PAPER NO.569

ANALYSIS OF TWO WAY R.C JOIST FLOORS HAVING DIFFERENT CONFIGURATIONS

BY

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Syed Ali Rizwan[1], Syed Ali Debaj[2], Husnain Ahmad[3]

ABSTRACT

Two way joist floors (waffle slabs) are extensively used in R.C construction to cover economically moderate squarish plans spanning up to 60 ft due to their excellent and pleasing appearance and are liked by the architects. Their exact analysis is rather complex as they are highly statically indeterminate (1).Therefore a simpler approach known as link-force method, originally adopted by Makowski for space structures in steel, is developed by appropriate modifications. Applications of link force method were presented by the authors for the purpose in their previous paper (2) for a simple configuration for demonstration. This paper is basically an extension of that method. The earlier attempt dealt with simply supported beams intersecting at right angles in two orthogonal directions. In this paper the method is applied to beams with fixed ends with different configurations. The method uses the concept that link forces are generated at the nodes where two beams intersect. Arguing that deflection at a node should be the same when determined from either of the intersecting beams, linear simultaneous equations are easily set up. Solving these equations by calculators or computers, the bending moments and shear forces at different sections can easily be found. The results of the method have also been compared with those based on SAP90 computer program and depend on the torsional stiffness of reinforced concrete. In addition, the significance of diagonal grids have also been discussed along with the application of the said method to analyze it easily. Thus, besides discussing several basic structural considerations, the paper presents a simple analysis and therefore design tool for rectangular and diagonal grids which may enable designers nowadays to tackle analysis problems of great complexity without undue difficulty even if access to computer/software facilities is not available.

INTRODUCTION

Two way joist floors (waffle slabs) can be considered as grids having intersecting beams in two orthogonal directions or at an angle and at the same level. Makowski (3) states that steel grids are very pleasing when viewed from below and possess remarkable acoustic performance. These could be used for public buildings, theatres, cinemas and parking garages etc. These girds are very stiff and avoid excessive deflections commonly occurring in the ordinary construction.

Owing to the interconnection of the elements forming the grids, the resulting structure is highly structurally indeterminate. However, for symmetrical layouts and symmetrical

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loadings, the analysis maybe simplified by using various methods applicable to grid frameworks. The easiest may be the comparison of deflections at the nodes which should be the same when determined from either of the intersecting beams running in orthogonal directions. The method is perfectly general and is applicable to any layout or loading. The application of the method results in linear simultaneous equations after using influence coefficients and the solution of these equations is not difficult after having set up those equations.

Generally speaking for rigidly connected grids at nodes, the influence of torsion is more for reinforced concrete than for steel, and maybe taken into account for important cases. It is noted that torsional stiffness of beams must always be considered for bridge decks supported on two sides only. Its effect for ordinary grids supported on all four sides is comparatively lesser (3). Therefore by neglecting the torsional stiffness of the intersecting beams at nodes, the external forces produces only vertical reactive forces acting in the fictitious link between the intersecting beams running in different directions. These vertical fictitious links can be visualized as having very infinitely small length with pin connections at the top and at the bottom. They serve as connectors to the interconnecting beams at the same level. The axial loads induced in these fictitious links are called "LINK FORCES Xi" as shown below.

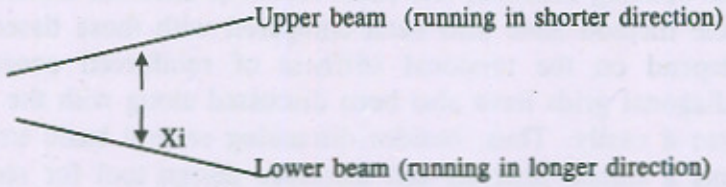


Figure. 1 Sign convention of link force (The direction shown is considered as positive link force)

These link forces forms the redundants in grid analysis. After the formation of linear simultaneous equations, the bending moment, shear forces and deflection of all beams can be determined very easily.

In the previous paper (2), a table was formulated and presented giving the deflection coefficients for simply supported beams under concentrated loads. Table 1, developed by the authors, at the end, gives deflection coefficients for fixed ended beams under concentrated loads.
The relevant details on space structure may be consulted elsewhere. (4, 5, 6).

ANALYSIS TECHNIQUE

The total number of unknown reactions Xi is equal to the total number of internal nodes. The same number of equations result from the compatibility requirements of displacements at any node i.

In case of R.C grid beams, appropriate values of Modulus of elasticity of concrete, effective moment of inertia and polar moment of inertia are to be used while analysing by SAP90 for comparison purposes.

EXAMPLE

The same example of the previous paper (2) is considered but with fixed ended beams for illustration purpose.

Consider an area of 14 ft. x 21 ft. to be covered by reinforced concrete grid beams and slab structures as shown in fig 1. The total factored load acting on the slab is lumped on to the number of nodes specified in fig. 2. The total nodal load P_u is found to be 3.78 kips (2). The nodal applied gravity load will be $P=P_u/2$ at nodes in upper and lower beams to satisfy equilibrium. Thus P = 1.89 kip

