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Study of Steel Bridge and Design of its Prototype

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Abstract: The "Study of Steel Bridge and design of its prototype" is based on reviewing existing literatures, project reports and researches in steel bridge structures. The study depends upon the different aspects in design considerations of a steel bridge where its main focus is to understand the scaling law and design of a prototype of a steel bridge structure.
The study includes
a) Classification of bridges which helps in categorizing the bridges on basis of their structures
b) Types of steels used in bridges and their strength which helps to understand the importance of types of steel, its strength and when to use it.
c) Tests conducted on bridges which help in determining safety, durability and loading capacity of bridge.
d) Loads on bridges to understand type of loadings a bridge has to sustain.
f) To reduce the cost of experimentation a technique is used its main objective is to conduct experiments on structures at reduced scales which is known as Scaling prototype. Cost is cheap due to the dropping in the loading equipment and dropping in the cost of test structure fabrication and testing.
The researchers must be watchful and pure on how far the model behaves similar to the prototype
By properly applying scaling laws, it is possible to infer the behaviour of a structure from the response of a similar model whose dimensions are scaled by a factor b. In some cases, however, e.g. in case of the strain rate sensitive of structures under serves the dynamic loads, these laws become inaccurate, rigorously limits this approach. It is exposed that the behaviour of a structure, if made of mild steel, can be predicted from the response of a model. The technique used here is publicised to be valid for simple structues subjected to the transverse and axial impact loads.
Keywords: Categorizing, Scaling, Prototype, Fabrication, Determining, Testing, watchful, Experimentation, Technique

I. INTRODUCTION

Steel bridges are widely used around the globe in different structural forms with different length, spans height, such as, railway bridges, highway bridges and footbridges. The main advantages of using structural steel over other traditional construction materials are its high strength, ductility, easy fabrication technique, and rapid construction. It has a greater strength in both compression and tension than conventional concrete, and has a relatively good stiffness to weight ratio and. Also strength to cost ratio
Steel is a versatile and effective construction material that provides efficient and a great sustainable solutions for bridge construction, particularly for long span bridges or bridges which requires high resistance against seismic loads.
The structural steel required for the construction of steel bridges should be selected according to the required material properties or the stress state where used, environmental conditions at that specific construction method, corrosion safeguard method, construction site, etc. The physical properties of a structural steel such as strength, toughness, ductility, weld ability, weather resistance, chemical composition, size, shape and surface characteristics are the important factors to be considered while designing and construction of steel bridges.

Following three categories of structural steel are often used for steel bridge construction including
1) Carbon steel,
2) High-strength steels, and
3) Heat-treated carbon steels.

The stiffness to weight ratio of structural steel is much greater than that of concrete as a construction material. Thus, structural steel is known as an efficient and economic material in construction of bridges. Structural steel has been a natural solution for bridges having longer span since 1890, when the Firth of Forth cantilever bridge, the world's major steel bridge at that time was completed. Steel is indeed suitable for most span ranges, but particularly for longer spans bridges.

II. LITERATURE REVIEW

A. Structural Modelling with Experimental Techniques

By Sabnis, and Harris, G.M. (2000).Concentrates on the modelling of the true inelastic behaviour of structures. Offers case histories detailing submissions of the modelling techniques to real structures. Deliberates the past background of model analysis and similitude principles leading the interpretation of models and testing of models Assesses the boundaries and paybacks of elastic models.

B. For Buckling A New Way For Launching Structural Similitude Of Symmetric Cross-Ply Covered Plates Are Exposed To Combined Loading

By Ungbhakorn, V. (2001), International journal of science and technology. The validity of the scaling laws is verified numerical experiments. It is done by measuring the buckling loads or the fundamental frequencies of the model for free vibration and substituting the values in scaling laws. The predicted values of the prototype from the scaling laws are matched with those values from the closed-form explanation. Examples for the whole similitude cases with various loading arrangements and radius ratios show precise agreement

C. When The Model And Prototype Are Made Of Different Materials It Impacts Scaling Of Structures

International Journal of Solids and Structures, Volume 43, Issue 9, May (2006), Pages 2744-2760, Marcílio Alves Roberto Eiki Oshiro. By appropriately applying scaling laws, it is likely to infer the behaviour of a structure from the response of a similar model whose dimensions are scaled by a factor β. In some cases, however, e.g. in strain rate sensitive structures it undergoes dynamic loading, these laws become inaccurate, severely limits this method. In this research, a methodology for the correction of this distortion is discovered for this case when the model and the structure are made of different materials having different physical properties. It is exposed that the behaviour of a structure, if made of mild steel, can be predicted from the reaction of a model, or if made of aluminium. The technique used here is exposed to be valid for simple structures subject to transverse and axial impact loads

D. Analytical Investigation And Experimental Research Based On Half (1/2) Scale Model For A Clear Room And Unit Module Consisting Of Structural Steel Unit And Reinforced Concrete Units

By woon choi 2 and sijun kim1, Advances in Materials Science and Engineering (2008). The rapid advances in high technology industries and the increased demand for high valuable and reliability of their production environments call for biggest structures and higher vertical vibration performance for high technology facilities. Therefore, there is an emergent demand for structural design and vertical shaking assessment technologies for high technologically advanced facility structures. For guesstimating the small vibration performance for a clean room unit module in high technology facilities, this study performs the scale modelling experiment or analytical justification.

