Journal of Advances and Scholarly Researches in Allied Education
Vol. XV, Issue No. 2, (Special Issue) April-2018, ISSN 2230-7540

Sesmic Retrofitting of Bridges

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Abstract – The immediate effect of the earthquake is dislocation,breakage and destruction of transpor and communicati on facilities.Bridge act as the vital connectivity element inroad networking. Bridges are also considered to be structures of post-earthquake importance because of the indeed for emergency response, relief and rehabilitation measures. It is known from experience that bridges are vulnerable to earthquake damage.Thus the safety and protection of bridges in earthquakes it is most important.There are number of bridges which are designed according tooldcodes when modern seismicpro visions were not developed. Such bridges are mostly found deficient and may need seismic retrofitting. Seismic retrofitting of existing bridge sis one method of mitigating the risk that currently exists.

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I. INTRODUCTION

Retrofitting of RCC bridges, in other words can be defined as strengthening of existing bridges in order to increase its seismicforce resistance level,so that it can successfully withstand any severe future earthquakes. There are two situations that necessitate retrofitting(I)seismically deficient existing bridges which have not yet experience deny earthquakes and have not meeting current code requirements (ii)bridges that are damaged in earthquakes. In the second case both repair and retrofitting is required.

Seismic retro fitting is natively new concept in bridge engineering and was motivated by the damage sustained by highway bridges during the1971San Fernando earthquake.The earthquake clearly pointed out the existence of a number of deficiencies in the then-current bridge design specifications. It also focused on the fact that numerous existing bridges may be expected to failing some major way during the is remaining life if subjected to strong seismic loads. The extensive damage of bridges all over the world in recent earthquakes has been the motivation in significant advancement in the earthquake resistant design and retrofitting of bridges. The bridges constructed prior to 1970 were not designed for adequate seismic resistance as the ductility provisions were not incorporated in the seismic codes till then. As a result the bridges designed before this year lack in earthquake resistance and ductility and may be vulnerable to significant damage even from moderate earthquake.

The post earthquake damage surveys in recent earthquakes have confirmed this view. It has also been revealed from damage surveys that many of the damages that occurred in bridges and flyovers could be prevented by proactive measures of seismic retrofitting prior to earthquakes. Many of the reinforced concrete piers designed earlier had inadequate shear capacity due to lack of transverse steel and confinement, inadequately lapped longitudinal steel, and premature termination of longitudinal steel. The superstructures were vulnerable to falling down in the absence of restraining devices; bearings were deficient in accommodating large seismic displacement and bearing seat was inadequate. These deficiencies had an adverse impact on the performance of bridges. An existing bridge can be replaced by a newly designed bridge to meet earthquake demands or upgraded in its strength by appropriate retrofitting measures.

II. LITERATURE REVIEW

Following are some theories and researches carried out till now:-

Waghmare P. (2011):- have studiedTo increase concrete confinement by transverse fibre reinforcement, especially for circular cross-sectional columns, To increase shear strength by transverse fibre reinforcement, To increase flexural strength by longitudinal fibre reinforcement provided. They were anchored at critical sections. Transverse fibre should be wrapped all around the entire circumference of the members possessing close loops sufficiently overlapped or welded in order to increase concrete confinement and shear strength. This is how members with circular cross-section will get better confinement than member with rectangular cross-section. Where square or rectangular cross-sections are to be jacketed, circular/oval/ elliptical jackets are most offtenly used and the space between the jacket and column is filled with concrete. Such types of multi-shaped jackets provide a high degree of confinement by virtue of their shape to the splice region proving to be more effective.

Kazuhiko Kawashima.(2000) have studied and proposed a new concept The traditional seismic coefficient method is being replaced with the ductility design method, and linear/nonlinear dynamic response analysis is used on routine basis in design of bridges with complex structural response.Verification of ductility evaluation of reinforced concrete/steel single/frame columns is being conducted in various regions. Verification for the effectiveness of steel jacket was conducted, and use of new composite materials such as the carbon fiber sheet is being studied. For preventing the flexure-shear failure at midheight, it is required to wrap CFS in not only horizontal direction but also vertical direction. Probably the effect of bilateral excitation for bridges may be considered in terms of difference of ductility capacity of piers.

