LIVE LOAD DISTRIBUTION BY THREE DIMENSIONAL ANALYSIS

Three dimensional analysis of a bridge superstructure explicitly considers the lateral stiffness and load transfer characteristics of the superstructure elements. The technique produces more exact girder live loading distribution and is therefore less conservative than the empirical AASHTO method. The use of this refined analysis for production work is limited. It shall not be used for the design of structures for normal HS and P live load.

LANELL and CURVBRG are two operational programs that utilize three dimensional analysis. LANELL is applicable to concrete box girder bridges; CURVBRG to steel girder bridges. For three dimensional analysis of other types of superstructures consult the Special Analysis Section.

In three dimensional analysis the concept of widely or closely spaced girders as defined in Bridge Design Specifications (BDS) does not exist.

Three dimensional analysis may be used to advantage for the following conditions:

- The live loading and its lateral location is relatively fixed such as for transit or construction loads.
- The live load capacity of an existing structure is to be determined.

Once the live load wheel lines per girder or bridge are determined by three dimensional analysis, design proceeds by conventional Load Factor methods. Loads are applied in accordance with Table 3.22.1A of (BDS) using Groups I_H and I_{P3D}. Load intensity is reduced in accordance with Article 3.12 of BDS.

The LANELL program is available through our Bridge Menu. Instructions for the use of LANELL is included with this Memo to Designers as Attachment A.

Direct questions related to the use of CURVBRG to Special Analysis Section.

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Attachment(s)

CONCRETE BOX GIRDER
LIVE LOAD DISTRIBUTION BY LANELL
FOR SPECIAL LOADS

GENERAL

LANELL is a computer program for determining transverse live load distribution to concrete box girder bridges. It may be used for special live loads that are relatively fixed in lateral position such as rail or construction loads.

In order to determine live load distribution for special loads it is necessary to utilize the influence lines provided by LANELL. The procedure will be described herein. The program also reports the wheel line distribution for HS20 and P loads but they are not to be used for design.

DESIGN PROCEDURE

The design procedure is exactly the same for both prestressed and reinforced box girder bridges as present practice except that the live load lanes per girder or bridge are obtained from influence lines produced by LANELL. Number of live load lanes will be span specific and in general will have a different value for each span even for constant width structures.

LANELL DESCRIPTION

LANELL becomes available to the designer by entering the word "LANELL" from the Bridge Menu. The input screen is self explanatory. As many live load distributions and influence lines as desired may be obtained from one computer run by simply adding lines of data. The user is prompted throughout program operation.

The input screen looks like this:

DESCRIPTION OF INPUT

The order of variables is as follows:

1. Number of Cells, N
2. Girder spacing, cw (ft)
3. Overhang (ft)
4. Girder slope factor, K
5. Support type, (FF, SS)
6. Span length, L (ft)
7. Structure type, (RC, PS)
8. Structure depth, S (ft) center to center of slabs

Modify the following line as desired (type 'file' when finished)

```
6  9.00  3.00  0.0  'SS'  150.0  'PS'  6.00
6  8.16  4.50  0.15 'FF'  100.0  'RC'  5.50
```

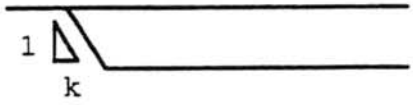
(add as many lines of input data as needed)

Warning: Do not delete any line above the input data.

LANELL VARIABLES:

Item 1, 2, 3, 6 are self explanatory. Note that the number of cells times the girder spacing + twice the overhang = overall deck width.

Item 4 Slope factor, K



Item 5 Support type FF means fixed-fixed. Use for fully continuous spans, for spans continuous at one end only, and for hinge spans.
Support type SS means simple-simple. Use for spans simply supported at both ends.

Item 7 Structure type RC does not mean reinforced. It means a D/S ratio of .050 or greater. Structure type PS does not mean prestressed. It means a D/S ratio less than .050. Choose the one that fits the D/S of the actual span in consideration.

Item 8 Structure depth S is used to check for interference between the bottom of a sloping exterior girder and the first interior girder.

The influence lines that LANELL produces are for the left half of the structure. It is necessary to visualize or draw the influence lines for the right half. Place the vehicle(s) in the proper positions on the influence lines for maximum effect.