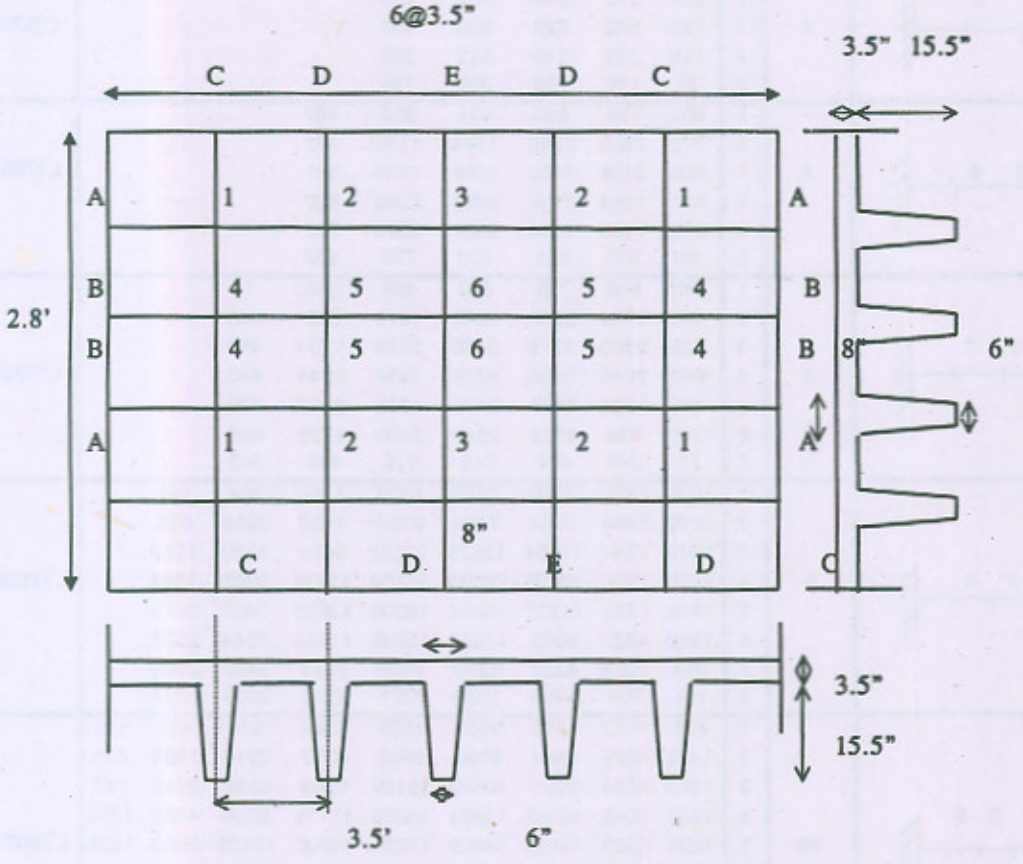
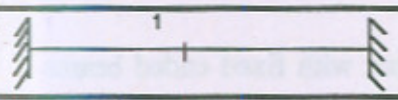
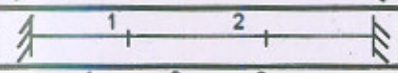
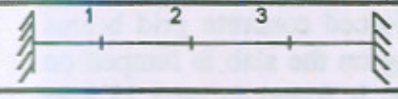
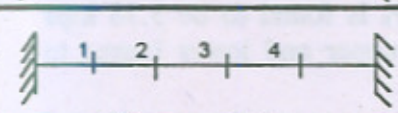
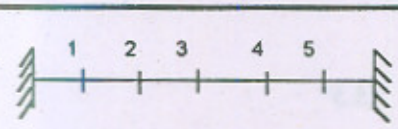
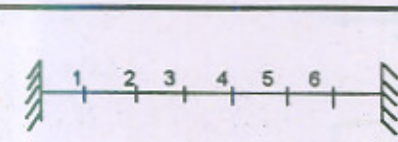
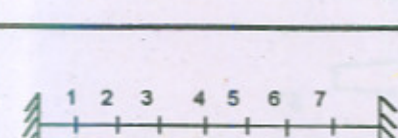
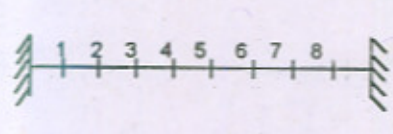


Figure 2. LAYOUT OF A TYPICAL TWO WAY JOIST PANEL AND NODE NUMBERING USING SYMMETRY AND ORTHOGONAL SECTIONS

TABLE 1

DEFLECTION COEFFICENTS FOR BOTH ENDS RESTRAINT BEAMS UNDER CONCENTRATED LOADS

KEY DIAGRAM	NO. OF SPANS n	def. AT	UNIT LOAD AT POINT K									MULTIPLY BY
			1	2	3	4	5	6	7	8	9	
	2	1	1									$L^3/192EI$
	3	1	8	1								$L^3/2187EI$
		2	1	8								
	4	1	27	32	13							$L^3/12288EI$
		2	32	64	32							
		3	13	32	27							
	5	1	128	189	136	47						$L^3/93750EI$
		2	189	432	368	136						
		3	136	368	432	189						
		4	47	136	189	128						
	6	1	125	208	189	116	37					$L^3/139968EI$
		2	208	512	540	352	116					
		3	189	540	729	540	189					
		4	116	352	540	512	208					
		5	37	116	189	208	125					
	7	1	432	775	800	621	352	107				$L^3/705894EI$
		2	775	2000	2368	1944	1136	352				
		3	800	2368	3456	3159	1944	621				
		4	621	1944	3159	3456	2368	800				
		5	352	1136	1944	2368	2000	775				
		6	107	352	621	800	775	432				
	8	1	343	648	725	640	459	248	73			$L^3/786432EI$
		2	648	1728	2200	2048	1512	832	248			
		3	725	2200	3375	3456	2673	1320	457			
		4	640	2048	3456	4096	3456	2048	640			
		5	459	1320	2673	3456	3375	2200	725			
		6	248	832	1512	2048	2200	1728	648			
		7	73	248	459	640	725	648	343			
	9	1	1024	2009	2376	2275	1856	1269	664	191		$L^3/3188646EI$
		2	2009	5488	7344	7400	6208	4320	2288	664		
		3	2376	7344	11664	12825	11232	8019	4320	1269		
		4	2275	7400	12825	16000	15104	11232	6208	1344		
		5	1344	6208	11232	15104	16000	12825	7400	2275		
		6	1269	4320	8019	11232	12825	11664	7344	2376		
		7	664	2288	4320	6208	7400	7344	5488	2009		
		8	191	664	1269	1856	2275	2376	2009	1024		
	10	1	729	1472	1813	1836	1625	1264	837	428	121	$L^3/3000000EI$
		2	1472	4096	5684	6048	5500	4352	2916	1504	428	
		3	1813	5684	9261	10692	10125	8208	5589	2916	837	
		4	1836	6048	10692	13824	14000	11776	8208	4352	1264	
		5	1625	5500	10125	14000	15625	14000	10125	5500	1625	
		6	1264	4352	8208	11776	14000	13824	10692	6048	1836	
		7	837	2916	5589	8208	10125	10692	9261	5684	1813	
		8	428	1504	2916	4352	5500	6048	5684	4096	1472	
		9	121	428	837	1264	1625	1836	1813	1472	729	

SETTING UP OF LINEAR SIMULTANEOUS EQUATIONS

Using the Table 1 for fixed ended beams under the action of point loads, the numerical values of the deflection coefficients can be obtained directly.

Thus by the principle of superposition the deflection at the joints are calculated as follows.

