IMPORTANCE OF SHEAR FORCE AND BENDING MOMENT DIAGRAMS FOR DIFFERENT CIVIL ENGINEERING STRUCTURES

Syed Nasir Abbas*[1], Saad Hassan, Talha Faisal, Azhar Iqbal, Danial Anwar, Abdullah bin Naeem,
[1]Departmenof Engineering Technology, College of Engineering and Technology, University of Sargodha, Sargodha, Pakistan
* Corresponding Author, E-mail: nasir051@gmail.com

ABSTRACT: *The following report discusses the importance and necessity of shear force and bending moment diagram working on different structures of civil engineering and also discusses their use in the field of civil engineering so that the shear force acting on the structure and understanding the importance of bending moment. At the same time, their objectives are stated. It describes the effect of shear force and bending moment on different structures of the building such as columns, beams, trusses, piles, and foundations. To show the importance of the share force and banding moment acting on each member, the research of different researchers is included with references so that the importance of share force and banding moment can be better highlighted. Finally, some recommendations have been made to make the shear force and bending moment diagrams better and more effective.*

Keywords: Shear force, Bending Moment, Types of beams, Conjugate beam Method

I.INTRODUCTION

The total force acting on any beam as a result of its own and external loads perpendicular to the longitudinal axis of the beam is called the shear force. This shear force is expressed in the form of a specific type of drawing that's called a Shear Force Diagram (SFD).

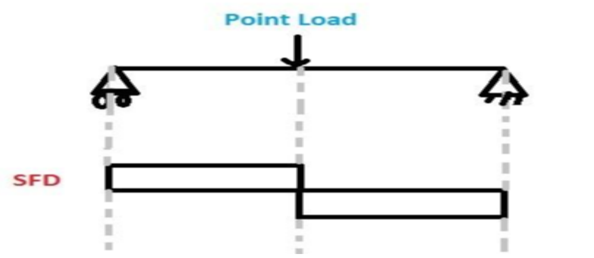

Figure. 1 Shear force diagram due to central point load

To determine the share force on a particular part of a beam, the algebraic sum of all the forces acting from one side of the beam to that point is found, and this value represents the share force at that point. In beam design, it is very important to know the share force at different places of the beam as well as the extreme share force.

The diagram shows a beam carrying loads. It is simply supported at two points where the reactions are assumed that the beam is divided into two parts by section XX. The resultant of the loads and reaction acting on the left of AA is F vertically upwards, and since the whole beam is in equilibrium, the resultant force to the right of AA must be F downwards. F is called the Shearing Force in section AA.

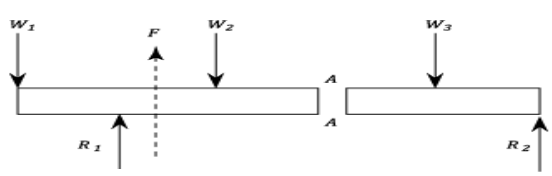

Figure. 2 Shear force distribution along the span of a beam

The moment that results from the load acting on a beam and its own weight is called the bending moment because it tries to bend the beam.

This bending moment is expressed in the form of a specific type of drawing that's called the Bending Moment Diagram (BMD).

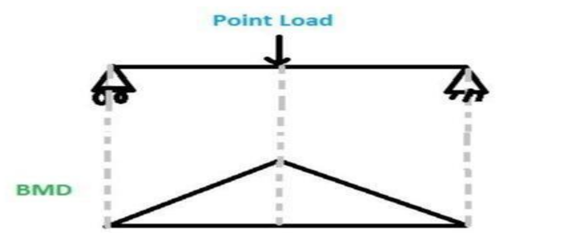

Figure. 3 Bending Moment diagram due to central point load

To determine the value of a moment at a point in the beam, the sum of all the forces applied from one end of the beam to that point and the product of their vertical distances is found. In a similar manner, it can be seen that if the Bending moments (BM) of the forces to the left of AA are clockwise, then the bending moment of the forces to the right of AA must be anticlockwise. The bending Moment at AA is defined as the algebraic sum of the moments about the section of all forces acting on either side of the section. Bending moments are considered positive when the moment on the left portion is clockwise and on the right anticlockwise. This is referred to as a sagging bending moment as it tends to make the beam concave upwards at AA. A negative bending moment is termed hogging.