E. Identification of model factors in a scale model for a Railway bridge

International journal of structural stability Vol. 16 (2016), By Ladislao R. Ticona Melo, Ramon Silva, Tulio Bitten court this paper presented two techniques for determination of the modal parameters of a bridge scale model constructed based upon a real bridge, as part of a real bridge monitoring project. In addition to the experimental scale model, numerical modelling was also used. For the natural frequencies, it can be stated that the experimentally measured values are very close to the numerical ones. Sometimes, the frequencies gained by the numerical model are greater than the experimental frequencies due to the fact that the mathematical model behaves more strictly than that of scale model. For the mode shapes, the MAC matrix obtained in this study shows that the three experimental mode shapes keep a good correlation to the numerical ones obtained.

III. STUDY AREA

For the purpose of study, we have chosen an existing bridge that is located over a river in Portugal.

A railway crossing which is over the River Sado located at Alcacer do Sal in Portugal required a 2.7 km long bridge, including two approach main bridge and via ducts. Steel-concrete composite decks were implemented, the approach via ducts has plate girder decks with 37.5 to 45 m spans, and the main bridge consist of three spans having lenth160 m each with box girder deck. The main bridge, with a continuous deck over 480 m, consists of three continuous bow-strings with a single plane of hangers on the bridge axis. The main features of the bridge concept design are described and the steel design is specifically discussed.

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The new crossing over the River Sado required a bridge 2735 m long, divided up as follows:

1) North approach viaduct – 1115 m
2) Main bridge – 480 m
3) South approach viaduct – 1140 m

Figure.1 Railway Bridge over river Sado aerial view

A ballasted track, with long welded rails was adopted. To take into account track-structure interaction effects together with the required longitudinal seismic resistance of the bridge, the superstructure was divided into continuous bridge decks, as long as possible, divided by simply supported neutral spans, where track expansion devices are placed. Displacements At these expansion devices were minimized by adopting the neutral spans.

The following division has been used:

a) North approach viaduct: 259.75 + 45.0 + 765.0 + 45.0 m
b) Main bridge: 480 m
c) South approach viaduct: 45.0 + 720.0 + 37.5 + 337.5 m

The new railway crossing over the River Sado in Portugal includes a steel-concrete composite bridge 2735 m long. Two plate girder approach viaducts, with typical spans of 45 and 37.5 m, and a bowstring arch bridge, with three main spans of 160 m each, have been adopted. The bowstring shave a single plane of hangers suspending the box girder deck on the bridge axis. The steel reinforced concrete was the great solution shown to have a multiple advantages with respect to concrete alternatives, lowering the environmental impact during the various stages of construction and the final
Structure by reducing the number of piers in the river. Incremental launching was shown to be adequate for erecting all the bridge deck structures

- The design train speed is 240 km/h.
- Concrete grade C40/50 and steel grade fe500 is used.
- According to European standard S 355NL, S460NL are used.

IV. METHODOLOGY

A. *Scaling Concept*

In this procedure the parameters of the structure are given in reduced scale modelling. It is used for studying the structures where detailed analysis of a design needs to be carried out. The prototype can be made of required size using scaling procedures. Here, small structures can be designed for higher scaled model and large structures can be designed on lower scaled models.

Name	G Scale	O Scale	HO Scale	N Scale	Z Scale
Scale	1:22.5	1:48	1:87	1:160	1:220
Gauge	1.75″/45mm	1.25″/31mm	.625″/16mm	.375″/9mm	.25″/6mm

