EFFECTS OF WIND AND EARTHQUAKE ON RC TALL BUILDING WITH EXPANSON AND WITHOUT EXPANSION JOINT USING GUST FACTOR/RSA ANALYSIS

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Abstract - Structures engineering are an integral part of our modern development and society. Traditionally, mostly structures are designed to resist static loads. However, they may be subjected to dynamic loads like seismic, winds, waves, and traffic. Wind-induced vibrations in structures increases the importance of structural design as the use of high-strength, lightweight materials, longer floor spans, and more flexible framing systems are used, results in structures that are more prone to vibrations. The diversity of structures that are sensitive to the effects of wind increases the need to improve the performance of construct structures. For longer span bridges, tall buildings and high towers or stack structures, wind load may be taken as a critical loading. The impact of wind loads is to be considered for the design of tall multi-storeyed buildings. 2nd one is the Expansion joint elimination. As observed and visited also some operational projects that expansion joint treatment is bigger challenges and due the failure of expansion joint mostly projects was effected from huge water leakages and seepage issues and some projects structures are detouring due the expansion joint. So, after the market feedback and structure challenges, we planned for the expansion joint elimination in tall building structure. I studied some expert literature and discussed with some senior professor and consultant also. After the all conclusion, I took decision for the expansion joint elimination, we can easily eliminate the expansion joint from the structure but thermal analysis input has to be taken in design and then accordingly, it can easily possible in design. Thermal analysis should be considering for the elimination of expansion joint in structure is mandatory, Elimination of Expansion joint not an impossible task, it is easily and taken by thermal analysis in structure design. Now, it is possible due to the upgraded available tools in structure design which is based on FEM technology. This study presents the wind effects on buildings with Expansion joint and without expansion joint by using the ETABS software. All the frame models are idealized as 3D models. Variations of bending moment and axial force in columns are considered to study the behaviour of frames. From the present study it can be concluded that wind effects are significant compared to gravity effect, when the aspect ratio is less and dynamic effect is not significant compared to static effect for symmetrical frames.

To get a fruitful outcome/desirable outcome for above mentioned system be using mentioned analysis.

• Response Spectrum Analysis

• Serviceability check

Results will be observed in terms of top story displacement, inter story drift, base shear, & mode shape, with expansion joint and without expansion joint structure outcome. The software program is used to perform a Response Spectrum analysis. The building was designed according to the regulations of IS 456:2000, IS :3414 :1968, IS: 1893:2016, IS: 13920, IS: 875: Part-3 2015 and IS: 16700: 2016 for both gravity and seismic loads and wind loads. Analysis is carried out using standard package ETAB 2018.

***Key Words*: *Wind effects, Earthquake effects, Gust factor analysis, aspect ratio, and dynamic analysis and Expansion joint elimination, temperature analysis and area optimization for the stakeholders*.**

1. INTRODUCTION

Buildings are defined as structures that utilized by the people as shelter for living, working or storage. Vertical tall building structures are most commonly used because of shortage of land and due to increasing population, there are many tall buildings have been constructed in India to provide the services and give the shelters to increasing population, tall buildings are complex structures and it can be designed carefully because there are many internal and external stresses have been introduced when we applying the wind and earthquake load whichever is dominant.

Tall buildings are designed either for wind or earthquake because if we can apply both phenomenon so the building would be designed uneconomical.

Tall buildings are critically affected by wind loads in following two ways:

- Firstly, it exerts forces and moments on the structure and its cladding.
- Secondly it distributes the air in and around the building mainly termed as Wind Pressure.

There are two types of analysis have been done in this paper. The first one is linear static analysis and second is linear dynamic analysis. In the static analysis we can calculate the pressure and forces and statically distribute the forces on the structure according the computational program and getting the values of deflection, B.M and Shear forces. In dynamic analysis building behaves in different manner in comparison to static analysis due to vortex and gustiness effect of the wind. Sometimes because of unpredictable nature of wind which is dangerous for tall building structures the structures have been collapsed due to improper designing and we should be careful while designing the tall building and use the best possible structural elements that can take the maximum effect of irregular wind pressure such as, shear wall, bracing system. Pressure have been increase when going to the upper floors of the structures because of the increasing of terrain category. The forces usually decreases in the dynamic due to the dropping of the hourly mean wind speed but the torsion, time period and modes of the building is quite different in comparison to static analysis. Tall building can free to move at high wind speeds in all the three global directions which is (x,y and z). the external and internal pressure coefficient are given in the codes and the codes do not expected the maximum wind speed for the life of the building and does not consider the high local suctions which cause the first damage to the trusses. Due to all these facts the Wind Load estimation for Tall Buildings are very much important.

