
1305 MX = BX * N * LX ^ 2
1310 M3 = K3 * MX
1315 MY = BY * N * LX ^ 2
1320 M1 = K1 * MY
1325 PRINT " "
1330 PRINT " "
1350 PRINT "NUMBER OF DISCONTINUOUS SHORT EDGES = "; NS; ""
1355 PRINT "NUMBER OF DISCONTINUOUS LONG EDGES = "; NL; ""
1360 PRINT "EDGE MOMENT Mex IN THE DIRECTION OF LX = "; M3; "KNm/m"
1365 PRINT "MIDSPAN MOMENT Msx IN THE DIRECTION OF Lx = "; MX; "KNm/m"
1370 PRINT "EDGE MOMENT Mey IN THE DIRECTION OF Ly = "; M1; "KNm/m"
1375 PRINT "MIDSPAN MOMENT Msy IN THE DIRECTION OF Ly = "; MY; "KNm/m"
1376 PRINT ""
1377 PRINT ""
1380 PRINT "DO YOU WISH TO PROCEED WITH THE DESIGN OF"
1385 PRINT "SECTION FOR BENDING"
1390 INPUT "TYPE Y AND PRESS ENTER ", CS
1395 IF (CS = "Y") THEN GOTO 1406
1400 IF (CS = "y") THEN GOTO 1406
1405 GOTO 1561
1406 PRINT ""
1407 PRINT ""
1408 PRINT "TITLE : SECTION DESIGN FOR BENDING"
1409 PRINT "=====
1410 PRINT "ENTER CONCRETE GRADE - N/mm"

```



```
1525 PRINT "AREA OF TENSION REINFORCEMENT REQUIRED", AX, "SQmm"
1526 PRINT ""
1530 PRINT "DO YOU WISH TO REPEAT CALCULATION FOR AREAS OF"
1535 PRINT "REINFORCEMENT FOR OTHER APPLIED MOMENTS"
1540 PRINT "AT OTHER SECTIONS (DIRECTION) OF SLAB"
1545 INPUT "TYPE Y AND PRESS ENTER ", E$
1550 IF (E$ = "Y") THEN GOTO 1406
1555 IF (E$ = "y") THEN GOTO 1406
1561 PRINT ""
1565 PRINT "DO YOU WISH TO DESIGN FOR SHEAR"
1570 INPUT "TYPE Y AND PRESS ENTER ", F$
1575 IF (F$ = "Y") THEN GOTO 1586
1580 IF (F$ = "y") THEN GOTO 1586
1585 GOTO 1985
1586 PRINT ""
1587 PRINT ""
1590 PRINT "TITTLE : DESIGN FOR SHEAR"
1591 PRINT "======"
1595 PRINT "ENTER CHARACTERISTIC STRENGTH OF SHEAR LINKS- N/Sqr .mm"
1600 INPUT FYV
1605 PRINT "ENTER AREA OF LONGITUDINAL TENSION STEEL- Sqr.mm"
1610 INPUT AX
1615 PRINT "ENTER ULTIMATE SHEAR FORCE, V - KN"
1620 INPUT V
1621 PRINT "ENTER EFFECTIVE DEPTH, D - mm"
1622 INPUT D
1623 B = 1000
1625  $VA = (V * 10^3) / (B * D)$ 
1630  $V1 = .8 * SQR(FCU)$ 
1636 PRINT ""
```

```
1638 IF (V1 > 5) THEN V1 = 5
1640 IF VA > V1 THEN GOTO 1649
1645 GOTO 1670
1649 PRINT ""
1650 PRINT "MAX ALLOWABLE SHEAR STRESS IS EXCEEDED"
1655 PRINT "YOU MAY HAVE TO INCREASE THE DEPTH OF SLABS"
1656 PRINT ""
1660 GOTO 1773
1670 RO = 100 * AX / (B * D)
1675 IF RO <= .15 THEN RO = .15
1680 IF RO >= 3 THEN RO = 3
1685 V = FCU
1690 IF FCU > 40 THEN V = 40
1695 DW = D
1700 IF DW > 400 THEN DW = 400
1705 VC = .79 * (RO ^ (1 / 3)) * ((400 / DW) ^ (1 / 4)) * (1 / 1.25)
1710 IF FCU > 25 THEN VC = VC * ((V / 25) ^ (1 / 3))
1715 IF D < 200 GOTO 1727
1720 IF VA < VC GOTO 1727
1725 GOTO 1740
1727 PRINT ""
1730 PRINT "SHEAR REINFORCEMENT IS NOT REQUIRED"
1735 GOTO 1773
1740 IF VA > VC + .4 THEN GOTO 1755
1745 AV = (.4 * B) / (.87 * FYV)
1750 GOTO 1760
1755 AV = (B * (VA - VC)) / (.87 * FYV)
1760 PRINT "ULTIMATE SHEAR FORCE =", V, "KN"
1765 PRINT "CHARACTERISTIC STRENGTH OF SHEAR LINKS =", FYV, "KN"
1770 PRINT "SHEAR LINKS ASV/SV=", AV, " "
```

