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The Parametric Study of Composite Skew Box Girder Bridge Having Corrugated Steel Web Under Varying Speed of Vehicles and Time History Analysis

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Abstract - *A box girder bridge is a bridge in which the primary beam involves a girder in the shape of a hollow box. In this bridge using a composite skew box girder bridge with corrugated steel webs. The thickness of corrugated steel web is 16 mm, and the skew angle of bridge varying between 0 to 60 degrees with interval of 15 degree. The objective of these studies is to find the dynamic behavior of box girders with corrugated steel web. Find the vertical displacement, transverse stress, transverse displacement, and base shear for different vehicle speeds of 30 km/h, 45 km/h, 60 km/h, and 75 km/h under non-linear time history analyses using two different ground motions. The moving load and nonlinear time history analyses were performed on each model in ANSYS workbench software. The results indicated that the vertical displacement and transverse displacement of the composite box girder increased with an increase in skew angle. The transverse stress and base shear increase with increasing in skew angle as compare to 0 degree skew angle but in case of transverse stress at 45 degree skew angle more than others degree skew angle and in case of base shear at 60 degree angle very less than others degree of skew angle.*

***Key Words*: Skew Bridge, Composite Box Girder, Corrugated Steel Web, Fem Analysis, Dynamic Behaviour, Moving Load, Non-Linear Time History.**