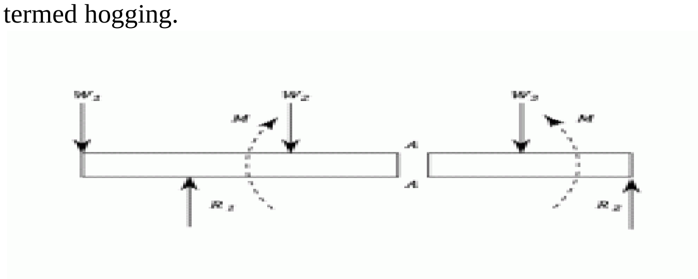

Figure. 4 Bending Moment distribution along the span of a beam

II. OBJECTIVES

The main objective of this research is to study shear force and bending moment in civil engineering. The main objectives are as under:

- We can use a shear force diagram to analyse the beams.
- The shear force diagram indicates the shear force resisted by the beam section along the length of the beam.
- The bending moment diagram indicates the bending moment resisted by the beam section along the length of the beam.
- Shear and bending moment diagrams are analytical tools used in conjunction with structural analysis to help perform structural design by determining the value of shear force and bending moment at a given point of an element.
- Using these diagrams, the type and size of a member of a given material can be easily determined.
- Another application of shear and moment diagrams is that the deflection can be easily determined using either the moment area method or the conjugate beam method.

III. LITERATURE REVIEW

In civil engineering, we determine the shear force and bending moment of each member for the construction of a building so that we can improve it ahead of time if necessary. We can find it in a special way.

Two methods able to capture with different levels of accuracy the discontinuities in the bending moment and shear force laws in the dynamic analysis of continuous structures subject to a moving system modeled as a series of spring masses are presented. The two methods are based on the dynamic-correction method, which improves the conventional series expansion by means of a pseudo-static term, and on an Eigen function series expansion of the continuous system response, which considers the effect of the moving masses on the structure, respectively [1].

Accurate construction of shear force and bending moment diagrams (V/M diagrams) is one of the most important skills students learn in the Statics course since mastery of this topic is a prerequisite to the successful design of beams and shafts in courses such as Mechanics of Materials, Machine Design, Structural Analysis, and Structural Design. Unfortunately, a significant proportion of Statics students do not attain adequate proficiency in constructing V/M diagrams. In response to this problem, several computer-based learning aids have been developed in recent years to improve student performance in constructing V/M diagrams. Although results have been encouraging, assessment of the effectiveness of these learning aids have often been limited in scope. Engineering mechanics instructors at the University of Missouri – Rolla have addressed this problem by developing and testing a series of computer-based learning aids on V/M diagrams for use by Statics students and instructors. Approximately 230 students participated in the assessment. About forty percent used computer-based learning aids and the rest served as a control group. Quantitative and qualitative measures were used for comparison, and subjective comments were solicited from each group. Students in the experimental group scored significantly higher on learning outcomes and confidence ratings with respect to the content covered in the computer-based learning aids. This paper describes the computer-based exercises developed for V/M diagrams and their assessment [2].

This paper describes the design, construction, and testing of a load cell to measure the axial force, shear force, and bending moment at the end of a structural beam. The capacities of the load cell are 780 kN in axial load, 350 kN in shear, and 200 kN/m in bending. These magnitudes, together with the requirement that the load cell should be kept as slim as possible, necessitate a novel design comprising three steel double-spring elements machined with semicircular channels to provide localized strain amplification. The load cell was designed with the aid of detailed finite element analysis and was machined from grade 55 steel. After strain gauging, it was subjected to an extensive series of calibration tests. Results from these tests are reported, together with those from some early experiments in which two load cells were used to measure the behavior of structural steel knee elements [3]..

The performance of a prestressed concrete beam, subjected to bending moment MM together with shear force VV, has been the object of many studies and is an important aspect to consider in the design. Some models, proposed by researchers and international codes, evaluate the shear strength of prestressed beams by modifying the truss model by Moesch, so as to account for the different slopes of stress fields in the web due to the prestressing action. More recent approaches add a strut-and-tie model to the traditional truss model. This paper generalizes a model that was previously proposed for box and I-shaped reinforced concrete cross-sections of structural elements. The model, which now includes the effect of prestressing tendons, considers variable-depth stress fields applied to the cross-section, subdivided into layers, and allows evaluation of normalized m–vm–v design domains depending both on the web and flange reinforcement and on the slope of the prestressing steel tendons. The reliability of the method has been validated by comparing its numerical results to the strength provided by tests on reinforced concrete beams and on thin-webbed prestressed concrete beams, referred to in the literature. Finally, it has been used in the design of a pretension bridge beam to evaluate the additional reinforcement necessary in the flanges, as a function of the reinforcement provided to the web [4].