```
1773 PRINT ""
1775 PRINT "DO YOU WISH TO DESIGN FOR PUNCHING"
1780 PRINT "SHEAR (IF ANY CONCENTRATED LOAD ON SLABS)"
1785 INPUT "TYPE Y AND PRESS ENTER ", G$
1790 IF (G$ = "Y") GOTO 1801
1795 IF (G$ = "y") GOTO 1801
1800 GOTO 1885
1801 PRINT ""
1802 PRINT ""
1805 PRINT "TITLE: PUNCHING SHEAR"
1807 PRINT "======"
1810 PRINT "ENTER LENGHT OF LOADED AREA IN X- DIRECTION A- mm"
1815 INPUT A
1820 PRINT "ENTER LENGHT OF LOADED AREA IN Y- DIRECTION B- mm"
1825 INPUT B
1830 PRINT "ENTER DEPTH OF SLAB H-mm"
1835 INPUT H
1840 PRINT "ENTER STEEL AREA SPANNING IN X-DIRECTION sqmm/m"
1845 INPUT A1
1850 PRINT "ENTER STEEL AREA SPANNING IN Y-DIRECTION sqmm/m"
1855 INPUT A2
1860 PRINT "ENTER SLAB'S EFFECTIVE DEPTH FOR STEEL SPANING IN X-DIRECTION mm"
1865 INPUT D1
1870 PRINT "ENTER SLAB'S EFFECTIVE DEPTH FOR STEEL SPANNING IN Y-DIRECTION mm"
1875 INPUT D2
1880 PRINT "ENTER ULTIMATE PUNCHING LOAD -KN"
1882 INPUT VP
1883 PRINT "ENTER CONCRETE GRADE - N/Sqr.mm"
1885 INPUT FCU
```

```

1890 DP = (D1 + D2) / 2
1895 VP1 = (VP * (10 ^ 3)) / ((2 * (A + B)) * DP)
1900 IF VP1 < (.8 / FCU) THEN GOTO 1910
1905 VP1 = .8 / FCU
1910 IF VP1 < 5 THEN VP1 = 5
1920 VPA = (VP * 103) / ((2 * (A + B)) + (8 * 1.5 * DP))
1921 IF VPA < VP1 THEN GOTO 1980
1922 XWX = (100 * A2) / (1000 * DP)
1923 IF XWX > 3 THEN XWX = 3
1924 ZWZ = 400 / DP
1925 IF ZWZ > 1 THEN ZWZ = 1
1926 VC = .79 * (XWX ^ (1 / 3)) * (ZWZ ^ (1 / 4)) / 1.25
1929 IF VPA < VC THEN GOTO 1980
1935 IF H < 200 GOTO 1980
1936 YWY = (VPA - VC)
1937 IF YWY < .4 THEN YWY = .4
1940 V = (2 * (A + B)) + (8 * 1.5 * DP)
1945 APV = (YWY * V * DP) / (.87 * FYV)
1947 PRINT "NOTE THAT THE AREAS OF REINFORCEMENT ARE AT "
1948 PRINT "INTERVALS OF 0.75 X (EFFECTIVE DEPTH)"
1949 PRINT "STARTING FROM THE FIRST CRITICAL PERIMETER OUTWARDS"
1950 PRINT "AREA OF SHEAR REINFORCEMENT REQUIRED = ", APV
1955 IF APV < 0 THEN GOTO 1965
1965 A = A + .75 * DP
1970 B = B + .75 * DP
1975 GOTO 1920
1980 PRINT ""
1981 PRINT "SHEAR REINFORCEMENT IS NOT REQUIRED"
1985 PRINT ""
1986 PRINT ""

```