1.INTRODUCTION

The moving load of vehicles problem is an unavoidable problem in structural dynamics. By using a beam that is subject to moving mass point-wise, which is also asked moving mass difficulty show in Fig - 1, moving load complexity can be established. The increasing speed and weight of cars and other moving bodies brought about by advancements in transportation technology and automotive engineering have increased vibration and dynamic stress on associated structures significantly. This experimental effort investigates the dynamic response of a beam to the application of a moving force. Hamid Reza et al. [1] Executed Non-linear time history dynamic studies were used to examine the dynamic behaviour and deformations of bridge components during near-field and far-field earthquakes on a continuous deck bridge with varying degrees of skewness. The values of these parameters increased in the event of near-field earthquakes with velocity pulses. Additionally, it was discovered that a rise in the bridge's skew degree was associated with an increase in the axial stresses acting on the columns and the transverse displacement of the structure. Tanmay gupta et al. [2] The goal of this research is to forecast the bending response of a single-cell inclined concrete box girder bridge with simple support. The skew angle was set at intervals of 10° from 0° to 50° to investigate the effects of asymmetry. The Road Congress carried out finite element analysis for the gravity and live load (LL) loads of the Type 70R tracked vehicles, and three-dimensional analytical models of the bridges were produced using CSiBridge. The Indian Ministry (IRC) mandates that implementation take place at a minimum distance from the side of the road. The results are shown as a contour map, which indicates that the angle of the inclined bridge is where the largest stress occurs, and that the angle of inclination increases as the bending moment diminishes. Won choi et al. [3] This study examines the distribution of live loads on box girders and calculates the midspan tensile stress, maximum negative stress at the piers, and deflection of the bridge under live load. The outcome showed the highest compressive stress at the bottom of the box girder at the piers and the maximum tensile stress at the bottom of the box girder along the span. Iman mohseni et al. [4] The dynamic behaviour of multicell box-girder bridges under shifting loads was the main emphasis of the current study. The superstructure's and the car's dynamic characteristics, such as speed and natural frequency, affect the dynamic impact factor. The outcome showed that as the bridge's span increased, the dynamic impact factor for response and shear force decreased and the bending moment increased. Ya na mao et al. [5] take single-cell and twin-cell composite box girder bridges with corrugated steel webs and find natural vibration frequency and dynamic impact coefficient value. The natural vibration frequency of the composite girder is lower than that of the corresponding concrete box girder. The dynamic impact coefficient of the composite box girder is larger than the concrete box girder. Chundi Si et al. [6] These studies examined the differences in the dynamic response between the concrete web box girder bridge and the deck pavement of a box girder bridge with corrugated steel web (CSWBG). The advantages of the CSWBG bridge in deflection control are more evident, and it is lightweight and has strong bending resistance. The CSWBG bridge has less transverse bending rigidity than the corresponding CWBG bridge. Due to the box girder bridge's low self-weight and stiffness and corrugated steel webs, the axle's dynamic interaction with vehicle motion is more noticeable. Demeke B. Ashebo et al. [7] These papers evaluated the dynamic stresses on a continuous skew box girder bridge. The bending vibration type is determined to be the fundamental mode for bridge skew angles ranging from 0 to 45 degrees, whereas a torsional mode is produced for the 60-degree model's skew angle. While the strain responses exhibit sensitivity in a lower frequency range, the acceleration responses exhibit sensitivity in a greater frequency range. S. Mahboubi et al. [8] Using a number of chosen ground motion data, a nonlinear time-history analysis is used in this research to assess the seismic damage of skew reinforced concrete (RC) bridges. The findings show that when the skew angle increases, bridge pier damage increases as well, especially for bridges with taller piers. On the other hand, damage indices demonstrate that for bridges with taller piers at larger skew angles, the effect of CFRP-confinement grows dramatically. X. H. He et al. [9] These paper skew box girder bridges investigate displacement, stress, natural frequency, mode form, and damping ratio at a 45-degree skew angle. Deformations, vertical bending moments, and skew angles all decrease. However, as differential reaction levels rise, so do torsional stresses and deformations. The effects of skew on damping were demonstrated to be minimal, with the damping effects being somewhat reduced when skew is present. Huang Zeng A et al. [10] study is conducted on the dynamic amplification factor (DAF) of the bridge reaction caused by moving cars. The bridge and vehicle are viewed as two independent systems that are only coupled at contact points that change over time and at tilt angles that range from 0 to 60 degrees, using a three-axle 3D vehicle model with an 11 degree of freedom system. DAF calculates the bridge's dynamic action as a percentage of its static action. The dynamic gain increases from 0 to 60 degrees as a result of increasing the tilt angle, with the middle of the deck housing the highest DAF. Ehsan Omranian et al. [11] This study examined the effects of several parameters on the fragility curve of an RC skew bridge subjected to mainshock and aftershock, including the skew angle of the deck and the direction of seismic excitation. The results show that aftershocks have a considerable impact on fragilities, making mainshock-only thinking nonconservative. Smaller skewness is less vulnerable than greater skewness when comparing median values for bridges. Because faults are very responsive to the direction of ground motion, skew bridge seismic vulnerability may be underestimated if incidence angle is the only factor taken into account. B. Kovesdi et al. [12] This study examined the effects of extra normal stress under various support reactions and transverse bending moments using a corrugated web I-girder with a flange. Supports in a flange minimize normal stresses and transverse bending moments; if additional lateral support is provided, these reductions in stresses and moments of transverse bending occur. A transverse bending moment is dependent on the profile of corrugation. Hongmeng Huang et al. [13] The change of web thickness, width-span ratio, and height-span ratio was described in this study along with their effects on sectional geometric parameters, stress results, and the restrained degree of sectional torsion. If the overall shear stress of the bottom slab and CSW can be decreased by increasing the girder height, girder width, and girder thickness. When the height-span ratio of the CBGCSW is set to 0.05, the total shear stress of the CSW can be reduced by 70.6%, and when the width-span ratio of the CBG - csw is set to 0.20, the total shear stress of the bottom slab can be reduced by 82.6% to that of the CBGCSW with a width-span ratio of 0.06. Monirule mallick et al. [14] Examine inclined bridges with tilt angles ranging from 0 to 60 degrees, allowing for the interaction of soil piles by around 15 degrees. Additionally, investigate the impact of seismic analysis on the bridge. As a result, the asymmetry has a significant impact on the bridge deck's rotational demand, suggesting that asymmetric bridges are more vulnerable to overturning incidents caused by deck rotation. Additionally, it was noted that as the inclination angle rose to 54% and 37%, respectively, there was a considerable increase in the pile shear and moment demand. Indicating that the design requirements for the foundation components of the oblique bridge are higher than for comparable conventional bridges, the maximum bending moment of the piling body also rose by up to 55%. Yulin Feng et al. [15] The study that was presented looked into the dynamic properties of CBBCWs, or composited box beams with corrugated web. The fraction of deflection resulting from shear deformation is greater on the CBBCW's high-order vibration curve, and the effect of the shear connection degree on the high-order vibration mode of the CBBCW has decreased. The order of the vibration mode improves the CBBCW's shear lag effect. M. F. hassanein et al. [16] This research analyses shear analysis and compares steel corrugated webs of normal strength with those of high strength. The ultimate shear load carried by the girder and the ultimate shear stress carried by the webs will both increase if the web thickness is raised. On the other hand, the net's cross-sectional area increased significantly but the final strength increased very slightly. The ultimate shear stress drops as web height increases, while the ultimate shear load value increases significantly. Ruijuan jiang et al. [17] This study examines the effective flange width coefficient, which may provide insight into the features of the shear lag effect. There is a positive shear lag effect across the entire bridge. When a bridge is simply supported, the shear lag effect's magnitude is greatest in the middle of the span and grows as the distance to the ends of the bridge decreases. For continuous bridges, on the other hand, the shear lag effect's magnitude decreases as the effective span length increases. Ahmed Jiang et al. [18] These papers examined the effects of base shear and maximum displacement while studying non-linear static and non-linear time history analysis. Maximum displacement in the transverse direction at the midspan center and maximum resulting base shear. Fan shi et al. [19] In order to precisely examine the flexural frequencies and mode shapes in this article, the shear lag effect of the box girder and the stress characteristics of the corrugated steel web are also taken into account. According to the findings of a parameters analysis, the flexural frequency increases as the girder's variable cross-section coefficient increases. Furthermore, as the girder's width-to-span ratio increases, the natural frequency rapidly decreases. Qiangbo li et al. [20] In this research, shear deformation, and natural frequency were examined. The height-to-span ratio increases with the natural frequencies of box girders with CSWs. By making the CSW thicker, the box girders' shear rigidity was increased. As the thickness of the web increases, the initial vertical bending vibration frequencies of box girders with CSWs essentially

