REVIEW ON APPROACHES FOR STRUCTURAL FAILURE PREDICTION OF RC BUILDING

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Abstract- Greatest design of the structure is essential in the field of structural design. The wide spread use of concrete materials in today's civil engineering has led to formulating of numerous methods for improving the performance of structures. An optimal solution generally means the most economical solution and also which would satisfy the operational aspects of the structure. Cost Effective Designs are obtained by optimization using numerical analysis methods and models of decision-making processes such that it satisfies the specified objectives. With the availability of all such methods of optimisation serves to improve design processes.

Keywords: RCC,optimization,prediction

I. INTRODUCTION

The lateral resistance of multi-storey reinforced concrete frame structures, designed before the availability of current seismic design codes, may not be adequate. In addition, buildings designed to low levels of seismic loads according to older codes that have since been upgraded, may also be deficient. The use of no ductile detailing in these codes results in low seismic capacity. One of the major challenges that faces structural engineers is how to determine the seismic capacity of these buildings and decide if they need rehabilitation or not and which rehabilitation technique to be used. One of the most common rehabilitation techniques is to provide additional reinforced concrete structural walls. The resisting mechanism of reinforced concrete shear panel is diagonal compression of the infilled concrete. Therefore, the initial stiffness and ultimate resistance are high. However, deformability is small because of compression fracture of concrete. In the past decade, existing RC buildings received attention by researchers. A number of experimental and analytical studies were conducted to gain better understanding of the behaviour of these buildings. However, on the analytical side, models to represent existing structures are still in the process of improvement. To determine the seismic capacity of existing buildings and analyse existing buildings after rehabilitation using structural walls, accurate, simple and practical models should be developed. The availability of such models allows the assessment of the seismic performance of existing structures which is necessary information for the development of rehabilitation codes. A representative model should contain the main characteristics that describe completely the hysteretic behaviour of reinforced concrete structural components. These characteristics include stiffness degradation, strength softening and pinching behaviour. In addition, the used model should be as simple as possible so that the analysis can be performed with reasonable computational effort, especially in the case of multistorey structural systems. Available models for representing RC structures are concerned only with the maximum load carrying capacity. Available models are mostly unable to predict the post peak strength response and most importantly the failure mechanism. Some researchers (Abouelfath, 1999; park et al., 1987) predicted the post peak response by using parameters that was calibrated using the available experimental results. Other researchers (Miramontes et al., 1996; Chung et al., 1989) used damage indices to define the degrading slope. These methods are doubtful as it might be correct for certain cases but can not be generalized. The model adopted for the analysis of reinforced concrete elements should be capable of simulating the behaviour due to different failure modes

1.1.1 RC (Reinforced Concrete)

Reinforced concrete is a combination of concrete and steel plates which enhance the strength of the concrete. This type of concrete is able to resist the applied force together. The combination of steel and concrete gives effective strength and able to handle the largest vibrations of earthquakes, winds and other forces. Basically it is and economic building material which is used now the days in most of the building construction. It is used in construction of beams, columns and storage structure like dams, tunnels and water tanks.

Common Materials used in RCC:

- Cement
- Coarse Aggregate
- Fine Aggregates
- Water
- Admixtures
- Steel

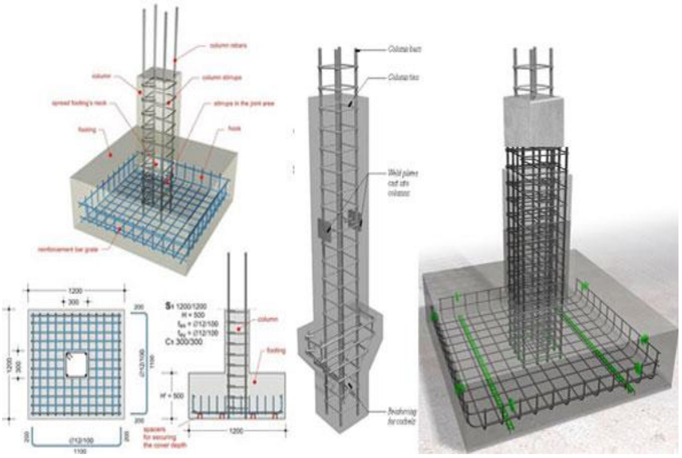

Figure 1.1 Structure of buildings in RCC

1.1.2 Advantages of RC

1. RC has high compressive strength as compared to the classical building materials.
2. Reinforced concrete provides the good tensile strength.
3. RC has good resistance against fire and weather conditions.
4. RC buildings are more durable than the normal building.
5. Economy to mold in any shape.
6. The maintenance cost of the RC is low.
7. It also effectively implemented by less skilled labours

1.1.3 Disadvantage of RC

1. The tensile strength of reinforced concrete is about one-tenth of its compressive strength.
2. The main steps of using reinforced concrete are mixing, casting, and curing. All of this affects the final strength.
3. The cost of the forms used for casting RC is relatively higher.
4. For multi-storied building the RCC column section for is larger than steel section as the compressive strength is lower in the case of RCC.
5. Shrinkage causes crack development and strength loss.

