A TYPICAL NON-LINEAR ANALYSIS OF ASYMMETRIC RCC BUILDINGS WITH BASE ISOLATION, DAMPER AND BRACING DURING EARTHQUAKE

[1] Ajay Kumar Chaubisa, [2] Prof. B. M. Purohit, [3] Prof. A. R. Darji
[1] M.E. [Structural Engineering] Student, [2] Assistant Professor, [3] Assistant Professor
[1, 2, 3] Department of Applied Mechanics, Government Engineering College, Dahod, Gujarat, India

Abstract:
In the current study, ‘Nonlinear Dynamic Analysis’ (or ‘Time-History Analysis’) has been carried out for various Storeys of ‘Asymmetric (L-Shaped) RCC Buildings’ with the help of ‘ETABS Software’. The ‘Base Isolation’ (Lead Rubber Bearing) provided at the foundation level and ‘Friction Damper’ (provided diagonally) & ‘Cross-Bracing’ both provided at the corner of building due to higher concentration of ‘Earthquake Forces’ at this point.

The Structural Models of different storeys have been compared with ‘Fixed Base Building’ versus Buildings provided with ‘Base Isolation’, ‘Friction Damper’ , and ’Cross-Bracing’ including parameters like ‘Storey Displacement’ and ‘Storey Drift’. The analysis depicts which ‘Seismic Response Control Device’ is the best in reducing ‘Storey Displacement’, ‘Storey Drift’ or providing Stability & Safety to Multi-Storey RCC Building with ‘Lateral Earthquake Load’ and find out at what ‘Storey Height’ which ‘Seismic Response Control Device’ is the most suitable or effective.

Keywords: Asymmetric RCC Building, Non-linear Analysis, Base Isolation, Damper, Bracing.

I. INTRODUCTION

An ‘Earthquake’ is an instant harsh movement within the earth’s crust causing great destruction especially of manmade structures. The Civil constructions like Buildings-basic structures for humans, it is essential that they should be designed to withstand earthquake forces. All over world, in earthquake events, it has been noticed that buildings with regular size, shape and geometry has performed well as compared to asymmetric shape buildings. Therefore, it is essential to control structural seismic response of asymmetric buildings when caused to undergo earthquake ground motion.

The current trend uses several new techniques adopted to minimize earthquake induced structural vibrations. In recent years, significant attention is being paid to research and development of structural response control systems and devices with particular importance on mitigations of seismic responses of buildings. Several Vibration Control Systems like Active, Semi-active, Passive and Hybrid Control Systems have been developed.

II. SEISMIC ANALYSIS

The “Seismic analysis” is a part of ‘Structural Analysis” as well as ‘Process of Structural Design’. The ‘Earthquake Engineering’ or ‘Structural Assessment’ & ‘Retrofit’ in regions where earthquakes are predominant is the computation of “Response of a building or Non-building Structure” to earthquakes.

A building has the possibility to move to & fro during an ‘earthquake’ or even an intense “Wind Storm”, it is termed as “Fundamental Mode [FM]”, & is the “Lowest Frequency of Building Response”, almost all the buildings, although, have “Higher Modes of Response” which are unusually activated during earthquakes. The figure depicts the “Second Mode”, yet there are higher “Abnormal Vibration Modes”, notwithstanding, the “First & Second Modes” prone to cause the greatest in amount or degree of damage in almost all cases.

III. NONLINEAR DYNAMIC ANALYSIS*:*

The “Nonlinear Dynamic Analysis” uses the combination of ground motion records with a detailed structural model, hence, is able to produce outcomes with comparatively low unpredictability. In “Nonlinear Dynamic Analyses”, the detailed structural model applied to a ground-motion record gives estimation of component deformations for each ‘Degree of Freedom’ in the model and the responses are combined using “Square-Root-Sum-of-Squares.

In “Nonlinear Dynamic Analysis”, the non-linear characteristics of structure are taken as part of “Time Domain Analysis”. This approach is most detailed & precise & is required by Various “Building Codes” for buildings of uncommon configuration or of special importance. Nonetheless, computed response can be highly susceptible to the features of individual ground motion used as seismic input; hence, Various analyses may be needed utilizing non-identical ground motion records to get a reliable assessment of probable spread of structural response.

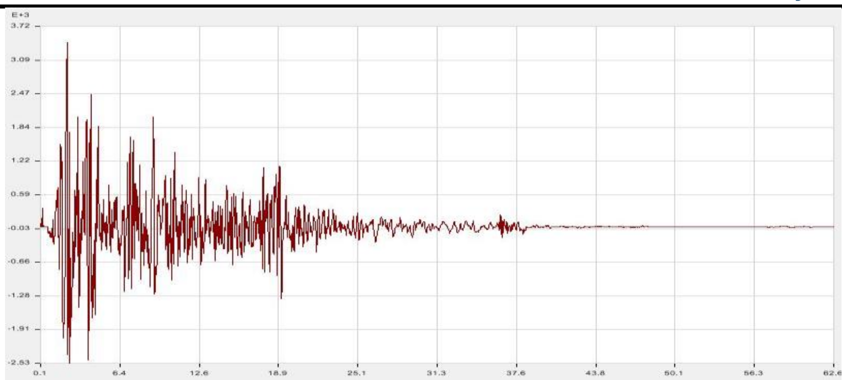


Figure: 1 Response Acceleration vs. Time Period of Plot of EL-CENTRO

As properties of seismic response are based on intensity or severity of seismic shaking, a detailed and complete assessment is required for many nonlinear dynamic analyses at various levels of intensity to present several earthquakes. This has brought to light methods like 'Incremental Dynamic Analysis'.

IV. SEISMIC RESPONSE CONTROL SYSTEMS [SRCS]:

There is a rapid increase in the number of tall buildings being constructed nowadays. They can be categorised as low rise, medium rise & high rise buildings, which are usually having low natural damping. In tall & super tall buildings, it is required to take into account damping capacity, rather increase it or add different devices or mechanisms to enhance 'damping capacity' of the 'structural system' while designing.

4.1 Basic Principles of Seismic Response Control [SRC] : Control systems add damping to structures or change dynamic properties of the structure. Adding damping enhances the 'Structural Energy Dissipating Capacity' , and changing structural 'Stiffness' consequently reducing 'Structural Seismic Response [SSR]'.

4.2 Techniques for Seismic Protection of Structures:

- The Traditional Techniques of a Seismic Design increase the "Stiffness" of structures by increasing the section of columns, beams, shear walls, or other elements.
- Modern Approach through Structural Controls: Modern Approach includes installation of certain mechanisms, devices and substructures in the structure to change or modify dynamic performance of structure.

4.3 Classification of "Structure Seismic Response Control Systems" [SSRCS]

1. **Passive Control Systems [PCS]:** External power source is not needed in this system. To control the response of structure it uses 'structural motion' to dissipate 'seismic energy' or structural vibrations may be isolated.
2. **Active Control Systems [ACS]:** In this system an external power source-"Control Actuators" are used to put in forces to the structure, these forces are used to either add or dissipate energy from the structure. The signals transmitted to "Control Actuators" are function of response of system that can be measured with sensors.
3. **Semi-Active Control Systems [SACS]:** This system has been introduced at a recent time for structural controls, it originated from "Passive Control System [PCS]" with later modification to permit adjustment of mechanical properties, e.g. supplemental energy dissipation devices which dissipate energy through shearing of viscous fluid, orificeing of fluid & sliding friction have been modified to behave in a semi-active manner.
4. **Hybrid Control Systems [HCS]:** The term "Hybrid Control" implies use of active & passive control systems in combination e.g. a Base Isolated Structure with Actuators or a Structure with Active Mass Damper close to top of structure actively controlled to further improve performance.

4.4 Base Isolation System [BIS]: To protect structural integrity of a building, base isolation system is used, which is a 'Passive Structural Control Technique' in which a group of structural elements decouple the building from its foundation that rest on shaking ground.