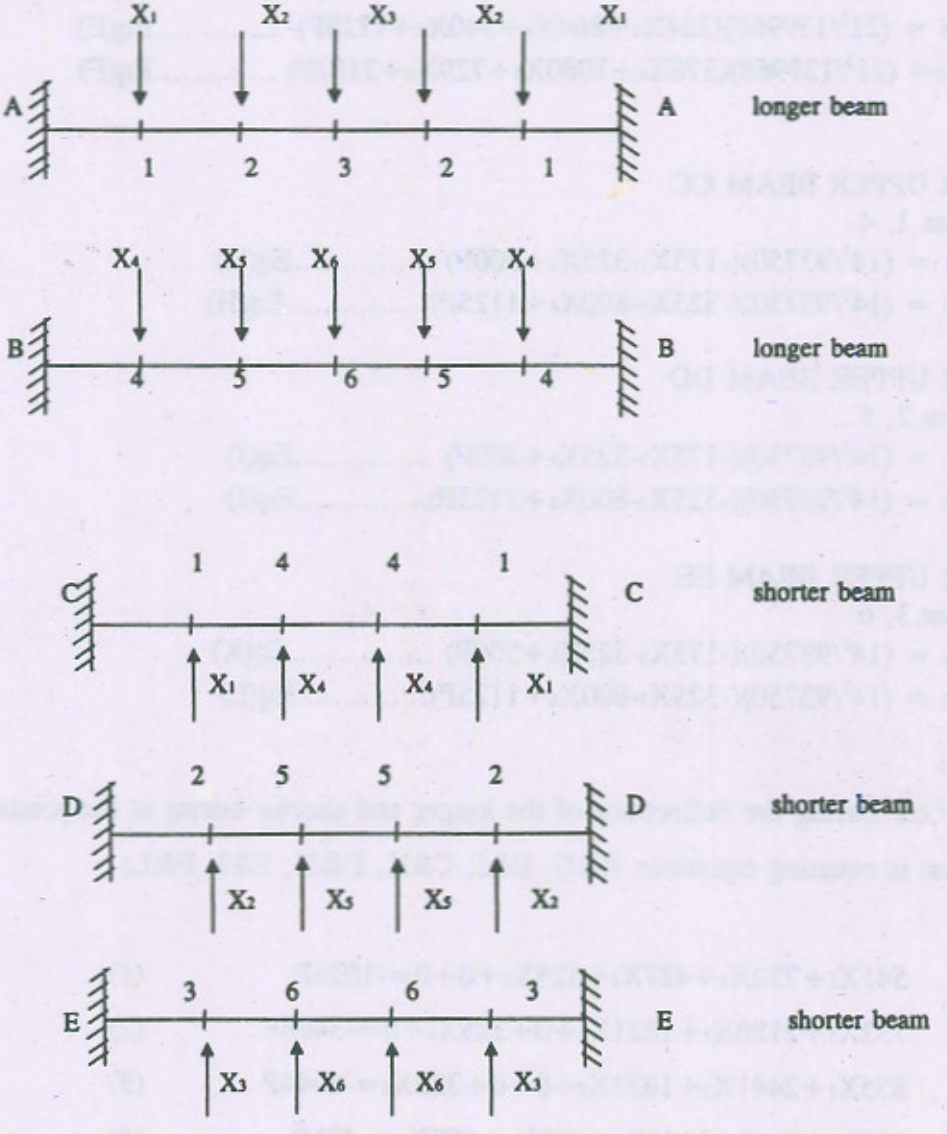


Fig 3a

Fig 3b

Fig 3c

Fig3d

Fig 3e

Fig 3. Beams under link forces

FOR LOWER BEAM AA
Nodes 1, 2, 3

$EI\delta_1 = (21^3/139968)(162X_1+324X_2+189X_3+675P)$ .....Eq(A)

$EI\delta_2 = (21^3/139968)(324X_1+864X_2+540X_3+1728P)$ .....Eq(B)

$EI\delta_3 = (21^3/139968)(378X_1+1080X_2+729X_3+2187P)$ .....Eq(C)

FOR LOWER BEAM BB
Nodes 4, 5, 6

$EI\delta_4 = (21^3/139968)(162X_4+324X_5+189X_6+675P)$ .....Eq(D)

$EI\delta_5 = (21^3/139968)(324X_4+864X_5+540X_6+1728P)$ .....Eq(E)

$E1\delta_6 = (21^3/139968)(378X_4+1080X_5+729X_6+2187P)$ .....Eq(F)

FOR UPPER BEAM CC
Nodes 1, 4

$EI\delta_1 = (14^3/93750)(-175X_1-325X_4+500P)$ .....Eq(G)

$EI\delta_4 = (14^3/93750)(-325X_1-800X_4+1125P)$ .....Eq(H)

FOR UPPER BEAM DD
Nodes 2, 5

$EI\delta_2 = (14^3/93750)(-175X_2-325X_5+500P)$ .....Eq(I)

$EI\delta_5 = (14^3/93750)(-325X_2-800X_5+1125P)$.....Eq(J)

FOR UPPER BEAM EE
Nodes 3, 6

$EI\delta_3 = (14^3/93750)(-175X_3-325X_6+500P)$ .....Eq(K)

$EI\delta_6 = (14^3/93750)(-325X_3-800X_6+1125P)$.....Eq(L)

Now comparing the deflections of the longer and shorter beams at the joints 1, 2, 3, 4, 5 and 6; that is equating equations A&G, B&I, C&K, D&H, E&J, F&L;

$541X_1+732X_2+427X_3+325X_4+0+0=-1026P$ (1)

$732X_1+2128X_2+1221X_3+0+325X_5+0=-3406P$ (2)

$855X_1+2441X_2+1823X_3+0+0+325X_6=-4444P$ (3)

$325X_1+0+0+1166X_4+732X_5+427X_6=-401P$ (4)

$0+325X_2+0+732X_4+2753X_5+1221X_6=-2781P$ (5)

$0+0+325X_3+855X_4+2441X_5+2448X_6=-3819P$ (6)

The linear simultaneous equations can be solved by any standard method. A generalized FORTRAN computer program was presented in the previous paper (2) to solve simultaneous equations and is attached at the end also.

Solving the equations, by the help of calculator or computer, the values of the reactive forces X_i are as follows.

$X_1 = -0.1924P$
$X_2 = -0.8680P$
$X_3 = -P$
$X_4 = 0.4411P$
$X_5 = -0.5810P$
$X_6 = -P$

Given that P= 1.89 kips acting at intersection of beams, these can be calculated and accordingly applied to the respective beams.

$X_1 = -0.3636$
$X_2 = -1.6405$
$X_3 = -1.8900$
$X_4 = 0.8337$
$X_5 = -1.0981$
$X_6 = -1.8900$

BEAMS UNDER NET LOADS

After applying the nodal link forces and applied nodal loads, the maximum moments could easily be picked up.

The procedure has been checked by SAP90 which gives comparable results. The structure data file, displaced position of structure and output file F3F is given in appendix.

BEAMS UNDER NET GRAVITY LOADS AND LINK FORCES (KIPS)