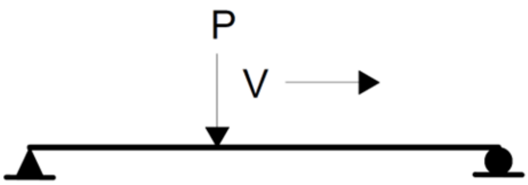

Fig - 1: Moving Force Model

stay constant. Fan shi et al. [21] The study that is being presented combines the benefits of high-strength steel (HSS) with tapered corrugated webs by examining the behaviour and strength of a tapered steel plate girder with corrugated webs that are constructed using HSS. According to the outcome, shear failure in all scenarios involving tapered girders is localized close to the tapered web's shorter height, when shear stress is at its highest. The maximum shear strength rises when the force in the slanted flange is directed in the same direction as the tension field. The objective of this study is to investigate the dynamic behaviour of composite skew box girder with corrugated steel web. Investigated the displacement, longitudinal stress, and transverse stress of the girder under varying vehicle speeds. Investigated the transverse displacement of the girder under different ground motions.

2.MODEL DESCRIPTION

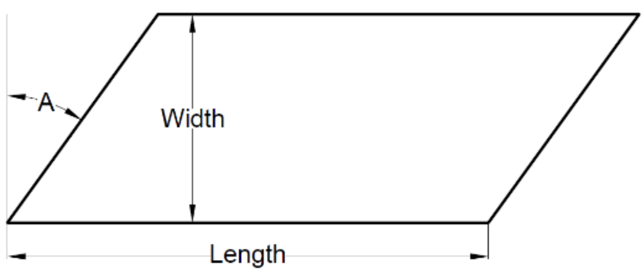

Fig - 2: Plan of Skew Bridge

This study takes 40 models of box girder bridges with corrugated steel web with different 15-degree interval having 0, 15, 30, 45, and 60 degree of angle skew bridge model shown A in Fig - 2. The bridge stand on two abutments. The bridge having single span having simply supported boundary condition. The length of the bridge 22.40 m and width of bridge is 9.8m as per show in fig. and also other dimensions are shown in fig. the dimension of corrugated steel web is shown in fig. the material is used concrete of M55 grade as per IRC 22 code and steel are fe250 used for this analysis. The density of concrete 2500 kg m^{-3}, coefficient of thermal expansion is 1.3 x 10^{-5} oC, Modulas of elasticity is 37 GPa, Poisson's ratio is 0.2, Tensile strength is 3.7 MPa, compressive strength is 55MPa. Also, properties of steel are density is 7850 kg m^{-3}, coefficient of thermal expansion is 12 x 10^{-6} oC, Modulas of elasticity is 2 x 10 5 MPa, Poisson's ratio is 0.3, Tensile strength is 451 MPa, compressive strength is 250 MPa.