4.4.1 Types of Seismic Isolator Devices

1. Laminated Bearings, 2.Lead Rubber Bearings (LRB), 3.Friction Pendulum Bearing, 4.Roller and Ball Bearings, 5.Sliding Bearing and 6.Spring.

4.5 Seismic Dampers [SD]: The device which can absorb energy and add damping to structural system is known as 'Damper'. Supplemental damping devices are particularly suitable for tall buildings which can't be effectively base-isolated. They are flexible in comparison to low-rise buildings and needs control over horizontal displacement that is achieved by use of damping devices, which absorb energy making displacement endurable.

4.5.1 Types of Seismic Dampers Devices:

1. "Fluid Viscous Dampers [FVD]", 2. "Friction Dampers [FD]", 3. "Visco-Elastic Dampers"4. "Penguin Vibration Damper (PVD)", 5. "Pall Friction Damper [PFD]", 6. "Metallic Damper [MD]", 7. "Lead Injection Damper (LID)",
8. "Shape Memory Alloy" [SMA]", 9. "Tuned Liquid Damper (TLD)" and 10. "Tuned Mass Damper [TMD]".

4.6 Bracing System [BS]: Bracing system is generally used in structures vulnerable to lateral loads. Adding a bracing frame enhances structure's stability against lateral loads like wind loading & seismic pressure. The components of a braced frame usually consist of structural steel, that can work successfully both in tension & compression.

4.6.1 Type of Bracings:

1. Vertical Bracing, 2.Horizontal Bracing, 3.Single Diagonal Bracing, 4.Cross-Bracing, 5.K-Bracing,
6. V-Bracing, 7.Eccentric Bracing, 8.Concentric Bracing and 9.Buckling-Restrained Bracing.

V. BUILDING MODELING & LOADING DATA:

The Storey Height of L-Shaped RCC Building : 3.5 m , No. of Bays in X & Y Direction : 8 & 6 , Width and Length of Bays : 4.0 m , Size of Column: 0.6 m X 0.6 m, Size of Beam: 0.5 m x 0.5 m & Thickness of Slab:0.2 m. Numbers of models:28 with different storeys (3,6,9,12,15,18,21) , Grade of concrete: M-30,Yield Strength of Steel: 415 N/mm^2. Fixed type foundation with medium soil property, Seismic Zone: IV, Importance Factor: 1, & Response Reduction Factor: 5. The building loading data: Typical story slab dead load and live load respectively taken as 1.5 KN/m^2 & 3 KN/m^2.

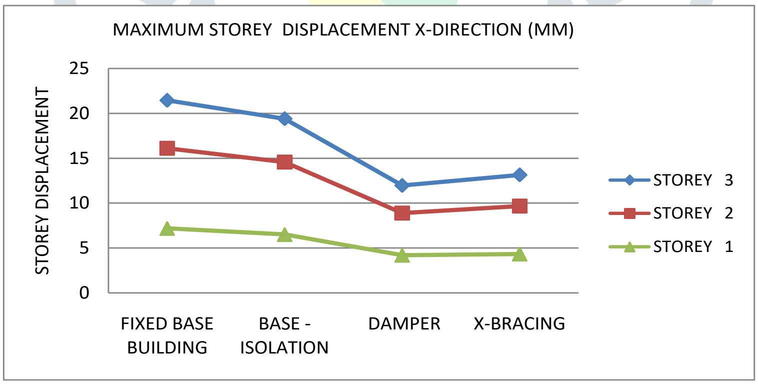
The analysis has been carried out with 3, 6,9,12,15,18,21 Storeys Asymmetric (L-Shaped) RCC Building with Nonlinear Dynamic analysis (El-Centro) with the help of Etabs software.

VI. RESULTS AND CONCLUSION

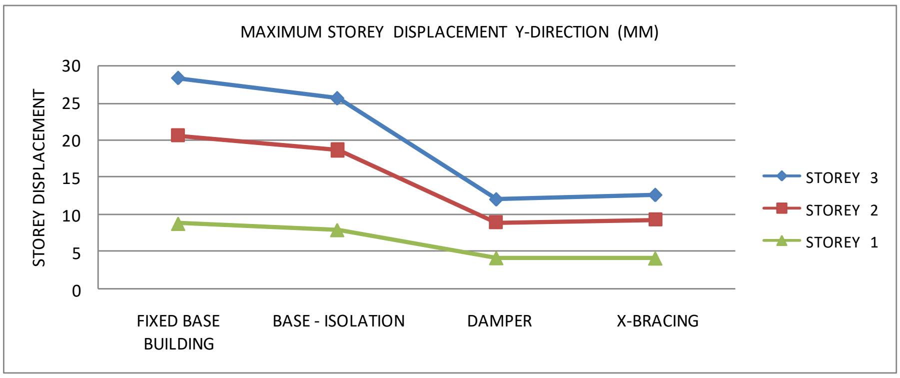
6.1 Analysis Outcome of Various 3-Storeyed Building Models

3-Storeyed Building: Fixed Base Building Results Compared with Building with Base Isolation, Damper and Bracing

6.1.1 Storey Displacement

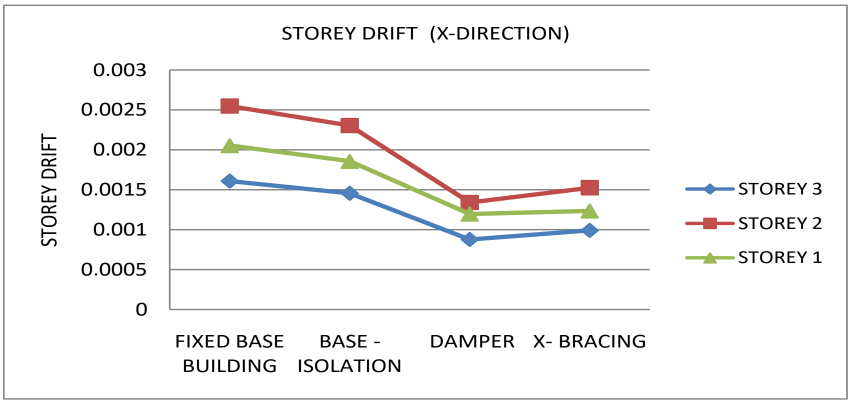


Graph: 1 (3 – Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

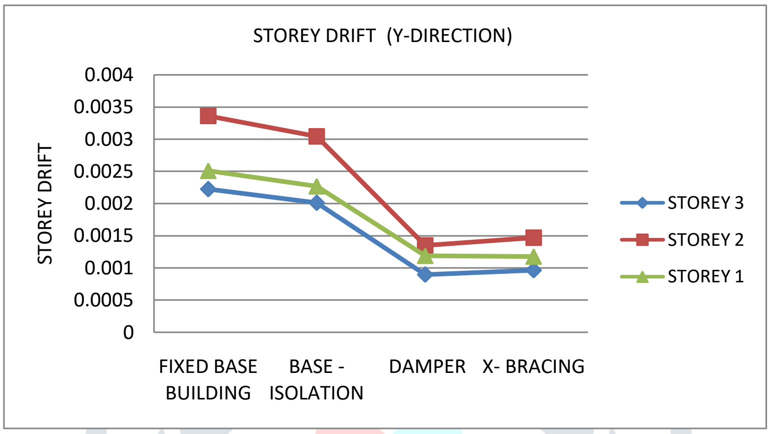


Graph: 2 (3 – Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.1.2 Storey Drift



Graph: 3 (3 – Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 4 (3 – Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.1.3: 3-Storey Analysis: Critical Remarks

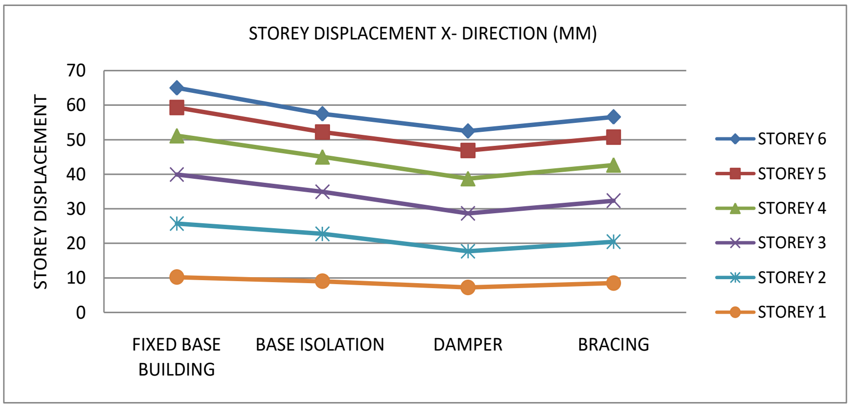
From the above analysis, it can be deduced that the deflection & drift of Fixed Base Building is larger as compared to Building with Base Isolation, Damper and Bracing. In terms of percentage, the reduction of deflection with base isolation, damper and bracing in X-Direction (10%, 45%, 39%) & Y-Direction (11%, 58%, 56%) respectively.