```
1987 PRINT "DO YOU WISH TO CHECK FOR DEFLECTION."
1990 INPUT "TYPE Y AND PRESS ENTER ", T$
1995 IF (T$ = "Y") THEN GOTO 2010
2000 IF (T$ = "y") THEN GOTO 2010
2005 GOTO 2170
2010 PRINT ""
2011 PRINT ""
2015 PRINT "TITLE; SPAN EFFECTIVE DEPTH RATIO CHECK FOR DEFLECTION"
2017 PRINT "=====
2020 PRINT "ENTER AREA OF TENTION STEEL PROVIDED- mm"
2025 INPUT ASP
2030 PRINT "ENTER AREA OF TENTION STEEL REQUIRED- mm"
2035 INPUT ASR
2040 PRINT "ENTER AREA OF COMPRESSION STEEL PROVIDED- mm"
2045 INPUT ACP
2050 PRINT "ENTER ULTIMATE DESIGN MOMENT AT MIDSPAN- KN-m/m"
2052 PRINT "IN Y DIRECTION"
2055 INPUT MU
2060 PRINT "ENTER SPAN LENGTH IN Y-DIRECTION- m"
2065 INPUT LY
2066 PRINT "ENTER CHARACTERISTIC STEEL STRENGTH- N/Sqr.mm"
2067 INPUT FY
2068 PRINT "ENTER EFFECTIVE DEPTH- mm"
2069 INPUT D
2070 IF (LY > 10) THEN GOTO 2085
2073 B = 1000
2075 SD = 20
2078 GOTO 2088
2085 SD = 200 / LY
2088 FS = 5 * FY * (ASR / ASP) / 8
```

```
2090 F1 = .55 + ((4.77 - FS) / (120 * (.9 + ((MU * 10 ^ 6) / (B * D ^ 2))))))
2100 IF (F1 < 2) GOTO 2110
2105 F1 = 2
2110 F2 = 1 + (((100 * ACP) / (B * D)) / (3 + ((100 * ACP) / (B * D))))
2115 IF (F2 < 1.5) GOTO 2125
2120 F2 = 1.5
2125 F3 = 1
2130 IF LY < 10 GOTO 2140
2135 F3 = 10 / LY
2140 RC = SD * F1 * F2 * F3
2145 RA = LY / D
2146 PRINT "SPAN EFFECTIVE DEPTH RATIO ACTUAL = "; RA
2147 PRINT "SPAN EFFECTIVE DEPTH RATIO CALCULATED = "; RC
2150 IF (RA < RC) GOTO 2165
2153 PRINT ""
2155 PRINT "DEFLECTION IS EXCESSIVE"
2161 PRINT ""
2162 GOTO 2173
2165 PRINT ""
2168 PRINT "SECTION IS O.K"
2170 PRINT ""
2171 PRINT ""
2173 PRINT "DO YOU WISH TO CALCULATE CRACK WIDTH"
2175 PRINT "(NOTE THAT THE CRACK WIDTH CONSIDERED IS AT THE MIDSTRIP"
2180 PRINT "OF THE LONGER SPAN AT THE TENSION FACE OF THE SLAB)"
2190 INPUT "TYPE Y AND PRESS ENTER", I$
2195 IF (I$ = "Y") THEN GOTO 2206
2200 IF (I$ = "y") THEN GOTO 2206
2205 GOTO 2395
2206 PRINT ""
```

```
2207 PRINT ""
2208 PRINT "TITLE : CALCULATION FOR CRACK WIDTH"
2209 PRINT "===== "
2210 PRINT "ENTER THICKNESS OF SLAB mm"
2215 INPUT H
2230 PRINT "ENTER DEPTH OF TENSION STEEL BARS mm"
2235 INPUT DT
2240 PRINT "ENTER TENSION STEEL BAR SPACING mm"
2245 INPUT S
2250 PRINT "ENTER DEPTH OF COMPRESSION STEEL mm"
2255 INPUT DC
2260 PRINT "ENTER SERVICEABILITY MOMENT KN-m/m "
2265 INPUT MS
2270 PRINT "ENTER DISTANCE FROM THE POINT UNDER CONSIDERATION"
2275 PRINT "TO THE NEAREST REINFORCING BAR mm"
2280 INPUT ACR
2285 PRINT "ENTER EFFECTIVE DEPTH mm"
2290 INPUT D
2295 PRINT "ENTER CONCRETE GRADE N/sqr.mm "
2300 INPUT FCU
2305 PRINT "ENTER MODULUS OF ELASTICITY OF STEEL"
2310 INPUT ES
2315 PRINT "ENTER AREA OF TENSION STEEL PER METRE STRIP Sqr.mm"
2320 INPUT AX
2325 PRINT "ENTER AREA OF COMPRESSION STEEL PER METRE STRIP Sqr.mm"
2330 INPUT AIS
2335  $EC = 20 + (.2 * FCU)$ 
2333  $B = 1000$ 
2340  $M = (ES * 1000) / EC$ 
2345  $ZX = ((M - 1) * AIS) + (M * AX)$ 
```

