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Effect of Skew Angle on Bending Moment Distribution between Main Girders in RC Girder Bridges

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الملخص العربى :

تعتبر الكباري من المنشآت الهامة و الحيوية لتخطي العقبات المرورية و المجاري المائية و تقاطعات الطرق. تختلف انواع الكباري طبقا للنظام الانشائي المستخدم و مواد البناء و محور الكوبري. ينتج الانحراف في محاور الكباري من تقاطع المحاور المائلة للكوبري مع محوره نتيجة وجود عقبات او اعمال صناعية ذات محور متقاطع بصورة مائلة مع محور الكوبري. الكباري ذات المحاور المنحرفه ينتج عنها الكثير من المشاكل في توزيع ردود الافعال عند الركائز و كذلك توزيع عزوم الانحناء بين الكمرات الرئيسية في الكباري الكمرية. بزيادة زاوية الانحراف تختلف ردود الافعال و كذلك عزوم الانحناء بصورة متباينة تعتمد علي زاوية الانحراف و المسافات بين الكمرات الرئيسية و كذلك تواجد و توزيع الكمرات العرضية. في هذا البحث تم دراسة تأثير تغيير زاوية الانحراف علي توزيع قيم عزوم الانحناء في الكمرات الرئيسية. تمت الدراسة التحليلية باستخدام طريقة العناصر المحددة **grillage model** و ذلك لسهولة و سرعة تطبيقه و نسبة قبول نتائجه المرتفعة. تم دراسة خمس كباري بزوايا انحاف مختلفة بداية من كوبري عمودي بزاوية انحراف **90** مع محور الكوبري و كباري ذات زوايا انحراف **50, 40, 30** و **20** و بحر كوبري يساوي **25** متر و عرضه **14** متر.تم وضع كمرات عرضية في الكباري علي مسافات الثلث و الثلثين في كل الكباري قيد الدراسة. تمت الدراسة تحت تأثير الاحمال الدائمة من اوزان عناصر الكوبري و كذلك الاحمال الحية طبقا للكود المصري للاحمال**2008**. تمت مقارنة نتائج عزوم الانحناء للكمرات الرئيسية للكباري ذات زوايا الانحراف المختلفة ب الكوبري العمودي و ذلك لكل كمرة علي حدة. اثبتت الدراسة تأثير ازدياد زاوية الانحراف علي قيم عزوم الانحناء للكمرات الطرفية بصورة مضطرده و طبقا لموقع المركبات في حالات التحميل المختلفة.

ABSTRACT

Bridges are important structures to overcome different obstacles in roads and highways. Variations in bridge types include variation in span length, statical system, construction material, construction methods and sustained loads. Alignment of bridge axis depends on the road alignment below. Skew bridges result from inclined intersection between bridge axis and the below road or water stream. Skew angle differs from case to another and affect bearings` reactions and bending moment values in main girders. Cross girders participate in distribution of loads between main girders and to achieve a relative smooth deflection curve. Stiffness of

cross girders especially near the skew edge affects noticeably the distribution of loads in main girders.

In this paper, analysis of skew RC girder bridge deck of different skew angles will be performed .Two cross girders in the two thirds of the bridge will be applied to all models. Analysis will be performed using grillage model [1] through FEM software package [2]. Analysis includes different skew angles under distributed gravity load patterns. The observed outputs in the analysis are bending moment values in the main girders. Analyzed bridges are medium span bridges of 25.0 m and bridge deck width 14.0 m. Skew angles (α) adopted in the analysis measured from horizontal axis are 20, 30, 40, and 50 degrees in addition to right bridge (α=90).

Keywords: skew bridges, RC girder bridge, skew angles.