This paper describes a mathematical tool for the calculation of the ultimate strength of reinforced concrete rectangular columns subjected to combined internal forces including shear. The proposed method is based on the application of the static theorem of limit analysis and considers simplified stress fields to simulate stresses in steel bars and (unconfined and confined) concrete. Both truss and arch effects are taken into account. To assess the effectiveness of the method, the relations developed are applied with reference to a large number of columns tested in the past by many researchers, and a comparison between the theoretical and experimental results is drawn. Finally, the results of the proposed method are compared to others deriving from the application of more simplified methods present in the literature [5].

Conclusions from a published longitudinal beam action calculation of the tunnel lining at the Shanghai Yangtze River Tunnel (SYRT) are evaluated against experience gained in Dutch research on longitudinal beam action. The former aimed at quantifying the shear force in the tunnel lining during the construction phase of the tunnel in relation to the grouting process. For the evaluation of calculated shear forces, a recently developed one-dimensional beam action model is applied. The paper compares the principles of the two calculation methods and the outcomes. Massive shear forces were predicted in the original calculations for the SYRT, whereas these are much smaller according to this recent model. This is attributed to differences in the treatment of boundary conditions, particularly regarding the longitudinal bending moment in the tunnel lining. It is advised to devise a method to measure the shear force that is transmitted by the set of hydraulic jacks between the TBM and the tunnel lining [6].

As early as 1973, Menkes and Opat (Exp Mech 1973; 13:480–6) conducted an experimental investigation on the dynamic plastic response and failure of fully clamped metal beams subjected to a uniformly distributed impulsive loading and identified three basic failure modes: large inelastic deformation (Mode I), tensile tearing (Mode II) and transverse shear failure at the supports (Mode III). A rigid-plastic analysis was later carried out by Jones (Trans ASME J England 1976; 98 (B1): 131–6), in which an elementary failure criterion was adopted to estimate the threshold impulsive velocities at the onset of Mode II or Mode III failure. A deep understanding of these three basic failure modes is of fundamental importance to failure analyses of various structures under intense dynamic loading. The present paper re-examines the plastic shear failure (Mode III) of impulsively loaded clamped beams, with a focus on two effects: (i) the interaction between the shear force and bending moment; and (ii) the weakening of the sliding sections during the failing process. Dimensional analysis is first performed to obtain a general form of the threshold impulsive velocity, which overlooks succeeding concrete analyses. The elementary failure criterion is then modified to incorporate the sliding sections' weakening effect. Interaction between the shear force and the bending moment at the supporting ends is considered by using a circular yield curve (Robinson, Int J Solids Struct 1973; 9:819), Hodge's curve (J Appl Mech 1957; 24:453–6), or a yield condition based on slip-line solutions. By taking into account the variation with time of the shear force and the bending moment over the failing cross-sections, the plastic deformation and failure process of the beams are traced and the ratio of plastic shear dissipation to the total plastic dissipation is thus calculated. This is followed by a discussion on a shear strain failure criterion. Finally, the predictions from various approaches are compared with each other as well as with relevant experimental results [7].

Fiber-reinforced polymer (FRP) plates can be bonded to the tension face of a reinforced concrete (RC) beam to increase its flexural capacity. Many studies have reported premature failure by de-bonding of the FRP plate before the ultimate flexural capacity of the plated section is reached, and the most commonly reported de-bonding failure mode occurs at or near the plate end. This paper presents the results of an experimental investigation into the interaction between shear force and bending moment at the plate end at de-bonding for FRP-plated beams by varying the length of the plate. The experimental results are compared with a plate end de-bonding strength model recently proposed by the authors in this interaction is ignored. A bi-linear approximation is then proposed to describe the interaction between the shear force and the bending moment at the plate end at de-bonding based on the present results. The effect of U-strip end anchorage used to delay or prevent plate end de-bonding is also assessed in this study but it is shown that U-strip end anchorage provides only limited strength enhancement [8].

A graphical method of analysis is presented for the preliminary design of outrigger truss-braced high-rise shear wall structures with non-fixed foundation conditions subject to horizontal loading. The method requires the calculation of six structural parameters: bending stiffness for the shear wall, bending and racking shear stiffnesses for the outrigger, an overall bending stiffness contribution from the exterior columns, and rotational stiffnesses for the shear wall and column foundations [9].