Hence, maximum reduction in deflection may be obtained with 3-storeyed building with damper. In terms of percentage, the reduction of drift with base isolation, damper and bracing in X-Direction (10%, 48%, 40%) & Y-Direction (9%, 60%, 56%) respectively. Hence, maximum reduction in drift may be obtained with 3-storeyed building with damper.

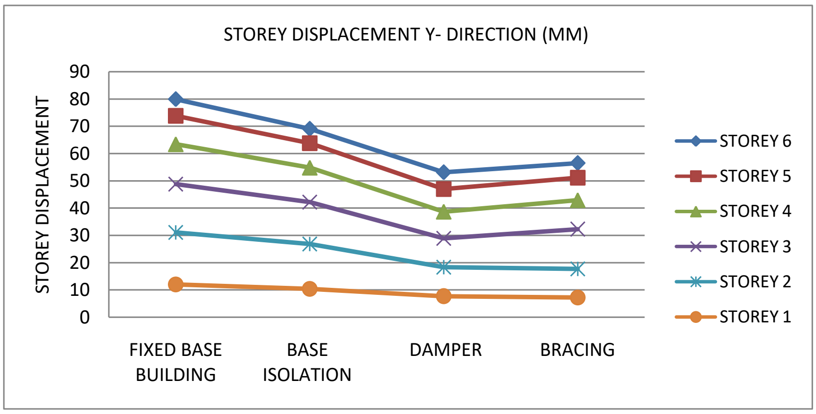
6.2 Analysis Outcome of Various 6 - Storeyed Building Models:

6-Storeyed Building: Fixed Base Building Results Compared with Building with Base Isolation, Damper and Bracing

6.2.1 Storey Displacement

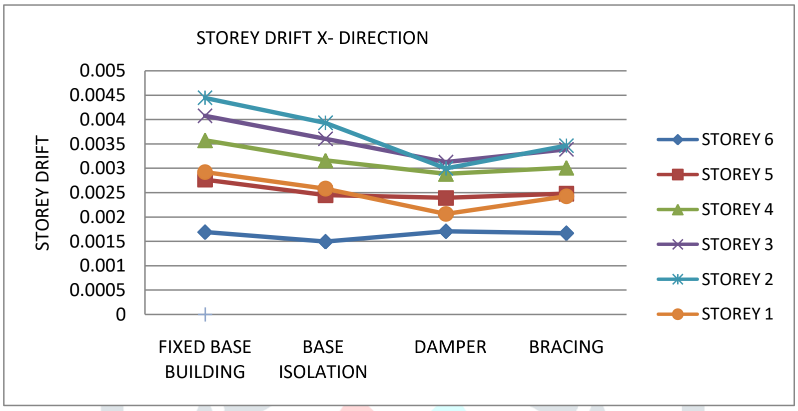


Graph: 5 (6–Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

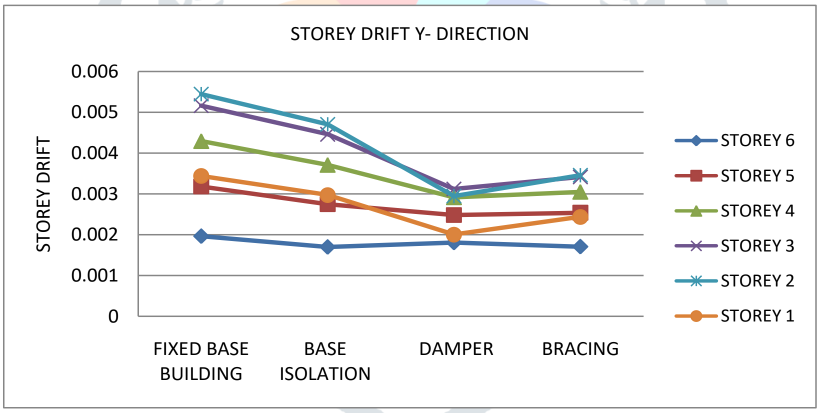


Graph: 6 (6–Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.2.2 Storey Drift



Graph: 7 (6 – Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 8 (6 – Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.2.3: 6-Storey Analysis: Critical Remarks

From the above analysis, it can be deduced that the deflection and drift of Fixed Base Building is larger as compared to building with base isolation, damper and bracing.

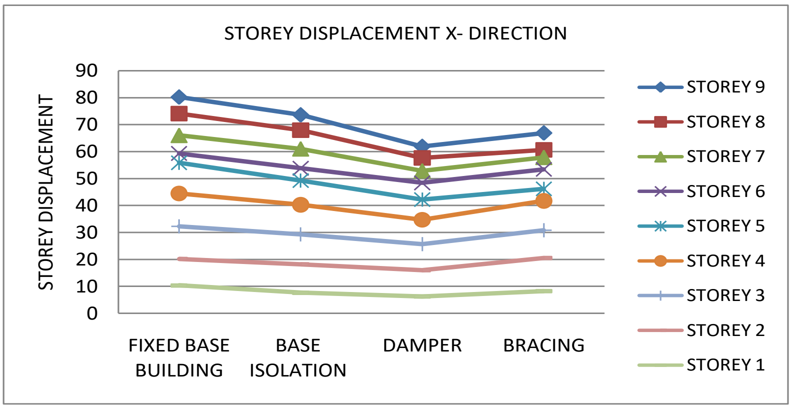
In terms of percentage, the reduction of deflection with base isolation, damper and bracing in X-Direction (13%, 19%, 13%) & Y-Direction (16%, 34%, 30%) respectively. Hence, maximum reduction in deflection may be obtained with 6-storeyed building with damper. In terms of percentage, the reduction of drift with base isolation, damper and bracing in X-Direction (12%, 30%, 22%) & Y-Direction (14%, 43%, 37%) respectively.

Hence, maximum reduction in drift may be obtained with 6-storeyed building with damper.