1.1.4 Common issues in the RC buildings

1. Sliding of roofs off the supports

2. Falling of infill walls.

3. Crushing of column ends and virtual hinging.

4. Diagonal cracking in columns

5. Collapse of gable frames.

6. Foundation sinking and Tilting

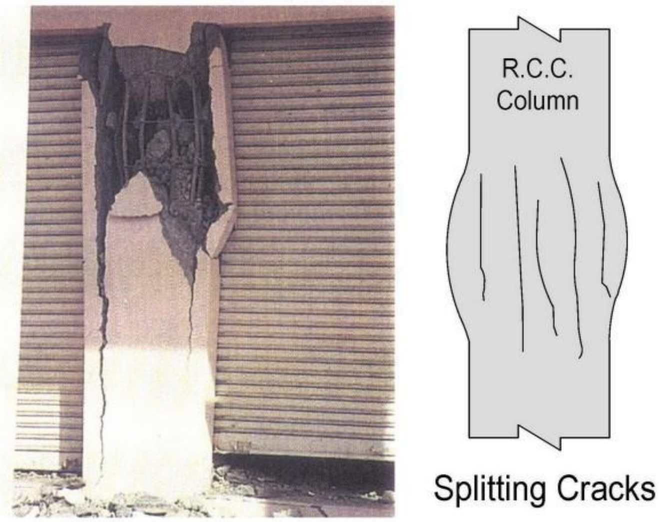

Figure 1.2 cracking in columns

1.1 Design Optimization in RCC Structures

Development method play a significant role in the design of structures, the objective which is to find super ways or techniques by which the designer or the decision makers can generate the maximum profit from the existing resources at hand. An engineer's main aim is to progress with an 'optimum design' for the concerned design job. An absolute solution usually demonstrates a beneficial structure without destroying the useful purposes. There is huge number of promising beam sizes and increased ratio's that outcome for the same moment of struggle, then it became tough tasks to achieve the least-cost construct by knowable iterative prospective. The mechanism of optimization can help designers to grab the best design.

Seismic Performance of Modern Buildings The design philosophy of modern seismic provisions recognizes needs for sufficient strength, ductility and energy dissipation capacity to prevent global collapses of structures by strong earthquake excitations. The fundamental concepts covered in these design provisions are: • "Strong column and weak beam" design to maintain structural integrity under gravity forces • Design of dissipative regions concentrated at the beam ends and at the base of the columns, which ensures the nodal zones have sufficient strength and rotation capacity in order to avoid brittle failure, • Ductile detailing design to provide structural ability of dissipating energy after yielding when subjected to a series of large inelastic deformation cycles, and • Proper design of structure to stand within allowable story-drift limits in order to keep vertical stability of the structure. Many structural collapses occurred in recent earthquakes have taken place in non-ductile frames such as older buildings designed with inadequate seismic design or other buildings with poor 9 quality of design and construction (Figure 2.1 and Figure 2.2). However, several collapses of modern structures have also been observed even when these structures were built in accordance with the requirements of seismic building code and construction practice standards (Villaverde, 2007). An example is the total collapse of the 22-story steel frame building of Pino Suarez complex during the 1985 Mexico City earthquake (see Figure 2.3). Ger et al. (1993) investigated the reasons of the collapse and performed dynamic analyses on a three-dimensional finite element model of the collapsed structure under the same ground motion. The authors have found that ductility demands in longitudinal girders exceeded the design-based ductility capacity leading the girders to redistribute the applied forces and so the nearby columns to fail in local buckling, therefore resulting in complete collapse of the building against gravity forces under amplified P-delta effects.

