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# SIMPLIFIED LOAD DISTRIBUTION FACTORS FOR CURVED STEEL I-GIRDER BRIDGES BASED ON ECP LIVE LOADS

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**ABSTRACT:**
Curved steel I-girder bridges have become an important component in highway systems. A simplified analysis method is needed for analyzing both existing and new bridges. If appropriate simplified formulas for load distribution factors exist, there is no need for complex analysis. In this study, a 3-D finite element model was used for the analysis of curved slab on girder bridges. A parametric study was carried out to calculate the load distribution factors for curved steel I-girder bridges based on *Egyptian Code of Practice* (ECP) live loads using F.E.M. The parameters considered in the study were: radius of curvature, girder spacing, span length, slab thickness, girder longitudinal stiffness, girder torsional inertia, number of girders, distance from center of exterior girder and inside edge of traffic barrier, and cross frame spacing. Simplified formulas for moment and shear distribution factors for inside and outside exterior girders were developed and an example to illustrate the use of these formulas was introduced.

**Keywords:** Curved bridges, ECP live loads, Moment distribution, Shear distribution, Steel I-girder

## 1 INTRODUCTION

Horizontally curved bridges have become an important component in highway systems, especially in densely populated cities such as Cairo and Alexandria in Egypt. Such bridges may be entirely constructed of reinforced concrete, prestressed concrete, or composite concrete deck on steel I- or box girders. Curved steel I-girder bridges are the preferred choice because of its simplicity of fabrication and construction, fast speed of erection, and excellent serviceability performance. I-shaped girder bridges are relatively strong and stiff under service loading and the behaviour gravitates towards that of a multicell box section when adequately provided with diaphragms and cross frames.

Both the longitudinal position and transverse distribution of the wheel loads are important for live load design. Longitudinally, the loads must be positioned to produce the highest bending moments, shears, and deflections in the girders. Transversely, the concrete slab distributes the wheel loads among the girders. If appropriate transverse distribution factors for curved girders were available, curved girders could be designed as equivalently isolated straight girders with the length equal to the centerline length of the curved girders, simplified lateral load distribution factors based on the Egyptian Code of Practice (ECP) [3]

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will help bridge designers in the analysis and design of curved bridges.
The main objectives of this paper is to study load distribution factors based on ECP live load, identify the key parameters that influence the lateral load distribution for curved I-girder bridges, and derive simplified formulas for moment and shear distribution factors based on ECP live load.

## 2 CURVED STEEL BRIDGES FIELD DATA FROM EGYPT

In order to get a representative sample of real bridges, data of some existing and newly designed bridges in Egypt were collected. Bridge parameters were extracted from bridge drawings and data were used in the bridge database [8]. The data contains information such as bridge design load, in-plane radius of curvature, *R,* span length, *L*, number of girders, *N*, edge to edge deck width, curb to curb roadway width, year built, slab thickness, $t_s$, distance from centerline of exterior girder to the interior edge of curb or traffic barrier (overhang), $d_e$, girder spacing, *S*, cross frame or diaphragm spacing, $S_c$, with or without lateral bracing, girder dimensions (girder web thickness, web height, top and bottom flange thickness and width). Girder area *A*, girder moment of inertia *I* and torsional inertia *J*, and girder longitudinal stiffness parameter, defined as $K_g = I + Ae^2$, where *e* is the slab eccentricity were calculated using the girder dimensions for each bridge. The database also includes information about cross frame configurations (K-frame or X- frame). The bridges data were used to perform a statistical analysis on various bridge parameters.
A simply supported bridge model with parameters equal to the mean values of the parameters was defined and referred to as the "Average Bridge" (see Fig. 1 and Table 1).

**Table 1:** Typical girder properties of the average bridge

| Girder Dimensions | Girder Properties |
|---|---|
| Top Flange Width= 40cm<br>Top Flange Thickness= 4cm<br>Web Height= 130cm<br>Web Thickness= 1.3cm<br>Bottom Flange Width= 55cm<br>Bottom Flange Thickness= 7cm | $A$= 1507.5cm$^2$<br>$I$= 6398936.34cm$^4$<br>$J$= 89827.97cm$^4$<br>$K_g$= 9911501cm$^4$ |

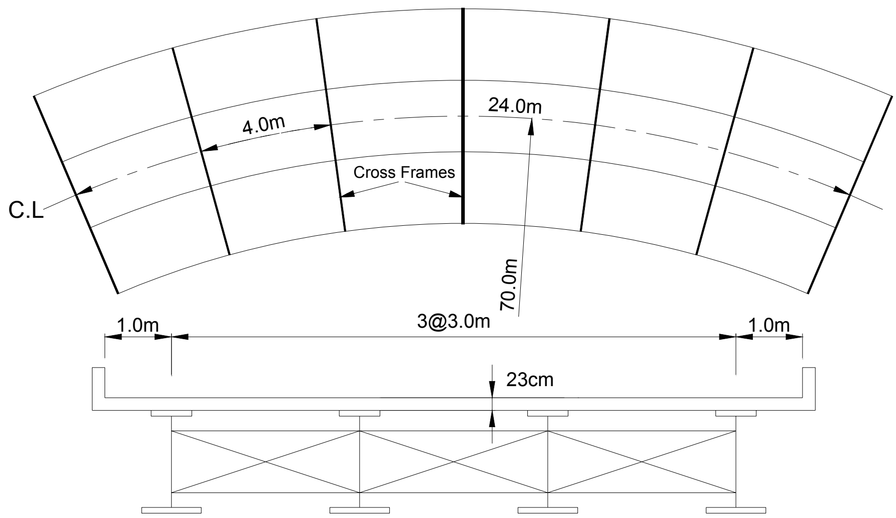


**Fig. 1:** Plan and cross section of the average bridge

## 3 BRIDGES ANALYSIS

The finite element method was used in this study due to its ability to consider non-linear and complex configurations, which helps in modeling the curved bridge elements in a more realistic manner and can get the most accurate results.