LANELL produces 2 sets of influence lines for the 'FF' condition, one for positive moment, and one for negative moment. It is recommended that the negative influence lines be used as a conservative approach.

The influence lines are based on unity. It is up to the designer to apply all appropriate factors to the results, including lane reduction factors if applicable. The LANELL specific "P Load Reduction Factor" should also be applied if appropriate. See example Problem #1 which follows.

LIMITATIONS OF LANELL

LANELL has many of the same limitations that presently exist with the AASHTO method of live load distribution. The effect of skew is not specifically considered nor is the variable width structure problem. Therefore the same judgement must be applied to the use of LANELL as is applied to present methods of load distribution.

The operation of the LANELL program depends on data that has been previously computed and stored in the program for later application to the specific span data input by the user. Thus LANELL does not perform any first order analysis but rather produces answers from stored data. The scope of LANELL is therefore limited by the data stored. The attached Table 1 shows the extent of this limitation.
Input parameters beyond the limitation of Table 1 will result in an error message and the program will not run. Structures that do not fall within the scope of LANELL should be designed by other methods. Extrapolation should be attempted with great caution.

The one extrapolation that may safely be made is for structures that are wider than the Table 1 limits. The user will note that for wide structures LANELL reports that wheel line distribution to girders near the centerline of the structure are all nearly the same. It is therefore correct to determine wheel lines by LANELL influence lines for a wide structure that is within Table 1 limitations and with the same parameters as the real structure except for number of girders. Wheel lines may then be added to the structure corresponding to those innermost girders to bring the structure to the width, and with the proper number of girders as the real structure.

*** " L A N E L L " LIMITATIONS ***

CELLS	Dpth/Spn	GIRDER SPACING (Ft)	SPAN (Ft.)
		7 — 13 — 15	60 — 150 — 200 — 270
3	< 0.05		
3	> = 0.05		
4	< 0.05		
4	> = 0.05		
5	< 0.05		
5	> = 0.05		
6	< 0.05		
6	> = 0.05		
7	< 0.05		
7	> = 0.05		
8	< 0.05		
8	> = 0.05		

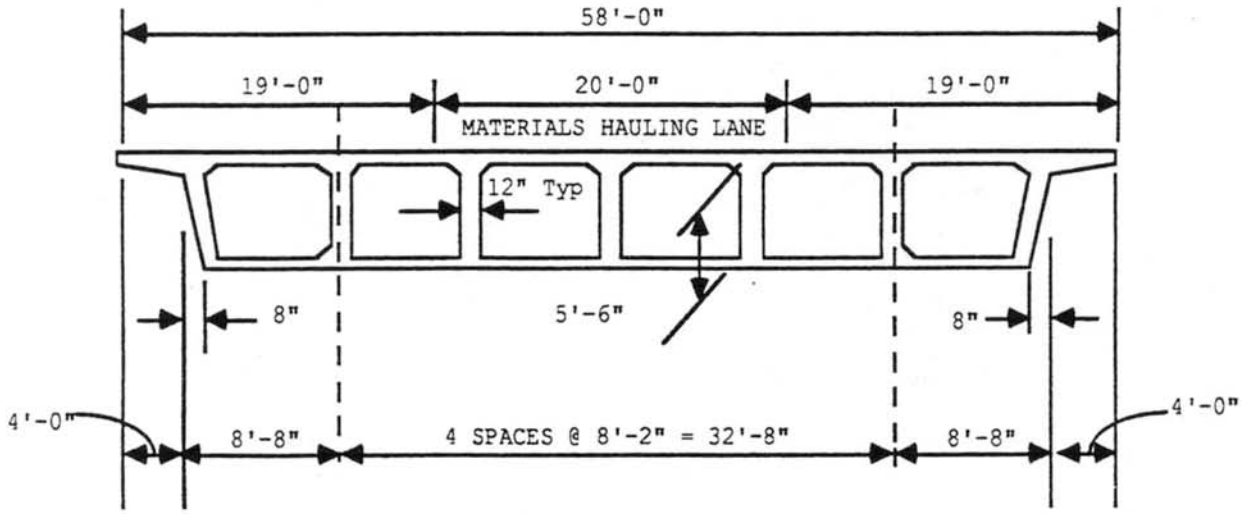
NOTES: 3 cells minimum; Maximum overhang = 1/2 girder space; K max = 1 (1: 1 slope on exterior girder)

TABLE 1

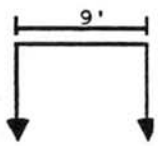
LANELL EXAMPLE PROBLEM #1

GIVEN:

Single span, simply supported, 100 foot long, box girder bridge with the following cross section:



Loading condition considered: one material hauling vehicle positioned within the material hauling lane. (See Memo To Designers 15-15.)