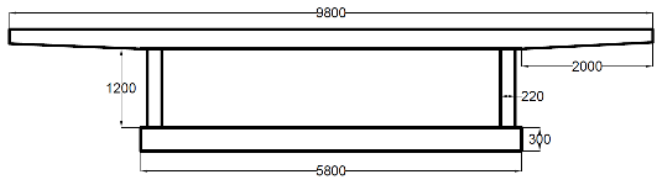

Fig - 3: Cross Section of Bridge

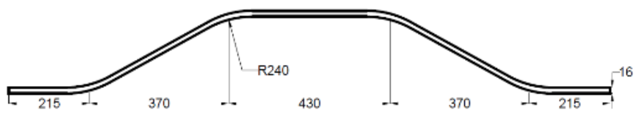

Fig - 4: Properties Corrugated Web

3.METHODOLOGY

3.1Finite Element Model

The finite element software ANSYS workbench are used for this study. The geometry of model is prepared by design modeler tool which provided by ANSYS workbench. The bonded connection is provided between every part of bridge. The meshing of bridge used hex dominant method for lower flange and web and automatic method for upper flange. The size of the meshing is 500mm for flange and 300mm for steel web. the vertical edge of flange divide in 3 parts and horizontal direction web is divide in 2 parts. use the face meshing in upper side of the concrete flange for improvement of quality of meshing which shown in Fig - 5. The remote displacement and apply in one end with hinged support which are free rotation in y direction and one end with roller support which are free displacement in x direction and rotation free in y direction.

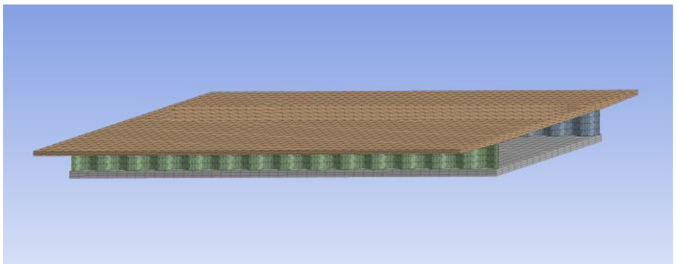

Fig - 5: Meshing

3.2Loading Condition

New bridges may be designed using this type of loading, especially those that carry enormous loads, such industrial, city and highway bridges. When loading a class AA vehicle, the following types of vehicles are typically considered. The total Class AA vehicle load 400 KN are taking for this analysis. Run the vehicles on different speed 30 km/h, 45 km/h, 60 km/h and 75 km/h.

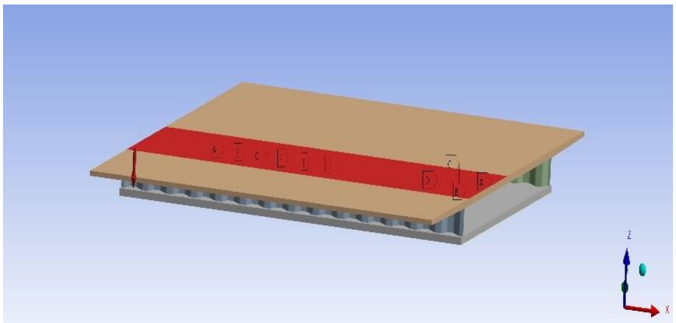

Fig - 6: Class AA Vehicle Loading

For time history analysis take a time history data of Fig - 7 which have two seismic ground motion in acceleration that apply in transverse direction. In these taking time step of 0.02s. the time period of the earthquake data one (Chamoli Earthquake) 24.34 s and another one Earthquake two (Bhuj Earthquake) of 30s, the damping is 0.05.