### 3.1 F.E.M Model Description

In this study, the concrete slab and steel girder web were modeled using four nodded quadrilateral shell elements with double action as they act simultaneously as membrane and plate bending shell elements (see Fig. 2). Girder flanges were modeled as space frame elements, while flange to deck eccentricity was modeled by imposing a rigid link between the two centroids of the slab and the steel girder top flange. Cross frames members were modeled as pin jointed truss elements with the flexural and torsional stiffness ignored. All models were simply supported with the bearing supports located at the centroid of the frame element representing the bottom flange of the girder.

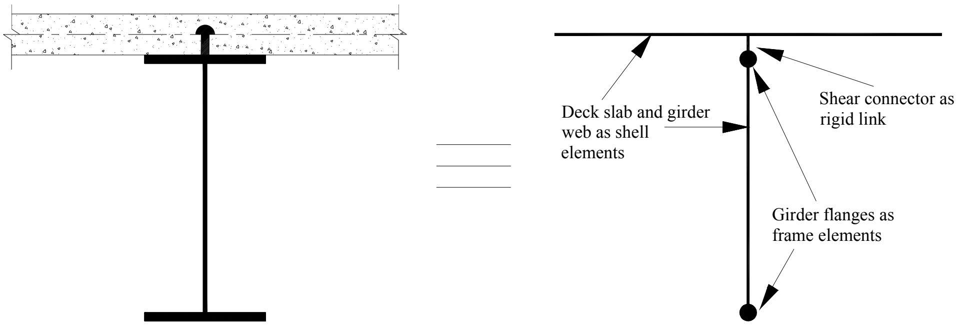


**Fig. 2:** Finite element model

### 3.2 ECP Bridge Loading

The ECP live load [3] shown in Fig. 3 was used in D.F (Distribution Factor) calculation. ECP live load consists of: (1) Main lane load of 3.0m width consists of 60tons main truck in addition to leading and trailing uniform load of intensity 500kg/m$^2$ on the rest of the lane area. The main lane must be positioned to give maximum straining actions in the bridge superstructure. (2) Secondary lane load consists of 30tons secondary truck in addition to leading and trailing uniform load of intensity 300kg/m$^2$ on the rest of the lane area. (3) The rest of the bridge carriage way is covered with a uniform load of intensity 300kg/m$^2$.

The dynamic load factor "I" is calculated using the following roadway bridge Impact formula "**I=0.4-0.008L**"; where L is the beam span length in m. Only the main lane load (truck + uniform) is to be magnified by the impact (dynamic) factors, neither the secondary lane load nor the uniform load is to be magnified.

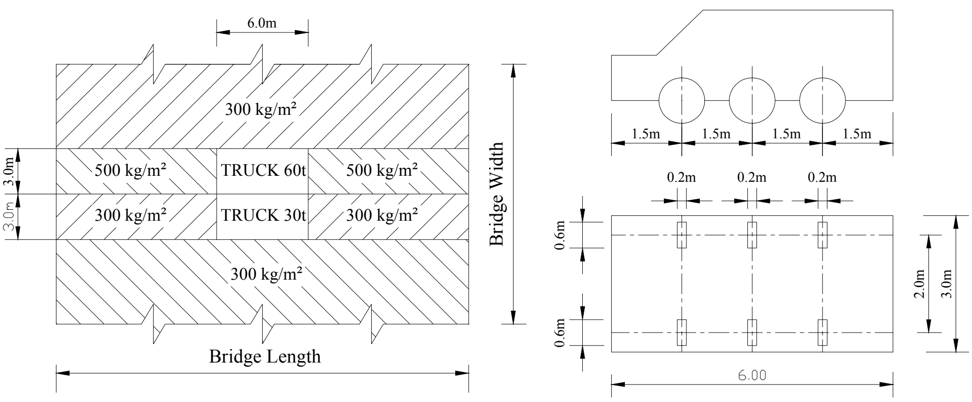


**Fig. 3:** ECP live loads

### 3.3 Load Distribution Factors Calculation

The bottom flange forces obtained from finite element results were used to compute moment distribution factors of the girders. The accuracy of calculation of moment distribution factors

based on the bottom flange force is checked and found to be accurate with maximum error of 1%.
For bending moment distribution factor see equation (1), the bridge was loaded with the ECP live load including impact effect then the load was positioned on the bridge deck to give the maximum moment in the considered girder. A single straight girder having a length equal to the bridge centerline length was then loaded was the main lane load only (truck+uniform) including impact to give maximum moment. For each case, the moment distribution factors can be calculated as:

$$D.F_{B.M} = \frac{\text{Max. bottom flange force in the actual bridge F.E.M model}}{\text{Max. bottom flange in single straight girder}} \qquad (1)$$

