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# Bridge Analysis with Unequal Pier Height and Variable Span Length

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**ABSTRACT:** Bridges are one of the most critical components of any transport infrastructure network, and their serviceability during earthquakes is vital to ensure the safety of society. To be able to overcome bridge failure, code committees started to focus on different methods to design bridges under the effect of seismic forces. They play an important role in the economic activity of a city or a region and their role can be crucial in a case of a seismic event since they allow the arrival of the first aid. Reinforced concrete (RC) bridges are worldwide used type view their durability, flexibility and economical cost. In fact, their behavior under seismic loading was the aim of various studies. In the present study the effect of different structural parameters i.e. the height and the type of piers of reinforced concrete bridges on seismic response is investigated. For that reason, different multi-span continuous girder bridges models with various geometrical parameters are considered.

**KEYWORDS:** Bridges, SAP2000, Time History, Response Spectrum, Unequal Pier.

## I. INTRODUCTION

Modern transportation system has great influence on nation's economy and Bridges are an important component of all type of modern transport system. The various types of bridges have simple geometry, still they attract structural designer attentions to have various types of geometry and their type of constructions. It has been observed that bridges perform very poorly due to lack of attention in the design details. Numbers of bridges were designed around the world during the period, when there were no provisions for the seismic loads in the bridge codes or when these provisions were inadequate according to the present standards. A large number of bridges are designed and constructed without considering seismic forces. Moreover, the linearly elastic procedures adopted for the analysis of bridges remain efficient as long as the structure behaves within elastic limit. If the structure response is beyond elastic limit, the elastic procedure is insufficient to perform assessment of the structures. This leads to an over estimating of structures thereby attracting more seismic forces. Presently there are no Comprehensive guidelines to assist the practicing structural engineer to evaluate existing bridges and their retrofitting.

### A. Unequal Bridge Pier

The bridges supported on piers on unequal heights were called as irregular pier bridge. The seismic design response of such bridges supported by unequal piers is tedious and challenging task. Irregular bridge pier are classified as long pier and short pier. When ratio of effective length to least lateral dimension is less than 12 it is classified as short column and when ratio of effective length to least lateral dimension is more than 12 it is classified as long column. In this case, it has been observed that the shorter piers often result in brittle shear failure and this limits its ductility capacity, while the longer piers are most likely to fail in a ductile flexural mode.

## II. STATE OF DEVELOPMENT

**Themelina S. Paraskeva et.al. (2009)** The key idea being that the deformed shape of the structure responding inelastically to the considered earthquake level is used in lieu of the elastic mode shape. The proposed MPA procedure is then verified by applying it to two actual bridges. The first structure is the Krystallopiqi bridge, a 638 m-long multi-span bridge, with significant curvature in plan, unequal pier heights, and different types of pier-to-deck connections



**T. S. Paraskeva et.al. (2006)** the aim of this study is to adapt the modal pushover analysis procedure for the assessment of bridges, and investigate its applicability in the case of an existing, long and curved, bridge, designed according to current seismic codes; this bridge is assessed using three nonlinear static analysis methods, as well as THA. Comparative evaluation of the calculated response of the bridge illustrates the applicability and potential of the modal pushover method for bridges.

**Yongliang Zhang et.al. (2020)** In this study, an improved pushover analysis model for the pile group foundation with consideration of pile group effect is presented and validated by the quasi-static test. The improved model uses simplified springs to simulate the soil lateral resistance, side friction and tip resistance. PM (axial load-bending moment) plastic hinge model is introduced to simulate the impact of the axial force changing of pile group on their elastic-plastic characteristics. The pile group effect is considered in stress-stain relations of the lateral soil resistance with a reduction factor. The influence factors on nonlinear characteristics and plastic hinge distribution of the pile group foundation are discussed, including the pier height, longitudinal reinforcement ratio and stirrup ratio of the pile, and soil mechanical parameters.

**Reza Akbari, et.al. (2012)** A set of fragility curves of a class of reinforced concrete bridges with different degrees of irregularity has been generated. Eighteen bridge configurations have been identified, from regular to so-called highly irregular models. The geometric irregularity in this class of bridges is assumed to vary with the height of the piers. Using non-linear analytical models and an appropriate suite of 60 ground motions, analytical fragility curves have been generated for the individual piers of each of these 18 bridge models. Discussions have been made about the imposition of the displacement ductility demand of the piers versus the earthquake intensity as well as the bridge regularity.