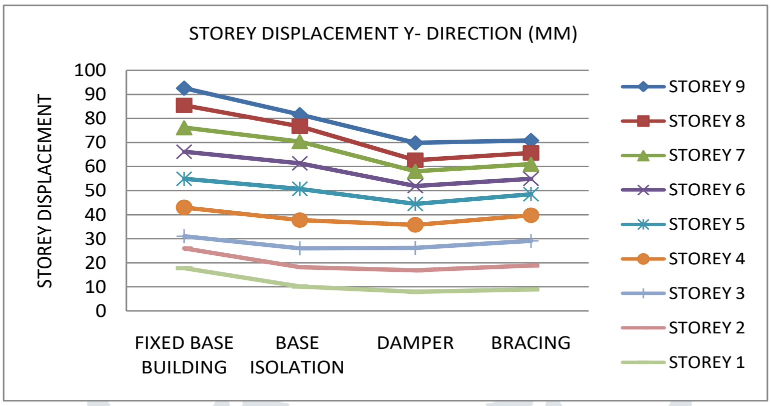
6.3. Analysis Outcome of Various 9- Storeyed Building Models

9-Storey Building: Fixed Base Building Results compared with Building with Base Isolation, Damper and Bracing

6.3.1 Storey Displacement

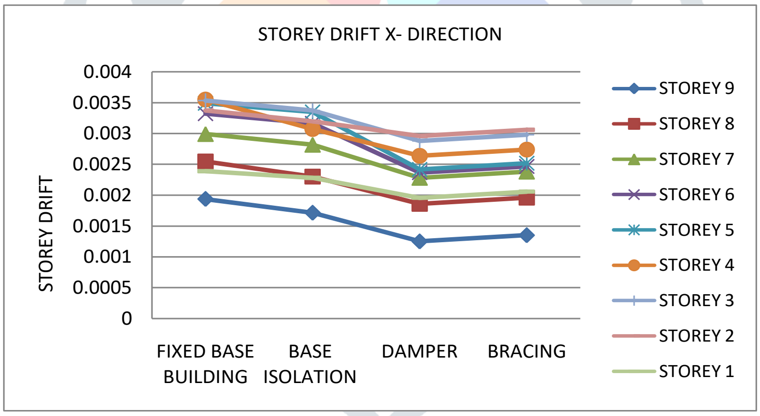


Graph: 9 (9 – Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

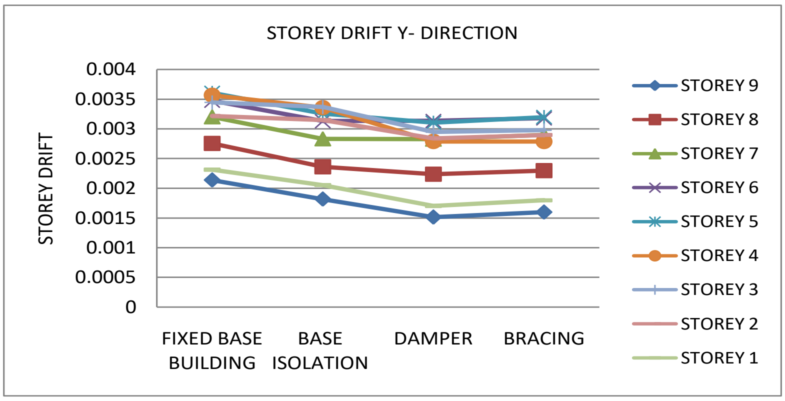


Graph: 10 (9 – Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.3.2 Storey Drift



Graph: 11 (9 –Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 12 (9 – Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.3.3: 9-Storey Analysis: Critical Remarks

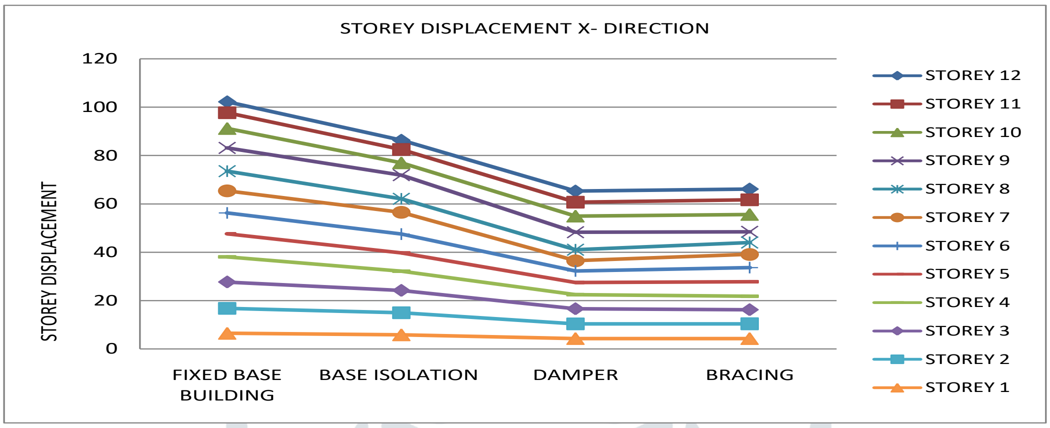
From the above analysis, it can be deduced that the deflection and drift of Fixed Base Building is larger as compared to building with base isolation, damper and bracing. In terms of percentage, the reduction of deflection with base isolation, damper and bracing in X-Direction (9%, 23%, 17%) & Y-Direction (14%, 25%, 24%) respectively.

Hence, the maximum reduction in deflection may be obtained with 9-storeyed building with damper. In terms of percentage, the reduction of drift with base isolation, damper and bracing in X-Direction (5%, 17%, 14%) & Y-Direction (7%, 13%, 11%) respectively. Hence, the maximum reduction in drift may be obtained with 9-storeyed building with damper.

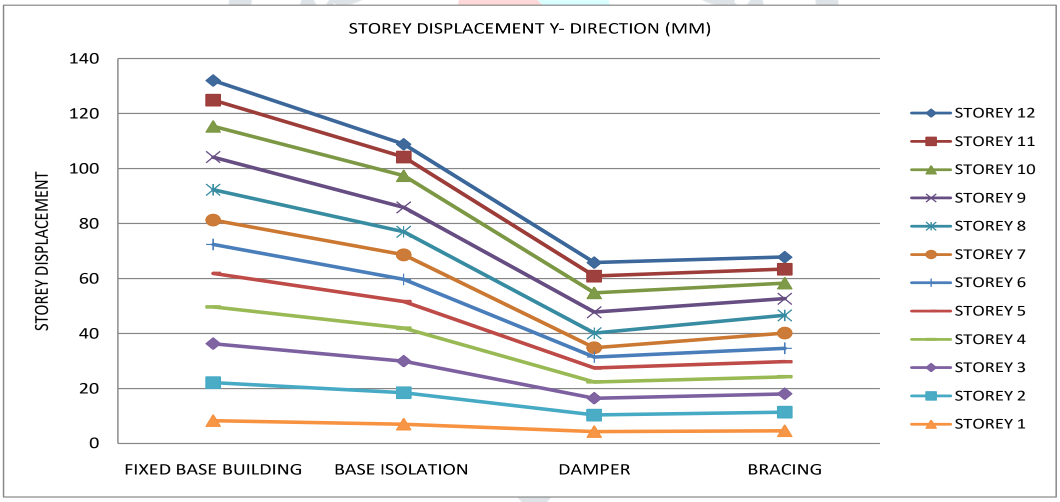
6.4 Analysis Outcome of Various 12-Storeyed Building Models

12-Storey Building: Fixed Base Building Results compared with Building with Base Isolation, Damper and Bracing