1. INTRODUCTION:

The objective of this research is to find out the relation between skew angle and the stiffness of main girders especially the external ones. Many researchers studied the behavior of skew angles on bridge deck behavior to study effect of variation of skew angle on the distribution of loads and straining actions in the bridge deck. Razzaq M.K. et al [3] had studied the effect of distribution factors in skewed composite steel I-Girder bridge due to dead loads, including effect of shoring and un-shored construction with different spans using CSiBridge FE program. They found that for large skew angles greater than 30 measured with the VL axis a noticeable increase in shear and moment values was noticed at the outer main girders with increase in shear values at the obtuse angle. Dicleli M., et al, [4] suggested a skew correction factors for girders, abutments and piles in skew bridges for LL through 2D and 3D models of numerous skew integral bridges. They concluded that in LL skew angles did not affect the distribution of LL especially in intermediate and outer girders. Rocha B.F., et al. [5] had studied the effect of skew reinforcement applied in slab and plates in RC bridges. They concluded that for large skew angles a higher steel reinforcement area at the mid panel with a noticeable increase of stresses in concrete at obtuse angle. Hassel H.L., et al. [6] had conducted a parametric study using 3D FE models on the effect of cross frames layout on the distortion of skewed steel bridges. They found that cross frame layout and its stiffness had a great effect on distortion induced fatigue. Theoret P., et al. [7] had studied how to determine the required straining action to design skew and straight slab bridges using grillage and FE models. They proved that grillage analysis was satisfactory to predict the amplitude and transverse distribution of longitudinal bending moments and shear forces. Nouri G., et al. [8] had studied analytically the effect of skew angle on continuous composite girder bridges. The results were compared to AASHTO LRFD specifications. They found that as the skew angle increases, the moment in interior and exterior girders rapidly decreases. Khaloo A. R., et al. [9] had studied load distribution factors in simply supported skew bridges. They analyzed different girders` spacing, skew angles and span lengths and found that AASHTO distribution factors are very conservative in skew bridges.

2. MODEL AND ANALYSIS

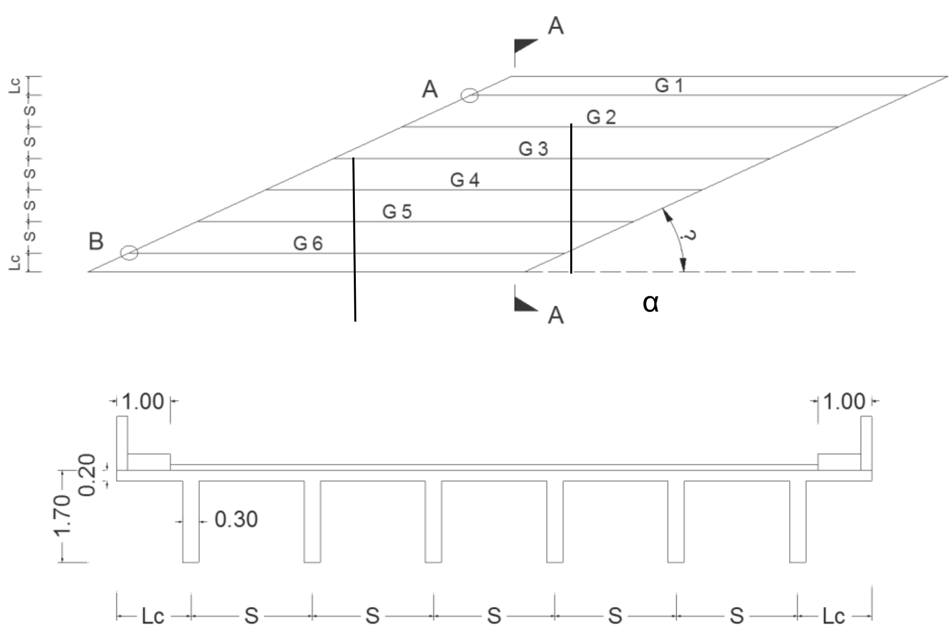
2.1 Grillage Model:

Grillage model was used in the analysis as it is easy to perform large numbers of models with good accuracy and less analysis time. In the performed models, as the skew angle starts from 20 which is less than 30 as recommended by Hambly, transverse elements will be in perpendicular direction to the horizontal axis in all models and to facilitate placing of different cross girders patterns.

Models` Specifications:

Table 1: Analyzed skew bridges configurations and layout.

