Evaluation Performance of Ductile and Damaged protected Bridge piers subjected to bi-directional Earthquake Attack: A Review

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Abstract: **Incremental Dynamic Analysis (IDA) procedures are advanced and then applied to a quantitative risk assessment for bridge structures. This is achieved by combining IDA with site-dependent hazard-recurrence relations and damage outcomes. The IDA procedure is also developed as a way to select a critical earthquake motion record for a one-off destructive experiment. Three prototype bridge substructures are designed according to the loading and detailing requirements of New Zealand, Japan and Caltrans codes. From these designs 30 percent reduced scale specimens are constructed as part of an experimental investigation. The Pseudo dynamic test is then to control on three specimens using the identified critical earthquake records. The results are presented in a probabilistic risk based format. The differences in the seismic performance of the three different countries' design codes are examined.**

Seismic response is expected to be resulting damage on structures, which may threaten post-earthquake serviceability. To overcome this major performance shortcoming, the seismic behaviour under bi-directional lateral loading is investigated for a bridge pier designed and constructed in accordance with Damage Avoidance principles. Due to the presence of steel armoured rocking interface at the base, it is demonstrated that damage can be avoided, but due to the lack of hysteresis it is necessary to add some supplemental damping. Experimental results of the armoured rocking pier under bi-directional loading are compared with a companion ductile design specimen.

The Pseudo dynamic (PD) test method was developed about 30 years ago by Takanashi et al. (1975) and is thought to be the most efficient and powerful alternative to both STT method and dynamic analytical method, especially when the real response behaviors, such as the damage state during and after a certain earthquake are need to be investigated. On the other hand, considerable number of the dynamic analysis programs running on conventional personal computers has been developed recently and the accuracy and reliability of the results improved as the new theories are applied to them. Also, the cost of running the computer becomes cheaper. Considering these background, the dynamic analysis is strong and reasonable tool for the seismic research except that the dynamic analysis method is needed to assume the simplified model for the properties of structures such as the lateral load and displacement relationship and hysteresis damping factors.

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Keywords: **Incremental dynamic loading, pseudo dynamics, seismic response, risk assessement, Serviceability, Bi-directional loading, Hazard-recurrence.**

I. INTRODUCTION

Incremental Dynamic Analysis (IDA) is applied in a Performance-Based Earthquake engineering context to identify critical earthquake ground motions that are subsequently to be used in physical testing or analytical studies to investigate structural response and damage outcomes. This quantitative risk analysis procedure consists of choosing a suitable suite of ground motions and appropriate intensity measures; performing IDA on a nonlinear model of the prototype structure; summarizing the IDA results and parameterizing them into 10th, 50th, and 90th percentile performance bounds; integrating these results with respect to hazard intensity recurrence relations; and identifying the strength of two or three critical earthquakes that will potentially encompass all damage states through to collapse. An illustrative example of the procedure is given for reinforced concrete highway bridge piers, designed to New Zealand, Japan and Caltrans specifications.

Performance Based Earthquake Engineering (PBEE) procedures require the prediction of the seismic capacity of structures which is then compared to the local seismic demand. The interrelationship between the two gives an inference of the expected level of damage for a given level of ground shaking. Incremental Dynamic Analysis (IDA) is a new methodology which can give a clear indication of the relationship between the seismic capacity and the demand. Engineers can estimate principal response quantities, such as the maximum drift of the structure for a given intensity measure (IM) such as peak ground or spectral acceleration. The need to identify a critical earthquake for the purpose of an experimental investigation or further advanced analysis and design can be accommodated by the application of IDA. A synthesis of IDA curves into 10th, 50th, and 90th percentile bounds helps the designer to single out critical ground motions which can then be used in physical testing or advanced analysis to investigate structural damage with a certain level of confidence.