6.4.1 Storey Displacement

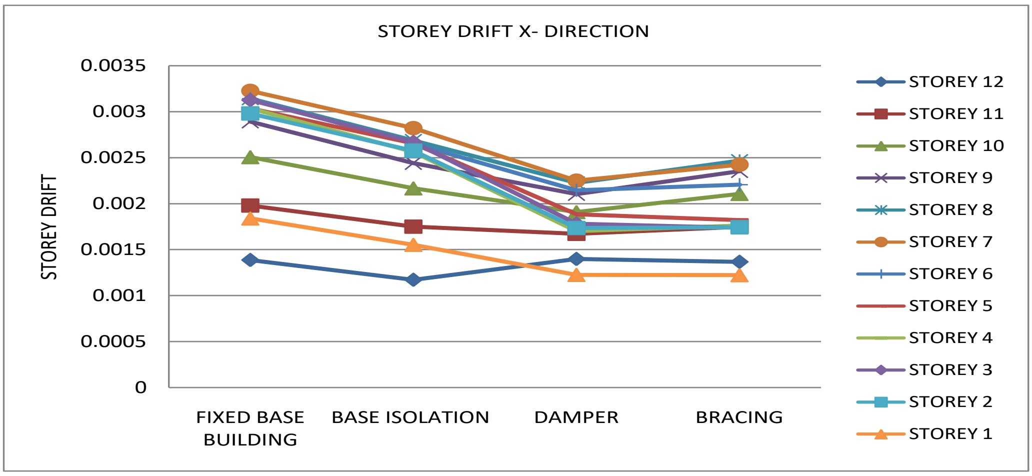


Graph: 13 (12–Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

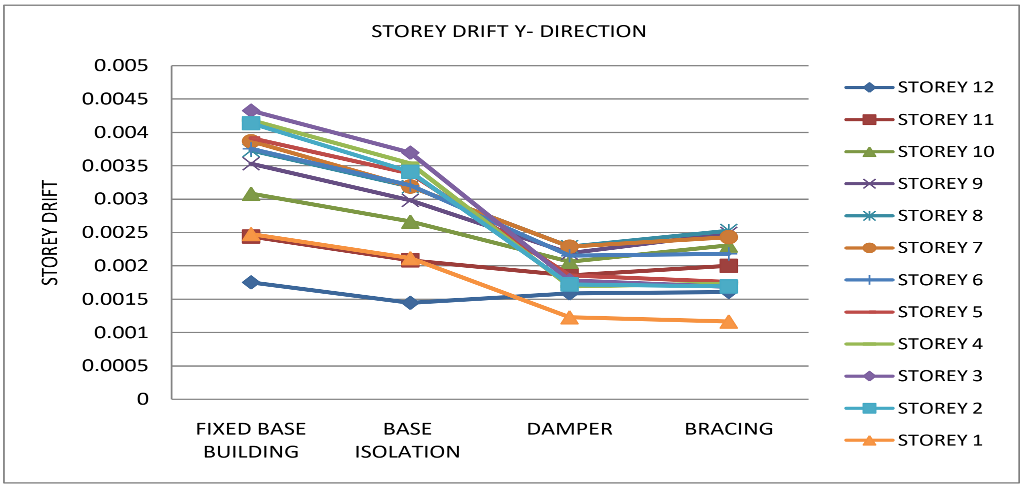


Graph: 14 (12 – Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.4.2 Storey Drift



Graph: 15 (12– Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 16 (12– Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.4.3: 12-Storey Analysis: Critical Remarks

From the above analysis, it can be deduced that the deflection and drift of Fixed Base Building is larger as compare to building with base isolation, damper and bracing.

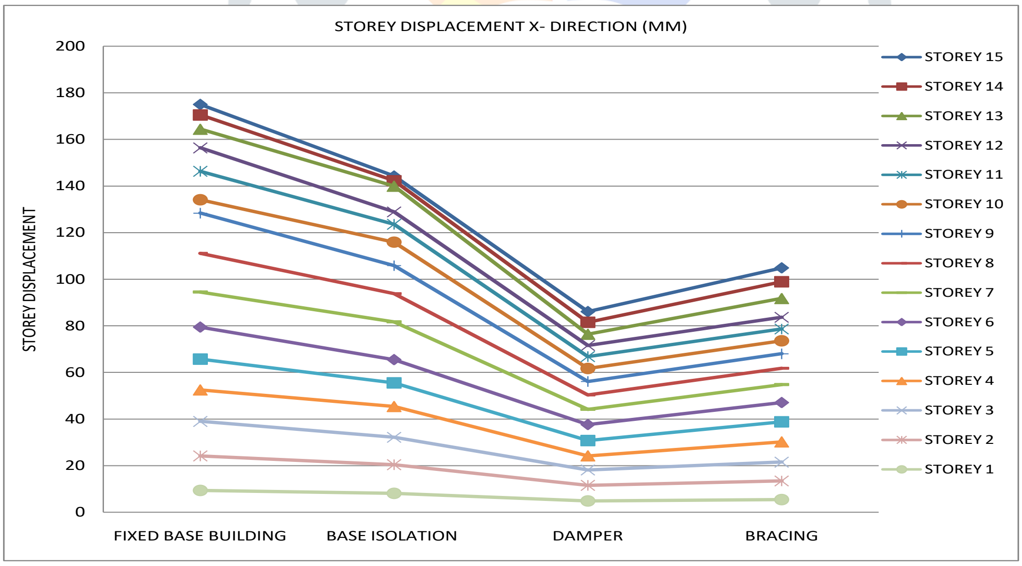
In terms of percentage, the reduction of deflection with base isolation, damper and bracing in X-Direction (19%, 36%, 35%) & Y-Direction (21%, 50%, 48%) respectively. Hence, the maximum reduction in deflection may be obtained with 12-storeyed building with damper, bracing. In terms of percentage, the reduction of drift with base isolation, damper and bracing in X-Direction (13%, 30%, 24%) & Y-Direction (15%, 47%, 42%) respectively.

Hence, the maximum reduction in drift may be obtained with 12-storeyed building with damper as well as bracing.

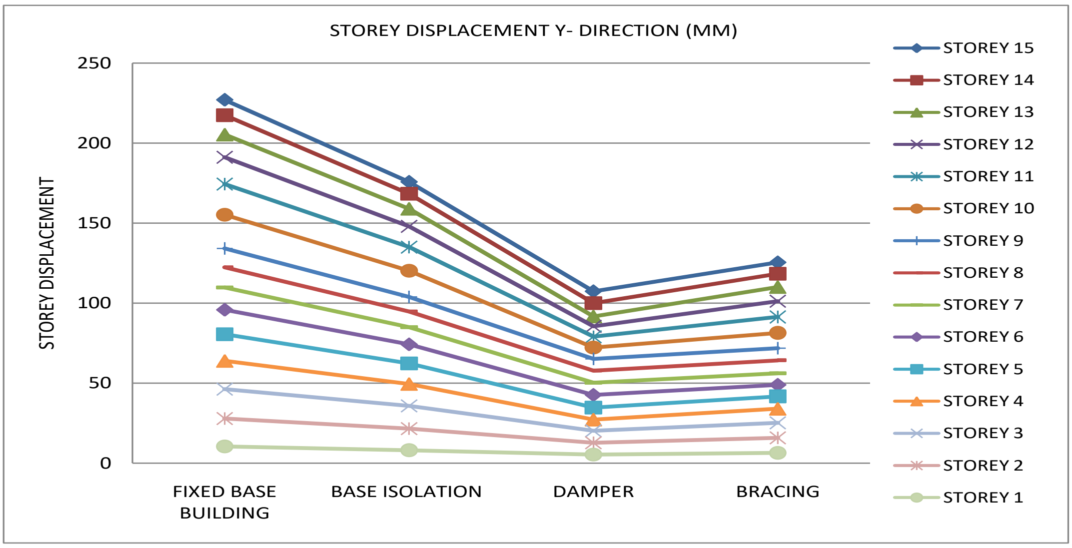
6.5 Analysis Results of Various 15 - Storey Building Models

15-Storeyed Building: Fixed Base Building Results compared with Building with Base Isolation, Damper and Bracing