2. Objective

1. Analytical determination of wind loads and earthquake loads as per IS-875 Part -3 and IS 1893-2016.

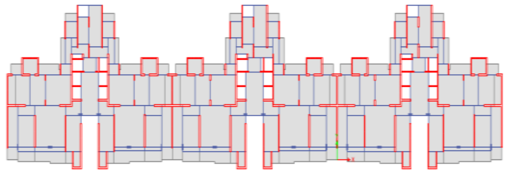
2. To determine the height beyond which wind loads combinations are critical as compared to seismic load combinations.

3. To Study the behavior of tall structures when subjected to along wind loads.

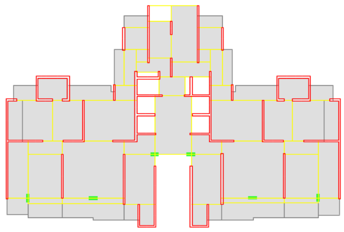
4. To study the effect of shape of the structure.

5. To study the contribution of shear wall and Bracing frames to check the lateral displacement of the structure with respect to the columns.

6. To determine the effect of wind load on various parameters like fundamental, time period, storey drifts, lateral joint displacements, bending moments and shear force in columns and beams etc.



COMBINED TOWER



ISOLATED TOWER

3. METHODOLOGY

3.1 DESIGN WIND LOAD

Designed wind load is defined as it can be designed with parameters of wind which are given in Indian standard codes IS(875-partIII) and in high rise structures there are gust factors and wind tunnel effects have been used to determine the actual behavior of wind on structures and the designed wind pressure should be applied on the model. Wind load have been applied on that structures which are applicable for wind analysis such as tall buildings, chimneys, trusses etc. There are various figures and phenomenon is used in explanatory handbook to apply wind forces on different type of structures and the pressure could not be steady, but highly fluctuating, partly as a result of the gustiness of the wind, but also because of local vortex shedding at the edges of the structures themselves. Sometimes the fluctuating pressure can causes the critical damage to the structure. If the structure is dynamically wind sensitive, then the pressure cannot be uniformly distributed over the structure and some irregular behavior can be observed while using dynamical effect on the structure. There are various shapes of the structures have been discussed in the Indian standard and we have to apply the wind according to the shapes of the building because wind can be varied if the shapes of the building are different.

3.1.1 Type of Wind Design

Typically for wind sensitive structures three basic wind effects need to be considered.

a). Environmental wind studies

b). Wind loads for façade

c). Wind loads for structure

3.2 DESIGN CRITERIA

In terms of designing a structure for lateral wind loads the following basic design criteria need to be satisfied.

Stability should be checked against overturning, uplift and/or sliding of the structure as a whole. Or if we are failing to achieve proper stability then we have to give the proper alignment and directions of the inertial forces to avoid the exceeding drift displacement and overturning of a whole structure. There are some limiting checks have been given in Indian standards and the stability cannot be exceed against the limiting values.

Strength of the structural components of the building is required to be sufficient to withstand imposed loading without failure during the life of the structure. We must provide the adequate stiffness to the structure to avoid the collapse of the structure. We are using computational program to calculate the strength of the structure and we are giving the collapse combination in the software to check the whole strength of the structure.

Serviceability-For buildings, where inter-story and overall deflections are expected to remain within acceptable limits. Control of deflection and drift is imperative for tall buildings with the view to limiting damage and cracking of non-structural members such as the facade, internal partitions and ceilings.