The distribution of longitudinal shear along an interface between steel and concrete of composite trusses are generally highly non-uniform, exhibiting peaks above truss nodes (unless after plastic redistribution). The investigation presented here examines experimentally the behavior of two steel and concrete composite truss girders, using the perforated shear connector to reach a full shear connection. Experimental results have served to calibrate the non-linear 3D numerical FE model formulated using the ANSYS software package. More than 30 variants of shear connections of a simple truss with Vierendeel panel at mid-span have been studied, having various load–slip relationships obtained from previous research. Distinctive peaks of shear flow in the connection above truss nodes have been found within elastic behavior–especially important for connectors loaded in fatigue–followed by plastic redistribution in the plastic region. Comparison of the numerical results with proposals given in Eurocode 4 and the influence of shear connection densification above truss nodes are discussed in a detail. Finally, some recommendations for practical design are presented [10].

Aspects relating to the shear strength of circular and rectangular columns under seismic loading are presented. An examination of existing design equations reveals wide differences in predicted responses. Particular emphasis is placed on models capable of representing the interaction between flexural ductility and shear strength. A simple method is proposed whereby the strength enhancement provided by axial compression is separated from the concrete component of shear strength and considered to result from arch action. The strength of the concrete component is reduced as flexural displacement ductility increases. Predictions of shear strength from the proposed and alternative methods are compared with results from a wide range of tests of columns failing in shear. The proposed method is shown to provide a significantly improved correlation with experimental results. Conservative modifications are made to enable the method to be used for design [11].

Bridge columns are subjected to combined actions of axial force, shear force, and bending moment during earthquakes, caused by spatially-complex earthquake motions, features of structural configurations, and the interaction between input and response characteristics. Combined actions can have significant effects on the force and deformation capacity of RC columns, resulting in unexpected large deformations and extensive damage that in turn influences the performance of bridges as vital components of transportation systems. This paper evaluates the seismic response of three prototype reinforced concrete bridges using comprehensive numerical models that are capable of simulating the complex soil-structural interaction effects and nonlinear behavior of columns. An analytical approach that can capture the shear-flexural interacting behavior is developed to model the realistic nonlinear behavior of RC columns, including the pinching behavior, strength deterioration, and stiffness softening due to combined actions of shear force, axial force, and bending moment. Seismic response analyses were conducted on the prototype bridges under suites of ground motions. Response quantities of bridges (e.g., drift, acceleration, section forces, section moment, etc.) are compared and evaluated to identify the effects of vertical motion, structural characteristics, and shear-flexural interaction on the seismic demand of bridges [12].

In August 2014, the Ruytenschildt bridge a reinforced concrete solid slab bridge in grassland in the Netherlands were tested until failure. One of the goals of the experiment is to analyze the failure mode of the slab bridge under a tandem of 4-wheel loads and to compare the capacity of the full bridge structure of the predicted results, to have an idea of the residua; strength of existing bridges. The methods used are experimental (testing of the bridge to failure in two of its five spans) and analytical. The analytical work involved predicting the bending moment capacity, the shear capacity, and the punching capacity of the bridge. In both spans, the bridge failed in flexure. The total capacity during the experiment was significantly higher than predicted the results indicate that the traditional rating procedures for shear are very conservative when applied to slab bridges that benefit from transverse load redistribution [13].

The girder bridge is one of the most popular bridge types throughout the world. Although much effort has been made to study the impact factor (IF) of simply supported bridges due to vehicle loading, fewer works have been reported on continuous bridges. In addition, most of the previous research on IFs has focused on the bending moment effect, whereas very few studies have focused on the shear effect. In this study, numerical simulations were performed to study the dynamic IFs of both simply supported and continuous bridges due to vehicle loading. IFs for both shear and bending moments were investigated. Some interesting findings were obtained regarding the relationships between the IFs of simply supported and continuous bridges, for both shear and bending moments. These findings can be used as additional references for bridge codes by practicing engineers [14].

