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Study and analysis for characterize seismic behaviour of T-beam Bridge

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Abstract-Utilising the capacity spectrum method (CSM) and modal pushover procedure (MPA), two inelastic analytical techniques, a pre-existing reinforced cement concrete T-beam bridge was assessed. MPA was carried out separately in the bridge structure's transverse and longitudinal orientations. The CSM assessed how the bridge structure responded to the El Centro and Kobe earthquake ground movements. MPA is used to create the capacity curves that depict the bridge's reaction to certain vibration modes in both transverse and longitudinal orientations. Using SAP2000 analytic software, the capacity-demand spectra for direction, and longitudinal direction were produced. The bridge's capacity spectrum curve stretched across the demand curves when it was exposed to an earthquake comparable to the El Centro Earthquake in both transverse and longitudinal orientations, suggesting that the bridge would survive in both directions. In contrast, during the Gujrat earthquake, the demand was significantly more than the bridge's capacity, resulting in its failure. The structure exhibits high inelastic energy absorption capabilities in the transverse modes without noticeably reducing strength and stiffness. In the transverse direction compared to the longitudinal direction, the bridge is more ductile to displacement. In order to improve overall stability, retrofitting applications to multi-column bents are recommended.

Keywords- Pushover analysis, Bridge construction, Pushover curves, Modal Pushover Procedure (MPA), SAP2000, Capacity Spectrum Method (CSM).

I. INTRODUCTION

Modern transportation is dependent on roads, and bridges are an integral element of this. A large number of bridges constructed throughout the globe were designed during a time when seismic design provisions in bridge codes were inadequate by current standards.

Recent bridge failures caused by earthquakes have raised awareness of the need to evaluate the structural vulnerability of bridges to seismic ground disturbances in order to develop the necessary remediation measures. In addition, many extant bridges in India are deteriorating due to ageing and the increase in the magnitude and volume of vehicular burdens.

As the construction of new bridges requires a significant investment of time and resources, it is necessary to restore and rehabilitate ancient and damaged bridges in order to preserve their load carrying capacity and service performance.

II. LITERATURE REVIEW

T. Nagayama and others (2017) Among the most fundamental characteristics of bridges is their inherent frequency. In contrast, the majority of bridges have unknown fundamental frequencies. If a large number of bridges are analysed, natural frequency detection using acceleration monitoring with sensors installed on bridges is not feasible. This paper presents a new method for estimating frequency using two vehicles. The primary principle is the use of data acquisition and a cross-spectral density function (CPSD) estimation to capture bridge disturbance, which is a fundamental characteristic of the various vehicle responses. At various travel times, the bridge's first natural frequency was determined, proving the effectiveness of the proposed strategy.

Akbari, Reza, et al. (2019) In this study, the fundamental natural frequencies of bridges are affected by the size of the bridge spans, the number of bridge spans, the bridge's diameter, the number of girders, and the height of the girders. According to the findings, the first bending frequency of bridge decking is inversely proportional to span length and directly proportional to the number of spans and bridge breadth. Other assumed parameters, such as elevation and number of girders, indirectly affect the number of spans and bridge breadth.

Mayara C and others (2020) Due to its ease of use, quick turnaround time, and capacity to produce complex structures, 3D printing has recently attracted a great deal of attention in the field of development. In this procedure, a thermoplastic filament is extruded through a heated nozzle and layered on a heated platform. Additionally, recent developments have enabled the use of high-performance polymers with desirable properties. Among polymeric materials, poly (vinylidene fluoride) (PVDF) and thermoplastic polyurethane (TPU) composites are said to offer superior engineering performance for a wide variety of industrial applications.

III. METHODOLOGY

The longitudinal and transverse girders of the bridge under study were subjected to a live load test to determine their flexural responses. The instrumentation was restricted to one span (the first span). The strain transducers were mounted non-destructively on one of the longitudinal girders and one of the cross girders of a single span. The gauge locations in the longitudinal girder near the abutment are as follows.