Benito Pacheco, Kazuhiko Kawashima, Romeo Estañero(2009) have studied anReinforced concrete columns& piers that were designed without taking into account the importance of plastic deformation and ductility are commonly deficient in flexural ductility, flexural strength, and/or shear strength under strong seismicexcitation.Seismic isolation reduces the force demands on the substructure andsuperstructure, but increases the displacement demands.Providing a jacket around an existing column that has insufficient ductility and strength capacity is effective to prevent premature failure. The jacket resists not only tension and compression but also shears of the column, as well as provides lateral confinement to the core concrete.Seismic isolation reduces the force demands on the substructure and superstructure, but increases the displacement demand.

Amy Floren , JamshidMohammadi (2001) have studied that the at least three levels of performance, ranging from fully operational to near collapse can be used to meet the post earthquake conditions, safety, usage, and occupancy for the varous levels of service expected from all types of structures. In this paper a critical evaluation of these performance criteria and their relevance to Highway Bridge design, in conjunction with the current design practice, is discussed. Various types of designs such as those based on strength, deformation, nonlinear behavior, and energy, which can be used to meet the specified performance levels in seismic design of highway bridges, are also discussed in the paper. Examples of real applications of the method in highway bridges are reviewed.to review the developments in performance-based design currently in progress for building structures and to investigate the effects of this design approach specifically as it applies to bridges.

Jangid R.S (2008) have studied that the Analytical seismic responses of structures retrofitted using base isolation devices are investigated and the retrofit schemes are illustrated. The retrofitting of various important structures using seismic isolation technique by incorporation of the layers of isolators at suitable locations is studied. Three specific structures such as historical buildings, bridges, and liquid storage tanks are selected to investigate the effectiveness of the base isolation in seismic retrofitting. Different types of isolation devices, such as elastomeric bearings and sliding systems are evaluated for their performance in the retrofitting works. The response of the retrofitted structural system is obtained numerically by solving the governing equations of motion under different earthquakes and compared with the corresponding conventional structure without any retrofit measures, in order to investigate the effectiveness of base isolation in retrofitting of structures. It is observed that the seismic response of the retrofitted structures reduces significantly in comparison with the conventional structures depicting effectiveness of the retrofitting done through the base isolation technique. This paper also distinctively elaborates on the methods of construction in retrofitting works involving base isolation.

III. METHODOLOGY

Need for Retrofitting

The bridges need retrofitting primarily because of two reasons (i) these were designed for smaller forces than that can occur, and (ii) these may be lacking in ductility in the absence of ductile detailing of reinforcement. The structural deficiencies in many of the existing bridges have been observed from seismic behavior in recent earthquakes. Several bridges constructed prior to existence of modern seismic codes fail to meet requirement of safety. Seismic retrofitting is required for protection of such bridges in future earthquakes. It is possible to retrofit many of the existing bridges against falling of spans and other distress by simple retrofitting measures. The key issues in retrofitting are: retrofit philosophy, seismic assessment, retrofit techniques, validating effectiveness of retrofit measures, application of composite materials and smart materials, in retrofitting. The bridge retrofit program is a necessity for the country and should be undertaken for vulnerable bridges that have not yet experienced earthquakes. The retrofitting of existing bridges has direct relevance towards mitigating disaster caused by earthquakes.

The need of seismic retrofitting in existing bridges can arise due to any of the following reasons.

- Upgrading of seismic coefficients as a result of revised seismic zone

- Updating of design criteria due to revision of code
- Bridges not designed to seismic force
- Bridges damaged in earthquakes
- Deterioration and agine

Design steps

1. Preliminary Screening

The seismically deficient bridge sari identified by preliminary screening. The screening procedure is mainly based on (a) Seismicity (b) Vulnerability and(c) Importance. The prioritization of bridges to be retrofitted can be made on the basis of rating procedures based on above factors.

2. Detailed Seismic Assessment

The detailed seismic evaluation of expected performance of existing bridges necessary to determine seismic capacity, weake r sections and mode of failure. The strength evaluation can be made according to codes. It is normally desired that assessment procedure should be more precise than code.

3. Selection and Design of Retrofit Measures

On the basis of detailed seismic assessment it should be confirmed when the individual component level retrofit such a tending seating width, providing restrainer so global retrofit of complete bridge is to be undertaken. The global retrofit may include: jacketing of bridge piers, replacement of bearings and retrofit of foundations.

4. Checking of Design of Retro fitted structure

Re-analysis of retro fitted structure will be required using dynamic method of analysis. The checking of design of retrofitted structure should be based on current design codes.