FIND:

Live load lanes per girder.

SOLUTION:

The first step in this solution is to generate influence lines to determine transverse load distribution for this particular box girder bridge.

Input to LANELL :

Number of cells N = 6
Girder spacing cw = 8.16'
Overhang = 4.5'
Girder slope factor K = .15
Support type = SS
Span length L = 100'
Structure type = RC (5.5'/100' > .05)
Structure depth S = 5.5'

Your input line should look like this:

6 8.16 4.50 0.15 'SS' 100.0 'RC' 5.50

NOTE:

check that (N * cw) + (2 * overhang) = overall deck width:
(6 * 8.16') + (2 * 4.5') = 58.0' OK!

File this information and request a plot (place a 'P' next to the plot option) on the run panel. When the plot is received, the live load distribution may be determined as follows: (refer to figure 1)

Place the wheel loads within the allowable constraints of the cross section (in this case that would be the 20 foot materials hauling lane in the middle of the cross section). The wheel loads are located within the 20 foot lane to create 'worst case' load distribution for each girder.

Once the loading placement is set, read the wheel lines per girder for the left and right wheel directly off the influence lines. The left and right wheel lines are added together and converted into live load lanes per girder. (There are two wheel lines per live load lane.) These steps are outlined in Table #2.

When you are using special loading conditions, you must determine if the P-load reduction factor applies (see page 9). In this case, the load configuration for a material hauling vehicle is similar to that of an HS-load (3 axles). Therefore, the reduction factors should not be applied. For cases in which the reduction factor applies, refer to the example on page 9.

TABLE #2

1 Girder	2 Left Wheel	3 Right Wheel	4 WL/girder	5 LLL/girder
1	0.13	0.09	0.22	0.11
2	0.20	0.14	0.34	0.17
3	0.24	0.16	0.40	0.20
4	0.23	0.17	0.40	0.20

column 1: girder identification

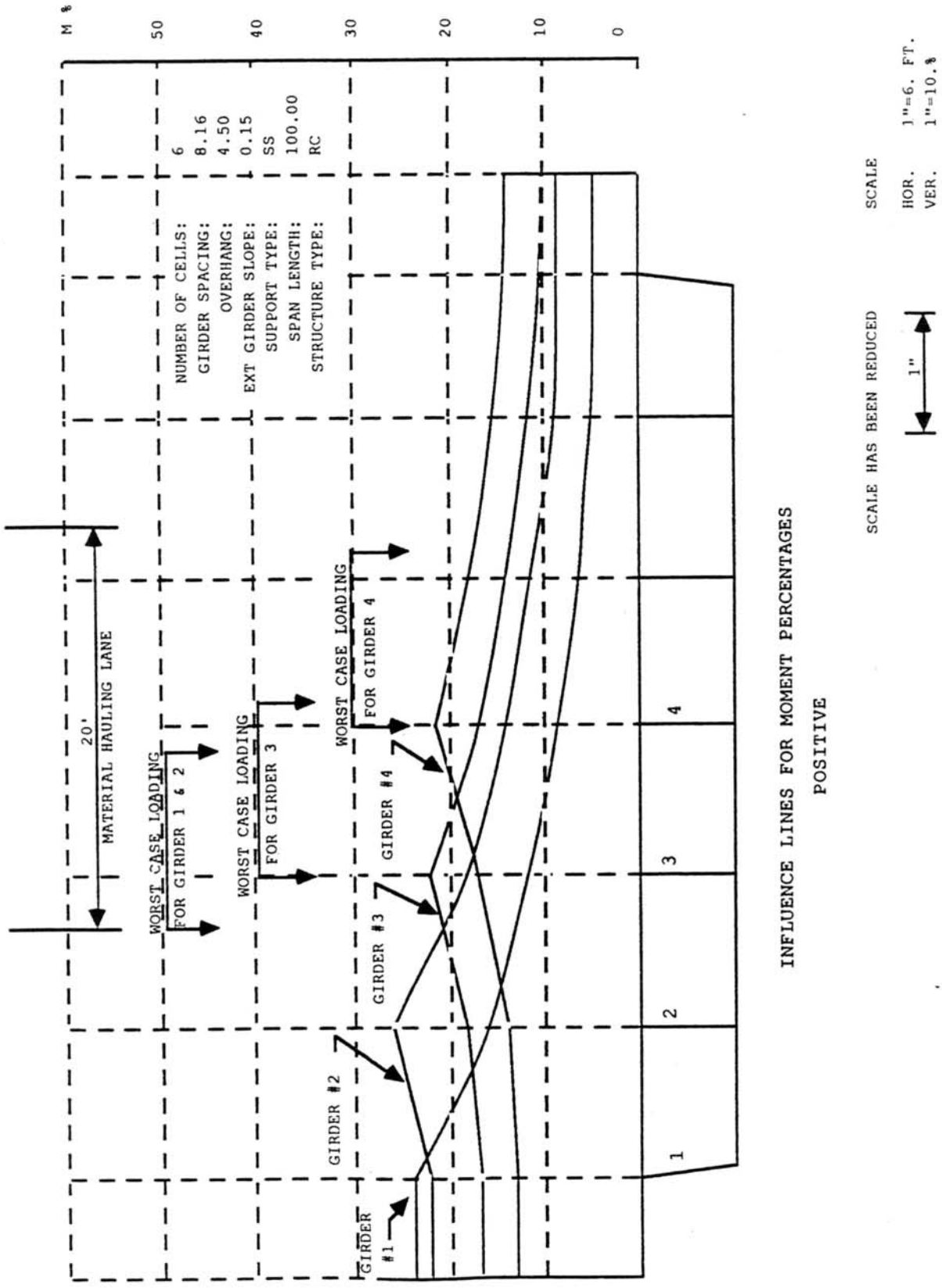
column 2 and 3: wheel loads as they are read off the influence lines