For shear (reaction) distribution factor see equation (2), the ECP live load including impact was positioned on the bridge deck to give the maximum shear in the considered girder. A single straight girder having a length equal to the bridge centerline length was then loaded with the main lane load only (truck+uniform) including impact to give maximum shear. For each case, the shear distribution factors can be calculated as:

$$D.F_{S.F} = \frac{\text{Max. girder reaction in the actual bridge F.E.M model}}{\text{Max. reaction of single straight girder}} \qquad (2)$$

## 4 PARAMETRIC STUDY

A parametric study was conducted to study the effect of each of the bridge parameters on load distribution factors based on ECP live loads. The following bridge parameters were considered: in-plane radius of curvature, girder spacing, distance between center of exterior girder to inside edge of traffic barrier or curb, span length, slab thickness, girder longitudinal stiffness, number of girders, girder torsional inertia, cross frame spacing. The effect of each parameter was studied separately by varying this parameter while keeping all other parameters at their average value.
In this study, only outside and inside exterior girders which are the girders having the largest and smallest radius of curvature respectively were investigated for ECP live load distribution factors calculation because they represent the extreme maximum and minimum values for both shear and moment distribution factors.

### 4.1 Effect of Radius of Curvature, R

The radius of curvature was varied between 40m and 200m (see Fig.4). It can be seen from this figure that as the radius of curvature increases, the outside exterior girder moment decreases while the inside exterior girder moment increases. The larger the radius of curvature is, the smaller the difference of the distribution factor between the outside exterior girder and inside exterior girder. When the radius of curvature reaches infinity, the load distribution factors of the outside exterior girder and the inside exterior girder would be the same as those for exterior straight girders.
Shear distribution factors have the same trend as that of moment distribution factors. The difference is that the shear distribution factors of the outside exterior girder and the inside exterior girder are close.

### 4.2 Effect of Girder Spacing, S

The girder spacing was varied between 2m and 4m (see Fig. 5). As expected, girder spacing has significant effect on curved bridge load distribution. Smaller girder spacing will cause more girders to share the load and therefore smaller load distribution factor. The trends of moment distribution factors for both outside exterior girder and inside exterior girder are the same.

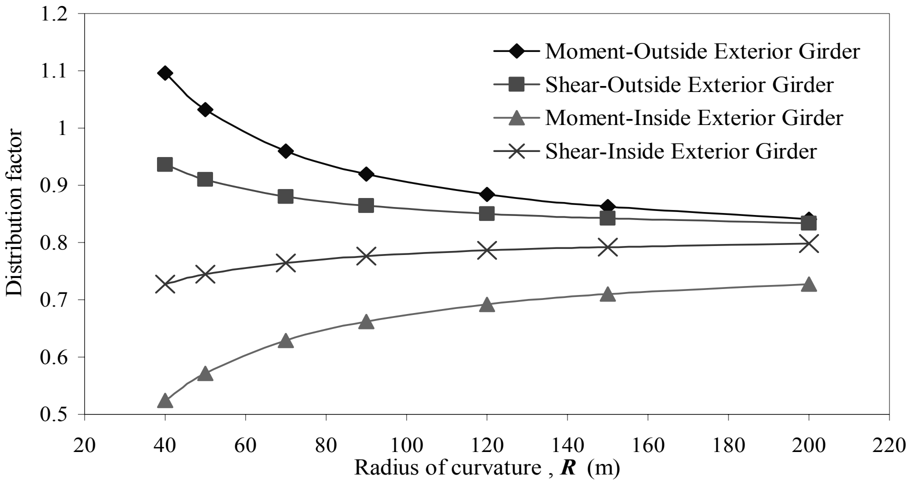


**Fig. 4:** Effect of radius of curvature on moment and shear distribution

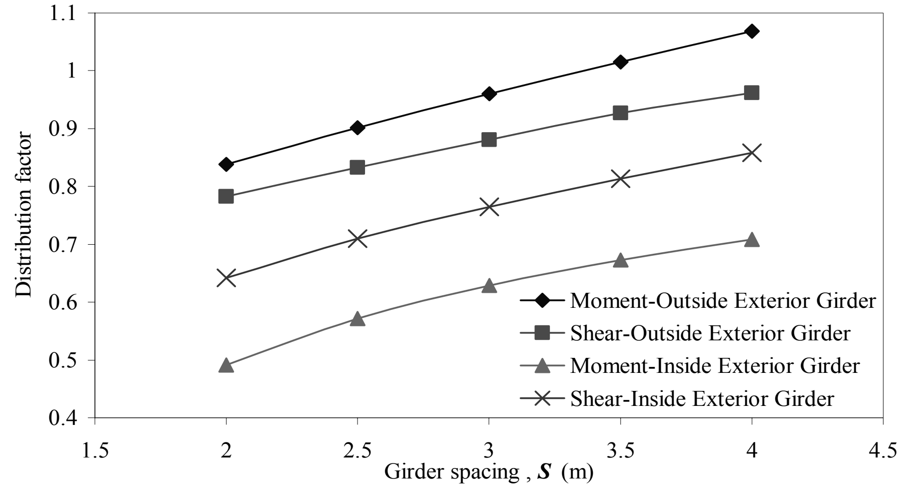


**Fig. 5:** Effect of girder spacing on moment and shear distribution

## 4.3 Effect of Span Length, L

The span length was varied between 16m and 40m (see Fig. 6). From the figure, it can be seen that span length has significant effect on outside and inside exterior girders moment distribution. With the increase of span length, moment distribution factor for inside exterior girder decreases and for outside exterior girder increases. With the increase of span length, shear distribution factor for inside exterior girder decreases and for outside exterior girder increases.