Figure 2 types of scales and their Ratios

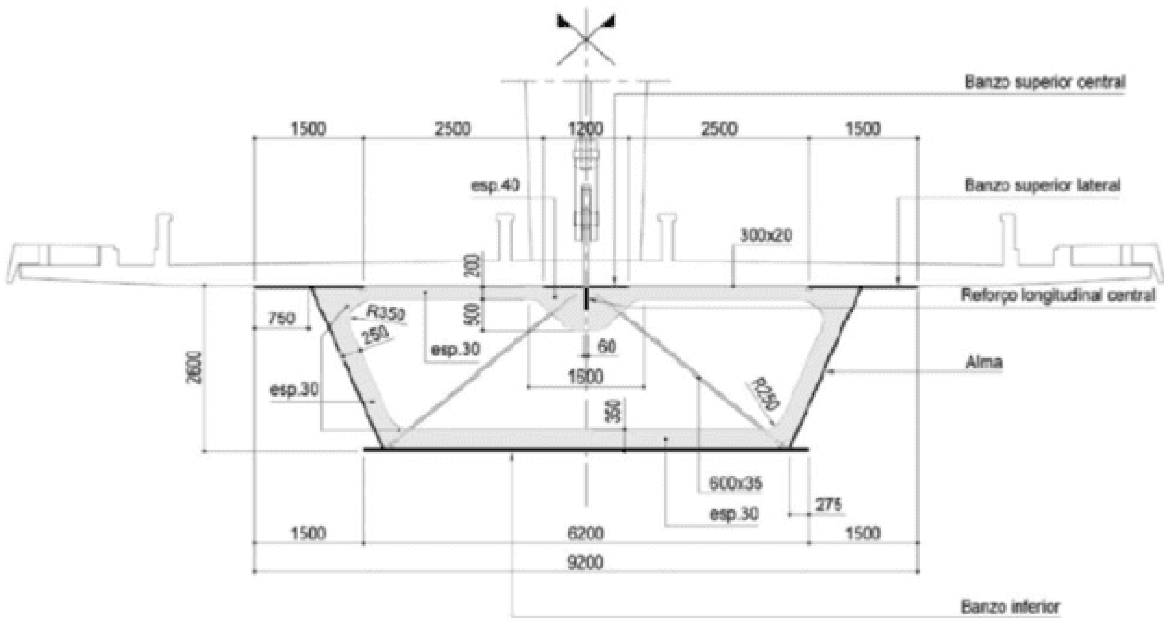

Figure 3 Main Bridge – Section through deck

Determination of the Dimensions using reduced scale method:

1) For making the prototype of the bridge scale used is O scale i.e. 1:37.5
2) The total length of prototype is 1m after reducing the scale.
3) The loading on the span is dynamic/static UDL so considering a section from the total span will have no effect on the design of the section.
4) The bridge is designed for standard train loads, therefore the prototype will also carry the same load on the reduced scale.
5) Actual load is 2500 KN/m.

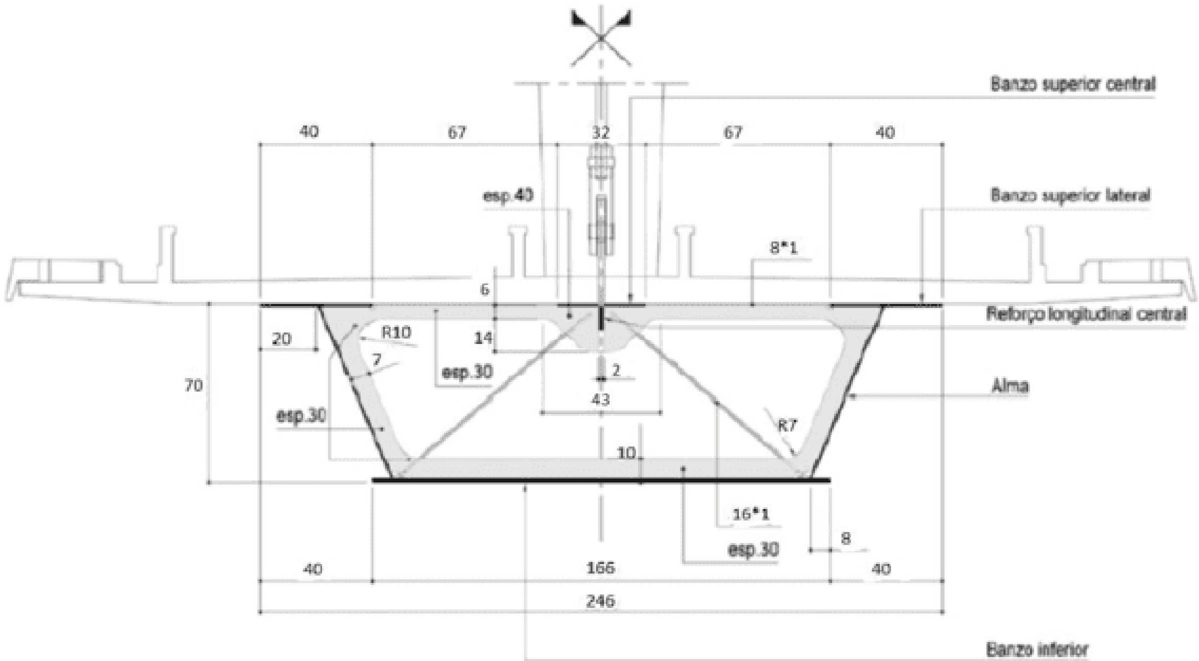

Figure 4 Main bridge section through deck after reduced scale

Here all dimensions are given in "mm".

The above main bridge consists steel-concrete trapezoidal composite deck, continuous over the support sections at the intermediate piers, axially suspended from a single plane of hangers. The bridge deck which is supported on 4 tubular reinforced concrete piers having hexagonal cross-section

B. Equations And Similitude Relations Of The Prototype

Similitude theory regarded to establishing the necessary and sufficient conditions of similarity among them. Here we are using applications of this theory for scaled model or prototype i.e for establishing relations between design and model.

The Buckingham π Theorem is as following

The relation between the prototype and model is called as similitude relation. Every structural model must be loaded, designed and interpreted according to a set of similitude requirements that relate the model to the prototype. Commonly , for any field problem three independent scale factors, which represent three fundamental dimensions, like mass (M), length (L) and time (T), need to be selected for designing the scaled model.