Another example is the collapse of Alto Río building in the 2010 Maule, Chile earthquake. It was a 15-story reinforced concrete structure completed in 2009, following the present Chilean building codes. The building was designed with reinforced concrete structural walls occupying nearly 7% of the floor area for earthquake resistance. Failure of the structural walls at the first story under the seismic actions caused the building to overturn entirely as seen in Figure 2.4. 10 Based on several analytical studies on a representative three-dimensional model, Song et al. (2012) showed that the maximum structural demand of drift ratio should be around 1% for the building to keep such integrity in Figure 2.4, therefore indicating a brittle failure mechanism. They also stated that overturning of the building required tension or bond failure in more than half of the vertical reinforcement at the failure surface. They explained that this failure can be due to the fracture of vertical bars at sections with low reinforcement ratios or unbonding of unconfined lap splices

The main idea behind indirect architecture in engineering is the past experiences, inspire behind design, unfinished logical processes, or sometimes irregular environmental conditions. This therefore doesn’t lead to best design or optimum design. This shortcoming of this type of indirect design can be overcome by adopting optimum design approach, which of only logical decisions. In this the designer sets out the pressure and then minimizes or maximizes the objective functions like cost, weight or merit. The structural optimisation techniques can also be according to the construct philosophy employed. The purpose function is attained by calculating each event and multiplying it to the respective possibility. The total of all such entries will be the total purpose function.

Discretization of Beam and Column Sections The lumped-plasticity and nonlinear beam-column elements require a section model to define the moment-curvature response at points along the length of the member. Two approaches can be employed to define the moment-curvature response for a section: use a one-dimension material model to define the moment-curvature relationship or use a fiber discretization of the section and one-dimensional material models to represent the stress-strain response of the plain concrete and reinforcing steel that compose the section. The use of a one-dimensional moment-curvature response has the advantage of reducing computational time and reducing the memory required to run the model. However, a onedimensional moment-curvature response model cannot represent variability in flexural response due to variation in axial load, which may be significant for columns. Additionally, accurate calibration of a one-dimensional moment-curvature response model for reversed cyclic loading is difficult and requires the analyst to introduce multiple assumptions about response. A fiber discretization model has the advantage that model is defined entirely by the geometry of the gross concrete section, the location and size of longitudinal bars, a one-dimensional concrete stress-strain model and a onedimensional steel stress-strain model. One-dimensional concrete and steel material models are well defined by experimental data. 3.4 Material Properties Standard one-dimensional concrete and steel stress-strain response models are used to define section response. These material models are discussed in the following sub-sections. 24 3.4.1 Concrete Open Sees provides three models that can be used to simulate concrete stress strain response. These models are named Concrete01, Concrete02, and Concrete03. All of these models define the same response under compressive loading: parabolic stress strain response to the point of maximum compressive strength, linear post-peak response to a residual compressive strength. This response curve is shown in Figure 3.2. Concrete01 defines zero tensile strength. Concrete02 defines a brittle response under tensile loading with complete loss of tensile strength once peak tensile strength is exceeded. Concrete03 defines a brittle response under tensile loading with an exponential decay in tensile strength once peak tensile strength is exceeded. In the current study, Concrete01 (concrete without tensile strength) is used, as previous earthquake loading of the structure is assumed have resulted in substantial concrete cracking and thus loss of concrete tensile strength.

II. RELATED WORK

H.Moharrami and D.E. Griesrson (1993) in their paper provide an effective computer aided technique for the finest design of the concrete building formworks. The dimensional parameters of width, depth and longitudinal reinforcement of members are taken as design variables. Both the member capacity sensitiveness and structure ability sensitiveness are taken into deliberation while formulating all the strength constraints. The techniques shows that it provides an efficiency way to optimise with iterative optimization which converges in a few cycles to a least cost design of reinforced concrete frameworks satisfying all relative requirements of the design codes.

C. A. C. Coello et al (1997): In his paper developed a simple Genetic algorithm for the design of supportive concrete beams; organise an optimization model for the design of rectangular reinforced concrete beams subject to a particular set of constraint. Their model is more materialistic than published formerly because it reduces the cost of the beam on fortifying design procedures, although the cost of concrete, steel and shuttering is also examined. Thus their design proceeds to very practical design. There is a number of unlimited numbers of possible beam dimensions and yield a same moment of struggle. An efficient search technique is favoured over the more traditional alternate methods. They also engage a simple genetic algorithm as a search engine. They also compare the results with those achieved via geometric programming. However the adjustment of parameters in a genetic algorithm is a significant issue for any application, they represent their own methodology to deal with this issue.