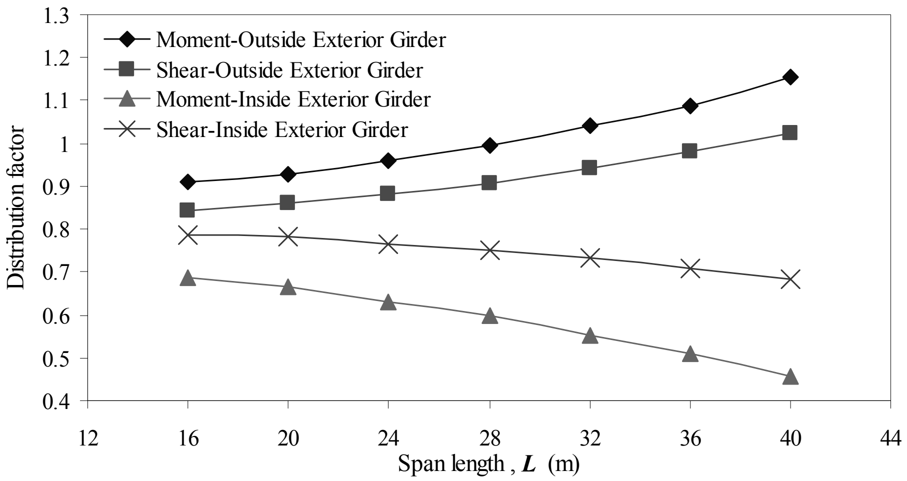


**Fig. 6:** Effect of span length on moment and shear distribution

### 4.4 Effect of Distance between Center of Exterior Girder and Inside Edge of Traffic Barrier or Curb (overhang), $d_e$

The overhang length was varied between -0.5m and 1.5m (see Fig. 7). As expected, exterior girder load distribution is sensitive to truck load position on the bridge. Both outside and inside exterior girder moment and shear distribution factors have a linear relation with parameter $d_e$. This is true for both straight bridges and curved bridges. Parameter $d_e$ have a very significant effect on moment and shear distribution factors for both the outside and the inside exterior girders.

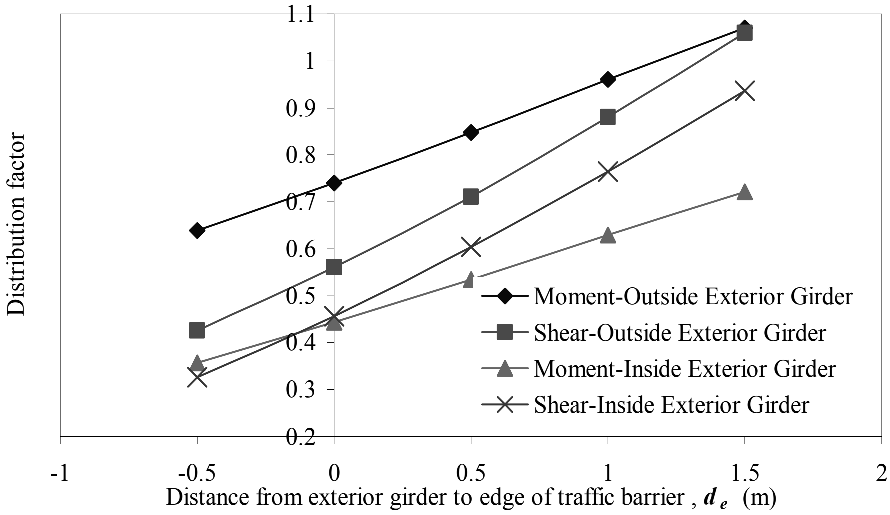


**Fig. 7:** Effect of distance between center of exterior girder and inside edge of traffic barrier on moment and shear distribution

### 4.5 Effect of Slab Thickness, $t_s$, Cross Frame Spacing, $S_c$, Girder Torsional Inertia, J, Number of Girders, N and Girder Longitudinal Stiffness, $K_g$

The slab thickness was varied between 19cm and 27cm. The effect of slab thickness on moment distribution is approximately a linear relationship. The effect of slab thickness on shear distribution is negligible [8].

Cross frame spacing was varied between 3m and 12m. When cross frame spacing changes, numbers of cross frames in each span vary while keeping the span length constant; the results show that cross frame spacing has negligible effect on moment and shear distribution [8].

To study the effect of girder torsional inertia on moment and shear distribution factors, girder flange width and web height were varied to keep the parameter $K_g$ at very small variation. The results showed that torsional stiffness of I-girders has negligible effect on moment and shear distribution factors, although it is important in resisting torsion in curved bridges [8].

The number of girders was varied between 3 and 7. the results show that the moment distribution factors for both outside and inside exterior girders decrease when the number of girders increases. However, for bridges having three girders, the moment distribution factor for inside exterior girder is smaller than that of four-girder bridges. The effect of number of girders on shear distribution is negligible [8].

To study the effect of longitudinal stiffness $K_g$ only the girder web height was varied to keep the parameter torsional inertia at very small variation. From results, it can be seen that moment distribution varies slightly with the variation of parameter $K_g$ and the effect of $K_g$ on shear distribution is negligible [8].