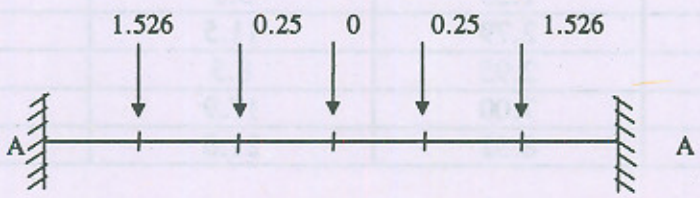


Fig 4a

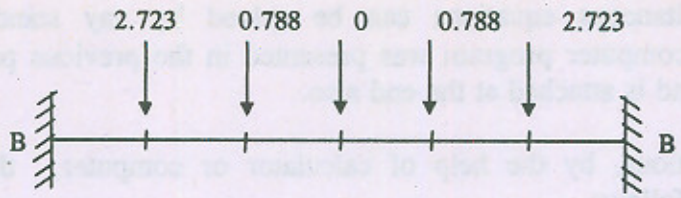


Fig 4b

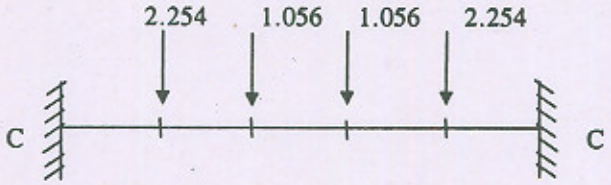


Fig 4c

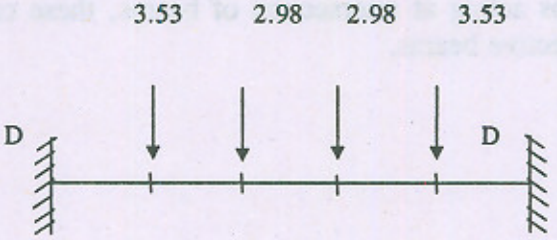


Fig 4d

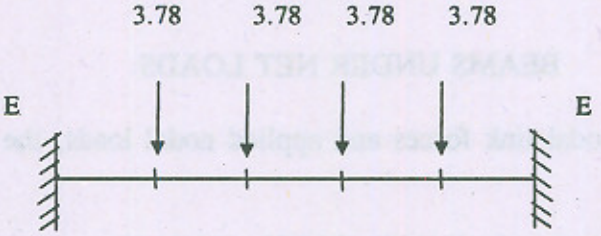


Fig 4e

Fig 4 Beams under net loads

TABLE 2: COMPARISON OF RESULTS OF LINK FORCE METHOD AND SAP90

BEAMS	Positive Max M (K-ft)	Positive Max M by SAP90 (K-ft)	Fixed End Negative M (K-ft)	Fixed End Negative M by SAP90 (K-ft)
Beam AA	1.473	1.23	5.5	4.66
Beam BB	3.420	2.79	11.5	9.47
Beam CC	3.625	2.95	8.5	6.91
Beam DD	8.670	7.00	17.9	14.41
Beam EE	10.584	8.52	21.0	17.00

DIAGONAL GRID

Makowski (3) states that it is interesting to note that, though the rectangular arrangement of beams is so popular, it is not the best, as far as the stress distribution is concerned. In an open grid framework, it is possible theoretically to arrange the beams in such a way as to follow the trajectories of the principal stresses. Such an arrangement would place the beams where they are most needed. But, it is doubtful whether such an arrangement - best from theoretical point of view would be economical. In practice a close approximation will be produced by a diagonal grid as shown in fig5. Diagonal grids can be successfully applied even to irregular boundaries (3)

The fundamental differences between diagonal and rectangular grids is that in the former the beams are of varying lengths, and therefore, even if all the beams have the same flexural stiffness EI, their relative stiffness EI/L varies very considerably.

The fact that the corners of a slab are the most highly stressed explains why the diagonal grids are much superior in the behavior to the rectangular grids, in which there are no members at the corners, and why the stress distribution is so much more even in diagonal grids.

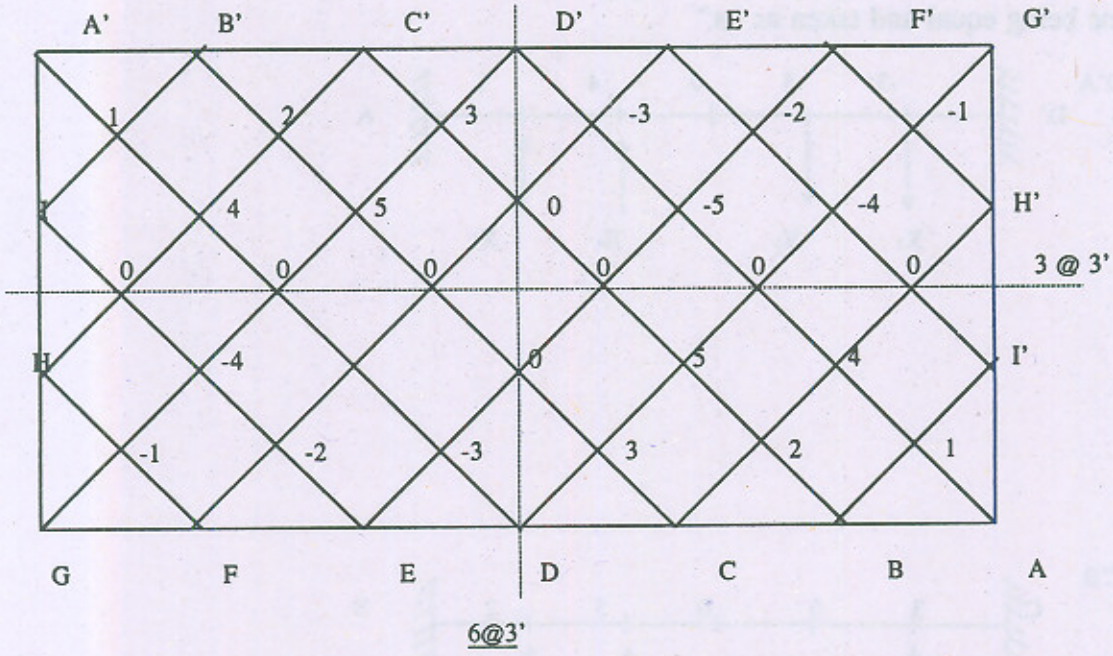


FIGURE 5. LAYOUT OF A TYPICAL TWO WAY DIAGONAL GRID JOIST PANEL AND NODE NUMBERING USING SYMMETRY AND THE ORTHOGONAL SECTIONS AND FIXED AT BOUNDARIES

ANALYSIS OF A DIAGONAL GRID

Consider a diagonal grid, shown in fig 5. The beams of the grid may be simply supported or fixed ended at extreme supports. The load may be lumped as in the previous example. Owing to symmetry only five unknown reactive link forces Xi have to be determined in this case. The nodes lying on the axis of symmetry are of particular interest as the link forces are zero at all such nodes. Furthermore it should be noted that an upper beam with positive link forces when reflected about the symmetrical axis becomes the lower beam but with the direction of the link forces remaining the same and hence such nodes are treated as negative nodes with negative link forces; so the node numbering is to be done carefully such that if the beams sloping down to the right are considered to be the upper beams while those sloping down to the left the lower beams then the node numbers in the second and fourth quadrant are positive whereas those in the first and third quadrant are negative, while the nodes on the line of symmetry are zero. The sign convention for the negative nodes will be opposite to that of the positive nodes already discussed.

Total net load P_u on each node is calculated to be 3.32 kips. As $P = P_u/2$ on each node, therefore $P = 1.66$ kips.