C. Buckingham Pi Theorem

The fundamental measures are commonly based on dimensions such as length, mass, time, temperature, electric charge etc. All equations of physical problems can be expressed as Eq. (1)

$f(x1, x2, \ldots, xk) = 0$ ……………………………(1)

Where x1, x2, upto xk are called k physical variables.

Eq. (1) is given in the form of Eq. (2):

$g(\pi 1, \pi 2, \ldots, \pi k\text{-}r) = 0$………………………………(2)

Whereas, π1, π2, ⋯, π k-r are dimensionless products of the k physical variables

Where r = the number of fundamental dimensions (M, L, T) that are involved in the physical problem (i.e. physical variable).

According to above, π terms are given as (π1, π2, ⋯, πk) which must be equal in the model and the prototype, for matching the functional relationship between them.

Dimensional analysis provides substantial advantage in the investigation of physical behaviour of any system because it allows the experimenter to combine the variables into convenient groups (π terms).

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*Using this theorem the procedure to find the dimensionless groups is as follows:

1) List down all the k variables involved in the problem
2) Decomposing the variables in terms of the basic dimensions such as M, L, T
3) Find the number of π terms
4) Find the repeating and non-repeating variables
5) Make a π term for each non-repeating variable forming a relation with the repeating variables
6) Make sure that each π term should be dimensionless.
7) Write down the functional relations between the π terms.

The standard s for selecting the repeating variables are as given below:

a) The repeating variables should be independent variables.
b) They shouldn't form a dimensionless group
c) Two repeating variables in eq^n should not have the same dimensions.
d) It includes the geometric parameters, field parameters and material properties

The above methodology is adopted for different test problems and the similitude relation for geometrical parameters, material properties and loadings can be derived as given in Table 1.

For a scaled down 1/10th model, the scale factor S = 10. And the geometry of the model given should be scaled by a factor S, i.e. lm = lp/S, where as lm and lp are one of the geometrical dimensions of the model and prototype respectively. Corresponding to that, the displacement of model will be S times less than the corresponding displacement in the prototype. The natural frequency of the model will be S1/2 times the given prototype. When the prototype and model are of the same material, then the stress field will be the same and if they are of different materials, then the magnitude of given stress field in the model should be SE times lesser than the stress field of prototype. The similitude relations for loads provide one major benefit on reduced scale elastic models. The concentrated loads are reduced from prototype loads by the factor SES2 .This factor will be very large for small scale plastic model; therefore the above product becomes large, resulting in extremely small loads in the model. The scale factor for the density of the model is equal to SE/S. Wherever there is a change in the derived density and the actual density of the model material, the variation in density is accommodated by either deducting or adding some mass uniformly over the test structure.

D. Analytical Validation of the Scaling Laws

The similitude relations for elastic model have been formulated as given in Table 1. The similitude relation between the prototype and the model was validated analytically by considering two cantilever beams with different loading conditions, boundary conditions, materials, etc. The original (i.e. prototype) beam is made up of steel and the scaled models are assumed to be made up of two different materials entitling Steel and Aluminium.

The properties of materials assumed are steel - Young's modulus E1=200 GPa
density ρ1=7850 kg/m3
Aluminium - Young's modulus E2=70 GPa density ρ2=2700 kg/m3

Parameters	Scale factor
Dimension (h_p = Height or t_p = Thickness)	S
Area A_p	S^2
Volume V_p	S^3
Linear Displacement U_p	S
Moment of inertia I_p	S^4
Frequency f	$S^{-1/2}$
Density ρ_p	S_E/S
Point Load F_p	$S_E \cdot S^2$
Line Load F_L	$S_E \cdot S$
Uniformly Distributed surface Load P_p	S_E
Shear force V_p	$S_E \cdot S^2$
Moment, M or Torque T	$S_E \cdot S^2$
Stress σ_p	S_E

S-Geometric scale factor, S_E-Ratio of Young's Modulus of model and prototype

Table 1 -Similitude Relations

Table 2 describes the similitude relation for the fundamental natural frequency, mass, deflection and stress of the two beams. It is clear from Table 2 that the mass of the scaled model will be S3 times less than the prototype mass for same material i.e. for a scale down factor of 10, the mass of the model will be 103 times lesser than prototype mass. If the model is of different material with considerable variation in the density as the mass of the model will change accordingly. This change in mass i.e., 0.62e-3-0.21e-3=0.41e-3kg for first cantilever beam in Table 2 of the model due to difference in density should be accommodated by adding the mass uniformly throughout the model to have same effect due to self-weight. The deflection in the scaled model will be S times less than the prototype deflection which is described in Table 3. This is correct only when the prototype and the model are made of same material. If both are made of different material, for example if the model is made of a material with low Young's modulus then the stiffness of the model structure will reduce. To maintain same deflection, the load has to be reduced by a factor SE

