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BEHAVIOUR OF FRAMES UNDER SEISMIC LOADING

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ABSTRACT

It is thought that there is a low to moderate seismic risk in many intratectonic plate areas. Nevertheless, these areas are susceptible to catastrophic earthquakes that have severe effects in terms of damage and casualties. In order to comprehend the seismic capability of the characteristically intricate Australian reinforced concrete (RC) frames, this research presents an experimental and analytical investigation. Using base motion and a design spectrum akin to that of firm soil sites as specified by the Australian Design Code, the experimental program comprised a series of earthquake simulator experiments with rising difficulty. This research aimed to explore the behaviour of seismically designed reinforced concrete frames and identify the range of earthquake magnitudes that are likely to result in excessive damage to the structure and non-structure or collapse of gravity-load-designed (GLD) reinforced concrete frames. In frame structure earthquake design, a variety of brace types are employed to improve frame structure performance. For example, X-braced, ZX-braced, inverted V-braced, and zipper braced frames. Among the many varieties of standard concentrically braced frames are Inverted-V braced frames. This system's behaviour is dictated by the first story braces buckling under compression, which causes a localized failure and a lack of lateral resistance.

Keywords: *Reinforced concrete frames; earthquake; drift; ductility; over strength; seismic loading; Zipper braced frame.*

INTRODUCTION

Since lateral inertia forces are typically used by seismic design algorithms to account for seismic ground motion effects, seismic design of structures is typically based on strength or force considerations rather than displacement. These static forces' distribution, and consequently their stiffness and strength, are implicitly based on the elastic vibration modes. Consequently, using inertia forces corresponding to elastic modes may not result in the best distribution of structural attributes when structures surpass their elastic limits during severe earthquakes [1-3].

The development of various structural optimization approaches has resulted from the requirement to identify optimal and cost-effective structural designs. Over the past few decades, a large number of scholars have examined the best way to design structures to withstand seismic loads. The conventional methods employed in these investigations are typically gradient-based solutions for solving problems that call for the fulfilment of particular mathematical requirements. These methods cannot be employed realistically for the optimal design of nonlinear structures subjected to seismic excitations because of the difficulties in calculating adequate expressions for optimisation constraints. [4]

The non-linear seismic response of structures is typically taken into consideration by the recently established performance-based design methodologies, which are also a good predictor of the direction that seismic design codes will go in the future. In order to determine the extent of damage during strong seismic occurrences, these techniques directly address inelastic deformations.

SEISMIC DESIGN FOR SINGLE EARTHQUAKE

Conventional reinforced concrete buildings undergo non-linear deformations during medium to moderate earthquakes, but they are supposed to remain in their elastic state during mild earthquakes. Because the concrete part contributes more significantly to lateral stiffness, it is primarily in charge of limiting elastic drift under light seismic loads. The dimensions of the beam and column elements are often selected at the beginning of the design process primarily to satisfy building code requirements, notably to limit lateral storey drift, even though the concrete volume can have a major impact on the cost of RC frames. According to the suggested design approach, the initial design is optimized for higher performance levels like collapse prevention and life safety, and it must achieve serviceability limit states under frequent earthquakes mostly based on elastic behaviour. The reinforcement ratio of structural elements is thought to be the primary design variable within the nonlinear response range since flexural reinforcement is crucial in preventing inter-storey drift and supplying the necessary ductility. Nonetheless, by applying one of the current elastic response optimization techniques, it is feasible to maximize the size of the beam and column elements in the original design. [5]

ZIPPER BRACED FRAME

Because buckling at the bracing system prevents Chevron braced frames from distributing huge, unbalanced forces, engineers found it challenging to design them. Concentrically zipper-braced frames are shaped to achieve benefits like resistance and stiffness to restrict the displacement ratio and also guarantee the stability of the structure's behaviour. ZBF theory was first put forth by Khatib in 1988. With the exception of one additional component, a vertical structural member known as a strut that is attached to the beams at the mid-span point, this system is comparable to the Chevron system. The zipper is the name of this vertical strut, and the zipper brace frame is the frame to which zipper braces were added. The zipper columns are fixed vertically and positioned 90 degrees’ perpendicular to the floor beams. The unbalancing force that results from the compressive member of the first-story bracing buckling can be transferred to the bracings on higher floors by means of these columns.