UPPER BEAMS (Lines sloping down to right)
All spans being equal and taken as "a"

BEAM D'A
For δ_1, δ_4

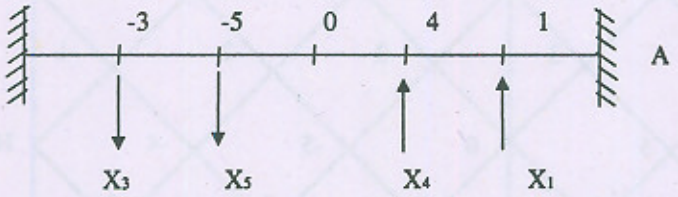


Fig 6a

BEAM C'B
For δ_2, δ_5

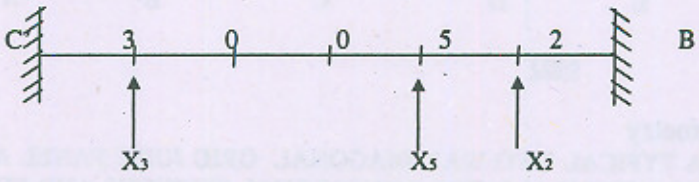


Fig 6b

BEAM B'C
For δ_3

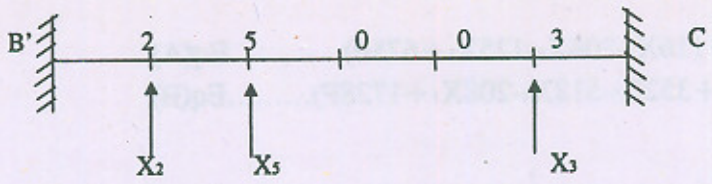


Fig 6c

LOWER BEAMS (Lines sloping down to left)
All spans being equal as taken as "a"

BEAM BI'
For δ_1

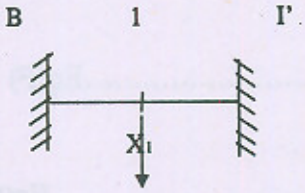


Fig 6d

BEAM CH'
For δ_2, δ_4

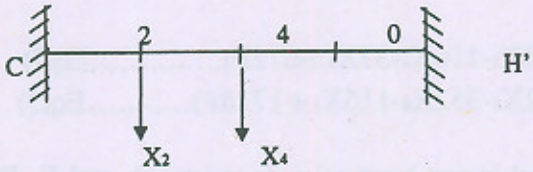


Fig 6e

BEAM DG'
For δ_3, δ_5

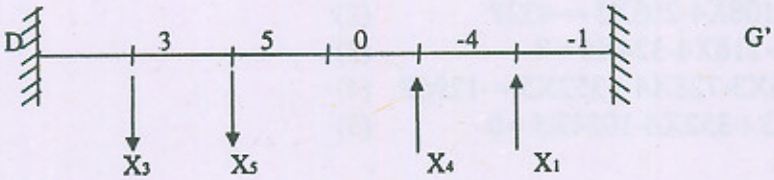


Fig 6f

Fig 6. Beams under link forces. (distance between joints is taken as 'a')

SETTING UP OF LINEAR SIMULTANEOUS EQUATIONS

Using the Table 1 for deflections coefficients , the equations can be easily set up equating corresponding deflections.

FOR UPPER BEAM DA'

$EI\delta_1=((6a)^3/139968)(37X_3+116X_5-208X_4-125X_1+675P)$.....Eq(A)

$EI\delta_4=((6a)^3/139968)(116X_3+352X_5-512X_4-208X_1+1728P)$.....Eq(B)

FOR UPPER BEAM C'B

$EI\delta_2=((6a)^3/139968)(-37X_3-208X_5-125X_2+675P)$ .....Eq(C)

$EI\delta_5=((6a)^3/139968)(-116X_3-512X_5-208X_2+1728P)$ .....Eq(D)

FOR UPPER BEAM B'C

$EI\delta_3=((6a)^3/139968)(-37X_2-116X_5-125X_3+675P)$ .....Eq(E)

FOR LOWER BEAM BI'

$EI\delta_1=((2a)^3/192)(X_1+P)$ .....Eq(F)

FOR LOWER BEAM CH'

$EI\delta_2=((4a)^3/12288)(27X_2+32X_4+72P)$.....Eq(G)

$EI\delta_4=((4a)^3/12288)(32X_2+64X_4+128P)$.....Eq(H)

FOR LOWER BEAM DG'

$EI\delta_3=((6a)^3/139968)(125X_5+208X_5-116X_4-37X_1+675P)$.....Eq(I)

$EI\delta_5=((6a)^3/139968)(208X_3+512X_5-352X_4-116X_1+1728P)$.....Eq(J)

Equating deflections for upper and lower beams i.e equations A and F, B and H, C and G, D and J, E and I, the following simultaneous equations are obtained,

-152X1+0+37X3-208X4+116X5=-648P (1)

0-216.125X2-37X3-108X4-208X5=-432P (2)

37X1-37X2-250X3+116X4-324X5=0 (3)

-208X1-108X2+116X3-728X4+352X5=-1296P (4)

116X1-208X2-324X3+352X4-1024X5=0 (5)

Solving the equations, by the help of calculator or computer, the values of the reactive forces Xi are as follows,

X1=3.474P = 5.767 kips

X2=1.217P = 2.020 kips

X3=0.270P = 0.448 kips

X4=0.815P = 1.353 kips

X5=0.341P = 0.566 kips

Where P = 1.66 kips

Following the same procedure as that of rectangular grid with beams running at right angles, and after applying the nodal link forces and the applied nodal loads, the maximum moments could easily be picked up. The analysis have been done by the authors and results

verified by SAP90 program. The structure data file, displaced position of structured and output file F3F is given in appendix.

CONCLUSIONS

This method is general and can be applied to any type of grid giving fairly accurate results with the help of a calculator. Thus this method can serve as a simple grid analysis and design tool for designers who do not have access to computer facilities such as SAP90.
In two way joist floor (waffle slabs) R.C systems, the torsional stiffness at intersecting nodes is of little consequence and hence maybe neglected.

REFERENCES

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2. Rizwan S.A and Bhatti A., " A simplified approach for the analysis and design of Two way joist floors", Paper No 567, pp 325 - 335 Proceedings, Pakistan Engineering Congress, 66th annual session, Lahore 1996.

3. Makowski, Z.S, "Distribution of loads on bridge decks", Discussion Article, Journal of structure division, Proc. ASCE, Jan 1958.

4. Makowski, Z.S, "A course on the analysis, design and construction of double layered grids", Vol 1, University of Surrey, U.K.

5. Rizwan, S.A, and Bhatti, A, "On the performance of double layer square-on-square grids", Vol 1, Proc, pp 664-621, Paper read at 4th International conference on space structures, University of Surrey, U.K, 5-10 Sept, 1993.