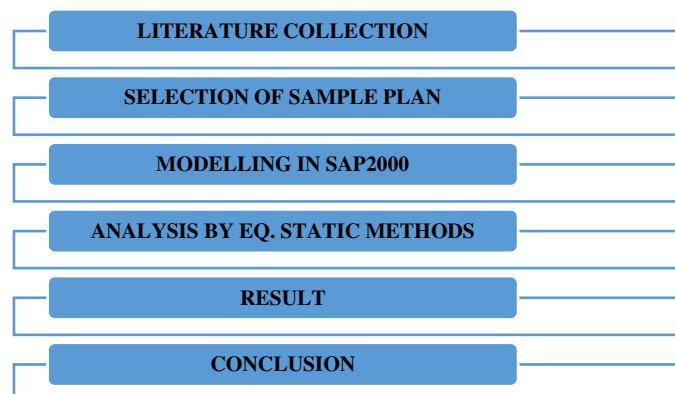
**T. Isakovic et.al (2003)** Single-degree-of-freedom (SDOF) models are frequently used in the seismic analysis of bridges, in particular in recent years when inelastic, SDOF-based push-over analysis has become increasingly popular. However, the scope of applicability of these models has not yet been clearly defined (e.g., in the Eurocode 8=2). Using SDOF models, displacements and forces could be significantly underestimated, especially in ‘irregular structures’. The authors have therefore proposed a more adequate criterion for the applicability of SDOF models, and a clearer definition of regularity.

**Kocaeli Üniversitesi (2016)** In this study, mode superposition method and time history methods are used in order to examine the performance of high rise reinforced concrete structures. Within the scope of the study, the behaviour of 5, 10 and 20 storey reinforced concrete framed buildings are analyzed by using finite element programs in both methods. Five different earthquake records are used in the analysis of time history method. Analysis results are used to investigate the variation of the reliability of approximate method in predicting the structural behaviour with the increase of the number of storeys are investigated.

### III. METHODOLOGY

#### A. Problem Statement

A parametric study of Bridges will be carried out by varying the height of piers and span length in different bridge models. Total 6 models of T Beam bridge will model by considering the number of lanes, carriage way widths, span length, pier cap, abutments etc. Total length of bridge is 45 m. All Bridge models having 2 lanes (Total width 10m with 7.5m Carriageway). Slab thickness consider as 300 mm. Grade of Concrete – M40 And Grade of steel – Fe415





**B. Bridge Configuration**

Table 1 Bridge Configuration

Bridge Models	Type of Bridge	Height of Piers (m)	Span Length (m)
B-1	Long bridge pier	16,16	15,15,15
B-2	Long bridge pier	16,16	10,25,10
B-3	Short bridge pier	8,8	15,15,15
B-4	Short bridge pier	8,8	10,25,10
B-5	Irregular bridge pier	8,16	15,15,15
B-6	Irregular bridge pier	8,16	10,25,10

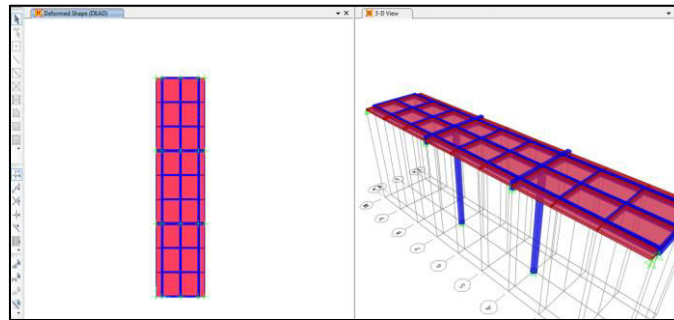
**C. Material Properties**

Table 2 Material Properties

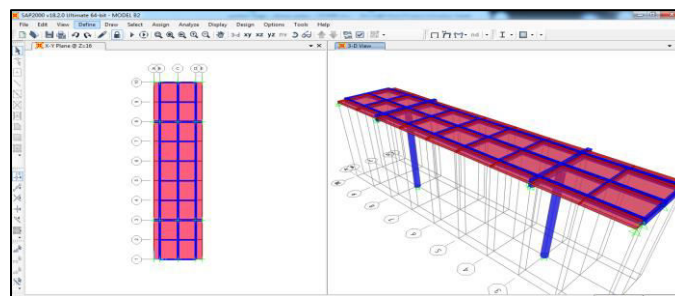
Sr. No.	Properties	Value
1	Steel Grade	Fe415
2	Concrete Grade	M40
3	Modulus of elasticity	200000 MPa
4	Density of Steel	78 KN/m <sup>3</sup>
5	Density of Concrete	25 KN/m <sup>3</sup>
6	Density of Wearing Coat	22 KN/m <sup>3</sup>