K.C Sarma and H.Adeli (1998) in their research say that as the construction of the concrete designers includes at least three separate materials namely concrete, steel and formwork. Thus the design optimization of concrete structures should not base on weight optimization, but instead on cost optimization. In this study analysis of numerous papers on cost optimization of concrete structures is accessible. The conclusion from it states that three is requires to research on cost optimization of three dimensional structures especially where huge savings can be made. Also supplementary research on cost optimization based on life cycle of structures, where instead of the initial cost of the structures, the life cycle cost is minimized.

C.C. Ferreira et al (2003): In this approach, finest design of reinforced concrete T-sections in winding present optimization of the steel area and the steel localization in a T-beam under bending is performed in the current work. The expressions giving the equilibrium of a single and double reinforced T-section in the various stages introduced by the non-linear behaviour of the steel and concrete are derived ones. The final material behaviour is defined accordingly to the designs codes alike EC2 and Model Code 1990. The objective is to gain the analytical optimal design of reinforcement of a T-section in terms of the unlimited design. The established expressions are applied to examples and design abacuses are supplied. A judgment is made with the available practice technique as indicated in CEB.

V. Govindaraj and J. V. Ramasamy (2005): in this paper presented the optimum design of reinforced concrete regular beams using genetic algorithms as per the design deliberation of the Indian standard codes. The optimum design is such designed that it observes with all the serviceability, ductility, durability, and all other design constraints of the code. In this examine only the cross sectional dimensions of the beam are considered as design variables. An example issue is illustrated and the results are presented.

B. Saini et al (2006): Studied Genetically, improved artificial neural network on the basis of optimum design of single and double fortify concrete beams, research optimum design of singly and double support beams with uniformly dispersed and concentrated load has been done by compromising exact self-weight beam. On the basis of steepest descent, flexible and malleable and back-propagation learning a technique, this design is skilful has also been composed of genetically optimized artificial neural network. With the use of limit state design, the initial solution has been achieved.

A.B Senouci and M.S Ansari (2009): This paper is about cost optimization of composite beams using genetic algorithm. It is based on the load and confrontation factor design specification of the AISC. The cost of concrete, steel beam and sheer studs are involved in the establishment of model. In this proposed model two designs are studied to illustrate its ability in optimizing composite beam design. The outcome achieved shows that the model is able to attain cost saving. Research has also been done to analyse the effects of beam spans.

A.Nimtawat and P Nanakorn (2011): This paper shows that PSO algorithm for beam slab layout design distribute with measurement of the design of beam slab layout is analysed and not algorithmic because the procedure cannot be segmented into an algorithm. In this research, the design work is written as an optimization issue, which can be solved by following suitable target and reducing functions on the basis of engineering consideration. A simple PSO used to resolve the problem of optimization. It has also been found that it is the best popular method due to its simplicity and excellent presentation. In order to employ this technique certain coding strategy for beam slab layout is used.

A.C Galeb and Z.F Atiyah (2011): In this paper optimum design of supplement concrete waffle slabs dealt with the optimum design to strength concrete waffle slabs with the use of genetic algorithms. Two case studies have been explained: the first is a waffle slab with solid heads and next is the waffle slab with band beam throughout the column center lines. The limitation involves the restrictions on measurements of the rib and limitation on the top of the slab wideness, the constraint on the areas area of steel reinforcement to gratify flexural behaviour and deliver sufficient concrete cover an the restriction on the longitudinal reinforcement o band beams. A computer program is written with the use of MATLAB to evaluate the structural investigation and design the waffle of slabs by the direct design techniques. The optimization procedure carried out by using built in genetic algorithm toolbox of matlab.

S.T Yousif and R.M. Najem (2012): in their study discussed the application of genetic algorithms in the cost optimization of the protected concrete beams based on the ACI standard stipulations. The resultant optimized design fulfils all the strength, serviceability, ductility, durability and all other constrains connected to design and detailing requirements. In this study the dimensions of the reinforcement steel were introduced as a variable taking into account flexural, shear and torsion influence on the beam. The forces, moments and deformations require in the Genetic algorithm constraints will be found by examines. The optimum results were calculated and then compared to the results in the previous literature.

A.Kaveh and M.S Massoudi (2012): Author analysed the Ant colony system model for cost optimization of a amalgamate floor system on the basis of load and confrontation factor design specification of AISC deals with the diverse cost of the concrete, steel bums and the shear studs need to add the cost of the structure which may be reduced on the basis of type of working in the structure.