6. Lin, T.Y and Stotesbury, S. D "Structural concepts and systems for Architects and Engineers", John Wiley and Sons 1981, pp183-20

```
2-D GRILLAGE ANALYSIS BY SAP90, K-FT.
SYSTEM
L=1

JOINTS
1           X=3.5       Y=0         Z=0
5           X=17.5      Y=0         G=1,5,1
6           X=0         Y=2.8
12          X=21        Y=2.8       G=6,12,1
13          X=0         Y=5.6
19          X=21        Y=5.6       G=13,19,1
20          X=0         Y=8.4
26          X=21        Y=8.4       G=20,26,1
27          X=0         Y=11.2
33          X=21        Y=11.2      G=27,33,1
34          X=3.5       Y=14
38          X=17.5      Y=14        G=34,38,1

RESTRAINTS

1,38,1  R=1,1,0,0,0,1
1,5,1   R=1,1,1,1,1,1
6,12,6  R=1,1,1,1,1,1
13,19,6 R=1,1,1,1,1,1
20,26,6 R=1,1,1,1,1,1
27,33,6 R=1,1,1,1,1,1
34,38,1 R=1,1,1,1,1,1

FRAME
NM=1    NL=1
1       A=0.875 J=0.003 I=0.128,0.128   E=402108        G=175000
1 WL=0,-0.158
1 6 7           M=1     LP=7,1  NSL=1   G=5,1,1,1
7 13 14         M=1     LP=7,1  NSL=1   G=5,1,1,1
13 20 21        M=1     LP=7,1  NSL=1   G=5,1,1,1
19,27,28        M=1     LP=7,1  G=5,1,1,1
25,1,7          M=1     LP=3,0  G=4,5,1,1
26,7,14         M=1     LP=3,0  G=4,5,1,1
27,14,21        M=1     LP=3,0  G=4,5,1,1
28,21,28        M=1     LP=3,0  G=4,5,1,1
29,28,34        M=1     LP=3,0  G=4,5,1,1

LOADS
7,11,1  L=1     F=0,0,-2.52
14,18,1         F=0,0,-2.52
21,25,1         F=0,0,-2.52
28,32,1         F=0,0,-2.52
```

```
DIAGONAL GRILLAGE ANALYSIS BY SAP90. K-FT.
SYSTEM
L=1
JOINTS
1       X=0             Y=0             Z=0
7       X=25.456        Y=0             G=1,7,1
8       X=2.121         Y=2.121
13      X=23.335        Y=2.121         G=8,13,1
14      X=0             Y=4.2426
20      X=25.456        Y=4.2426        G=14,20,1
21      X=2.121         Y=6.3636
26      X=23.335        Y=6.3636        G=21,26,1
27      X=0             Y=8.4852
33      X=25.456        Y=8.4852        G=27,33,1
34      X=2.121         Y=10.6062
39      X=23.335        Y=10.6062       G=34,39,1
40      X=0             Y=12.728
46      X=25.456        Y=12.728        G=40,46,1

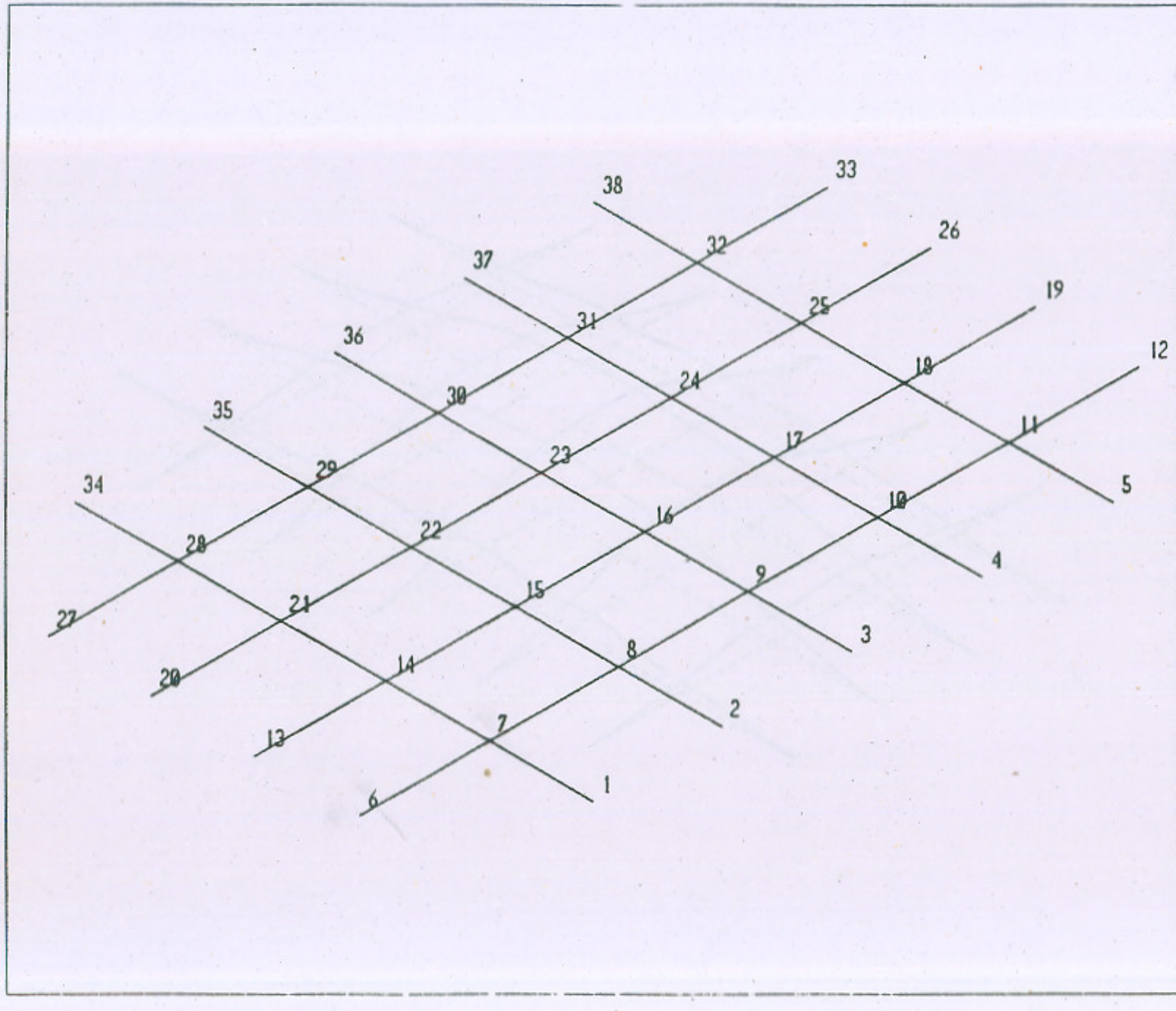
RESTRAINTS
1,46,1  R=1,1,0,0,0,1
1,7,1   R=1,1,1,1,1,1
14,20,6 R=1,1,1,1,1,1
27,33,6 R=1,1,1,1,1,1
40,46,1 R=1,1,1,1,1,1

FRAMES
NM=1    NL=1
1       A=0.875 J=0.003 I=0.128,0.128   E=402108        G=175000
1       WL=0,-0.158,0
C       FRAME INDECIS
1,27,34         M=1     LP=34,40        G=1,1,7,7       NSL=1
3,14,21         M=1     LP=34,40        G=3,1,7,7       NSL=1
7,1,8           M=1     LP=34,40        G=5,1,7,7       NSL=1
13,2,9          M=1     LP=34,40        G=5,1,7,7       NSL=1
19,3,10         M=1     LP=34,40        G=5,1,7,7       NSL=1
25,4,11         M=1     LP=34,40        G=5,1,7,7       NSL=1
31,5,12         M=1     LP=34,40        G=3,1,7,7       NSL=1
35,6,13         M=1     LP=34,40        G=1,1,7,7       NSL=1
37,2,8          M=1     LP=9,16          G=1,1,6,6       NSL=1
39,3,9          M=1     LP=9,16         G=3,1,6,6       NSL=1
43,4,10         M=1     LP=9,16         G=5,1,6,6       NSL=1
49,5,11         M=1     LP=9,16          G=5,1,6,6       NSL=1
55,6,12         M=1     LP=9,16          G=5,1,6,6       NSL=1
61,7,13         M=1     LP=9,16          G=5,1,6,6       NSL=1
67,20,26        M=1     LP=9,16          G=3,1,6,6       NSL=1
71,33,39        M=1     LP=9,16         G=1,1,6,6       NSL=1

LOADS
8,13,1  L=1     F=0,0,-2.32
15,19,1 L=1     F=0,0,-2.32
21,26,1 L=1     F=0,0,-2.32
28,32,1 L=1     F=0,0,-2.32
34,39,1 L=1     F=0,0,-2.32
```

```
C     ************************************************************
C     PROGRAM BY SYED ALI RIZWAN TO SOLVE SIMULTANEOUS
C     EQUATIONS USING GUASS ELIMINATION WITH ROW INTERCHANGES
C     SO THAT LARGEST ELEMENT IS PLACED ON THE DIAGONAL.
C     ************************************************************

      DIEMSNSION A(50,50),B(50),X(50)
      READ (5,*) N,((A(I,J),J=1,N),I=1,N)
      DO 40 J=1,N
      L=J + 1
      DO 30 I=L,N
      IF (ABS (A((J,J)).GE.(ABS(A(I,J)))) GOTO 30
      S=B(I)
      B(I)=B(J)
      B(J)=S
      DO20 K=1,N
      S=A(I,K)
      A(I,K)=A(J,K)
      A(J,K)=S
20    CONTINUE
30    CONTINUE
40    CONTINUE
      DO 70 I=2,N
      DO 60 J=1,N
      IF (J.GE.I) GOTO 70
      IF (A(I,J).EQ.0.0) GOTO 60
      E=A(I,J)/A(J,J)
      B(I)=B(I)-B(J)*E
      DO 50 K=1,N
      E=E*A(J,K)
      A(I,K)=A(I,K) - E
50    CONTINUE
60    CONTINUE
70    CONTINUE
      DO 100 I=1,N
      SUM=0.0
      DO 80 J=1,N
      L=N+1-J
      K=N+1-I
      IF (K.GE.L) GOTO 90
      IF (A(K,L).EQ.0.0 GOTO 80
      SUM=X(L) * A(K,L) + SUM
80    CONTINUE
90    X(K)=(B(K)-SUM)/A(K,K)
100   CONTINUE
      WRITE (1,200)(I,X(I),I=1,N)
200   FORMAT (6X,'X(',I2,') = ',G11.4
      STOP
      END
```