### 4.6 Summary

From the parametric study results, it can be seen that: radius of curvature, span length, girder spacing, and distance from center of exterior girder and inside edge of traffic barrier have significant effect on distribution factors. Slab thickness, number of girders and longitudinal stiffness have slight effect. Effects of cross frame spacing and girder torsional inertia have negligible effect.

## 5 SIMPLIFIED FORMULAS

The load distribution formulas are derived using the regression analysis. Assume that parameters are independent and could be modeled by functions $f(R)$, $f(S)$, $f(L)$, $f(t_s)$, $f(Kg)$, $f(N)$, and $f(d_e)$, respectively, the distribution factor could then be modeled in the form of D.F = (a) f(R) f(S) f(L) f($t_s$) f(Kg) f(N) f($d_e$) [10]. *a* is the scale factor to be determined based on the variation of the distribution factor with these parameters. Regression analysis was then required to find the best function to match the variation of distribution factors with each parameter.

As an example, for outside exterior girder moment distribution factor, the best form to model the variation of moment distribution factor with the variation of the parameters is:

$$\text{D.F} = (a)\left(\frac{1}{R} + c_1\right)(d_e + c_2)(S)^{b_1}(L)^{b_2}(N)^{b_3}(K_g)^{b_4}(t_s)^{b_5} \tag{4}$$

where $c_1$ and $c_2$ are constants to be determined based on the variation of distribution factor with parameters $R$ and $d_e$, respectively. $b_1$, $b_2$, $b_3$, $b_4$, and $b_5$ are exponential coefficients to be determined based on the variation of distribution factor with parameters $S$, $K_g$, $L$, $t_s$, and $N$, respectively. Assuming that for two cases all bridge parameters are kept at the average values except for $R$, then

$$\text{D.F}_1 = (a)\left(\frac{1}{R_1} + c_1\right)(d_e + c_2)(S)^{b_1}(L)^{b_2}(N)^{b_3}(K_g)^{b_4}(t_s)^{b_5} \tag{5}$$

$$\text{D.F}_2 = (a)\left(\frac{1}{R_2} + c_1\right)(d_e + c_2)(S)^{b_1}(L)^{b_2}(N)^{b_3}(K_g)^{b_4}(t_s)^{b_5} \tag{6}$$

therefore,

$$c_1 = (\text{D.F}_1 \times R_1 - \text{D.F}_2 \times R_1)/[R_1 \times R_2 \times (\text{D.F}_2 - \text{D.F}_1)] \tag{7}$$

If $n$ different values of $R$ are examined and successive pairs are used to determine the value of $c_1$, then (n-1) different values of $c_l$ can be obtained. The average of ($n$-l) values of $c_l$ is used to achieve the best match. Exponential coefficient $b_1$ is determined as

$$b_1 = \ln\left(\frac{\text{D.F}_1}{D.\text{F}_2}\right) / \ln\left(\frac{S_1}{S_2}\right) \tag{8}$$

and so on.

Once all the coefficients were determined, the value of $a$ was obtained from the average bridge, that is.

$$a = \text{D.F}_0 / \left[\left(\frac{1}{R_0} + c_1\right)(d_{e0} + c_2)(S_0)^{b_1}(L_0)^{b_2}(N_0)^{b_3}(K_{g0})^{b_4}(t_{s0})^{b_5}\right] \tag{9}$$

where $R_0$, $d_{e0}$, $S_0$, $L_0$, $N_0$, $K_{g0}$ and $t_{s0}$ are the parameters of the average bridge.

In the preliminary developed formulas, all parameters that have effect on moment and distribution factors were considered. In the final phase, the parameters as $K_g$, $N$, and $t_s$ that have the smallest effect on distribution factors is omitted. Then the formulas were reformulated using the previously defined procedure neglecting those parameters. Table 2 shows the finally adopted simplified formulas for moment and shear distribution factors of outside and inside exterior girders.

**Table 2:** Simplified formulas for distribution factors of curved steel I-girder bridges

| Girder | Factor | For $d_e$ = 1.0 m | For different $d_e$ values, multiply the formulas by |
|---|---|---|---|
| Outside Exterior Girder | Moment | $\left(\frac{4.365}{R} + 0.271\right)(LS)^{0.26}$ | $\left(\frac{d_e}{4.5} + 0.78\right)$ |
| | Shear | $\left(\frac{2.679}{R} + 0.43\right)(L)^{0.21}\left(\frac{S}{10} + 0.71\right)$ | $\left(\frac{d_e}{2.85} + 0.65\right)$ |
| Inside Exterior Girder | Moment | $\left(2.02 - \frac{26.911}{R}\right)\left(\frac{S}{L}\right)^{0.45}$ | $\left(\frac{d_e}{3.44} + 0.71\right)$ |
| | Shear | $\left(1.846 - \frac{8.03}{R}\right)\left(\frac{1}{L}\right)^{0.15}\left(\frac{S}{10} + 0.43\right)$ | $\left(\frac{d_e}{2.57} + 0.61\right)$ |

The distribution factors of interior girders could be assumed to be proportional between the values of distribution factors for the outside and inside exterior girders calculated using simplified formulas listed in Table 2 with an acceptable accuracy. This is valid for (overhang) $d_e \geq 0.0$m in case of moment distribution factors and $d_e \geq 1.0$m in case of shear distribution factors.
The bottom flanges lateral moment, $M_{Lat.}$ can be calculated using the following empirical formula [1]:

$$\frac{M_{Lat.}}{M_V} = \frac{S_c^2}{10RD} \qquad (10)$$

where $M_v$, $S_c$, $R$ and $D$ are the girder moment due to bridge loading which is calculated using the simplified formulas, the cross frame spacing, the bridge radius of curvature and the girder depth respectively. For all studied bridges, the values of the lateral flange moments from the F.E. analysis was compared with the values obtained using this formula. It was found that this formula agrees with the results of the F.E.M results.