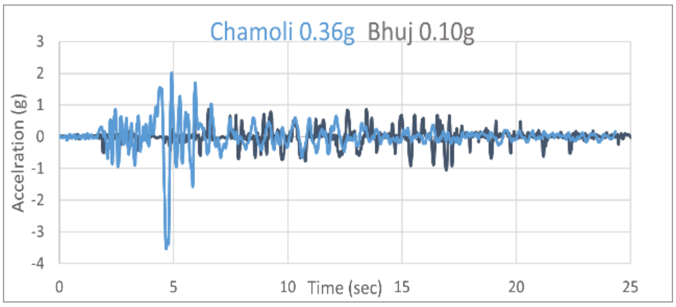

Fig - 7: Earthquake Data

4.RESULT

The parametric study was performed on composite skew box girder with different skew angle bridge model. The vertical displacement, Transverse stress, Transverse Deformation and Base shear were obtained using FEM analysis. The various dynamic behaviour of composite skew box girder with corrugated steel web model investigated the parameter, the following results are obtained.

4.1Vertical Displacement

Fig - 8 show the maximum vertical displacement of models under moving vehicles load with different vehicle speeds. The average of single degrees result indicated very little difference between 0 to 15 degrees but after it is increasing 30.80% in 15 to 30 degrees, 36.94% in 30 to 45 degrees and 39.15% in 45 to 60 degrees. The displacement of girder is slightly changes in 0, 15 and 60 degrees but increasing speed of vehicle more in skew angle 30 and 45 degrees.

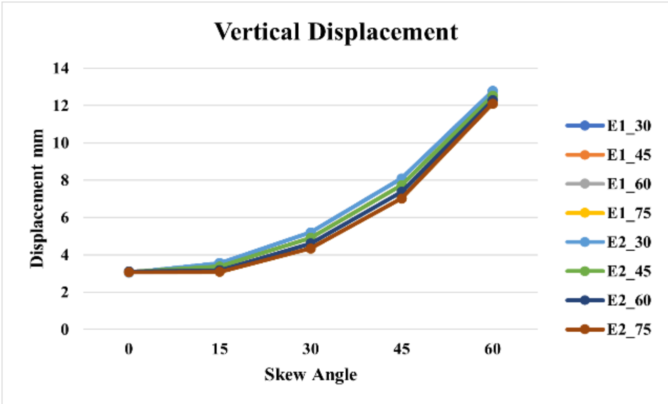

Fig - 8: Vertical displacement

4.2Transverse Stress

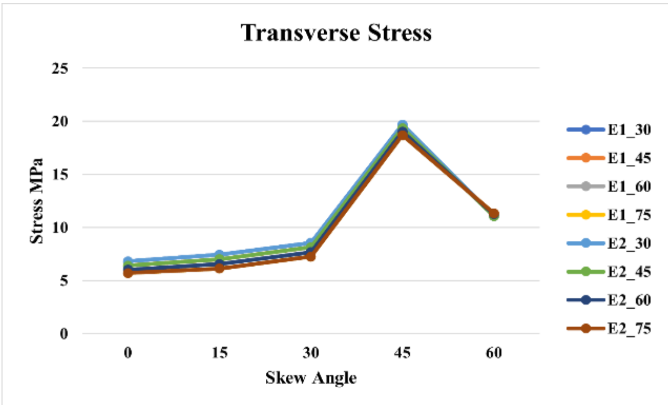

Fig - 9: Transverse stress

Fig - 9 show the maximum transverse stress of models under moving vehicles load with different vehicles speed. The average of single degrees result indicated little difference between 0 to 15 degrees, 14.234% in 15 to 30 degrees, but after it is increasing 58.78% in 30 to 45 degrees and then it 71.56% decrease in 45 to 60 degrees. Transverse stress slightly increases between 0 to 30 degrees. It increases

58.78% at 45 degrees, then drops 71.56% at 60 degrees. the transverse stress of girder is slightly changes in 45 and 60 degrees but increasing speed of vehicle more in skew angle 0, 15 and 30 degrees.

4.3Transverse Deformation

Fig - 10 show the maximum transverse displacement of models under non-linear time history analysis. The transverse displacement of the girder is very small, it changes from 0 to 15 degrees in both earthquake analyses. When an earthquake one applies a displacement of the girder of 0 to 15 degrees 7.14% increase, 15 to 30 degrees increase 13 to 20%, 30 to 45 degrees 13.48% increase and again slightly increases between 45 to 60 degrees of 4.55%. Same as in earthquake 2, the displacement of the girder slightly changes between 0 to 15 degrees, then increases by 12 to 27% between 30 to 45 degrees.