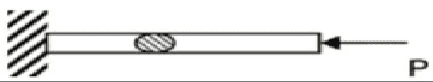
Prototype Structure	Maximum Deflection, δ in m		
	Prototype	Model	
		Same material	Different material
Diameter = 0.01 m, length = 1 m, P = 1000 N 	$\frac{Pl}{AE_1}$ $= 6.37e^{-5}$	$\frac{\left(\frac{P}{S^2}\right)\frac{l}{S}}{\frac{A}{S^2}E_1}$ $= 6.37e^{-6}$	$\frac{\left(\frac{P}{S_E S^2}\right)\frac{l}{S}}{\frac{A}{S^2}E_2}$ $= 6.37e^{-6}$
Width w = 0.1 m, height h = 0.01 m, length = 1 m, P = 1000 N 	$\frac{4Pl^3}{Ewh^3}$ $= 0.2$	$\frac{4\left(\frac{P}{S^2}\right)\left(\frac{l}{S}\right)^3}{E_1\left(\frac{w}{S}\right)\left(\frac{h}{S}\right)^3}$ $= 0.02$	$\frac{4\left(\frac{4}{S_E S^2}\right)\left(\frac{l}{S}\right)^3}{E_2\left(\frac{w}{S}\right)\left(\frac{h}{S}\right)^3}$ $= 0.02$

Table 2 -Similitude Relation for the Mass of a Scaled down Model i.e (S=10)

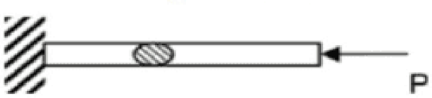
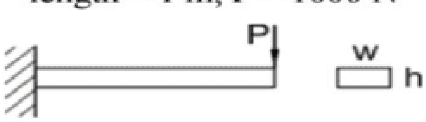
Prototype Structure	Mass of the structure in kg		
	Prototype	Model	
		Same material	Different material
Diameter = 0.01 m, length = 1 m 	$\rho_1\left(\frac{\pi d^2 l}{4}\right)$ $= 0.62$	$\rho_1\left(\frac{\pi\left[\frac{d}{S}\right]^2\frac{l}{S}}{4}\right)$ $= 0.62e^{-3}$	$\rho_2\left(\frac{\pi\left(\frac{d}{S}\right)^2\frac{l}{S}}{4}\right)$ $= 0.21e^{-3}$
Width w = 0.1 m, height h = 0.01 m, length = 1 m, P = 1000 N 	$\rho_1 whl$ $= 7.85$	$\rho_1\left(\frac{whl}{S^3}\right)$ $= 7.85e^{-3}$	$\rho_2\left(\frac{whl}{S^3}\right)$ $= 2.7e^{-3}$

Table 3 -Similitude Relation for Deflection of a Scaled down Model i.e (S=10)

And the stress induced in the scaled model will be the same as that of the prototype which is described in Table no 4. This is also valid only when the model and the prototype are of same material. As given above, in order to obtain same deflection irrespective of the material, the load should be reduced by the factor SE. Due to this calculation, the stress induced will also be lesser by SE times. For the example

Problems considered in Table 3 and 4, the value of SE = 2.857 in case of different materials.

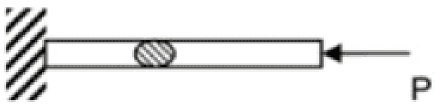
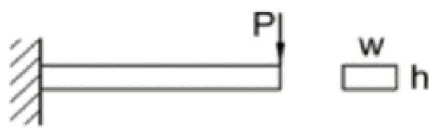
Prototype Structure	Maximum stress, σ in MPa		
	Prototype	Model	
		Same material	Different material
Diameter = 0.01 m, length = 1 m, P = 1000 N 	$\frac{P}{A}$ $= 12.73$	$\frac{\left(\frac{P}{S^2}\right)}{\left(\frac{A}{S^2}\right)}$ $= 12.73$	$\frac{\left(\frac{P}{S_E S^2}\right)}{\left(\frac{A}{S^2}\right)}$ $= 4.46$
Width w = 0.1 m, height h = 0.01 m, length = 1 m, P = 1000 N 	$\frac{6Pl}{wh^2}$ $= 600$	$\frac{6\frac{P}{S^2}\frac{l}{S}}{\frac{w}{S}\left(\frac{h}{S}\right)^2}$ $= 600$	$\frac{6\left(\frac{P}{S_E S^2}\right)\frac{1}{S}}{\left(\frac{w}{S}\right)\left(\frac{h}{S}\right)^2}$ $= 210$

Table 4- Similitude Relation for Stress Induced in a scaled Down Model i.e (S=10)

Hence, the stress induced in the model will be 2.857 times lesser than the prototype stress. On multiplication of the stress value obtained in the model with different material with SE value of 2.857, the actual stress in the prototype can be computed, i.e., [4.45*2.857=12.73]. Then once the similitude relation for the deflection is obtained, the fundamental natural frequency for free vibration can be calculated as per Table 5. It is proved that the fundamental natural frequency will increase by $\sqrt{S}$ times. For a scale down factor of 10, the natural frequency of the model will increase by$\sqrt{10}$ times, i.e., 3.16 times higher. According to Table 5, the natural frequency of the prototype can be calculated by dividing 3.16 with the natural frequency of the model i.e., [(3.53/3.16) =1.12].