### 5.1 Limitations

The proposed simplified formulas are accurate for bridges with parameter ranges (see Table 3) within those of the studied bridge models. In this table, the radius of curvature and span length are measured along the centerline of the bridge. If the bridges are outside of these ranges, the formulas may be less accurate. Skew effect was not studied in this paper, so all the supports were assumed along bridge radial lines.

**Table 3:** Formulas range of applicability

| Parameter Name | Range of Applicability |
|---|---|
| Radius of Curvature | $R > 40$ m |
| Edge Distance | $-0.5 < d_e < 1.5$ m |
| Girder Spacing | $2.0 < S < 4.0$ m |
| Span Length | $16 < L < 40$ m |
| Slab Thickness | $19 < t_s < 27$ cm |
| Number of Girders | $3 < N < 7$ |
| Ratio of Radius to Span Length | $R/L < 0.6$ |
| Girder Longitudinal Stiffness | $6X10^6 < K_g < 22X10^6$ cm$^4$ |

## 6 EVALUATION OF THE SIMPLIFIED FORMULAS

Since in the derivation of the formulas some bridge parameters were ignored, it is important to verify the accuracy of these formulas. The distribution factors obtained from the F.E.M analysis were compared with the results of the simplified formulas. Figs. 8 and 9 show the comparisons with the variation of radius of curvature and girder spacing respectively and the rest of comparisons are available in [8].

The moment distribution formula for outside exterior girder showed a difference around +5 % with the variation of radius of curvature $R$, a difference up to +6 % with the variation of span length $L$, a difference between +2.13% and +8.72% with the variation of girder spacing $S$ max. difference at S = 2.0m, and a difference around +6% with the variation of overhang $d_e$.

The moment distribution formula for inside exterior girder showed a difference around +1 % with the variation of radius of curvature $R$. The formula showed a difference between up to +11.96 % with max difference at $L$ = 16m and 40m with the variation of span length $L$ and this is acceptable because the difference for span length 20m $\leq L \leq$ 36m do not exceed 5%. The formula showed a difference between +1.9% and +8.87% with the variation of girder spacing $S$ with max. difference at S = 2.0m and a difference between around +2% with the variation of overhang $d_e$.

The shear distribution formula for outside exterior girder showed a difference around +4.3% with the variation of radius of curvature $R$, a difference up to +4.78 % with the variation of span length $L$, a difference around 5% with the variation of girder spacing $S$ and a difference between +1.93 % and +6.56% with the variation of overhang $d_e$.

The shear distribution formula for inside exterior girder showed a difference around +2.5% with the variation of radius of curvature $R$, a difference between +2.1% and +6.33 % with the variation of span length $L$, a difference up to +5.5% with the variation of girder spacing $S$ with max. difference at S = 2.0m and a difference between up to +4.87% with the variation of overhang $d_e$.

In all cases the distribution factor based on simplified formulas are larger than those based on F.E. analysis (i.e. it is on the safe side).

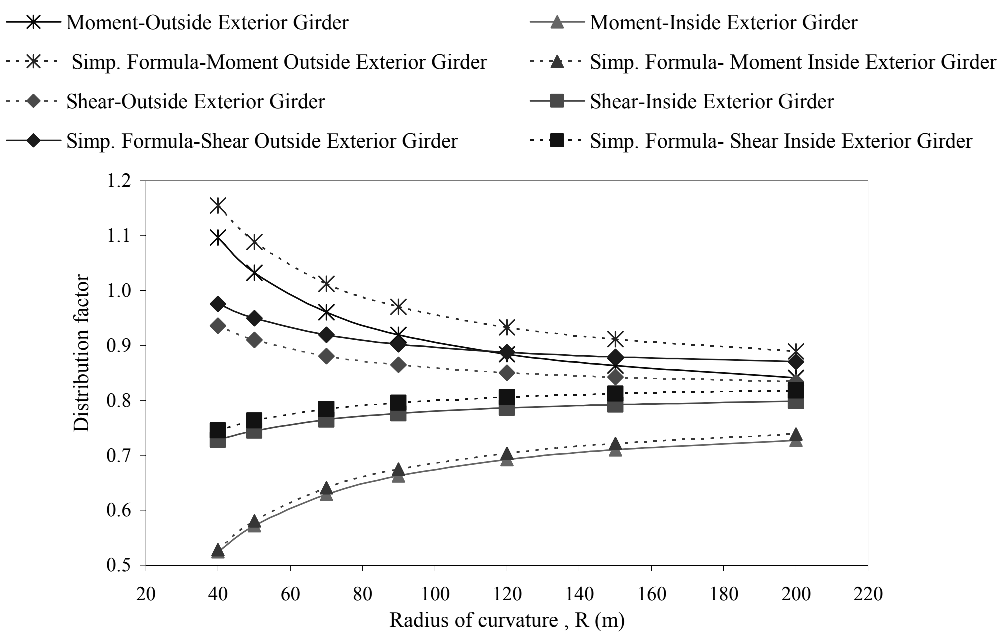


**Fig. 8:** Comparisons between distribution factors based on simplified formulas and F.E.M with the variation of radius of curvature, $R$