	Model	L (m)	W (m)	Lc (m)	S (m)	α
1	**M1-20**	25.0	14.0	1.375	2.25	20
2	**M1-30**	25.0	14.0	1.375	2.25	30
3	**M1-40**	25.0	14.0	1.375	2.25	40
4	**M1-50**	25.0	14.0	1.375	2.25	50
5	**M1-90**	25.0	14.0	1.375	2.25	90



Sec. A-A

Fig.1 : Skew bridge general layout and concrete dimensions

2.2. Load Patterns:

Analysis of finite element models (grillage models) was performed under permanent loads (DL) and live loads (LL). Live load (LL) values are according to Egyptian code of loads and forces in structures and construction works 2008 [10]. Load pattern 1 as in Figure (2) were applied to all analyzed skew bridges.

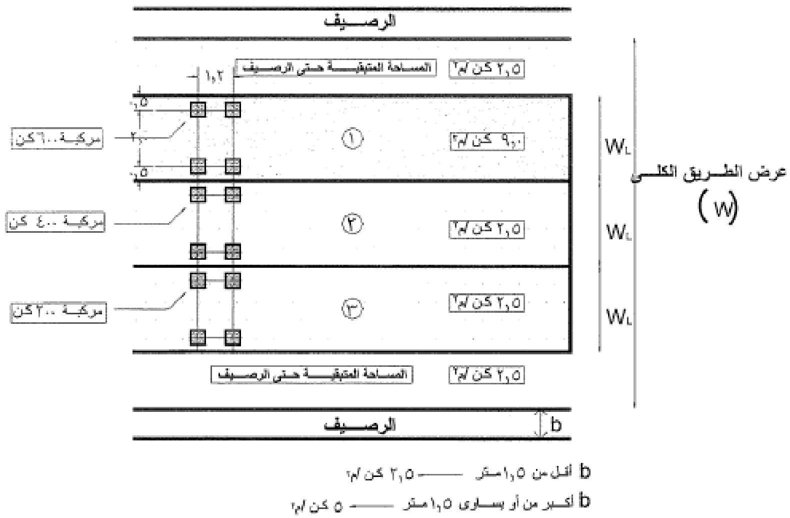


Fig.2: Live Load Pattern according to Egyptian code for loads and forces in structures 2018 – Load Pattern No.1 [10].

3. RESULTS AND DISCUSSIONS

3.1 Effect of Skew Angle on B.M values in Bridge Main Girders:

3.1.1 BM values in main girders due to DL and LL.

As the skew angle changes, position of vehicles change relative to main girders` maximum BM position. In addition, existence of cross girders affects the distribution of BM between the external and internal main girders. In right bridge with skew angle= 90 values of BM in main girders in DL and almost similar. Figures 3 and 4 illustrate BM values in main girders 1 to 6 due DL and LL with different skew angles. Tables 2 and 3 indicates the percentage of change in BM values in main girders G1 to 6 and different skew angles compared to right bridge.

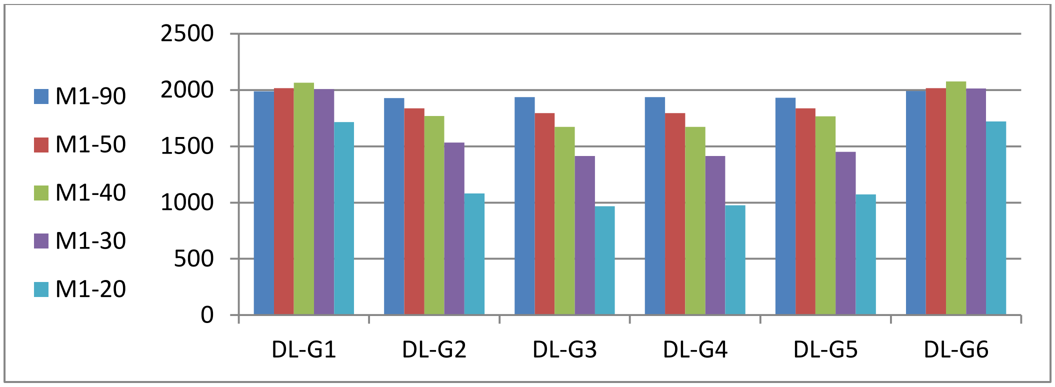


Fig.3: Model (M1) change in BM values in main girders (G1 to G6) due to DL with different skew angles.