3.3 ALONG AND ACROSS WIND LOADING:

Along wind and Across wind loading is applied when wind is blowing normal to the structure and perpendicular to the structure. We are taking the wind in both the directions IN 0^0 and 90^o. So, along wind direction is taken when the wind is applying normal to the structure and Across wind motion is taken when the wind have turbulence effect, vortex shedding. Along wind and Across wind can be applied in tall buildings, chimneys, O.H.T. The torsional effect is also noticed while applying the along and across wind loading on the structure. Building tends to vibrate in rectilinear and torsional modes. The amplitude of such oscillations is dependent on the nature of the aerodynamic forces and the dynamic characteristics of the building.

3.3.1 Along-Wind Loading

The along-wind loading is applied normal to the wind direction on the structure we can take the angle of wind along-wind load is 0^0. Wind can be assumed to consist of a mean component due to the action of the mean wind speed (eg, the mean-hourly wind speed) and a fluctuating component due to wind speed variations from the mean.

3.3.2 Across-Wind Loading

Across-wind loading is applied perpendicular to the direction of wind we can take the wind directions independently in both the directions and when we applied the wind in along-wind loading at 0^0 so we have to apply Across-wind loading at angle of 90^0 which is perpendicular to the along-wind loading. We have many examples of slender structures that are to be designed dynamically across-wind loading. Tall chimneys, street lighting standards, towers.

The excitation of modern tall buildings and structures can be divided into three mechanisms and their higher time derivatives, which are described as follows:

(a) Vortex Shedding.

(b) The incident turbulence mechanism.

(c) Higher derivatives of crosswind displacement.

3.4 CODAL CRITERIA FOR THE BUILDINGS TO BE EXAMINED FOR DYNAMIC EFFECTS OF WINDS

Building can be examined as per the clauses of the Indian standard codes. The code is used for wind analysis is IS(875-partIII). Building should be Slender structures and structural elements shall be investigated to a certain the importance of wind induced oscillations or excitations along and across the direction of wind. In general, the following guidelines may be used for examining the problems of wind induced oscillations:

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0, and

b) Buildings and closed structures whose natural frequency in the first mode is less than1.0 Hz. Any building or structure which satisfy either of the above two criteria shall be examined for dynamic effects of wind.

1) The fundamental time period (T) may either be established by experimental observation on similar building or calculated by rational method of analysis in the absence of such data, T may be determined as follow for multi stories building.

a) For moment resisting frames without bracing or shear walls for resisting the lateral loads.

T = 0.1 n

b) For all others

T = 0.09 $H\sqrt{d}$

3.5 HOURLY MEAN WIND SPEED (VZ)

The basic wind speed is in Gust Factor to be used as a hourly mean wind speed and it depends upon the k2' factor in IS(875-partIII) refer table 33:

a) Risk level;

b) Terrain roughness, height and size of structure; and

c) Local topography.

Vz = Vb k1.k2.k3

Vz = hourly mean wind speed in m/s, at height z

Vb = regional basic wind speed in m/s

k1 = probability factor (risk coefficient) (Table 3.1)

k2 = Terrain and height factor (Table 3.2)

k3 = topography factor

Design wind speed up to 10 m height from mean ground level shall be considered constant.

We have been used the tables and graphs in IS(875-partIII) to calculate the design wind speed and design wind pressure.

3.6 DESIGN WIND PRESSURE (pz):

The design wind pressure can be obtained at any height above mean ground level shall be calculated by the following relationship between wind pressure and wind velocity

$Pz = 0.6\ Vz^2$

3.7 FORCE COEFFICIENT

The value of force coefficients have been calculated according to the Indian standards and it will apply to a whole structure, we are using a graph in IS (875-Part 3) to calculate the values of Cf (force coefficient) with respect to the length, width and height of the building and value of Cf is multiplied by the effective frontal area Ae of the building or structure and by design wind pressure, pa gives the total wind load on that particular building or structure.

F = Cf*Ae*pa

Where F is the force acting in a direction specified in the respective tables and Cf is the force coefficient for the building.

Refer Fig. 3.4 for the value of Cf with respect the value of a=length of building), b=(width of building), h=(height of the building).

3.8 GUST FACTOR METHOD

Application Only the method of calculating load along wind or drag load by using gust factor method is given in the code since methods for calculating load across –wind or other components are not fully matured for all types of structures. However, it is permissible for a designer to use gust factor method to calculate all components of load on a structure using any available theory. However, such a theory must take into account the random nature of atmospheric wind speed.