6.5.1 Storey Displacement

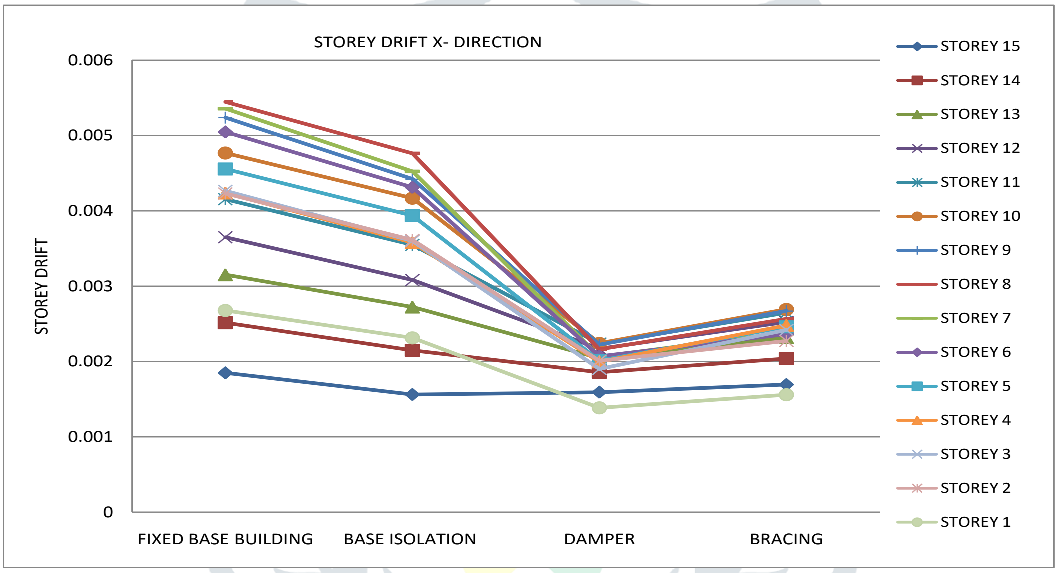


Graph: 17 (15 – Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

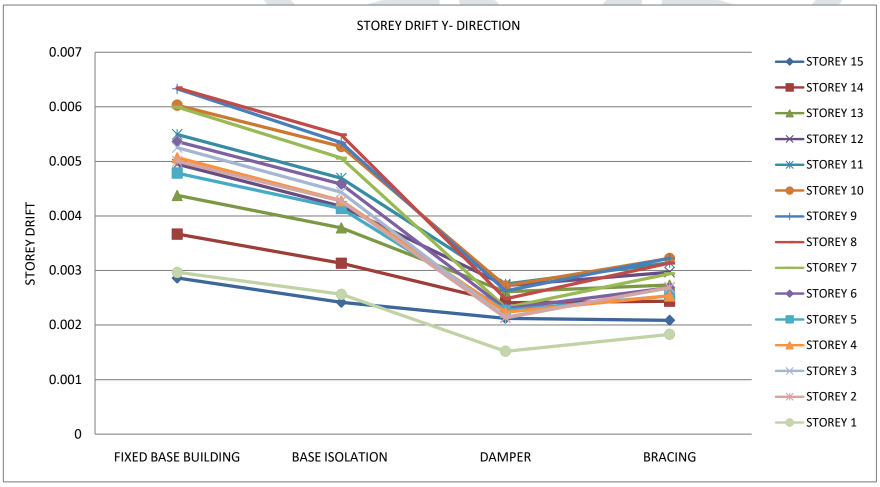


Graph: 18 (15 – Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.5.2 Storey Drift



Graph: 19 (15– Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 20 (15– Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.5.3: 15-Storey Analysis: Critical Remarks

From the above analysis, it can be deduced that the deflection and drift of Fixed Base Building is larger as compare to building with base isolation, damper and bracing.

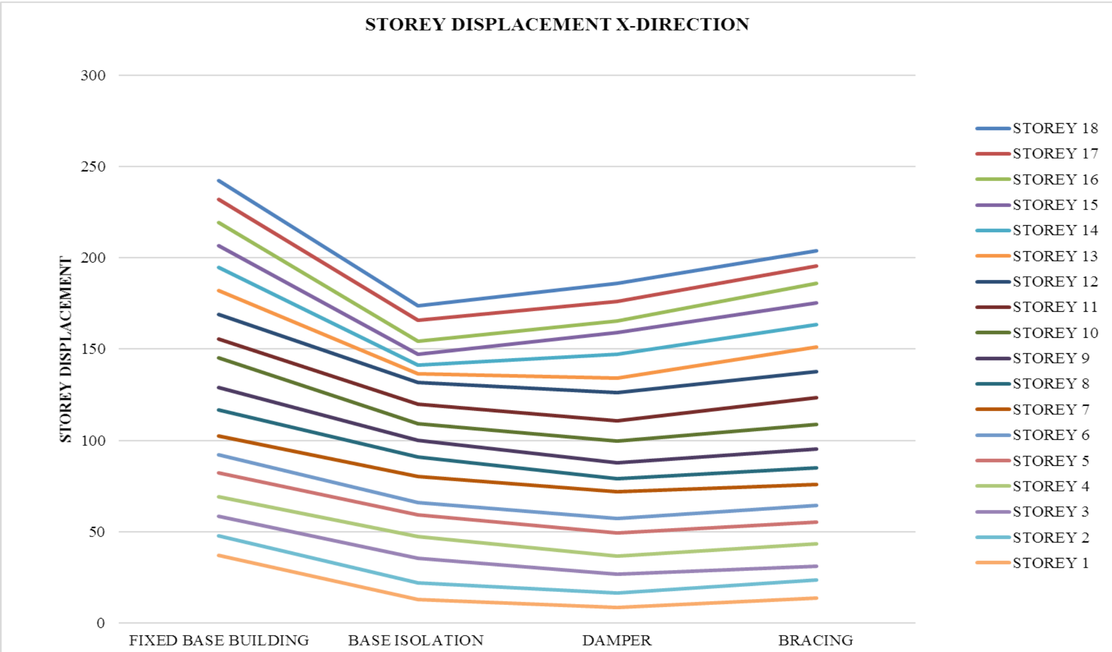
In terms of percentage, the reduction of deflection with base isolation, damper and bracing in X-Direction (22%, 51%, 40%) & Y-Direction (29%, 53%, 45%) respectively. Hence, the maximum reduction in deflection may be obtained with 15-storeyed building with damper, bracing. In terms of percentage, the reduction of drift with base isolation, damper and bracing in X-Direction (13%, 59%, 51%) & Y-Direction (14%, 57%, 49%) respectively.

Hence, the maximum reduction in drift may be obtained with 15-storeyed building with damper as well as bracing.

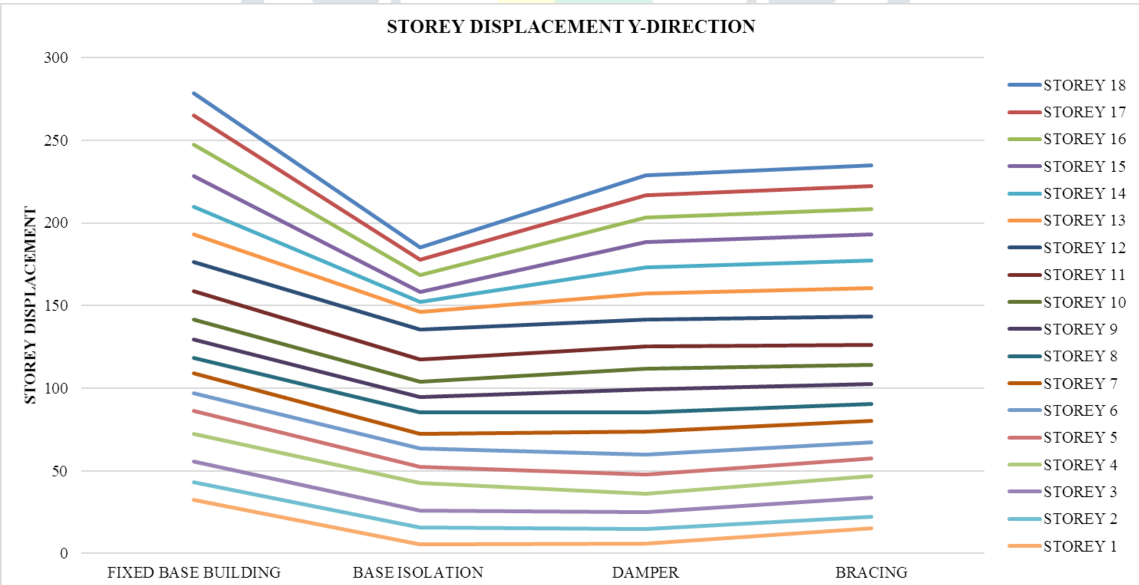
6.6 Analysis Results of Various 18 - Storey Building Models