Table 2: Percentage of change in BM values due to DL in G1 to 6 with different sew angles compared to right bridge.

	M1-50	M1-40	M1-30	M1-20
DL-G1	1%	4%	1%	-14%
DL-G2	-5%	-8%	-20%	-44%
DL-G3	-7%	-14%	-27%	-50%
DL-G4	-7%	-14%	-27%	-50%
DL-G5	-5%	-8%	-25%	-44%
DL-G6	1%	4%	1%	-13%

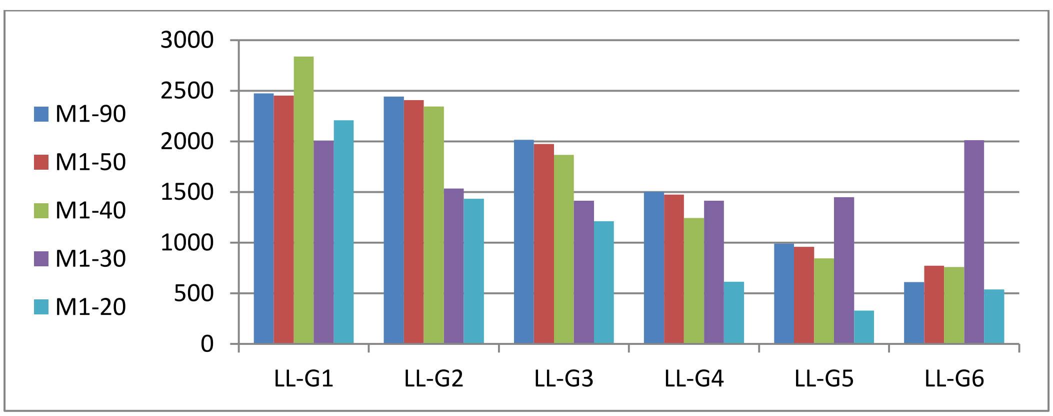


Fig.4: Model (M1) change in BM values in main girders (G1 to G6) due to LL with different skew angles.

Table 3: Percentage of change in BM values due to LL in G1 to 6 with different sew angles compared to right bridge.

	M1-50	M1-40	M1-30	M1-20
LL-G1	-1%	15%	-19%	-11%
LL-G2	-1%	-4%	-37%	-41%
LL-G3	-2%	-7%	-30%	-40%
LL-G4	-2%	-17%	-6%	-59%
LL-G5	-3%	-15%	46%	-67%
LL-G6	27%	24%	229%	-12%

3.1.2 Variation in BM values in main girders 1and 2 due to DL and LL.

Distribution of BM between main girders showed a noticeable variation with the increase of skew angle. In the following a comparison between BM values in main girder 1 and 2 in Model (1). From this figure it was noticed that for skew angles 50 and 40 in main girder 1 the percentage of variation in BM due to DL was about 10%. BM values in G1 compared to right bridge were almost the same. Similar results were noticed in skew bridge with skew angle 40. In skew bridge with skew angle 30 variation in BM values in G1 was also about 10% with reduction in BM due to DL about 5% relative to right bridge. In skew bridge with skew angle 20 a noticeable reduction in G1 BM values due to DL compared to right bridge was about 20% decrease. For skew bridge with skew angle 20 the variation in BM due to LL in was about 20% reduction. In skew bridge of 50, and 40 skew angle the average increase in BM in G1 was 10% and 22% relative to right bridge respectively. Similar results were observed in G2 for BM due to DL for skew angle 50 and 40 the average decrease in BM values due to DL was up to 12% however for skew angle 20 a 25% reduction in BM values were observed and this percentage was increased to 40% for LL. In the following Figures 5, 6, 7 and 8 summarize the obtained BM values in main girders G1 and G2 due to DL and LL.