Earthquakes are natural hazards which because disasters are mainly caused by damage to or collapse of buildings and other man-made structures. Experience has shown that for new constructions, establishing seismic-resistant controls and their implementation is an important safeguard against seismic-induced damage. Structure design must be such to ensure that the structure has acceptable strength, and high ductility, and will remain as one, even when applied to very large deformations. Socio-economic development and the High rise in buildings are products of scientific and technological progress. With the development of large cities, urban land shortages, and urban land prices rising, prompting the emergence of modern High rise buildings, elevators' invention of more high-rise buildings are constructed higher. The magnificent high-rise building is a symbol of economic strength and has an important propaganda effect, in an increasingly intense business competition, but also played an important role. Shear walls in buildings must be symmetrically located in a plan to reduce the ill effects of twists in buildings. They could be placed symmetrically along one or both directions in the plan. Shear walls are more effective when located along the exterior perimeter of the building such a layout increases the resistance of the building to twisting. In reality, installing a shear wall to a structural system will surely improve the seismic capacity of the structure. The intention of this study is therefore, to investigate the effect of the position of the shear wall in earthquake performance while taking regular and irregular structures by comparing it with the shear wall at the different positions as taken axial forces, bending moments, and displacements are parameters. This is going to be done in this study work, by carrying out a comprehensive literature survey and analysis of 10-story buildings for zone II and zone IV earthquake zones. Keywords Seismic forces, shear wall, position, bending moment, shear force, etc.[15].

The pile parts above the soil and embedded in the soil are called the first region and the second region, respectively. The fourth-order partial differential equations of both regions for free vibration of a partially supported pile subjected to bending moment, axial force, and shear force are obtained using the small-displacement theory and the Winkler model. It is assumed that the behavior of the material is linear-elastic and that axial force along the pile length and modulus of sub-grade reaction for the second region is constant. The shear effect is included in the partial differential equations by the second derivative of the elastic curve function with respect to shear deformation. Natural circular frequencies and relative stiffness of the pile are calculated for a non-trivial solution of a linear homogeneous system of equations obtained due to the values of axial forces acting on the pile, the shape factors, and the boundary conditions of the pile with both ends free and both ends simply supported; the results are presented in graphs [16].

An experimental apparatus was developed to investigate the behavior of vertically loaded free-head piles in sand undergoing lateral soil movement (*w*f). A large number of tests have been conducted to date. Presented here are 14 typical model pile tests concerning two diameters, two vertical pile loading levels, and varying sliding depths with the movement of driven by a triangular loading block. Results are provided for driving force as well as for induced shear force (*T*), bending moment (*M*), and deflection (*y*) along the piles with *w*f / normalized sliding depth. The tests enable simple expressions to be proposed, drawn from the theory for a laterally loaded pile. The new expressions well capture the evolution of *M*, *T*, and *y* with soil movement observed in current model tests, and the three to five times difference in the maximum bending moment (*M*max) from the two modes of loading. They further offer a good estimate of *M*max for eight in situ pile tests and one centrifuge test pile. The study quantifies the sliding resistance offered by a pile for the given *w*f profiles, pile location (relative to the boundary), and vertical load. It establishes the linear correlation between the maximum thrust (resistance *T*) and *M*max, regardless of the magnitudes of *w*f [17].

IV. CONCLUSION

The film highlights the importance of share force and bending moment diagrams in civil engineering. The results of the studies show that we cannot build a strong and stable structure if we ignore the shear force and banding moment. The share force is actually the total vertical force of the y-axis as a result of a structure's own load and the external load acting on it. Specific methods are used to find out. The moment that results from the load acting on a structure and its own weight is called the banding moment because it tries to bend the structure. The effect of share force and bending moment on different members of the structure such as beams, columns, piles, foundations, and trusses is also discussed. We also included some recommendations for improving bending moment and shear force diagrams.

V. RECOMMENDATIONS

The following are recommendations for further improving share force and banding moment diagrams in civil engineering.

- We can make this easier and more effective by improving the way we know the share force and bending moment and the way we make diagrams.
- We can be further improved by inventing new methods and further researching the old methods so that we can learn more about the members and design them in more stable ways.
- By improving the quality of materials used in construction, we can improve a member's shear force and bending moment accordingly by strength like compression & tensile.
- In today's modern age, in order to know the shear force and bending moment and to get it right and as soon as possible, we have designed the relevant software like auto disk pro in our work is so a currently.
- In Practical Life, the quality of work can be improved by upgrading and further improving the shear force and moment detection machinery of various products, which will increase the accuracy of the results.
- In this regard, we can also design various soft wares to make the preparation of shear force and bending moment diagrams easy, accurate, and fast.

As research continues in today's modern age and so on, without stopping, by following the points mentioned above, we can reach our relevant results, which in Which will improve the work in the coming time and further Consume our time.