grid3

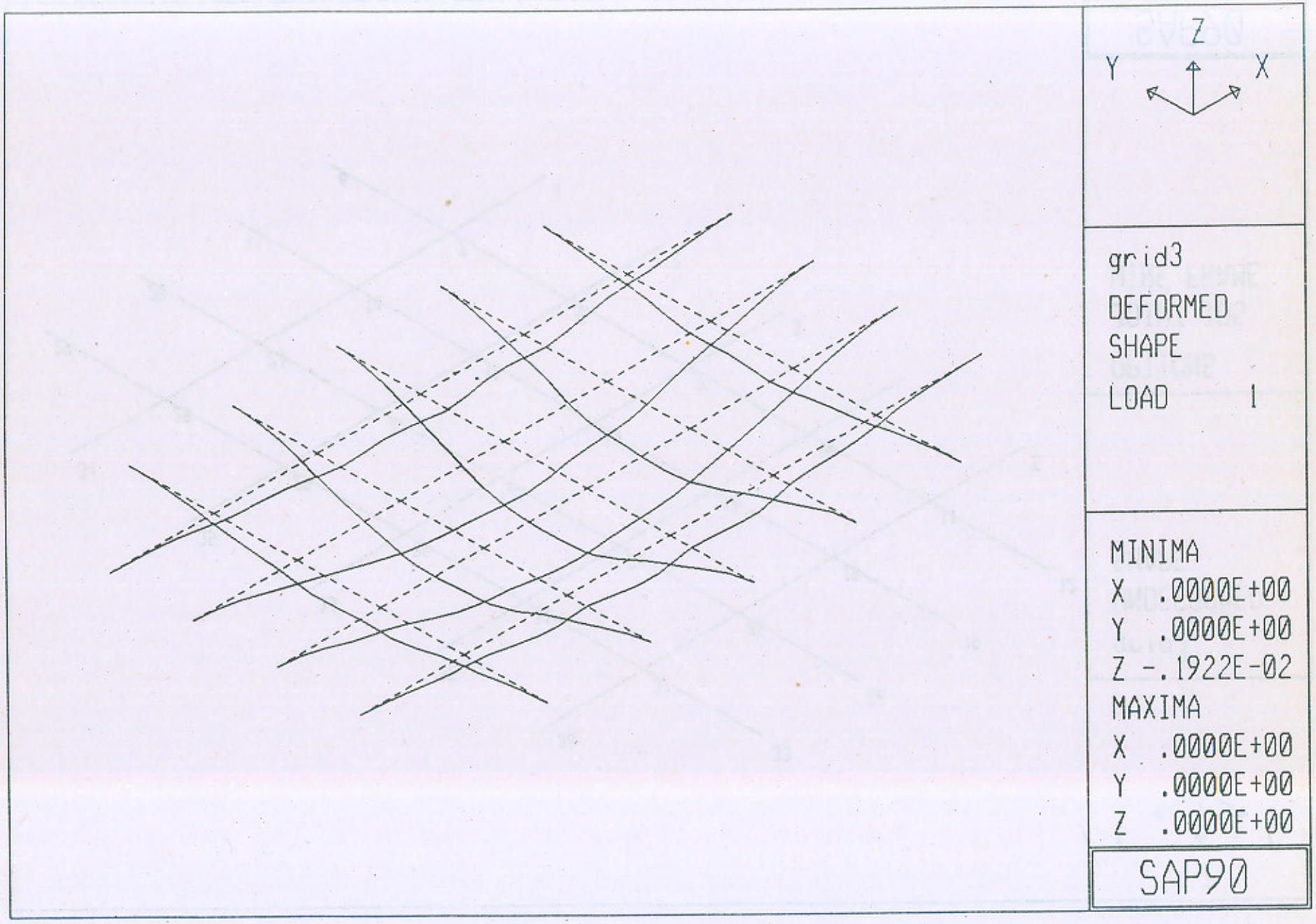
UNDEFORMED SHAPE

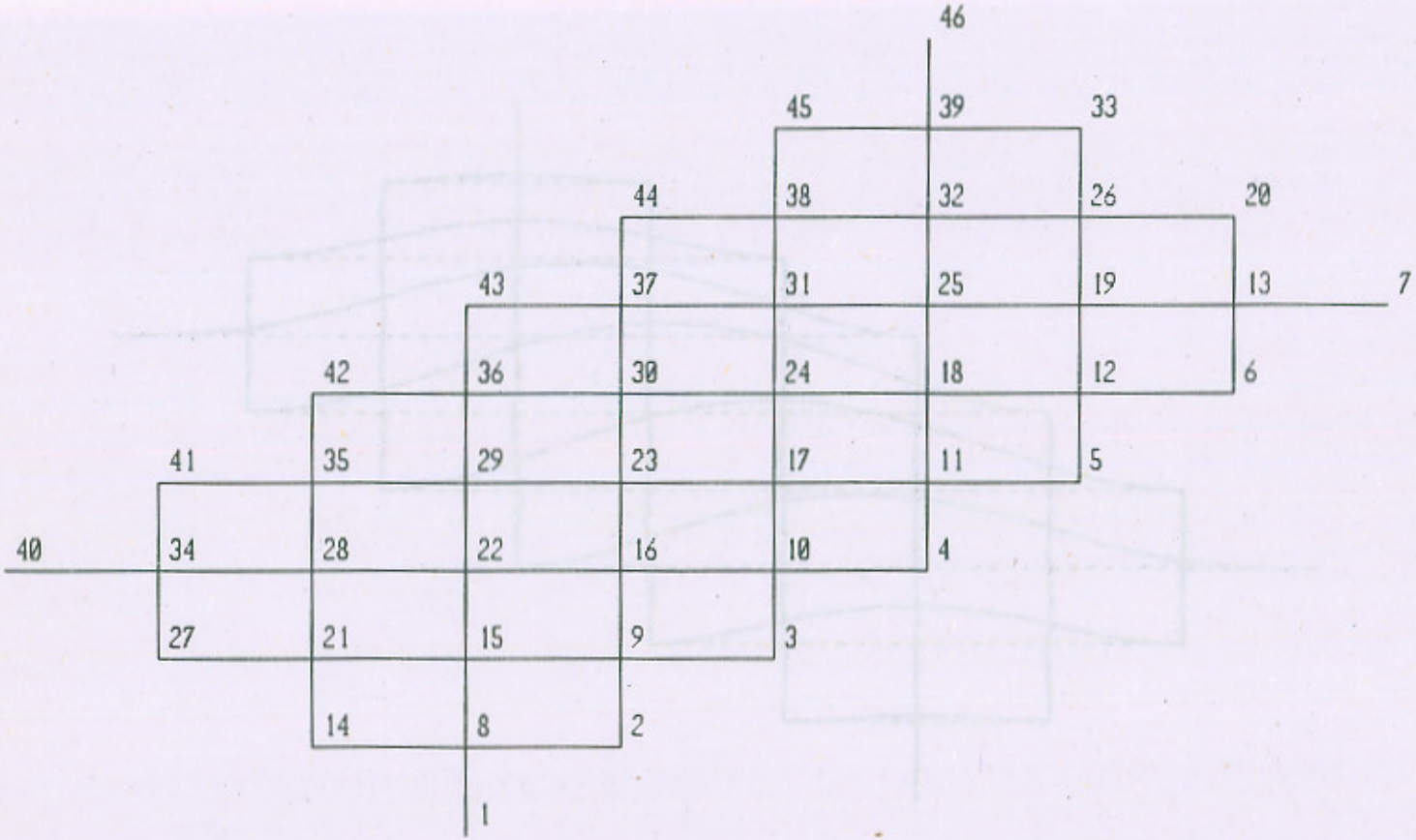
OPTIONS

JOINT IDS

WIRE FRAME

SAP90


Z
Y
X
grid3
DEFORMED
SHAPE
LOAD 1
MINIMA
X .0000E+00
Y .0000E+00
Z -.1922E-02
MAXIMA
X .0000E+00
Y .0000E+00