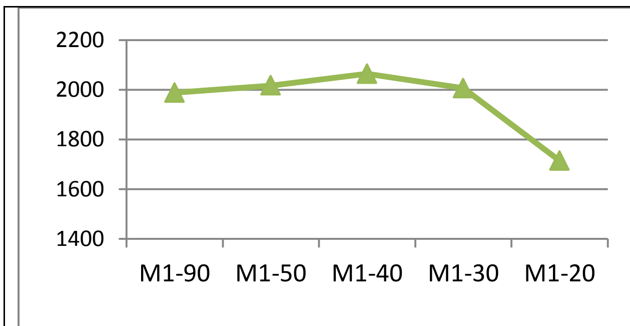


Fig.5: Model (M1) change in BM values in main girder (G1) due to DL and different skew angles.

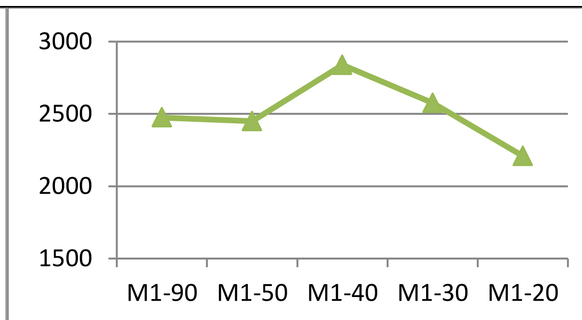


Fig.6: Model (M1) change in BM values in main girder (G1) due to LL and different skew angles.

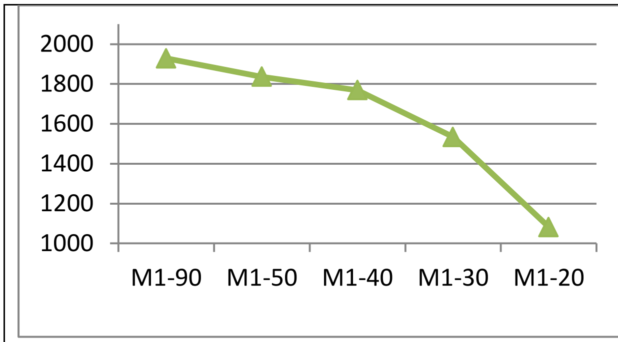
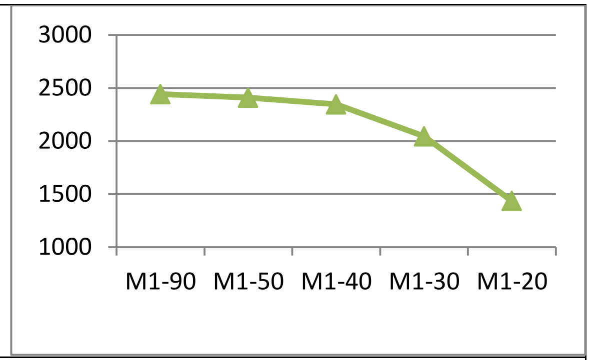
	

Fig.7: Model (M1) change in BM values in main girder (G2) due to DL and different skew angles.	**Fig.8: Model (M1) change in BM values in main girder (G2) due to LL and different skew angles.**

4. CONCLUSIONS

In this paper analysis of 10 bridges with different skew angles was performed through grillage model and live load patterns according to Egyptian Code of Practice. The analysis aimed at to find the effect of skew angle BM values in main girders due to DL and LL. From the previous analysis the following conclusions were drawn:

1- BM values in main girders in model (M1) showed a noticeable in main girder G1, the percentage increase in BM values due to DL was maximum 4% in skew angles 40 and 30 compared to right bridge and reduction percentage 14% in case of skew angle 20.

2- The largest percentage of increase in BM values due to LL was observed in G6 in skew bridge deck with skew angle 50 by 27% compared to right bridge.

3- BM results for G1 and G2 due to LL indicated that severe skew angles affected the BM values by decrease percentage up to 67% in G5 in case of skew angle 20.

4- A major increase in BM values due to LL was observed in G6 was 229% compared to right bridge in case of skew angle 30.

5- The decrease in skew angle measure with the bridge axis the higher the increase in BM value due to LL in the outer girders.

6- Grillage model was a simple and fast analysis model with acceptable results which helps to carry out large number of models.

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