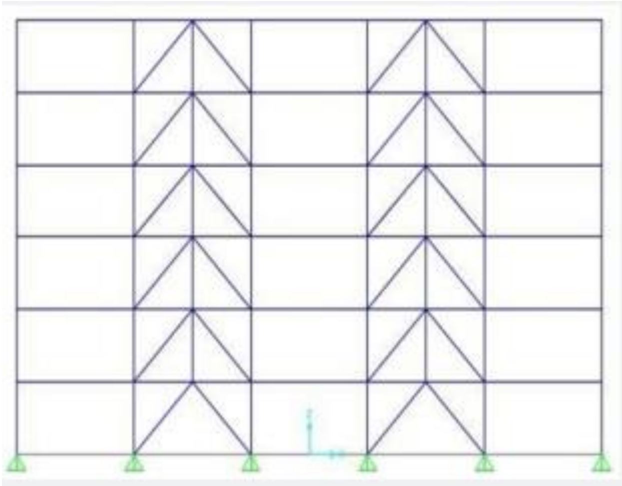

Figure 1: Zipper braced frame

SEISMIC PERFORMANCE OF ZIPPER BRACED FRAME COMPARED WITH DIFFERENT BRACED FRAME

The addition of a vertical zipper element improved the way the frames behaved. The amount of energy absorbed by the Zipper bracing members exceeds that of Chevron. By applying acceleration to the structure and performing time history analysis, it is found that the zipper strut-equipped system exhibits a stronger tendency to form shear links, leading to greater dissipation capacity in plastic, improving the seismic performance of the structure. Compared to X-bracing, zipper bracing improves yielding mechanism, ductility, and lateral strength. The capacity of the IVF, VBF, and ZBF buildings is higher than that of other buildings, according to seismic performance of various buildings measured in terms of performance point. ZBF improves the performance of the structure against seismic loads. Bracing elements will significantly impact how a structure behaves during an earthquake. When compared to code-based buildings, structures constructed with zipper braced frames have a global ductility ratio that is up to 50% lower for a given structural weight. [6]

NONLINEAR MODELLING OF R/C FRAME AND ANALYSIS

A detailed approach has been developed for the modelling, analysis, and assessment of R/C frame structures' structural seismic damage characteristics.

The software IDARC2D was employed. This program, which used a member-by-member macro-modelling approach, has been used to do nonlinear studies. A deteriorating moment-curvature relationship with a non-symmetrical triliniar envelope curve was used to model the cyclic behaviour of the member cross-sections in beams and columns, which were represented as the inelastic component elements with dispersed plasticity. The stiffness loss at unloading and reload mg, the strength deterioration, and the slip and pinching effects are all controlled by four factors that the hysteretic model relies on. [7]

OBJECTIVES

- Classify the behaviour mechanism of RC frames.
- Examine the RC frame on the seismic response of the structure.
- Identify the mechanism of masonry walls, the stiffness, ductility and energy dissipation.
- Analysis of nonlinear modelling of R/C frame structure.

RESEARCH METHODOLOGY

A few of the secondary sources we used to learn about comparative study on public policy were books, government papers, journals on education and development, and print and online reference materials.

The internal and external validity of comparison research determines their quality. The degree to which inferences may be accurately made about the study's design, participants, intervention, measurements, analysis, and interpretations is known as internal validity. The ability to extrapolate the results to different contexts is known as external validity.

REVIEW OF LITERATURE

A performance-based design approach for basic elastic structural systems functioning in an unpredictable dynamic environment was created by Beck et al. Ganzerli et al. integrated structural optimization techniques with the modern idea of performance-based design. They presented a nonlinear analysis-based method in which plastic rotations of beams, columns, and frames were used to apply performance-based constraints. [8]

According to Pourbaba P et al.'s study, adding a vertical zipper member improved the way the frames behaved. Therefore, it was observed that the internal force in the Zipper braced member was zero, even if the compressive braced frame members on the first floor were not collapsing at the onset of lateral loading. Reduced mid-point beam deflections in the braced system and improved ductility are both achieved by using the zipper column in CBF. [9]

In a 2017 study, Jinkoo Kim and Younghoo Choi examined the seismic performance of a staggered wall structure created using a traditional strength-based design methodology. They compared this performance to that of a structure created using a capacity design approach, which guarantees the strong column-weak beam principle. By contrasting the seismic performance of seismic reinforcement schemes, like incorporating rotary friction dampers at the ends of tie beams or adding internal columns, with that of a standard model structure, the schemes are validated, Customary. They discovered that, in accordance with thrust analysis, the outer columns of structures intended for strength failed most, whereas in structures intended for capacity, the outer columns' disintegration is what primarily causes the strength to decline. Beams with plastic hinges. According to fragility analysis, the likelihood of dynamic instability is lowest in structures equipped with friction dampers and largest in structures intended to be loaded. The power design used in this study is thought to work best in large-magnitude earthquake scenarios that result in significant structural damage. A mild or moderate failure state can occur in the model with internal columns with a very high probability, while a complete failure state can only occur in the structure with dampers when there is a sufficient reduction in friction. [10]

The impact of oblique seismic input on the strong-column weak-beam mechanism for RC frames was investigated by Hua Ma, Chunyang Liu, Zhenbao Li, Jianqiang Han, and Shicai Chen in 2011. Conveniently, using the X and Y directions is the primary seismic input flow for building calculations. The primary axes of the building are X and Y, and only these main axes are taken into consideration while analysing the damage mechanism of the strong columns and weak beams. In contrast to the main axis, the building's reaction is larger in the diagonal direction, and its frequency is higher in the diagonal direction than it is in the X or Y direction. They describe how dimensional mechanical analysis, repeated load measurements, and finite element analysis of dimensional beam-column connections influence the damage mechanism of strong column weak beams in RC frames when there is oblique seismic input. For future structural planning to accomplish actual strong column weak beam dynamics, it is required to discuss from and account for the seismic input in the tilt direction. [11]

RESULT AND DISCUSSION

The suggested design technique was used to the 5-story frame for a more effective seismic design in order to achieve a goal drift ratio of 1.5% using the average synthetic earthquake. In this instance, the needed longitudinal reinforcement weight is about 9.1 tons, which is 5% less than the weight of an ordinary RC frame.