Z .0000E+00
SAP90





DIAGONAL

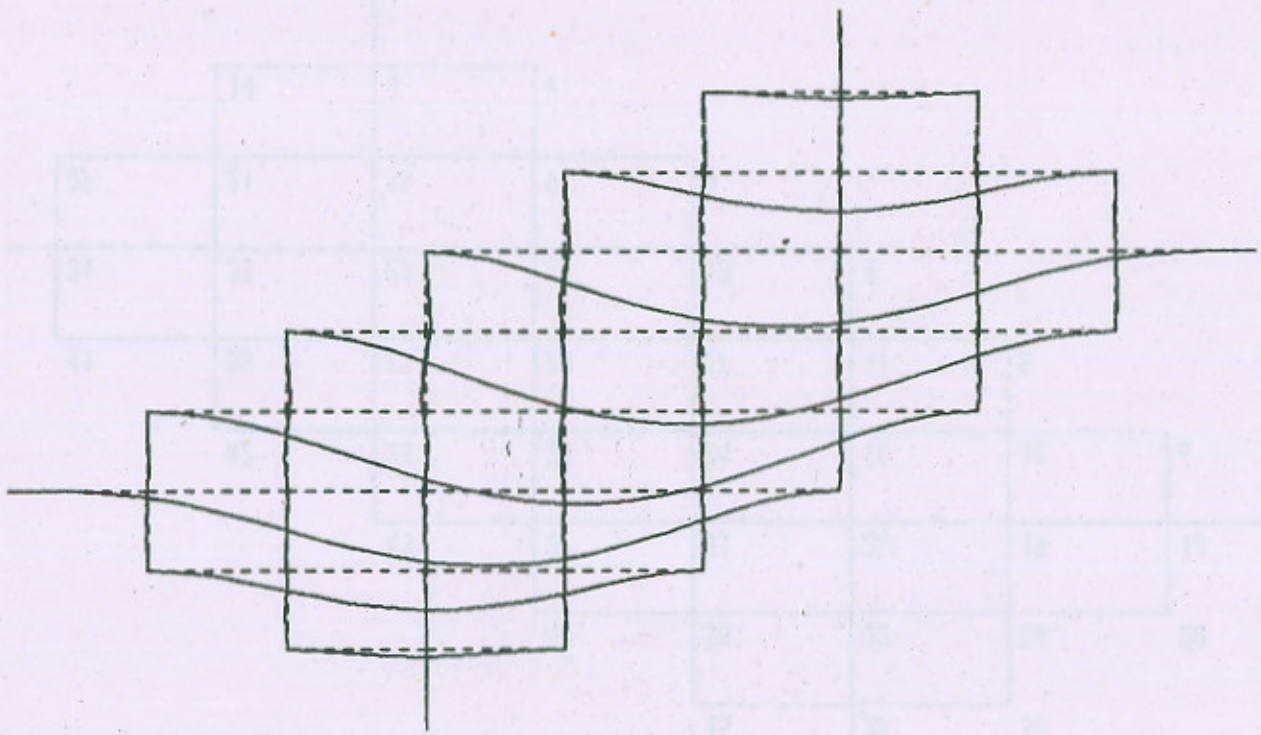
UNDEFORMED SHAPE

OPTIONS

JOINT IDS

WIRE FRAME

SAP90



Z
Y X

DIAGONAL

DEFORMED SHAPE

LOAD 1

MINIMA
X .0000E+00
Y .0000E+00
Z -.1608E-02
MAXIMA
X .0000E+00
Y .0000E+00
Z .0000E+00

SAP90