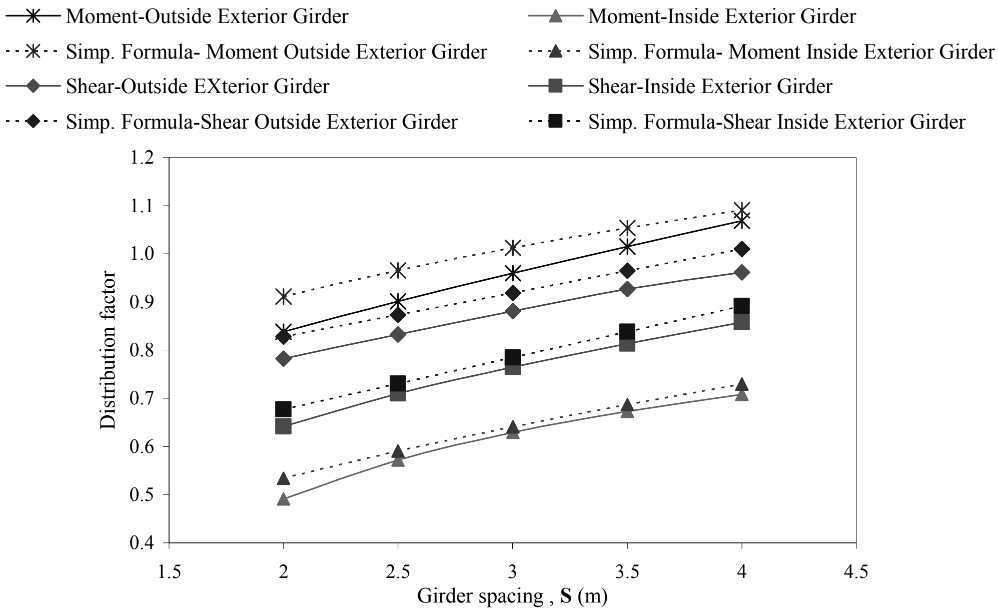


**Fig. 9:** Comparisons between distribution factors based on simplified formulas and F.E.M with the variation of girder spacing , *S*

## 7 ILLUSTRATIVE DESIGN EXAMPLE

To illustrate the use of the proposed simplified formulas , an example is presented in the following: A curved bridge having four steel I-girders with a composite concrete deck slab is to be designed for ECP2000 live loading. The system dimensions and properties (see Fig. 10) are as follows: Radius of curvature, $R$ = 60 m; Girder spacing, $S$ = 2.5 m; Span length, $L$ = 24 m; Deck thickness, $t_s$ = 25 cm; Distance between outside girder centerline and inside edge of curb, $d_e$ = 1.0 m; Cross frame spacing, $S_c$= 4.0 m; Girder depth, $D$ = 130 cm; Girder modulus of elasticity, $E_s$ = 2100 t/cm$^2$ ; Deck modulus of elasticity, $E_c$ = 262.5 t/cm$^2$.

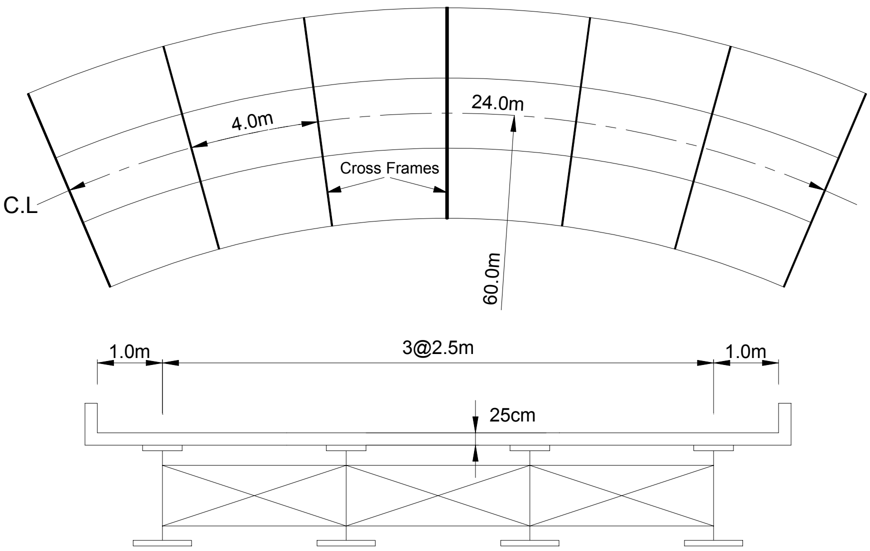


**Fig. 10:** The example bridge plan and cross section

**Step 1: Calculate equivalent straight girder response:**

The analysis of a simple straight girder with span length equal to the bridge centerline arc length was carried out. The girder was loaded by only the main lane loads of the ECP live load including the impact ( see Fig. 11).