Figures 1 show the longitudinal and transverse girders of the bridge instruments installed in the longitudinal girder near the midspan and at the bottom of the cross girder, respectively. The dimensions of the longitudinal girder without the deck plank and the cross girder are shown in above the figures. After the structure was fully instrumented, controlled load experiments with a multi-axle vehicle with known axle weights were conducted. The auto clicker and reflector assembly were attached to the wheel to facilitate the automatic recording of strains corresponding to each rotation of the wheel. When the truck was driven along a prescribed longitudinal path, strains were automatically measured for each wheel rotation while the vehicle's position was monitored remotely using a wireless structural testing system.

Fig 1. The Longitudinal and Transverse girders of the bridge of Gujrat.

1. Analysis of Modal Pushover:

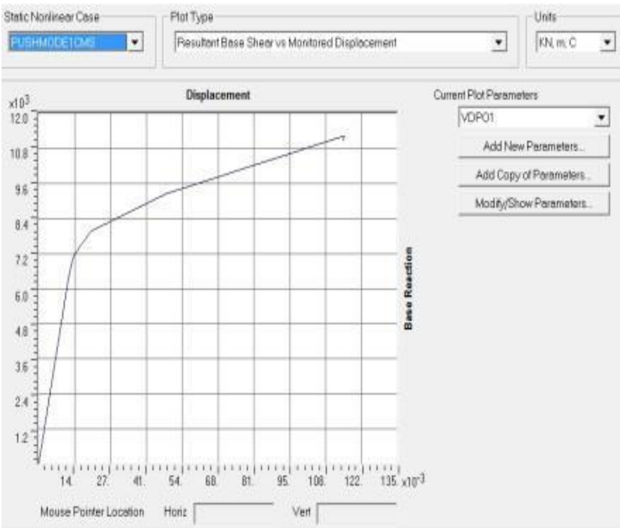
The pushover analysis is a nonlinear, inelastic examination of the structure's reaction to a global force-displacement relationship (capacity curve). Pushover analysis was carried out in both the longitudinal and transverse directions while taking into account P-effects, starting from the baseline circumstances brought about by gravitational forces. In order to comprehend the bridge's structural performance better, the impacts of higher modes were taken into account. The resulting mode shapes were used to configure the displacement pattern.

The product of the lumped mass at the node and the modal amplitude at the corresponding node was used to distribute lateral forces proportionately along the span of the bridge. In the bents, the lateral loads were distributed vertically according to the height of the nodal masses. Up until the goal displacement was attained or the structure collapsed, the lateral forces were applied in a monotonically rising manner. The study took into account both geometric (P- effect) and material nonlinear factors.

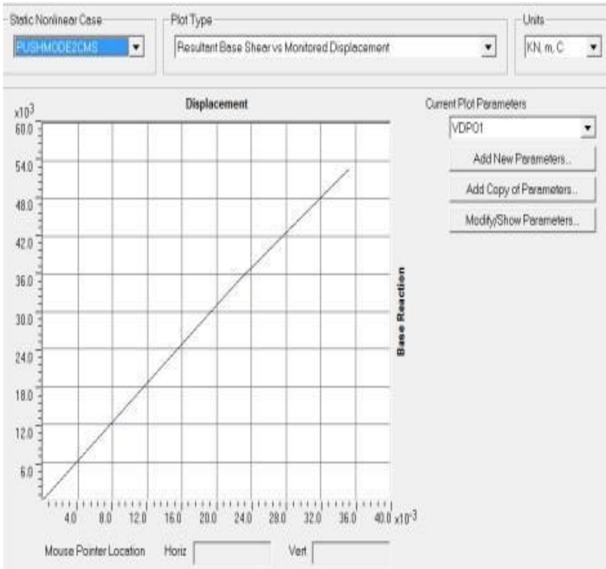
IV. RESULT

Both the transverse and longitudinal orientations were used in the modal pushover study. The form of the global pushover curve is thought to represent the global or local process at play when the structure nears dynamic instability. The total lateral force or base shear (Vb) on a structure is graphically plotted against the lateral deflection () of the control node of the bridge structure to form the capacity curve (pushover curve). Figure 2(a) shows the pushover curve.