18-Storeyed Building: Fixed Base Building Results compared with Building with Base Isolation, Damper and Bracing

6.6.1 Storey Displacement

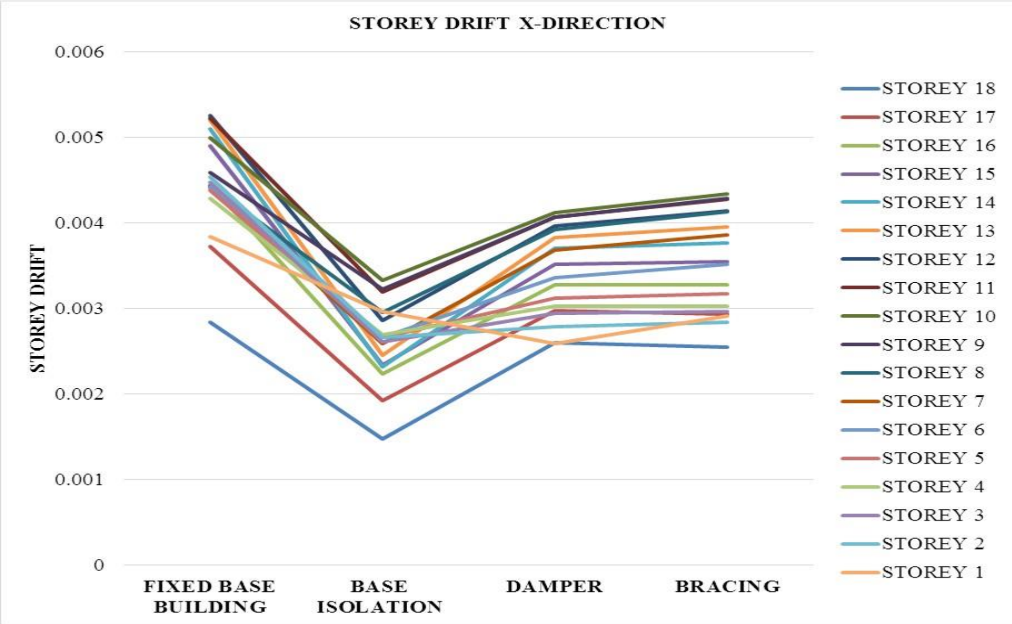


Graph: 21 (18 – Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

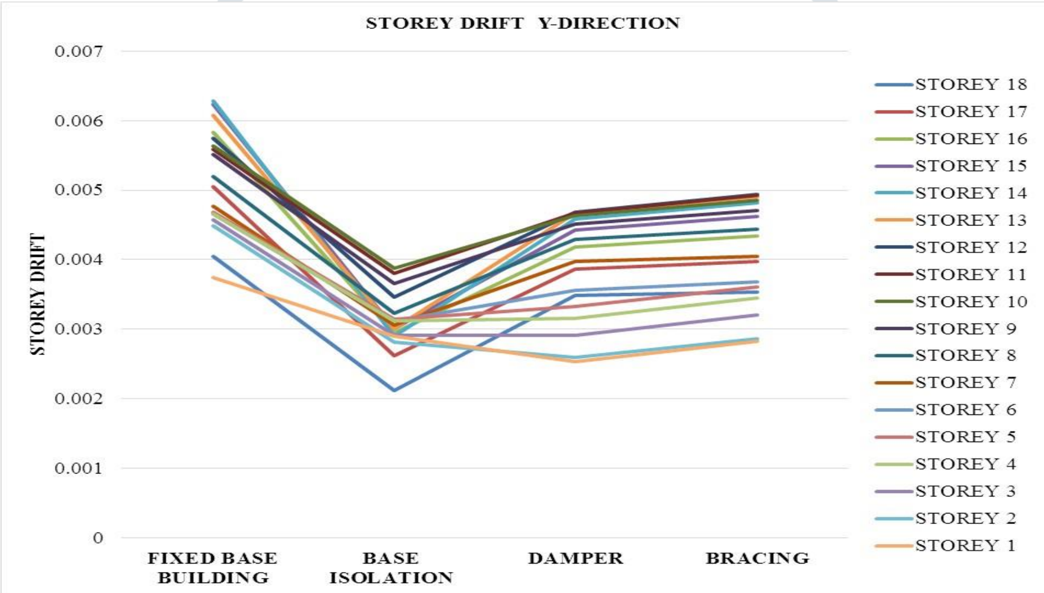


Graph: 22 (18 – Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.6.2 Storey Drift



Graph: 23 (18– Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 24 (18– Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.6.3: 18 -Storey Analysis: Critical Remarks

From the above analysis, it is concluded that the deflection and drift of fixed base building is larger as compare to building with base isolation, damper and bracing.

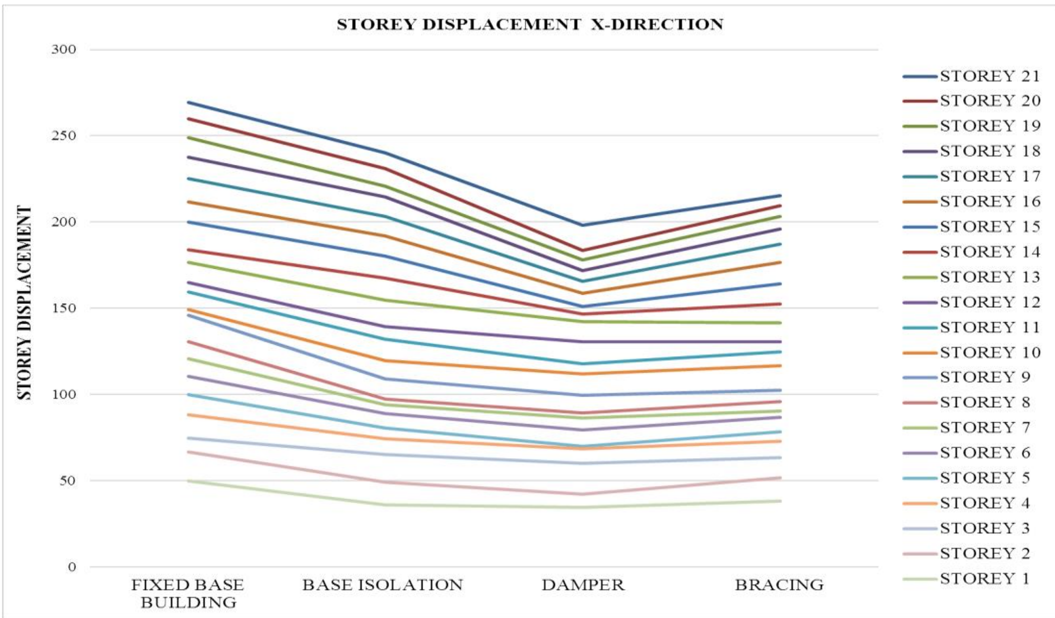
In terms of percentage it can be stated that the reduction of deflection with base isolation, damper and bracing is approximately in X-Direction (28%, 23%, 16%) & Y-Direction (34%,18%,16%) respectively. Hence, the maximum reduction in deflection may be obtained with 18-storeyed building with base isolation as well as damper.

In terms of percentage it can be stated that the reduction of drift with base isolation, damper and bracing is approximately in X-Direction (37%, 22%, 18%) & Y-Direction (38%,26%,22%) respectively. Hence the maximum reduction in drift may be obtained with 18-storeyed building with base isolation as well as damper.