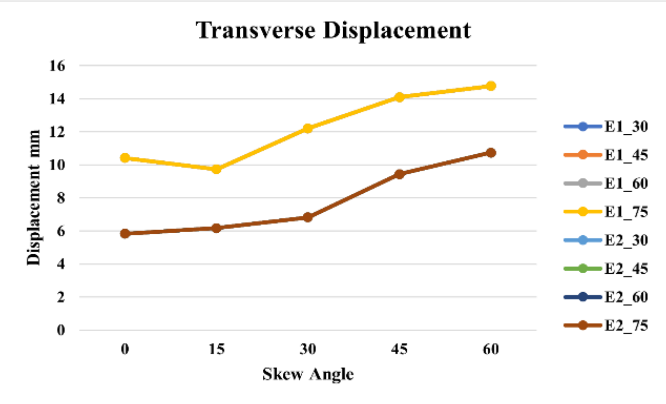

Fig - 10: Transverse Displacement

4.4Base Shear

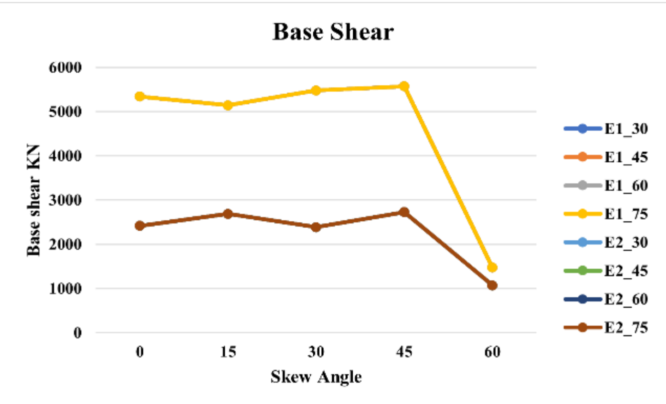

Fig - 11: Base Shear

Fig - 11 show the maximum base shear of models under non-linear time history analysis. In the case of earthquake one, base shear is a 3.89% decrease between 0 to 15 degrees, 15 to 30 degrees 6.20% increase, 30 to 45 degrees 1.61% increase and in 60 degrees it will decrease of difference with 4093.5KN. In the second earthquake analysis, it changed 10 to 13% between 0 to 45 degrees, but it decreased at 60 degrees of skew angle.

5.CONCLUSION

In this study analysis of composite skew box girder bridge with corrugated steel web is carried out & dynamic response of the same bridge has been observed considering different speed & non-linear time history.

The result of vertical displacement shows increases of 22.37% at a skew angle of 15 degree, 35.50% at a skew angle of 30 degree, 59.33% at a skew angle of 45 degree, 75.25% at a skew angle of 60 degree as compare to transverse displacement of 0-degree skew angle.

Results of transverse stress shows slightly increases for skew angle between 0 to 30. It shows increase of 67.48% for the skew angle of 45 degrees & further increases in skew angle at 60 degree shows it 44% of increases as compare to transverse displacement of 0-degree skew angle.

Result of base shear and transverse displacement shows very minor difference between skew angle of 0 to 45 degrees for the earthquake 1(Chamoli Earthquake) and earthquake 2(Bhuj Earthquake) but for the skew angle 60 degrees it shows 29.43% and 45.72% increase in result of transverse displacement for earthquake 1(Chamoli Earthquake) and earthquake 2(Bhuj Earthquake) respectively and the increase in skew angle of 60 degrees shows 72.35 % and 55.64 % decrease in result of base shear respectively.

REFERENCES

[1] Hamid Reza Ebrahimi Motlagh, Alireza Rahai, "Dynamic response of a continuous-deck bridge with different skew degrees to near-field ground motions", International Journal of Civil Engineering, 2017.

[2] Tanmay Gupta, Manoj Kumar "Flexural response of skew-curved concrete box-girder bridges", Engineering Structures, 2018.