3.8.1 Hourly mean wind

Use of the existing theories of gust factor method require a knowledge of maximum wind speeds averaged over one hour at a particular location. Hourly mean wind speeds at different heights in different terrains is given in Table 3.2. IS 875 3

3.8.2 Along wind Load

Along wind load on a structure on a strip area (Ae) at any height (z) is given by:

Fz = Cf.Ae.pz.G

G =Gust Factor = (peak load/ mean load) and is given by:

$$G = 1 + g_f r \sqrt{[(1 + \emptyset^2)] + \frac{SE}{\beta}}$$

Where

gf = peak factor defined as the ratio of the expected peak value to the root mean value of a fluctuating load,

r = roughness factor which is dependent on the size of the structure in relation to the ground roughness.

B = background factor indicating a measure of slowly varying component of fluctuating wind load.

SE/β= measure of the resonant component of the fluctuating wind load.

S = size reduction factor.

E = measure of available energy in the wind stream at the natural frequency of the structure.

B = damping coefficient (as a fraction of critical damping) of the structure.

$$\emptyset = \frac{g_f r}{4}\sqrt{B}$$

and is to be accounted only for buildings less than 75 m high in terrain Category 4 and for buildings, less than 25 m high in terrain Category 3, and is to be taken as zero in all other categories.

$$\lambda = \frac{b.c_y}{h.c_z} \text{ and } F_0 = \frac{h.C_z.f_0}{V_h}$$

Where,

Cy = lateral correlation constant which may be taken as 10 in the absence of more precise load data,

Cz = longitudinal correlation constant which may be taken as 12 in the absence of more precise load data,

b= breadth of a structure normal to the wind stream,

h = height of a structure,

Vh = Vz = hourly mean wind speed at height z

F_o = natural frequency of the structure, and

L(h) = a measure of turbulence length scale

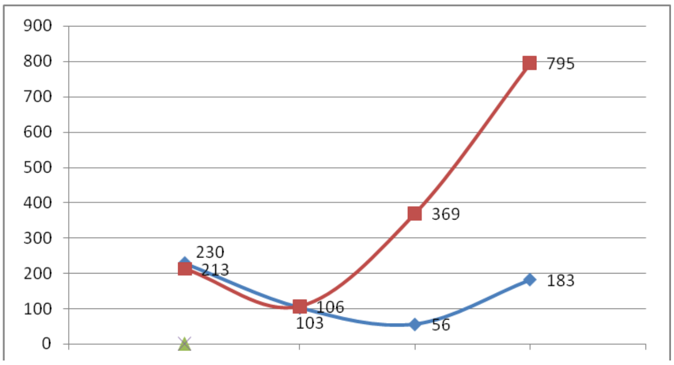
4. DISPLACEMENT IN X-DIR. AND Y-DIR. FOR COMBINED TOWERS AND ISLOATED TOWER

Limiting deflection of (H/500) = 270mm for the combinations of limit state of serviceability

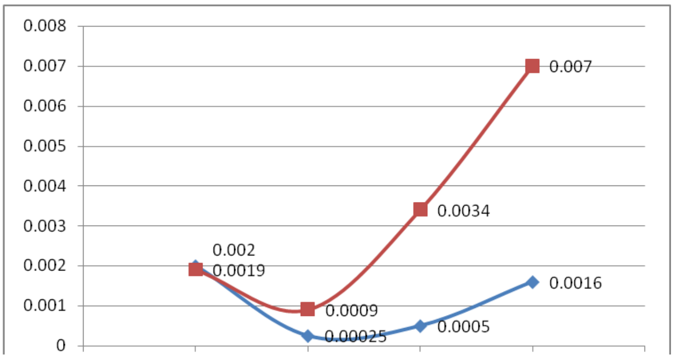
MAX. DISPLACEMENT AT 135 METRES HEIGHT		
DEF. DUE TO EQ AND WIND	COMBINED TOWER	ISOLATED TOWER
	DISPL.	DISPL.
EQX	230	213
EQY	103	106
WX	56	369
WY	183	795

It has been observed that the displacement in Earthquake and wind is given in table above, we shall calculate the expansion joint as per IS1893:2016 clause 7.11.3 but our maximum governing force is 759mm in WY for isolated tower.