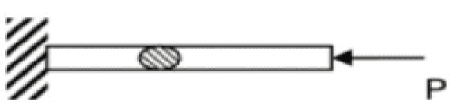
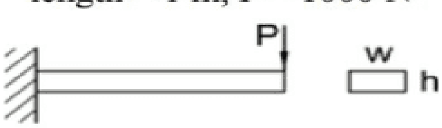
Prototype Structure	Natural Frequency in Hz		
	Prototype	Model with same material	Model with different material
Diameter = 0.01 m length = 1 m, P = 1000 N	$\frac{1}{2\pi}\sqrt{\frac{g}{\delta}}$	$\frac{1}{2\pi}\sqrt{\frac{gS}{\delta}}$	
	62.49	197.61	197.61
Width w = 0.1 m, height h = 0.01 m, length = 1 m, P = 1000 N 	1.12	3.53	3.53

Table 5 - Similitude Relation for Natural Frequency in a Scaled down Model i.e (S=10)

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V. TEST CONDUCTED

A. Impact Test

This test is used in studying the toughness of material. Toughness of material is a factor of its ability to absorb the energy during plastic deformation of the material. Brittle materials have low toughness levels as a result of the small amount of plastic deformation that they can endure. The impact value of a material changes with the temperature. At lower temperature, the impact energy of a material decreases. The size of the specimen may also affect the value of the Izod impact test because it may allow a different imperfection in the material, which can act as stress riser and decrease the impact energy.

Impact testing consists of Charpy and IZOD Specimen configuration. The Charpy impact test are conduct on instrument machines capable of measuring less than 1 foot-pound to 300 foot-pounds at temperature ranging from -320°F to over 2000°F. Impact test specimen type include notch configurations such as V-Notch, U-Notch, Key-Hole Notch, as well as Un-notched and ISO (DIN) V-Notch, with capability of impact testing sub size specimens down to ¼ size. IZOD Impact Testing can be done up to 240 foot-pound on standard single notch and type-X3 specimens.

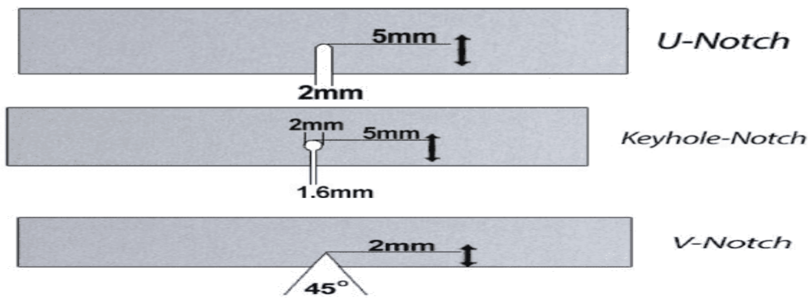

Figure 5 Types of Notches

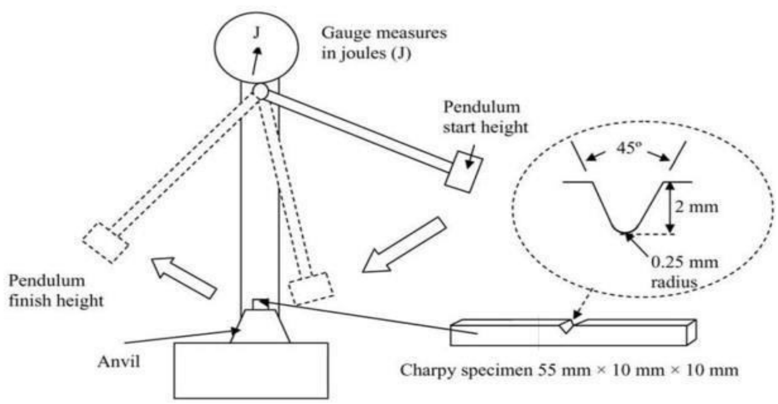

Figure 6 Charpy impact tests

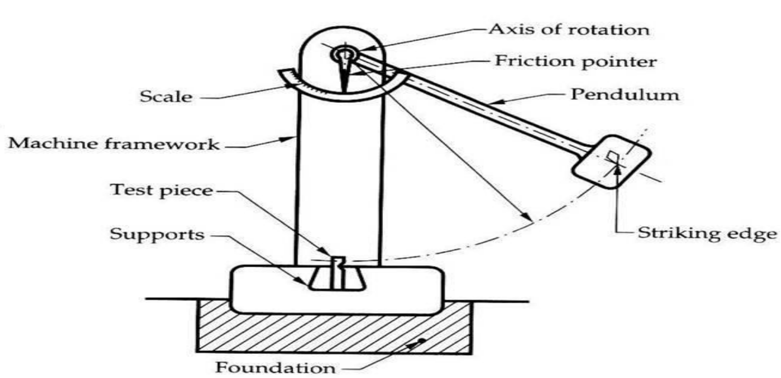

Figure 7 IZOD Impact Strength Test

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B. Drop Weight Test

Drop weight tear testing is performed to ASTM E 208. This test is conducted to determine the nil ductility transition temperature (i.e NDT) of materials. Impact test can also be conducted to according to our temperature requirements from elevated temperature down to -320°F.