Impact factor (ECP 2000), $I$ = 0.4-0.008$L$ = 0.208

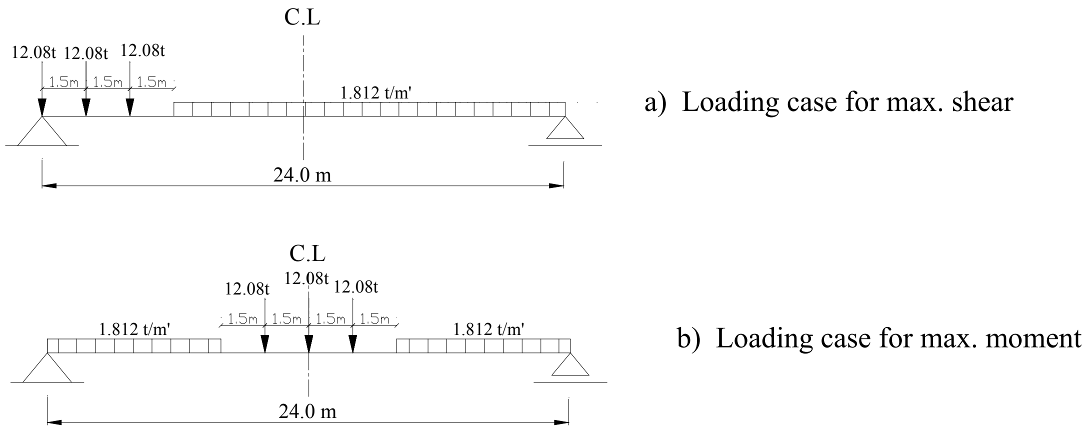


**Fig. 11:** Cases of loading for the single straight girder

The straight girder maximum moment for main lane loading including impact is 472.03m.t.
The straight girder maximum shear for main lane loading including impact is 82.305t.

**Step 2: Calculate distribution factors**

The distribution factors of moment are calculated as follows:

Outside exterior girder:

$$D.F = \left(\frac{4.365}{R} + 0.271\right)(LS)^{0.26} = \left(\frac{4.365}{60} + 0.271\right)(2.5 * 24)^{0.26} = 0.997$$

Inside exterior girder:

$$D.F = \left(2.02 - \frac{26.911}{R}\right)\left(\frac{S}{L}\right)^{0.45} = \left(2.02 - \frac{26.911}{60}\right)\left(\frac{2.5}{24}\right)^{0.45} = 0.568$$

The distribution factors of shear are:

Outside exterior girder:

$$D.F = \left(\frac{2.679}{R} + 0.43\right)(L)^{0.21}\left(\frac{S}{10} + 0.71\right) = \left(\frac{2.679}{60} + 0.43\right)(24)^{0.21}\left(\frac{2.5}{10} + 0.71\right) = 0.888$$

Inside exterior girder:

$$D.F = \left(1.846 - \frac{8.03}{R}\right)\left(\frac{1}{L}\right)^{0.15}\left(\frac{S}{10} + 0.43\right) = \left(1.846 - \frac{8.03}{60}\right)\left(\frac{1}{24}\right)^{0.15}\left(\frac{2.5}{10} + 0.43\right) = 0.723$$

**Step 3: Calculate outside and inside exterior girder vertical moments and shears.**

Exterior girders moments

$M_v$ (outside) = (0.997) x (472.03) = 470.61m.t

$M_v$ (inside) = (0.568) x (472.03) = 268.12 m.t

Exterior girders reactions/shears

$R$ (outside) = (0.888) x (82.305) = 73.09 t

$R$ (inside) = (0.723) x (82.305) = 59.51 t

**Step 4: For interior girders assume the moment and shear values proportional between the exterior girders**

| Girder | Outside girder | Girder 2 | Girder3 | Inside girder |
|---|---|---|---|---|
| Moment (m.t) | 470.61 | 403.12 | 335.62 | 268.12 |
| Shear (t) | 73.09 | 68.57 | 64.04 | 59.51 |

**Step 5: Corresponding bottom flange lateral moments are calculated using an empirical formula as**

$$\frac{M_{Lat.}}{M_V} = \frac{S_c^2}{10RD} = \frac{4^2}{10 * 60 * 1.3} = 0.021$$

$M_{Lat.}$ (outside) = 470.61x 0.021 =9.883 m.t
$M_{Lat.}$ (inside) = 268.12x 0.021= 5.631m.t

## 8 SUMMARY AND CONCLUSIONS

In this study, the effect of various bridge parameters on moment and shear distribution factors was investigated based on ECP live load. The parameters considered in the study were: radius of curvature, girder spacing, span length, slab thickness, girder longitudinal stiffness, girder torsional inertia, number of girders, distance from center of exterior girder and inside edge of traffic barrier, and cross frame spacing. The variations of these parameters were based on the statistical analysis of the real bridge data collected. A parametric study was carried out using F.E. models to calculate the lateral load distribution factors based on ECP live loads. Based on the extensive F.E. analysis, simplified formulas for moment and shear distribution factors for inside and outside exterior girders were developed. A comparison was made between the formulas and the F.E.M results to evaluate the accuracy of the formulas. An example was presented to illustrate the application of these formulas to the designers of curved I-girder bridges. The following conclusions can be drawn from the results of this study:

1. The parameter sensitivity study showed that for variable bridge width:
   -Radius of curvature, span length, girder spacing, and distance from center of exterior girder and inside edge of traffic barrier had significant effect on distribution factors.
   -Slab thickness, number of girders and longitudinal stiffness had slight effect.
   -Effect of cross frame spacing and girder torsional inertia could be neglected.
2. This study produced simplified formulas for moment and shear distribution factors of curved steel I-girder bridges based on ECP live load.
3. Since the simplified formulas were derived within specified parameters ranges, so the formulas would be most accurate when applied to bridges within similar parameters ranges.

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