STRUCTURAL DEFICIENCIES

The observation of performance of bridges in past earthquakes world over has highlighted following deficiencies in bridges:

Superstructure:

Traditionally there is no linkage provided between two adjacent spans in the case of multi–span simply supported bridges as a result spans are dislodged from supports due to out of phase motion in piers or bearing failures. The bearing failure occurs in fixed bearings when these are unable to withstand the seismic force generated in the superstructure. In many cases, spans fall down from their supports resulting into irrepairable damage. Superstructure deficiency is also associated with inadequate seat length at expansion joints on the supports or at the abutments resulting into unseating of span.

Bearings:

The traditional rocker and roller bearings have not shown satisfactory performance in earthquakes. There have been problems of jumping, inadequacy of bearings in accommodating displacements.

Inadequate seat width on supports: The inadequacy of seat width on bearing supports or at expansion joints have caused unseating of span.

Substructure:

The various types of deficiencies observed in RC columns and piers are

(i) Lack of flexural strength,

(ii) Lack of shear strength

(iii) Insufficient transverse reinforcement and confinement

(iv) In adequate lap splicing of longitudinal steel

(v) In adequate ductile detailing in plastic hinge region of columns

(vi) Premature termination of longitudinal steel in piers

(vii) Insufficient strength of joints between pile cap beams.

Retrofitting of superstructure

Superstructurefailsmainlyduetocollapseofspan.Thiso ccursmainlyduetothe following reasons:

- Unseating of spanat the unrestrained movement joints.
- Pounding of adjacent segments
- Liquefaction of the ground
- Fault rupture under neath the bridges

- Destruction of shoes, bearing, excessive sliding
- Vertical jumping of the girders.

Case study of Static analysis of bridge component part in IRC 70R Loading in STAAD PRO Software.

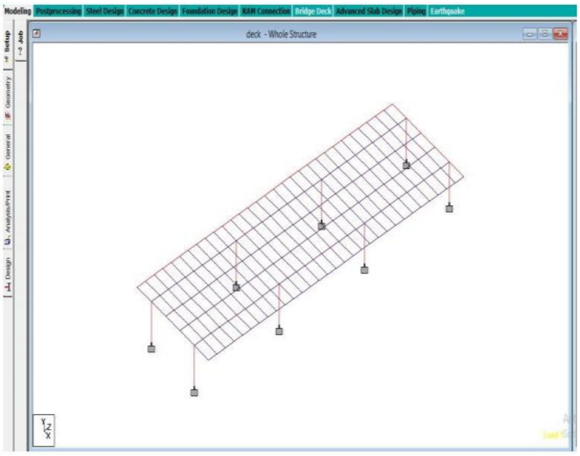

Fig .1.Staad pro modeling in BewaIRC loading

Member Specification

Rectangular column size: - 0.3 x 0.3 m.

Rectangular beam size: - 0.3 x 0.3 m.

Deck slab: - 0.2 m plate thickness.

Support specification

All support conditions are fixed supported.

Loading

Dead load: - self weight

Type	L/C	Name
Primary	1	DEAD
Primary	2	IRC: SLS CLASS 70R LOADING N166: DISP Y -VE
Primary	3	IRC: SLS CLASS 70R LOADING N1: REACT FY +VE
Primary	4	IRC: SLS CLASS 70R LOADING N7: REACT FY +VE
Primary	5	IRC: SLS CLASS 70R LOADING N9: REACT FY +VE
Primary	6	IRC: SLS CLASS 70R LOADING N15: REACT FY +VE
Primary	7	IRC: SLS CLASS 70R LOADING N17: REACT FY +VE
Primary	8	IRC: SLS CLASS 70R LOADING N23: REACT FY +VE
Primary	9	IRC: SLS CLASS 70R LOADING N25: REACT FY +VE
Primary	10	IRC: SLS CLASS 70R LOADING N31: REACT FY +VE
Primary	11	LOAD CASE 11

Analysis Results

Number of Nodes	194	Highest Node	194
Number of Elements	208	Highest Beam	353
Number of Plates	150	Highest Plate	359