**IV. SYSTEM DEVELOPMENT**

**A. Modelling**



**Fig.1 Model B1**



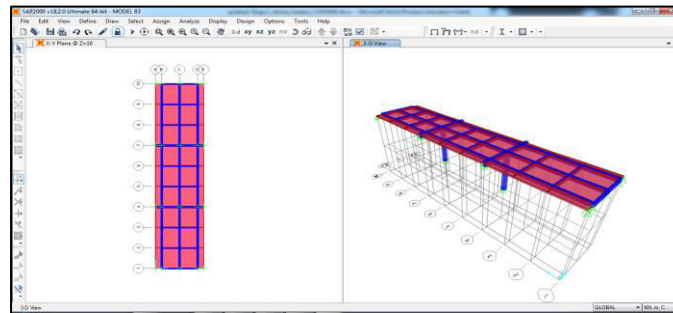
**Fig.2 Model B2**



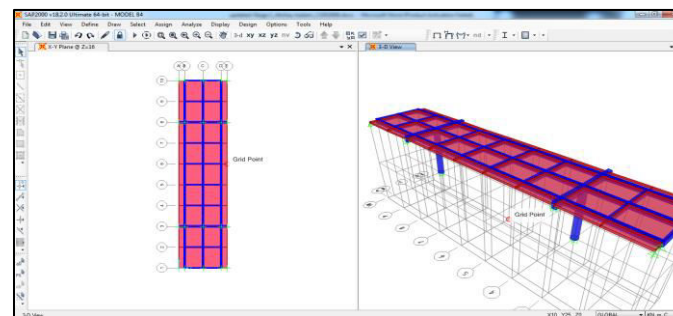


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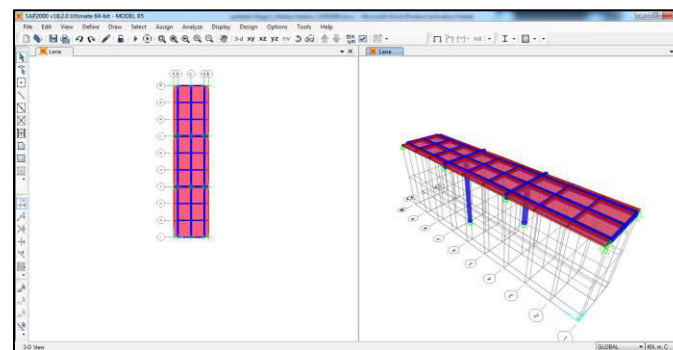
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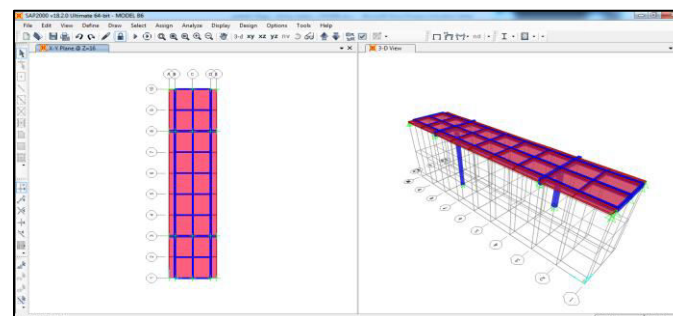
**Fig.3 Model B3**



**Fig.4 Model B4**



**Fig.5 Model B5**



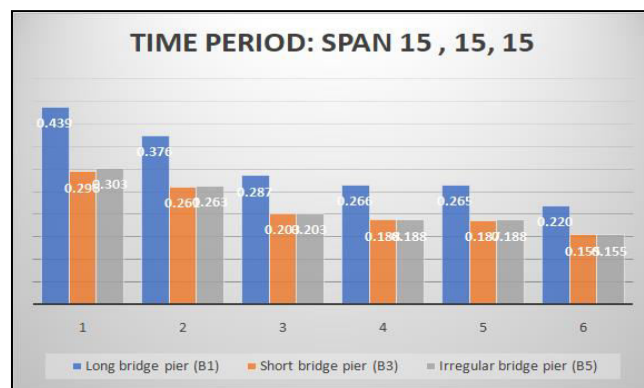
**Fig.6 Model B6**



**B. Time Period**

Table 3 Time Period Span 15, 15, 15

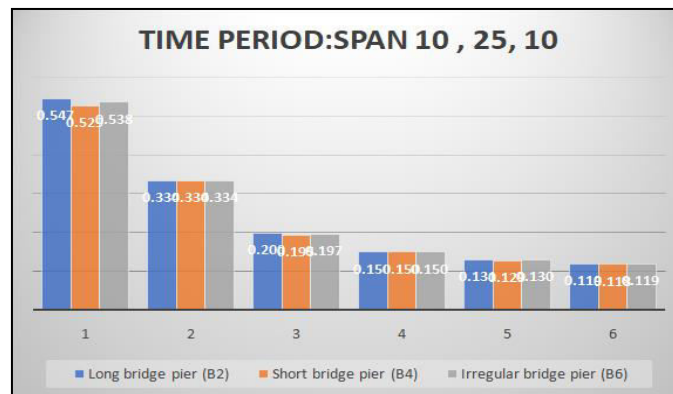
SPAN 15, 15, 15			
Mode	Long bridge pier (B1)	Short bridge pier (B3)	Irregular bridge pier (B5)
1	0.439	0.296	0.303
2	0.376	0.261	0.263
3	0.287	0.203	0.203
4	0.266	0.188	0.188
5	0.265	0.187	0.188
6	0.220	0.155	0.155