A.Kaveh and A.F. Benham (2012): in their study conducted the Cost optimization of a multiple floor system using a charged system search algorithm, and deal with design optimization of special floor systems which includes multiple slab, one way waffle slab. All this is performed using the most recent meta-heuristic algorithms. The most favourable design is based on LRFD-aisc and ACI 318-05. The purpose function here is the cost function. The cost function contains cost of all the materials used and construction cost. The problem is also optimized using by enhanced Harmony search system algorithm and then compared with the output of the charged system search algorithm.

Chintanpakdee and Chopra (2004) evaluated the effects of strength, stiffness and combination of strength and stiffness irregularity on seismic response of multistorey frames. For analytical study, different 12 storey frames were modeled based on strong column – weak beam theory. The irregularity in strength and stiffness were introduced at different locations along height of the building models. The building models were analyzed using time history analysis by subjecting the building model to 20 different 57 ground motion data. From analytical study it was concluded that irregularities in strength and stiffness when present in combination had the maximum effect on the seismic response. Further maximum variation in the displacement response along height was observed when irregularities were present on the lower storeys.

Tremblay and Poncet (2005) evaluated the seismic response of building frames with vertical mass irregularity designed according to NBCC provisions by static and dynamic analysis. Based on the analytical study it was concluded that both static and dynamic method of analysis (as prescribed by NBCC provisions) resulted in similar values of storey drifts and hence they were ineffective in predicting the effects of mass irregularity.

Fragiadakis et al. (2005) determined the seismic response of building systems with irregular distribution of strength and stiffness in vertical direction. After conducting the analytical study it was concluded that seismic performance of the structure depended on type and location of irregularity and on intensity of seismic excitation. Modal pushover analysis (MPA) procedure is an important analytical tool to evaluate the seismic performance and several researchers like

Lignos and Gantes (2005) investigated the effectiveness of Modal pushover analysis procedure (MPA) in determination of the seismic response pf multistorey steel braced frame (4, 9 storey) with stiffness irregularities. Based on the results of analytical study it was concluded that MPA procedure was incapable of predicting failure mechanism and collapse of the structure.

Khoury et al. (2005) designed a 9 storey steel framed structure with setback irregularity as per Israeli steel code SI 1225(1998). The height and locations of setback were varied for the analytical study. Results of analytical studies confirmed that higher torsional response was obtained in tower portion of setbacks.

Tremblay and Poncet (2005) who conducted extensive study on multistorey building frames with mass irregularity as per NBCC code,

Ayidin (2007) evaluated the seismic response of buildings with mass irregularity by ELF procedure (as prescribed by Turkish code of practice) and by time history analysis. The researcher had modeled multistorey structures ranging from 5 to 20 storey height. The mass irregularity was created by variation in mass of one storey with constant mass at other storeys. Based on the analytical study author concluded that the mass irregularity affects the shear in the storey below and ELF procedure overestimates the seismic response of the building systems as compared to the time history analysis. Some researchers preferred dynamic analysis over MPA procedure to evaluate seismic response due to its accuracy.

Fragiadakis et al. (2006) proposed an IDA (Incremental dynamic analysis) procedure for estimating seismic response of multistorey frame (9 storeys) with stiffness and strength irregularity contrary to Lignos and Gantes (2005),

Alba et al. (2005) who used MPA procedure to evaluate the seismic response of building frames with stiffness irregularity. 58 Based on the analytical results the authors concluded that the proposed method was effective in predicting effects of irregularity in building frames. Finally, the authors concluded that the effect of irregularity is influenced by location and type of irregularity and building systems subjected to unidirectional seismic excitation underestimate the seismic demand significantly.

Basu and Gopalakrishnan (2007) developed a simplified method of analysis for determination of seismic response of structures with setbacks and torsional irregularity. The assessment by the proposed method was made by applying it on four building models. In case of building models with scattered positions of CM the proposed method evaluates seismic response considering average value of position of CM whereas perturbation analysis considered the exact location of CM at different floor levels to evaluate the seismic response. Results of analytical study showed that for building systems with vertically aligned CM. The frequencies obtained by proposed procedure and perturbation analysis were observed to be in close agreement. However, the results of frame shear forces differed by 7%. In case of second example, the modal response obtained by proposed method and perturbation analysis was similar, but difference in frame shear force was found to be 4% for upper storeys and 1% for base storeys. In case of third building model, the frequencies obtained by proposed procedure and perturbation analysis were in close agreement, but difference of results in case of frame shear forces as 10 % at ground storey level and 4% at first storey level. In case of fourth example the difference of results in estimation of frame shear forces as high as 50%, Thus, it was concluded that the proposed position is not applicable to the building models where the prescribed limit of scattering of CM was exceeded.