C. Dynamic Tear Test

This test has a wide range of Researches and the Development applications in the world.

ASTM E604 is the standard method for Dynamic Tear testing of metallic materials as suggested by ASTM Internationals. For studying the effects of the metallurgical variables such as heat treatment, composition and the processing methods on the dynamic tear fracture resistance of material. Manufacturing processes like welding can be effectively assessed for their effect on dynamic tear fracture resistance. Normally, it includes the evaluating appropriateness for selecting a material for an application where the baseline correlation between the Dynamic Tear energy and the actual performance also developed.

D. Shaking Table Test

A specimen is set up on the table which can be driven by the controllers. Test specimens are normally manufactured for the shaking table test, hence a destructive test can be performed. Miniaturized specimens are sometime used because of the capacity and limits of the table.

The shaking table test is realistic. And this test is clear when the response of a structure during an earthquake is discussed.

In the BRI, one-dimensional middle-sized shaking table is given in the Structural Testing Lab. Newly constructed shaking tables are driven in two- or three-dimensions. They can reproduce actual earthquake motions more faithfully than the one-dimensional tables. Amplitudes of the input harmonic waves are minimum and that their response of specimen remains in the elastic range. Random shaking test using the white noise is used to check the dynamic properties in the elastic range also.

Random shaking using detected strong motions can be simulate actual situation during an earthquake. The amplitude of the strong motion record is adjusted corresponding to the seismic capacity of the specimen and its testing purpose.

Artificial earthquake motions may be used when the strong motion records with the desired characteristics cannot be found out.

But this shaking table test is costly to execute. The construction of shaking table facilities is a big project. Specimens must be newly built only can use for testing. Also there are limitations of size, limitation of the weight due to the shaking table capacity. It is most difficult to reproduce an actual situation.

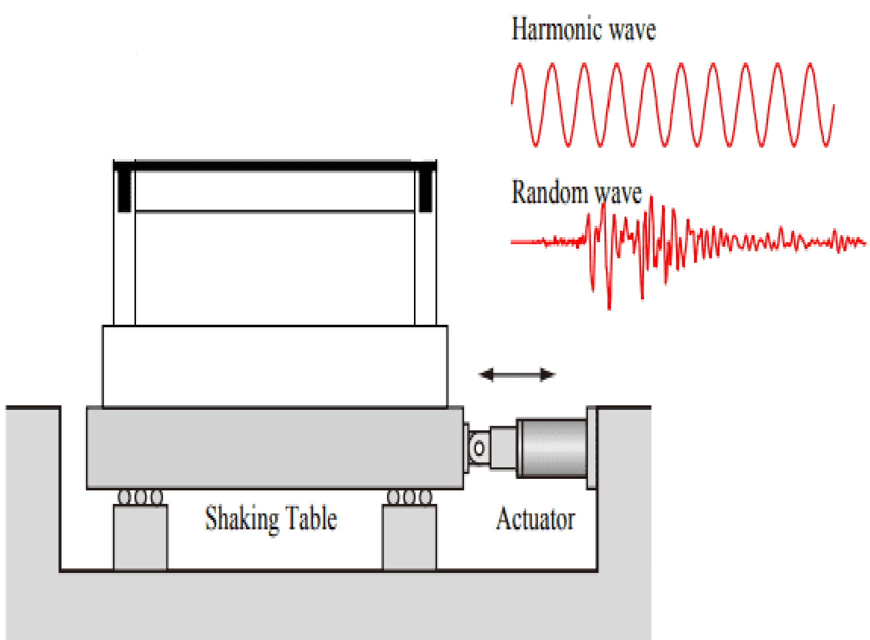

Figure 8 shaking table test

VI. DISCUSSION AND CONCLUSION

After the brief introduction, the structural steel used in bridges and its properties were discussed. The broad classification of bridges was mentioned and also various loads to be considered while designing railway and highway bridges in India were discussed.
The scaled model theory suggests the following approaches-

A. The employment of the similitude theory to establish similarity among structural systems can save considerable expense and time provided, proper scaling laws are found and validated. This study presents the importance of development and applicability of similitude relations of elastic models made of same or different materials. The establishment of similarity conditions and their use in design and analysis of models is presented in this study. An analytical investigation was done and undertaken using simple test problems to understand the better usage of scaled down model in the design of massive structures.