Graph. 1. Time Period: Span 15, 15, 15

Table 4 Time Period Span 10, 25, 10

SPAN 10, 25, 10			
Mode	Long bridge pier (B2)	Short bridge pier (B4)	Irregular bridge pier (B6)
1	0.547	0.529	0.760749
2	0.334	0.334	0.472699
3	0.200	0.195	0.27926
4	0.150	0.150	0.212796
5	0.131	0.129	0.183936
6	0.119	0.118	0.168095



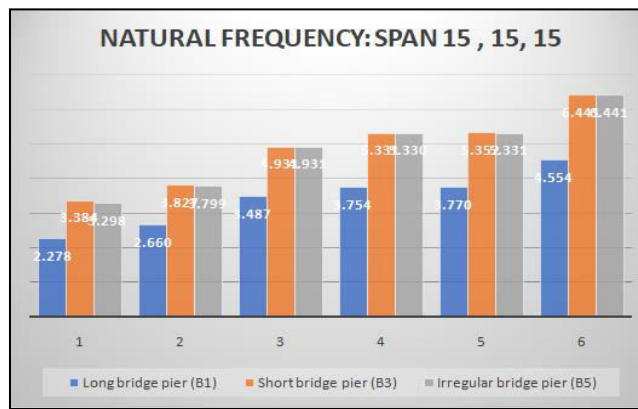
Graph. 2 Time Period Span 10, 25, 10



B. Natural Frequency

Table 5 Natural Frequency Span 15, 15, 15

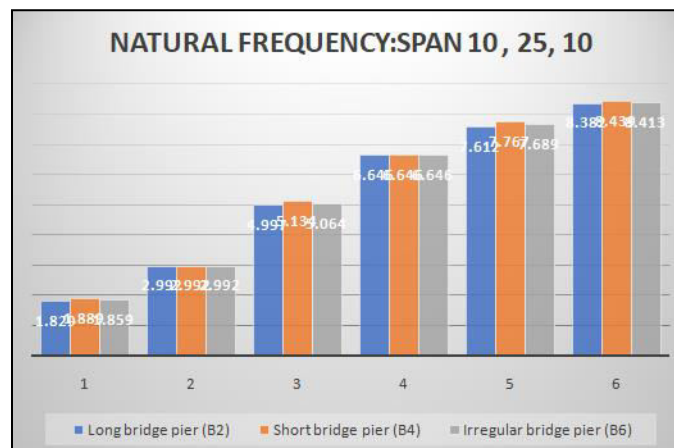
SPAN 15, 15, 15			
Mode	Long bridge pier (B1)	Short bridge pier (B3)	Irregular bridge pier (B5)
1	2.278	3.384	3.298
2	2.660	3.827	3.799
3	3.487	4.931	4.931
4	3.754	5.331	5.330
5	3.770	5.352	5.331
6	4.554	6.441	6.441



Graph 3 Natural Frequency Span 15, 15, 15

Table 6 Natural Frequency Span 10, 25, 10

SPAN 10, 25, 10			
Mode	Long bridge pier (B2)	Short bridge pier (B4)	Irregular bridge pier (B6)
1	1.829	1.889	1.859
2	2.992	2.992	2.992
3	4.997	5.134	5.064
4	6.646	6.646	6.646
5	7.612	7.767	7.689
6	8.382	8.439	8.413



Graph 4 Natural Frequency Span 10, 25, 10



## VI. CONCLUSION

A parametric study of Bridges carried out by varying the height of piers and span length in different bridge models. Total 6 models of T Beam Bridge with having bearing and the design of bridge and bearings are carried out analytically. Total Six models of Bridge model are consider with span of equal and unequal spans and pier heights and analyze this modes in FEM software SAP2000 for various seismic analysis methods such as, response spectrum, time history analysis etc .to investigate and measure the performance of the bridge with different span and pier conditions the analysis conclude that the Short pier height models are economic than the unequal and long pier model as compare, but as compare with Unequal pier models having equivalent results with short pier model, so the bridge having unequal span and pier conditions are recommended for the seismic design purpose, the all final conclusions are carried out from the following results.

- In the seismic coefficient Method time period and natural frequency of the bridge are compare, as compare with time period results for equal and unequal spans, long span pier having more time period than Short & Irregular piers, the Short & Irregular piers time period difference are around 15-20%
- As compare with natural frequency results for equal and unequal spans, long span pier having less natural frequency than Short & Irregular piers, the Short & Irregular piers natural frequency difference are around 5-10%

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