STORY DRIFT FOR COMBINED AND ISOLTAED TOWERS		
DRIFT LIMIT	COMBINED TOWER	ISOLATED TOWER
EQX	0.002	0.0019
EQY	0.00025	0.0009
WX	0.0005	0.0034
WY	0.0016	0.007



DISPLACEMENT Chart.no.1



DRIFT Chart.no.2

5. MAXIMUM DRIFT

Permissible drift as per IS (1893-2016) Earthquake resistant and design is 0.004*H. 0.004 Drift is Unitless.

RESPONSE SPECTRUM ANALYSIS:

Response spectrum analysis is linear static dynamic analysis; response spectrum analysis shall be done as per Is 1893:2016. RSA depends on many factors such as, Zone factor, Sa/g(acceleration due to gravity) and Time period. RSA measure the contribution of each natural mode of vibration to get the maximum response of the building, First three mode need to be check carefully, in the very first mode we need to avoid torsion. 90% of mass shall participate in RSA.

Response-spectrum analysis provides insight into dynamic behavior by measuring pseudo-spectral acceleration, velocity, or displacement as a function of structural period for a given time history and level of damping.

In this research paper wind force are governed so this is just a explanation for Response spectrum Analysis.

THERMAL EXPANSION ANALYSIS:

Thermal Expansion Analysis has been done as per IS456:2000 and IS 875-5. We have checked and analyze that we can eliminate the Expansion joint by giving Shrinkage

Strip/pour Strip for expansion and contraction due to change in temperature. We are getting the expansion joint as per displacement given in above table is 1704 mm.

To avoid the expansion joint we can go for shrinkage strip/pour strip.

6. CONCLUSIONS

1. As the building length is increased by keeping its width fixed, the story stiffness goes on decreases. Gust factor is more in case of building having less length dimension.

2. Story displacement value will have increased if the isolated tower building to be considered.

3. Story drift values larger from the permissible limit in single building.

4. For the Displacement and drift control, additional stiffness has to be required for the permissible limit range.

5. Torsional moment will also increase in single tower building as compared to combined building.

6. **As per the IS: 1893:2016 – Clause 7.11.3 Separation between Adjacent units:** Two Adjacent building or two adjacent units of the same building with separation joint between them, shall be separated by distance equal to R times sum of story displacement D1 and D2 calculated of the two buildings or two units of the same building, to avoid pounding as the two buildings or two units of the same building oscillate towards each other.

   When floor levels of the adjacent units of a building or buildings are at the same level, the separation distance shall be calculated as (R1*D1+R2*D2), where R1 and D1 correspond to building 1, and R2 and D2 to building 2.

   Separation space needed for the buildings –

   R1=R2 for the same height and specification building.

   R = 4

   D1=D2

   Maximum Displacement in Wind X direction is 369mm

   Then separation space required for 1st to 2nd Buildings = (4X213+4X213) i.e. 1704mm and for the 2nd to 3rd Buildings required 1704mm, so, needed total **1704mm separation** space for the expansion joint.

   Now, as per the above statement for the isolated tower with Expansion joint more spaces has to be required which will become waste of money and for the space and most important is huge maintenance cost.

7. The dynamic response factor increases with height. This is because of the increase in the slowly varying background component of the fluctuating response.

8. From the present study it is observed that for symmetrical frames the dynamic effect is not significant compared to static effect.

9. Wind effects are significant compared to gravity effects, when the aspect ratio is less, however its effect reduces as aspect ratio increases.

ACKNOWLEDGEMENT

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N. Lakshmanan, S. Gomathinayagam*, P.

Harikrishna, A. Abraham and S. Chitra Ganapathi, 2009, Long-term data on hourly wind speed from 70 meteorological centres of India Meteorological Department have been collected. The daily gust wind data have been processed for annual upper limit wind speed (in kmph) for each site. Using the Gumbel probability paper approach, the intense value quantiles have been derived. A design basis wind speed for each site for a return period of 50 years has also been evaluated. The site-specific changes in the design wind speeds in the contemporary wind zone map for the design of buildings/structures are highlighted and revision to the map is suggested.