Karavasilis et.al. (2008a) performed extensive parametric study on steel frames with different types of setback irregularity designed as per European seismic and structural codes (EC 8 :2004). From analysis, the databank of output parameters corresponding to number of storeys, beam to column strength ratio, geometrical irregularity etc. was created. Based on the deformation demands four performance levels were identified and these were (a) occurrence of first plastic hinge, (b) Maximum inter-storey drift ratio (IDRmax) equal to 1.8 % ; (c) IDRmax equal to 3.2%, (d) IDRmax equal to 4.0%. The results for different types of setback structure were expressed in terms of these performance levels. From analytical study it was concluded that interstorey drift ratio (IDR) increased with increase in storey height and tower portion of setback experienced maximum deformation as compared to the base portion.

Athanassiadou (2008) made the assessment of seismic capacity of the RC structures irregular in elevation. The author modeled three multistorey frames. Out of these three frames ,two ten storey plane frames were modeled with two and four large setbacks in their upper floors and the third frame was regular in elevation. These three frames were 59 subjected to 30 different ground motions and designed as DCH and DCM frames (designed for high ductility and medium ductility) as per Euro code 8. Then non linear dynamic analysis of the frames was carried out by subjecting the frame to the ground motion data of the earthquake and parameters of rotation, base shear and interstorey drift were evaluated. Based on the analytical study it was found that the performance of both DCM and DCH frames was found to be satisfactory as per guidelines of EC 8.

Karavasilis et al. (2008b) evaluated the seismic response of family of 135 plane steel moment resisting frames with vertical mass irregularities and created databank of analytical results. The authors used regression analysis technique to derive simple formulae to evaluate seismic response parameters using the analysis databank. Results of analytical studies suggested that the mass ratio had no influence on deformation demand. The results obtained from proposed formulae were found to be comparable with results of dynamic analysis.

Sadasiva et al. (2008) evaluated the effect of location of vertical mass irregularity on seismic response of the structure. A 9 storey regular and irregular (with vertical irregularity) frame was analyzed and designed as per New Zealand code of practice in two ways. Firstly, it was designed to have maximum interstorey drift at all levels (represented as CDCSIR). Secondly, it was designed to have a constant stiffness (represented by CS) at all levels. To make clear distinction between regular and irregular structure, a special notation form was used by the authors of form NS-M-L-(A), where Nno.of storeys, S-Shear beam, M- Type of model [i.e. S(Shear beam) or SFB (Shear Flexure beam), (A) – Mass ratio].The deformation was represented in the form of graphs. For the study Los Angeles earthquake records had been used and inelastic time history analysis of the structure was performed using Ruamoko software. Based on this analysis it was concluded that in case of both CS and CISDR model the interstorey drift produced is maximum when mass irregularity is present at topmost storey and irregularity increases the interstorey drift of the structure. However, this magnitude varied for both CS and CISDR type of models.

Ambrisi et al. (2009) proposed a modified pushover analysis method for determining the seismic response of building structures, and found the comparable results by both pushover and inelastic dynamic analysis for setback frames.

Dinh Van Thuat (2011) determined the storey strength demands of irregular buildings under strong earthquakes. The strength irregularity in the building models was introduced in terms of storey strength factor which represents the relative reserve strength of the storey against failure. A large number of analysis of building models ranging from 7 storeys to 19 storeys were conducted. The analysis results indicate the variation in seismic demands due to introduction of irregularity. 60

Kappos and Stefanidou (2010) proposed a new deformation design method based on inelastic analysis for the setback frames. From analysis results, adequate seismic performance of the setback frames designed as per the proposed method was observed. Kim and Hong (2011) determined the collapse resisting capacity of the building models with stiffness and strength irregularity. The irregularity in the building models was created by removal of column in the intermediate storey. However, analysis results suggested minor variation in the collapse potentials of regular and irregular structures.

Lu et al. (2012) performed non-linear time history analysis of the tall setback building and found excessive damage concentration in storeys adjacent to setbacks.

III. CONCLUSION

Reinforced concrete is a combination of concrete and steel plates which enhance the strength of the concrete. This type of concrete is able to resist the applied force together. The combination of steel and concrete gives effective strength and able to handle the largest vibrations of earthquakes, winds and other forces. Basically it is and economic building material which is used now the days in most of the building construction. It is used in construction of beams, columns and storage structure like dams, tunnels and water tanks. In this work Failure prediction

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