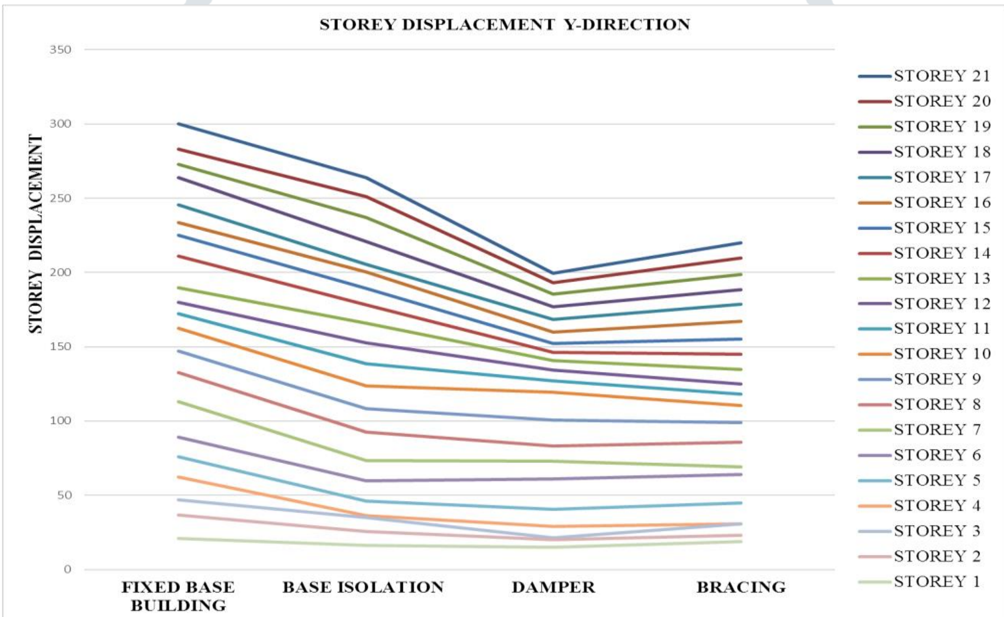
6.7 Analysis Results of Various 21-Storeyed Building Models

21-Storeyed Building: Fixed Base Building Results compared with Building with Base Isolation, Damper and Bracing

6.7.1 Storey Displacement

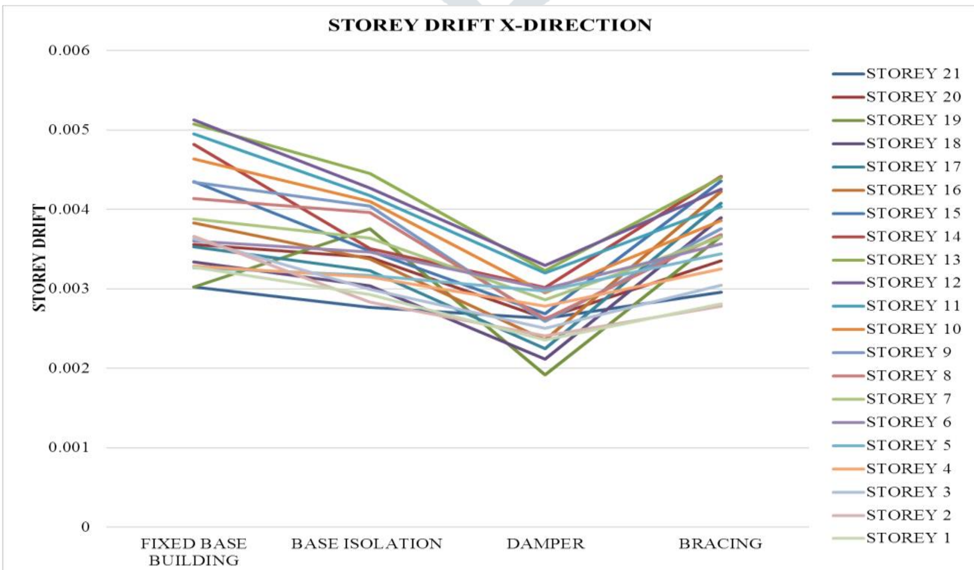


Graph: 25 (21–Storey) Graph B/W No. of Storey V/S Storey Displacement (X-Direction)

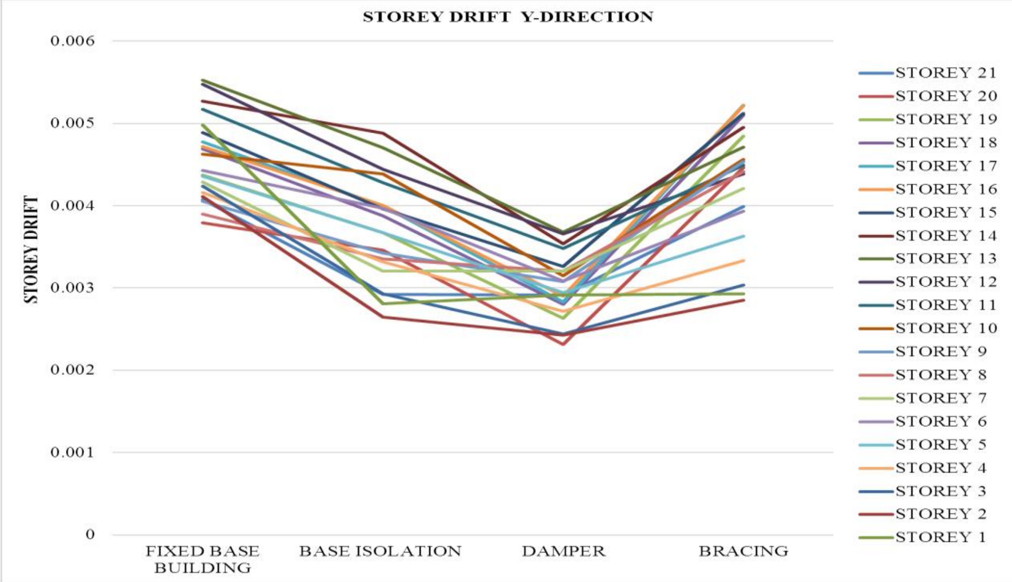


Graph: 26 (21–Storey) Graph B/W No. of Storey V/S Storey Displacement (Y-Direction)

6.7.2. Storey Drift



Graph: 27 (21– Storey) Graph B/W No. of Storey V/S Storey Drift (X-Direction)



Graph: 28 (21– Storey) Graph B/W No. of Storey V/S Storey Drift (Y-Direction)

6.7.3: 21-Storey Analysis: Critical Remarks

From the above analysis, it is concluded that the deflection and drift of fixed base building is larger as compared to building with base isolation, damper and bracing.

In terms of percentage, it can be stated that the reduction of deflection with base isolation, damper and bracing is approximately in X-Direction (11%, 27%, 20%) & Y-Direction (12%,34%,27%) respectively. Hence, the maximum reduction in deflection may be obtained with 21-storeyed building with damper as well as bracing.

In terms of percentage, it can be stated that the reduction of drift with base isolation, damper and bracing is approximately in X-Direction (13%, 36%, 14%) & Y-Direction (12%,34%,06%) respectively. Hence, the maximum reduction in drift may be obtained with 21-storeyed building with damper as well as bracing.

VII. Concluding Remarks From 3, 6,9,12,15,18,21 Storey Building Model Analysis (Compared WITH FIXED Base Building With Base-Isolation, Damper, Braced Building

From the above analysis, it can be deduced that the deflection and drift of 'Fixed Base Building' is larger as compared to building with base isolation, damper and bracing.

In terms of average percentage, the reduction of deflection with base isolation, damper and bracing in X-Direction (15%, 32%, 26%) & Y-Direction (18%, 39%, 35%) respectively. Hence, the maximum reduction in deflection may be obtained with 3, 6, 9, 12, 15, and 18, 21-storeyed building with damper as well as, bracing. In terms of percentage, the reduction of drift with base isolation, damper and bracing in X-Direction (14%, 35%, 26%) & Y-Direction (16%, 40%, 32%) respectively.

Hence, the maximum reduction in drift may be obtained with 3, 6, 9, 12, 15, and 18, 21-storeyed building with damper as well as bracing. From the above analysis, it can be deduced that the deflection and drift of 'Fixed Base Building' is larger as compared to building with base isolation, damper and bracing. So most effective device is damper and then bracing for reducing 'Storey Displacement' and 'Storey Drift' in RCC Building.

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