B. The numerical design expedition was also carried out using an existing case study to validate the approach adopted. The study suggests the use of similitude relations to interpret the results of prototype using the advanced model can also be carried out. It is also appealing that the models and the prototypes can be invented from different materials and hence it is possible to make a steel model and assume the behavior of the prototype from the response of steel model. From analysis, we can easily accomplish the complete similarity between the full-size structure and its scaled model. It is also assumed that the technique presented in this paper will provide a useful tool for solving the relevant problems. This study will also help the researchers to grow and apply the similitude relations for their physical problems. Where, the modelling accuracy depends upon the properties of the material used to make the scaled model and also on fabrication accuracy, loading techniques, interpretation of results and measurement methods. Elastic models can easily made to give the high co-relation with the prototype, when the model is fabricated and loaded perfectly.

C. The prototype designed represents one span of the main bridge mentioned in the thesis above. The scaled down bridge or the prototype bridge when fabricated perfectly is expected to show exact same characteristics as of the original bridge constructed under loading. So the study concludes that the experimentations can be carried out on the prototype at lower cost and will exhibit valid results.

The study concludes the pure understanding to the categories of bridges, type of steels used in bridges and scaled modelling and prototyping of designed structure. We carried out prototype design for existing bridge but prototyping methods can also be used for experimental testing of newly designed bridge structures or models. The study mentions a few methods which are generally carried out on structures and when inhibited can also be used for design prototype model

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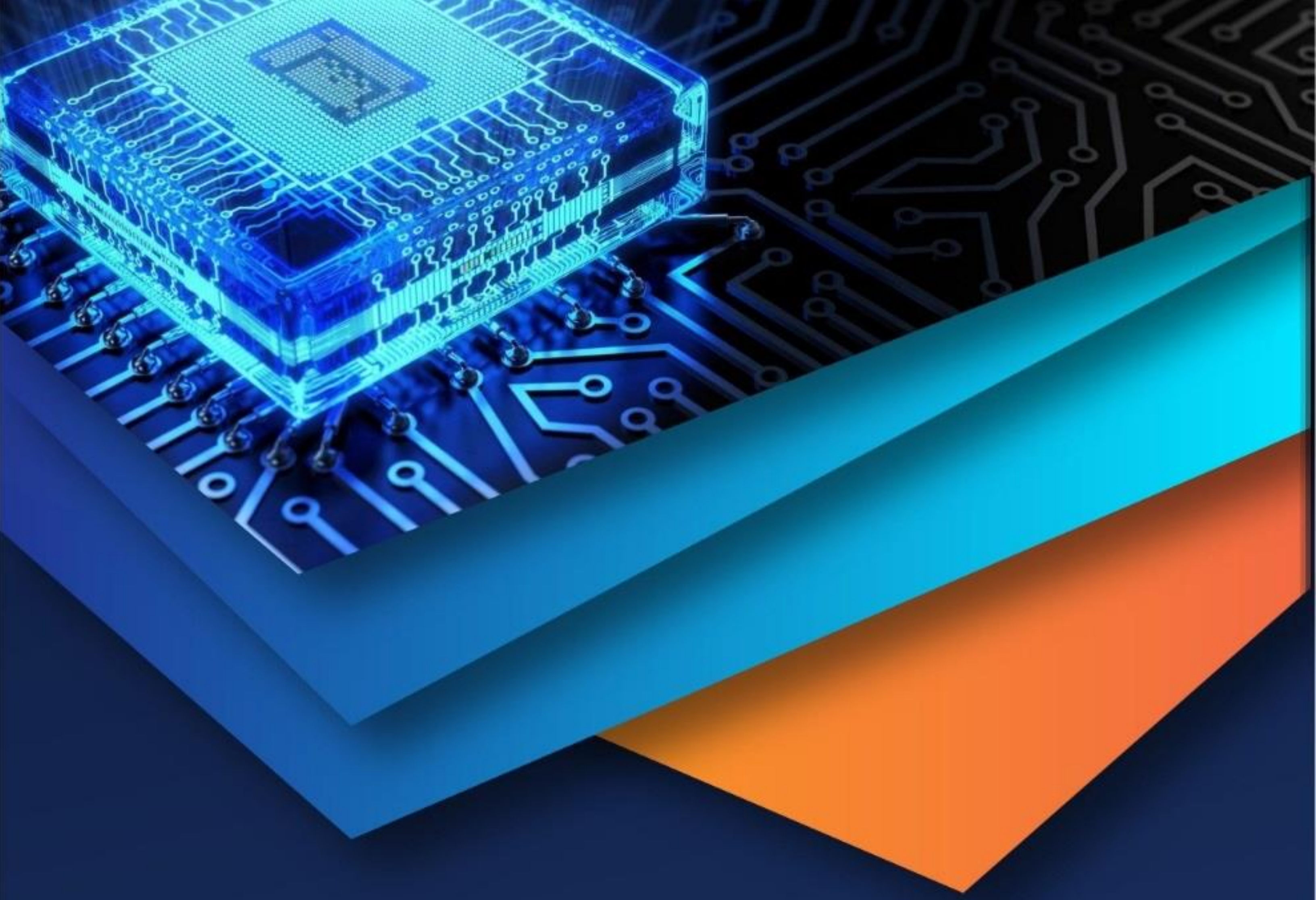

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