column 4: sum of column 2 and 3 - the total wheel load per girder

column 5: column 4 divided by 2 wheel loads per live load lane - the live load lanes per girder

Based on symmetry, the number of live load lanes per girder for girders 5, 6, and 7 are as follows:

girder 1 = girder 7
girder 2 = girder 6
girder 3 = girder 5



INFLUENCE LINES FOR MOMENT PERCENTAGES
POSITIVE

FIGURE 1

REDUCTION FACTOR FOR P-LOADING
(and it's application to similar loading types)

The data used in LANELL to generate the influence lines is based upon HS-loading, (this loading configuration consists of only 3 axles). When applying a P-load (a much longer, many-axled loading configuration), a reduction factor is applied to the generated output for positive moment to account for a reduction in the moment distribution coefficients. It is recommended that these reductions are applied to other many-axled loads, (such as Cooper loads and LRV loads).

It should be noted that the error introduced by not applying the reduction factor to the influence lines is on the conservative side.

The reduction formula's are as follows:

for a depth to span ration that is 0.05 or greater -

exterior girders $R = (L - 48)/[600(1 + K)]$
interior girders $R' = R/2$

for a depth to span ratio less than 0.05 -

exterior girders $R = (240 - L)/[1000(1 + K)]$
interior girders $R' = R/2$

where R, R' = Reduction Factors
K = Exterior Girder Slope Factor
L = Span Length, in feet

for span lengths exceeding 240 feet -

the P-load reduction factor is not applied. In these cases, use the live load distribution information as it is taken directly from the influence lines.

For example:

You have generated the influence lines for a 110' span, 3 celled box girder bridge with a depth to span ratio greater than 0.05. Exterior girders are vertical, (K = 0). From the influence lines you have determined the wheel lines for the left and right wheels for each girder.

The loading applied is the P-load. Therefore, you must consider P-load reduction:

Exterior girder: $R = (110 - 48)/[600(1 + 0)]$
$R = 0.10$
$1 - R = 0.90$

Interior girder: $R' = 0.10/2$
$R' = 0.05$
$1 - R' = 0.95$

Girder	Left wheel	Right wheel	(1 - R)	Wheel line/girder
1	0.27	0.23	0.90	0.45
2	0.31	0.33	0.95	0.61
3	0.26	0.27	0.95	0.50
4	0.17	0.18	0.90	0.32

Note: One live load lane equals two wheel lines.