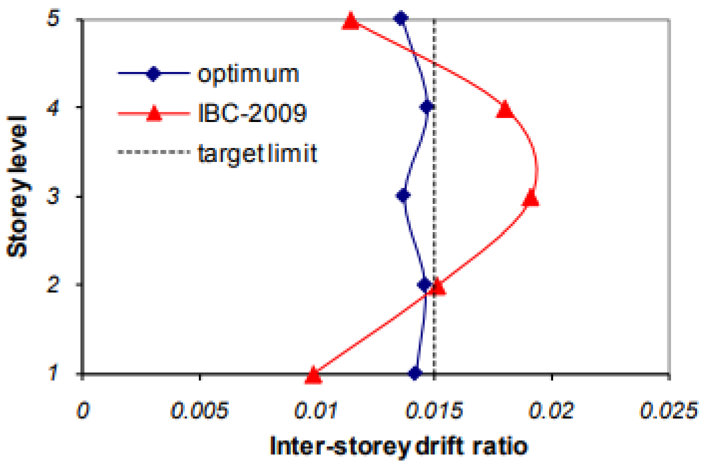

Figure 2: Inter-storey drift distributions of IBC-2009 and near optimum design models to earthquake

The inter-storey drift distributions of near-optimal design models and IBC-2009 under average synthetic earthquakes are contrasted in Figure [2]. It is demonstrated that the inter-storey drift ratio of the nearly ideal designed structure is less than 1.5% for all storeys, even if the IBC-2009 RC frame does not achieve the intended performance objective. This demonstrates that the final design frame has greater seismic performance and less longitudinal reinforcement. [12]

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The near-optimal storey building was developed using the average simulated earthquake and the IBC-2009 in order to examine the effectiveness of the technique for actual seismic excitations. Table 1 displays the maximum inter-storey drifts.

Table 1: Maximum inter-storey drifts for IBC-2009 and near optimum design model in four different seismic excitations

Maximum inter-storey drift ratio (%)								
Storey	Kobe		Landers		Northridge		Cape Mendocino	
	IBC	Opt	IBC	Opt	IBC	Opt	IBC	Opt
5	1.77	2.31	0.53	0.62	1.20	1.83	1.00	1.70
4	2.93	2.82	0.65	0.64	1.59	1.22	1.86	1.52
3	3.66	2.80	0.71	0.62	1.83	1.31	2.81	1.92
2	2.92	2.63	0.68	0.67	1.41	1.36	2.49	2.45
1	1.44	2.36	0.32	0.55	0.58	0.95	1.29	2.12
COV	0.36	0.09	0.28	0.07	0.36	0.24	0.41	0.19

According to the results, the near-optimal RC frame consistently had a more uniform inter-storey drift distribution—that is, less COV and less maximum inter-storey drift—than the conventionally designed frame. [13]

The peak ground accelerations, which correlate to the yield and final limit state, are found in numerous nonlinear dynamic analyses of the WC frame under study. Table 2 lists the many combinations of suggested limit states that are similar to these.

Table 2: nonlinear dynamic analysis of WC frame of different limit states

Excit.	q(1,A)	q'(2,A)	q'(1,B)	q'(2,B)	q_D'(A)	q_D'(B)
1	2	3	4	5	6	7
Acc. 1	13,93	6.12	19.73	8.65	16.71	22.02
Acc. 2	14,3	4.12	16.97	6.12	14.52	18.19
Acc. 3	10,87	3.73	14.13	4.45	13.02	14.01
Acc. 4	12.44	3.92	17.88	4.89	13.51	14.84
Mean	12.87	4.576	17.16	6.0	14.44	17.27
Mean/ Design	2.574	0.925	3.432	1.2	2.888	3.453

Column 6's behaviour factor qd provides information about the behaviour factor employed in design, while column 3's behaviour factor q' represents the inherent behaviour factor. We acquire these two numbers for distinct yield states as well as for the same ultimate limit state. [14]

CONCLUSION

This work suggests a more effective performance-based design approach for RC structure earthquake design. The results show that a superior seismic performance can be achieved by employing an average simulated earthquake in the suggested design procedure. It is demonstrated that RC frames created using a typical simulated earthquake invariably display less overall damage and more consistent inter-storey drift distribution. For reinforced concrete structures exposed to seismic and gravity loads, a more effective way to distribute longitudinal reinforcement is through the application of the uniform distribution of deformation demands idea. The study's findings indicate that the most promising method for seismic rehabilitation is this one. The conclusion is that the use of zipper braced frames seems to account for the procedure's increasing conservatism as the number of stories increases.

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