Tharaka Gunawardena1*, Shiromal Fernando 2,

Priyan Mendis 1, Bhathiya Waduge 2, Dilina Hettiarachchi 2, 2017, Urban habitats around the world are becoming more congested with rising populations and the need for tall buildings is as high as ever. Sri Lanka is experiencing this reality at present as Colombo's skyline expands rapidly with a large number of upcoming complex high-rise buildings. The response of tall buildings to wind forces is a critical design criterion and it requires both conventional force based designs as well as performance based solutions. This paper discusses these challenges and the engineering solutions that they require to successfully design a tall building which is not only stable, safe and strong under wind loads but also performs excellently providing usable and highly functional design.

Umakant Arya1, Aslam Hussain2, Waseem Khan3. (2014), In this study paper, the investigative result of wind speed and structural response of building frame on sloping ground has been studied and analyze. Considering various frame geometries and slope of grounds. Combination of static and wind loads are considered. There is many type of sloping ground. For combination, 60 cases in different wind zones and three different heights of building frames are analyzed. STAAD-Pro software has been used for analysis purpose. Results are collected in terms of Storey wise drift, Shear force, moment, axial force, support reaction, and Displacement which are critically analyzed to count the effects of a variety of slope of ground.

K.R.C. Reddy1 (2015) In different type of high rise structure chimney has its own importance. Along wind analysis of tall reinforced concrete chimneys by casual vibration approach and Codal methods of India (IS 4998 (part 1)), America (ACI 307) and Australia (AS/NZS 1170.2) are offered in this paper. For the analysis based on casual vibration approach, the RC chimney is model as multi-degree-of freedom system subjected to static load due to mean constituent of wind pace and dynamic load due to changeable component of speed. The changeable component of wind speed at a point is careful as temporal random process. Subsequently, the codal procedures for along-wind analysis of tall RC chimneys from Indian, American and Australian codes are reviewed. Four RC chimneys are analyzed using these methods to achieve their responses. It is found that the codal methods of along-wind analysis are basic, are not prepared to estimation the deflection of the chimneys and producing mixed results. The simplifying assumptions used in these codes are discussed.

LITERATURE REVIEW ON RSA:

Mr. Ashish A. Mohite - The wind-induced response of a structure with a damper system and to estimate the suppressing effects of dampers under earthquake loadings. Analysis of symmetrical moment resistance frame (MRF) 10th, 12th, 14th, 16th, 18th, and 21th story three – dimensional model with tuned mass damper and without tuned mass damper by using software ETABS Parameters/Model/Software: Tuned Mass Damper, TABS.

The following parameters to be used in the following discussion. The optimum natural frequency of the damper and the optimum damping ratio of damper are given by equation (1) and (2) respective. This study is aimed as tuned mass dampers in reducing structural (story drift, story displacement and base shear) of seismically excited 10th, 12th, 14th, 16th, 18th, and 21th story building. It has been found that the TMDs can be successfully used to control vibration of the structure.

A. Ravi Kumar- Designed and analyzed a G+9 floor earthquake resisting building with shear wall with the help of modeling ETABS software. In this study, the earthquake load was calculated and applied to a multi-storied building of plan 26mx26m and 10 no. of (G+9) floors with 40 meters height.

He concluded that shear walls are one of the most effective building elements in resisting lateral forces during earthquake and also provides larger stiffness to the buildings there by reducing the damage to structure and its contents.

Mr. Khemraj S. Deore - Time History Analysis and Response Spectrum Analysis is a vital technique for structural seismic analysis particularly once the structural is high rise. This thesis study of the damper effect in the frame (MRF) is an important factor for the analysis. A tuned mass damper (TMD) is placed on top floor of building and Response spectrum analysis has performed.

For Analysis purpose practical (G+16) story building modeled with and without tuned mass damper by using software ETABS.

Thakur V.M - In this paper TMD is used as soft story which is considered to be made up of RCC, constructed at the top of the building. A six storied building with rectangular shape is considered for analysis. Analysis is done by FE software SAP 2000 by using direct integration approach. TMDs with percentage masses 2% & 3% are considered. Three different recorded time histories of past EQ. are used for the analysis. Comparison is done between the buildings with TMD and without TMD.