In order to investigate the likely seismic performance of multi-storey precast concrete buildings, Matthews (2004) adopted the method given by Equation. Then based on analysis he derived a protocol for super-assemblage specimen testing that was a physical representation of a family of typical prototype precast concrete buildings. In order to estimate structural performance under seismic loads, Vamvatsikos and Cornell (2004) presented a procedure called "Incremental Dynamic Analysis (IDA)". This approach involves performing nonlinear dynamic analyses of a prototype structural system under a suite of ground motion records, each scaled to several intensity levels designed to force the structure.

II. LITERATURE REVIEW

1. **KEVIN SOLBERG, N.MASHIKO**
   Recent earthquakes such as Loma Prieta, Northridge, and Kobe have demonstrated a need for a new design philosophy of bridge piers that avoids damage in order to ensure post-earthquake serviceability and reduce financial loss. Damage Avoidance Design (DAD) is one such emerging philosophy that meets these objectives. DAD details require armoring of the joints; this eliminates the formation of plastic hinges. Seismic input energy is dissipated by rocking coupled with supplemental energy dissipation devices. In this paper the theoretical performance of a DAD bridge pier is validated through bi-directional quasi-static and pseudodynamic tests performed on a 30% scale specimen. The DAD pier is designed to rock on steel-steel armored interfaces.

2. **Shriharsh Satish Modak**
   Bridges are very important structures and play important role during an earthquake for evacuation of people as well as in the post earthquake events. Pile and well foundations are the two types of deep foundation, mostly used for both the railway and road bridges spanning the river. Due to the availability of manpower and skill for construction, the well foundation has been more popular in India. Since the well foundations are massive structures, deeply embedded in soil, it was believed that they are immune to seismic damage.

3. **Shijiazhuang**
   Plastic hinge model has been widely used in bridge seismic design codes such as Japan, Caltrans, New Zealand and China (revised edition), to evaluate deformation capacity of RC bridge columns. With the development of bridge performance/displacement based seismic design, several damage indices have been suggested, such as ultimate curvature and curvature ductility factor of critical section, maximum strain of confined concrete and reinforced steels, low cycle fatigue damage indices of longitudinal reinforcement etc.

4. **Diwaker Katiyar**
   Reinforced concrete (RC) frame members under seismic loads are likely to experience large inelastic deformations and therefore, adequate ductility is essential to avoid brittle failure mode and enhance energy dissipation potential. The satisfactory post-yield performance of these RC members during a seismic event largely depends on the characteristics of material used in their fabrication, namely, reinforcing steel and concrete. This study is concerned with the effect of reinforcing steel characteristics and their manufacturing process on the flexural behavior of beams up to failure. Properties of reinforcing steel bars which could affect the seismic behavior of structural members are yield strength (YS), ultimate strength (UTS), strain value at which strain-hardening commences, UTS/YS ratio, fracture strain and their dependence on the manufacturing process, such as cold-twisting deformed(CTD) vs. quenched self-tempered (QST) or thermo-mechanically treated (TMT). Effect of reinforcing steel and concrete properties on ductility and moment resisting capacity was studied using moment-curvature analyses of RC beam sections which considered nonlinear behavior of concrete and actual stress strain curve of individual reinforcing steel bars.

III. CONCLUSION

This synopsis has presented a study based on using IDA in the context of a quantitative seismic risk assessment. The following conclusions are drawn:

1. It is important to analyze bridge structures under high level of shaking as large displacements can occur that can lead to structural collapse. The IDA approach is a systematic method for achieving this end. It is possible to parameterise the

outcomes using the Ramberg-Osgood (R-O) function. Statistical analysis of the control parameters in the R-O equation give a good indication of the level of shaking needed to cause collapse.

2. A seismic risk analysis can be developed when IDA is combined with site-dependent hazard-recurrence relations and compiled with damage indices. In this way, risk can be posed as the probability of the hazard times the consequential outcome for a given level shaking in terms of structural damage for a level of confidence in that outcome.
3. The IDA methodology can be adapted to identify critical earthquakes along with their required intensity for advanced analysis or physical testing.

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