```

2346 ZY = ((M - 1) * AIS) + (M * AX ^ 2)
2347 ZZ = 2 * B * (((M - 1) * AIS * DC) + (M * AX * DT))
2348 X = -(ZX + SQR(ZY + ZZ)) / B
2350 XX = ((1 / 3) * (B * X ^ 3)) + ((M - 1) * AIS * ((X - DC) ^ 2))
2353 WW = (M * AX * ((DT - X) ^ 2))
2354 I = XX + WW
2355 E1 = (MS * 10 ^ 6 * (D - X) * M) / (ES * I)
2360 EM = E1 - (B * (H - X) ^ 2) / (3 * ES * 1000 * AX * (D - X))
2361 W = (3 * ACR * EM)
2362 IF EM < 0 THEN GOTO 2367
2366 GOTO 2372
2367 PRINT "AVERAGE STRAIN = "; EM
2368 PRINT "THE AVERAGE STRAIN AT THE LEVEL CONSIDERED IS NEGATIVE"
2369 PRINT "AND THIS INDICATES THAT THE SECTION IS UNCRACKED ie O.K."
2370 GOTO 2380
2372 PRINT ""
2373 PRINT ""
2375 PRINT "CALCULATED CRACK WIDTH ="; W
2376 IF (W < .3) GOTO 2390
2378 PRINT "THE CRACK WIDTH IS EXCESSIVE (NOT SATISFACTORY)"
2380 GOTO 2395
2390 PRINT "THE CRACK WIDTH IS LESS THAN THE LIMIT SPECIFIED"
2391 PRINT "i.e 0.3 mm HENCE IT IS O.K "
2395 END

```



APPENDIX B  
TEST RESULTS

*Example 8.5*

DATA

Slab is simply supported

Short span of slab $L_x$	-	4.5m
Long span of slab $L_y$	-	6.3m
Characteristic concrete grade $F_{cv}$	-	30N/mm <sup>2</sup>
Characteristic Steel Strength $F_y$	-	460 N/mm <sup>2</sup>
Characteristic Dead Load $G_k$	-	5.3KN/m <sup>2</sup>
Characteristic Live Load $Q_k$	-	10.0KN/m <sup>2</sup>
Cover to compression steel $D$	-	25mm
Effective depth in X direction	-	150mm
Effective depth in Y direction	-	176mm
Number discontinuous edges in X direction	-	0
Number of discontinuous edges in U direction	-	0
Thickness of slab	-	200mm
Minimum cover to reinforcement	-	200mm

**RESULTS**

	Manual Calculation	TW Slab
Midspan moment in X direction	46.9 KN-m/m	47.037 KN – m/m
Area of tension steel in X direction	666 mm <sup>2</sup> /m	684 . 4994mm <sup>2</sup> /m
Midspan moment in Y		

direction	24.0 KN-m/m	23.9987 KN – m/m
Area of tension steel in Y direction	369mm <sup>2</sup> /m	367.093mm <sup>2</sup> /m
Span – effective depth Ratio	Actual 35.96 Limiting = 25.00 (Calculated)	Actual 35.96 Limiting = 24.803 Section is O.K.
Crack width	Actual = 0.021mm Limiting = 0.3mm	Actual = 0.02467 Limiting = 0.3m Section is O. K.

**EXAMPLE 8. 6**

DATA

**Slab has continuity**

Short span of slab  $L_x$  = 5.0

Long span of slab = 6.0

Characteristic dead load = 2.0

Characteristic Live Load = 4.5

No. of discontinuous sides in X direction  $N_S$  = 0

No of discontinuous sides in Y direction  $N_L$  = 1

All other parameters not mentioned remain the same with example 8.5.

## RESULTS

	Manual Calculation	TW Slab
Midspan moment in X direction	10.0 KN-m/m	9.1485
Moment at support in X direction (at one support)	14.0 KN-m/m	12.1981 KN –m/m
Midspan moment in Y direction	7.0 KN – m/m	6.87500 KN –m/m
Moment at support in Y	9.3, KN – m/m	9.16667 KN – m/m
Area of tension steel in Y direction	95mm <sup>2</sup>	105.1622
Area of tension steel in X	153mm <sup>2</sup>	163.316mm <sup>2</sup>
Area of tension steel at one unrestricted support in Y of direction	225mm <sup>2</sup>	221.312mm <sup>2</sup>
Area of tension steel at restrained support in X direction	225mm <sup>2</sup>	221.312mm <sup>2</sup>
Span – effective depth ratio	Actual = 32.5 Limiting (Calculated ) 35.2	Actual = 32.5 Limiting (Calculated) 34.978
Crack width	Actual = 0.19mm Limiting = 0.3mm	Actual = 0.201mm Limiting = 0.3mm