Govardhan Bhatt et al (2017) made analysis for different models with Shear walls curtailed at different heights and compared those using ETABS, to understand the effect of curtailment of shear walls on the response of the structure.

They found that Storey Drifts increases tremendously at the level of curtailment for all the models. Also, the storey forces vary hugely in all the six models. Maximum forces were observed in SW10 while SW4 displayed the minimum forces because of the higher stiffness of SW10 model, enabling it to withstand higher lateral forces as compared to the others.

Jaimin Dodiya - Analyzed the multi-storey building with response spectrum using ETABS modeling software. Equivalent static method, Response spectrum method and time history methods were adopted. The area of building was 376m2 and height was 60m. Total number of floors was 20 and slab thickness was 150mm. Column size was 900x600mm.

He concluded that providing shear wall at opposite direction, performing better and more efficient than all other cases. Also, the provision of shear wall position in an appropriate location is advantageous and the structure performs better for an existing or a new structure.

Mr. K. Lova Raju- He studied the effective location of shear wall on performance of building frame subjected to earthquake load. In this paper, four types of structures with G+7 are considered in which one of the frame without shear wall and three frames with shear wall in various positions. The Non Linear Static analysis is done using ETABS v9.7.2 software

Syed Mohammad Umar- Investigated the effects of openings in shear wall on seismic response of structures. For parametric study 15 storied 4mx5m bays apartment buildings with typical floor plan of 25mx12m and floor height of 3m with different openings size and location in shear walls were modeled in ETABS-2015.

However, the response of the building was better when the openings are provided in the center of the wall as compared to their eccentric positions.

LITERATURE REVIEW ON EXPANSION:

By James M. Fisher, S.E –In this paper Mr. James M. Fisher said that on the most basic sense, the need for an expansion joint in a structure depends on the consequence of not having an expansion joint. Will the lack of an expansion joint hamper or destroy the

Function of the facility, or cause damage to the structural or architectural components?

The number and location of building expansion joints is a design issue not

Fully treated in technical literature. The *LRFD Specification* (AISC, 1999) lists expansion and contraction as a serviceability issue and provides the statement in Section L2, “Adequate provision shall be made for expansion and contraction appropriate to the service conditions of the structure.”

ASCE 7-02 *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2002) states, “Dimensional changes in a structure and its elements due to variations in temperature, relative humidity,

Or other effects shall not impair the serviceability of the structure.” This paper will focus on the basic requirements used to determine whether An expansion joint is required at a given location, or locations within a structure. Requirements of expansion joints as they pertain to commercial, industrial, and long span structures are discussed. Area dividers as provided in roof membranes to control the effects of thermal loads for roofing are not discussed, as they are relief joints in the membrane and do not require a joint in the roof structure below.

BY NATIONAL ACADEMY OF SCIENCES Washington, D.C. 1974 EXPANSION JOINTS IN BUILDINGS

Many factors affect the amount of temperature-induced movement that takes place in a building and also the extent to which this movement can take place before serious damage will occur or extensive maintenance will be required. Because of the complexity of the problem, no one has yet established nationally acceptable procedures for precisely determining the size and location of expansion joints required in a particular structure. In the absence of such definitive procedures, most designers and federal construction agencies have individually developed guidelines based on rough calculations and experience.

Although relatively few serious problems attributable to inadequate provision for temperature-induced movement have been reported, significant differences are found in the various guidelines used for locating and sizing expansion joints, suggesting that at least some of the guidelines must be in error. Therefore, it is quite likely that in some cases joints are being omitted where they are needed--thus creating a risk of structural failure or causing unnecessary operations and maintenance costs--and in other cases they are being used where they are not required--thus increasing the initial cost of construction and creating space utilization problems.

As a consequence, the Federal Construction Council (FCC) undertook the study reported herein in hopes of developing more definitive criteria for expansion joints than have existed in the past. The study was carried out for the Council by the FCC Standing Committee on Structural Engineering.

This report has been reviewed and approved by the Federal Construction Council, and, on the recommendation of the Council, the Building Research Advisory Board (BRAB) has approved the report for publication.

The Board gratefully acknowledges the work of the FCC Standing Committee on Structural Engineering in conducting the study and developing this report.

BIOGRAPY

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