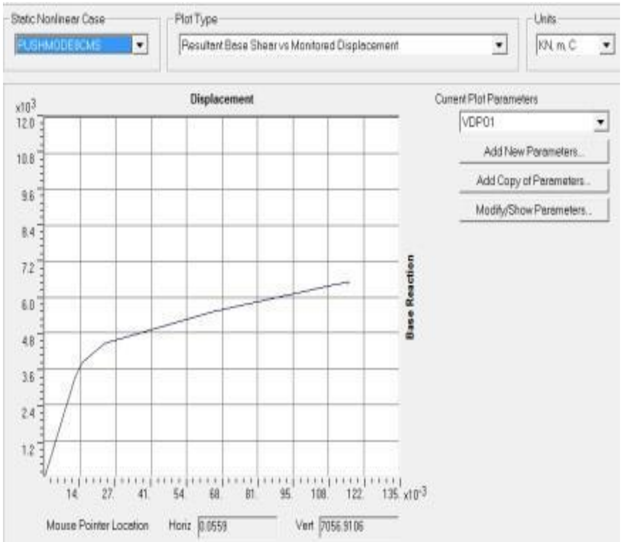
According to the graph, the control node displaced 19.7 mm and the first yielding occurred at a base shear of 7961.26 kN. Beyond the first yield, the base shear rises together with an increase in the control node displacement. With increasing lateral stresses, it was observed that the pushover curves in the multi-column bents of the bridge structure were becoming softer, which was related to the gradual creation of plastic hinges. The bridge structure rotated around its base as a result of the first mode's global plastic mechanism and rising force intensity (bottom local plastic mechanism). The control node kept moving in the direction of the lateral force application. The pushover curve behaved normally and did not reverse. The development of the mechanism resulted in an incremental displacement and a reduction in stiffness. The highest displacement of the structure was 115 mm, and the base shear was 11229.20 kN, indicating a loss of lateral stiffness.



(a)



(b)



(c)

Fig 2. (a)(b),(c): shows the pushover curve.

Figure 2(b) shows the capacity curve for. According to the pushover curve, the overall system strength appeared to be greater (i.e., yielding occurred at a higher level of base shear). The longitudinal shear force at the structure's base was significantly greater than the transverse shear force.

In the longitudinal pushover analysis, when the push load was applied in the longitudinal direction, the expansion joints between adjacent sides of a deck joint allowed relative translations and rotations on both sides of the bridge decks. At a base shear of 34644.03kN, the first yield occurred, and a control node displacement of 22.3mm was observed. The maximal displacement of the structure was 35.2mm with a base shear of 52610.17kN. Figure 2(c) shows the capacity curve for the number eight. In the pushover analysis conducted in the transverse direction for mode number eight, the first yield occurred at a base shear of 4468.55 kN with a control node displacement of 22.8 mm. The maximal displacement of the bridge structure was 115.9 mm, with a maximum base shear value of 6517.11 kN. The bridge structure had shifted significantly into the inelastic range, resulting in a significant reduction in lateral capacity.

V. CONCLUSIONS AND RECOMMENDATIONS

The following are the conclusions and recommendations drawn from the T-beam bridge's analysis.According to the modal analysis, two modes contributed to the vibration of the bridge structure in the transverse direction, while only one mode contributed in the longitudinal direction. Thus, higher modes have a significant effect on the efficacy of bridges.

According to the results of the modal pushover analysis in the transverse direction, the hinges at the bottom of all the mid-bent columns exceeded the collapse prevention (CP) performance level. The performance levels of all other hinges in the other bends fell between the immediate occupancy (IO) and life safety (LS) performance levels, which are considered safe. In all bent cap beams, the performance levels of the plastic hinges were in an elastic state. Consequently, the structure faltered because of global instability.

When the performance levels of the hinges exceed the performance level for collapse prevention, significant structural damage has occurred. The damages may include concrete cracking, reinforcement yielding, and significant spalling of concrete, necessitating either the closure of the bridge structure for repairs or its partial or complete replacement.

Using the capacity spectrum procedure, the bridge's resistance to the El Centro and Kobe earthquakes was evaluated. It was discovered that the study bridge could withstand El Centro Earthquake, but not Gujrat Earthquake. Therefore, retrofitting applications to multi-column bents is recommended in order to improve global stability.

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