[3] Won Choi, Iman Mohseni, Jongsup Park, Junsuk Kang, "Development of live load distribution factor equation for concrete multicell box-girder bridges under vehicle loading", International Journal of Concrete Structures and Materials, 2019.

[4] Iman Mohseni, A. R. Khalim, Ehsan Nikbakht, "Effectiveness of skewness on dynamic impact factor of concrete multicell box-girder bridges subjected to truck loads", Arab J Sci Eng, 2014.

[5] Ya-Na Mao, Chi Ma, Shi-Zhong Liu, Li-Yuan Li, "Study on the dynamic response of composite box girder bridges with corrugated steel webs" Advances in Civil Engineering, 2023.

[6] Chundi Si, Xin Su, Enli Chen, Zhan You Yan, "Comparative study on dynamic response of deck pavement of two kinds of box girder bridges under moving loads", Advances in Civil Engineering, 2019.

[7] Demeke B. Ashebo, Tommy H. T. Chan, Ling Yu, "Evaluation of dynamic loads on a skew box girder continuous bridge part i: field test and modal analysis", Engineering Structure, 2006.

[8] S. Mahboubi, M. R. Shiravand, "Failure assessment of skew rc bridges with frp piers based on damage indices", Engineering Failure Analysis, 2019.

[9] H. He, X. W. Sheng, A. Scanlon, D. G. Linzell, X. D. Yu, "Skewed concrete box girder bridge static and dynamic testing and analysis", Engineering Structure.

[10] Huang Zeng, Charles W. Bert, "Dynamic amplification of bridge/vehicle interaction: a parametric study for a skewed bridge", World Scientific,2003.

[11] Ehsan Omranian, Adel E. Abdelnaby, Gholamreza Abdollahzadeh, "Seismic vulnerability assessment of rc skew bridges subjected to mainshock-aftershock sequences", Soil Dynamic and Earthquake Engineering, 2018.

[12] B. Kovesdi, B. Jager, L Dunai, "Bending and shear interaction behavior of girders with trapezoidally corrugated webs", Journal of Constructional Steel Research, 2016.

[13] Hongmeng Huang, Yuanhai Zhang, Wei Ji, Kui Luo, "Theoretical study and parametric analysis on torsion of composite box girder bridge with corrugated steel web", Journal of Bridge Engineering, 2023.

[14] Monirul Mallick, Prishati Raychowdhury, "Seismic analysis of highway skew bridges with nonlinear soil-pile interaction", Transportation Geotechnics, 2015.

[15] Yulin Feng, Lizhong Jiang, Wangbao Zhou, "Improved analytical method to investigate the dynamic characteristics of composite box beam with corrugated webs", International Journal of Steel Structure, 2018.

[16] M.F. Hassanein, A.A. Elkawas, A.M. EI Hadidy, Mohamed Elchalakani, "Shear analysis and design of high strength steel corrugated web girders for bridge design", Engineering Structure, 2017.

[17] Ruijuan Jiang, Qiming Wu, Yufeng Xiao, Manlin Peng, Francis Tat Kwong Au, "The shear lag effect of composite box girder bridges with corrugated steel webs", Structure, 2023.

[18] Ahmed Abdel-Mohti, Gokhan Pekcan, "Seismic response of skewed rc box girder bridges", Earthquake Engineering and Engineering Vibration, 2008.

[19] Fan Shi, Dongsheng Wang, Lei Chen, "Study of flexural vibration of variable cross-section box-girder bridges with corrugated steel webs", Structure,2021.

[20] Qiangbo Li, Man Zhou, "Study on the natural frequency of box girder with corrugated webs", Journal of Constructional Steel Research, 2023.

[21] Fan Shi, Dongsheng Wang, Lei Chen, "Numerical investigation on the nonlinear shear behaviour of high strength steel tapered corrugated web bridge girders", Engineering Structure, 2016.

[22] IRC 06, Load and Loads Combinations, standard Specification and Code of Practice for Road Bridges; Indian Road Congress, New Delhi, 2017.

[23] IRC 22, standard Specification and Code of Practice for Road Bridges, Composite Construction, 2015.

[24] Vibration of solids and structures under moving loads, institute of theoretical and applied mechanics, 1999.