Results are as follows

Node displacement summery

	Node	L/C	X (mm)	Y (mm)	Z (mm)	Resultant (mm)	rX (rad)	rY (rad)	rZ (rad)
Max X	5	2:IRC: SLS	**0.316**	0.040	-1.418	1.454	0.000	-0.000	0.000
Min X	113	11:LOAD	**-7.342**	10.580	0.000	12.878	-0.000	0.000	0.005
Max Y	116	11:LOAD	-7.342	**41.983**	-0.000	42.620	0.000	0.000	0.005
Min Y	165	2:IRC: SLS	-0.814	**-40.414**	-1.621	40.455	0.001	-0.000	-0.002
Max Z	40	5:IRC: SLS	-0.352	-4.208	**0.630**	4.270	0.003	0.000	-0.001
Min Z	27	2:IRC: SLS	-1.041	1.144	**-1.721**	2.314	-0.012	-0.000	-0.000
Max rX	147	2:IRC: SLS	-0.673	-19.484	-1.610	19.562	**0.011**	-0.000	-0.001
Min rX	189	2:IRC: SLS	-0.999	-11.957	-1.640	12.110	**-0.012**	-0.000	-0.002
Max rY	3	5:IRC: SLS	-0.378	1.787	0.630	1.932	0.003	**0.000**	-0.001
Min rY	27	2:IRC: SLS	-1.041	1.144	-1.721	2.314	-0.012	**-0.000**	-0.000
Max rZ	169	2:IRC: SLS	-0.811	-20.892	-1.339	20.951	0.001	-0.000	**0.006**
Min rZ	147	8:IRC: SLS	0.138	-5.154	-0.585	5.189	0.003	0.000	**-0.005**
Max Rst	116	11:LOAD	-7.342	41.983	-0.000	**42.620**	0.000	0.000	0.005

Reaction Summary

			Horizontal	Vertical	Horizontal	Moment		
	Node	L/C	FX (kN)	FY (kN)	FZ (kN)	MX (kNm)	MY (kNm)	MZ (kNm)
Max FX	9	6:IRC: SLS CLASS 70R LOADING N15: REACT FY +VE	**41.255**	302.966	-0.723	-2.429	0.021	-40.338
Min FX	23	8:IRC: SLS CLASS 70R LOADING N23: REACT FY +VE	**-41.195**	456.331	10.825	12.738	-0.028	40.991
Max FY	17	7:IRC: SLS CLASS 70R LOADING N17: REACT FY +VE	29.955	**575.072**	12.007	14.037	0.072	-30.451
Min FY	7	11:LOAD CASE 11	0.753	**-41.4E 3**	0.731	0.716	0.002	-24.646
Max FZ	17	2:IRC: SLS CLASS 70R LOADING N166: DISP Y -VE	15.173	310.961	**69.446**	73.699	0.155	-16.848
Min FZ	25	2:IRC: SLS CLASS 70R LOADING N166: DISP Y -VE	19.056	245.278	**-86.012**	-79.448	0.166	-22.190
Max MX	17	2:IRC: SLS CLASS 70R LOADING N166: DISP Y -VE	15.173	310.961	69.446	**73.699**	0.155	-16.848
Min MX	25	2:IRC: SLS CLASS 70R LOADING N166: DISP Y -VE	19.056	245.278	-86.012	**-79.448**	0.166	-22.190
Max MY	31	2:IRC: SLS CLASS 70R LOADING N166: DISP Y -VE	-18.670	82.738	-42.240	-37.249	**0.169**	14.974
Min MY	7	5:IRC: SLS CLASS 70R LOADING N9: REACT FY +VE	-11.125	25.704	9.785	7.983	**-0.058**	9.712

IV. CONCLUSION

It is observed that bridges, designed, detailed and constructed with appropriate seismic considerations can with stand any severe earthquakes ,although there may be some repairable damage .The bridges need retrofitting primarily because of two reasons that these were(i)designed for smaller forces than that can occur ,and(ii)lacking in ductility in the absence of ductile detailing of reinforcement.Several bridges constructed prior to existence of modern seismic codes fail to meet requirement of safety.Seismic retrofitting is required for protection of such bridges in future occurring earthquakes. It is possible to retrofit many of the existing bridges against falling of spans and other distress by simple retrofitting measures .The key issue in retrofitting are ,retrofit philosophy ,seismic assessment ,retrofit techniques ,testing effectiveness of retrofit measures ,application of composite materials and smart materials,in retrofitting.The bridge retrofit program is necessary and should be undertaken for vulnerable bridges that have not yet experienced earthquakes.

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