VI. REFERENCES

1. B. Biondi, G. Muscolino, and A. Sidoti, "Methods for calculating bending moment and shear force in the moving mass problem," J. Vib. Acoust. Trans. ASME, vol. 126, no. 4, pp. 542–552, 2004, doi: 10.1115/1.1804992.
2. R. Hall, C. Campbell, N. Hubing, and T. Philpot, "Assessment Of Interactive Courseware For Shear Force And Bending Moment Diagrams," pp. 10.235.1-10.235.16, 2020, doi: 10.18260/1-2--14778.
3. A. Blakeborough, D. Clément, M. S. Williams, and N. Woodward, "Novel load cell for measuring axial force, shear force, and bending movement in large-scale structural experiments," Exp. Mech., vol. 42, no. 1, pp. 115–122, 2002, doi: 10.1177/0018512002042001796.
4. A. Recupero, A. D'Aveni, and A. Ghersi, "Bending Moment–Shear Force Interaction Domains for Prestressed Concrete Beams," J. Struct. Eng., vol. 131, no. 9, pp. 1413–1421, 2005, doi: 10.1061/(asce)0733-9445(2005)131:9(1413).
5. P. P. Rossi, "Evaluation of the ultimate strength of R.C. rectangular columns subjected to axial force, bending moment and shear force," Eng. Struct., vol. 57, pp. 339–355, 2013, doi: 10.1016/j.engstruct.2013.09.006.
6. A. M. Talmon and A. Bezuijen, "Calculation of longitudinal bending moment and shear force for Shanghai Yangtze River Tunnel: Application of lessons from Dutch research," Tunn. Undergr. Sp. Technol., vol. 35, pp. 161–171, 2013, doi: 10.1016/j.tust.2013.01.001.
7. T. X. Yu and F. L. Chen, "A further study of plastic shear failure of impulsively loaded clamped beams," *Int. J. Impact Eng.*, vol. 24, no. 6–7, pp. 613–629, 2000, doi: 10.1016/s0734-743x(99)00038-x.
8. S. T. Smith and J. G. Teng, "Shear-bending interaction in debonding failures of FRP-plated RC beams," Adv. Struct. Eng., vol. 6, no. 3, pp. 183–199, 2003, doi: 10.1260/136943303322419214.
9. J. C. D. Hoenderkamp, "Shear wall with outrigger trusses on wall and column foundations," Struct. Des. Tall Spec. Build., vol. 13, no. 1, pp. 73–87, 2004, doi: 10.1002/tal.235.
10. J. Machacek and M. Cudejko, "Longitudinal shear in composite steel and concrete trusses," *Eng. Struct.*, vol. 31, no. 6, pp. 1313–1320, 2009, doi: 10.1016/j.engstruct.2008.07.009.
11. M. J. N. Priestley, R. Verma, and Y. Xiao, "Seismic

Shear Strength of Reinforced Concrete Columns," J. Struct. Eng., vol. 120, no. 8, pp. 2310–2329, 1994, doi: 10.1061/(asce)0733-9445(1994)120:8(2310).

12. J. Zhang and S. Y. Xu, "Seismic response simulations of bridges considering shear-flexural interaction of columns," Struct. Eng. Mech., vol. 31, no. 5, pp. 545–566, 2009, doi: 10.12989/sem.2009.31.5.545.
13. E. O. L. Lantsoght, C. van der Veen, and A. de Boer, "Shear and moment capacity of the Ruytenschildt bridge," Maintenance, Monit. Safety, Risk Resil. Bridg. Bridg. Networks - Proc. 8th Int. Conf. Bridg. Maintenance, Saf. Manag. IABMAS 2016, pp. 2212–2219, 2016.
14. A. González, D. Cantero, and E. J. Obrien, "Dynamic increment for shear force due to heavy vehicles crossing a highway bridge," Comput. Struct., vol. 89, no. 23–24, pp. 2261–2272, 2011, doi: 10.1016/j.compstruc.2011.08.009.
15. S. Gupta, S. Akhtar, and A. Hussain, "Effect of Shear Wall Location on Bending Moment and Shear Force of Multistory Building Subjected to Earthquake Loading," Int. J. Comput. Adv. Eng. Res., vol. III, no. II, pp. 1–21, 2016.
16. H. H. Catal, "Free vibration of partially supported piles with the effects of bending moment, axial and shear force," Eng. Struct., vol. 24, no. 12, pp. 1615–1622, 2002, doi: 10.1016/S0141-0296(02)00113-X.
17. W. D. Guo and H. Y. Qin, "Thrust and a bending moment of rigid piles subjected to moving soil," Can. Geotech. J., vol. 47, no. 2, pp. 180–196, 2010, doi: 10.1139/T09-092.