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Comparative Analysis of G+5 RCC Structure With and Without Base Isolators

Siddhartha Ray*, Harsh Kate**, Nitin Lahute**, Viraj Naik**, Amar Narsinge**

*(Assistant Professor, Department of Civil Engineering, NHITM, and Thane
Email: siddhartharay@nhitm.ac.in)

** (U.G Student, Department of Civil Engineering, NHITM, and Thane
Email: harshkate201@ nhitm.ac.in)

** (U.G Student, Department of Civil Engineering, NHITM, and Thane
Email: nitinlahute201@ nhitm.ac.in)

** (U.G Student, Department of Civil Engineering, NHITM, and Thane
Email: virajnaik201@ nhitm.ac.in)

** (U.G Student, Department of Civil Engineering, NHITM, and Thane
Email: amarnarsinge201@ nhitm.ac.in)

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Abstract:

The seismic vulnerability of critical public structures, such as (G+5) buildings, demands innovative engineering solutions to enhance their resilience and ensure the safety of occupants. In regions prone to seismic activity, the implementation of a base isolation system has emerged as a promising approach to mitigate the destructive effects of earthquakes. The analysis encompasses a comprehensive evaluation of the structural response, considering the dynamic interaction between the base isolation system and the building. Dampers, bearings, and isolator are meticulously modeled within ETABS, and the seismic performance of the structure is assessed under varying load scenarios, including seismic forces, dead loads, and live loads. This study presents an analysis of a base isolation system applied to a (G+5) critical public structure. The research explores the seismic hazards, design considerations, and structural performance improvements associated with the integration of base isolation technology. The investigation encompasses the principles, components, and advantages of base isolation systems, with a specific focus on their application in critical public infrastructure. By assessing the behavior of the structure with and without base isolation, this study offers insights into the efficacy of these systems in reducing seismic risk and minimizing structural damage. The findings underscore the significance of base isolation as a proactive measure to safeguard the integrity and functionality of (G+5) critical public structures during seismic events, ultimately contributing to the safety and well-being of communities.

Keywords — **Dampers, Seismic Hazards, Structural Damage, Base Isolation.**

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I. INTRODUCTION

A common perception on how to resist an earthquake force is by strengthening the structure. The traditional engineering design strategy based on increasing the design capacity and stiffness to accommodate foreseeable lateral forces may not be the most efficient solution. The problem with the latter is that all seismic forces from the foundation will be absorbed by the superstructure. The base isolation technique is exactly the opposite of traditional engineering design strategy.

Earthquake has a huge impact on our day to day life. Earthquakes in India can have a significant and wide-ranging impact due to the country's geological location and population density. India is located on the boundary of the Indian Plate, which is colliding with the Eurasian Plate. As a result, the country experiences frequent seismic activity. Here are some of the impacts of earthquakes in India.

The unequal heating of the Earth's surface also causes the wind. When the air over a given region becomes warmer and therefore lighter, it rises and as result of the rising, cooler air moves in from another area to take its place. This air movement will be proportional to those temperature differentials and is what we perceive as wind. Atmospheric pressure, as related to temperature, will also and directly affect the movement of wind, which will flow from a region of high pressure to one of low pressure. The pressure differential between the two regions will determine the velocity of wind flow. A small difference will create a breeze while a large difference may lead to a storm.

Base isolation is a structural engineering technique that aims to mitigate the effects of earthquake forces on buildings the main use of isolation system is to reduce the displacements, base reactions and member forces in structure. Base isolation concept was coined by engineers and scientists as early as in the year 1923 and consequently different method of isolating the buildings and structures from earthquake forces have been urbanized world over. Country like, Japan, China, US, New Zealand and European countries have adopted these techniques as their standard routine for many public buildings and residential building as well. Hundreds of buildings are being built each year with base isolation technique in these countries.

Fig 1: Base Isolators

II. AIM & OBJECTIVES

To study the base isolation system used in critical public building for zone 5.

OBJECTIVES

- To study the structural behaviour of a public building under Earthquake loads & Wind load with base isolation.
- To analyse a G+5 RCC building with and without base isolators.
- To compare the structural components of the RCC building like Story Drift, Displacement & Diaphragm Centre of mass Displacement of a RCC building.

III. PROBLEM STATEMENT

A (G+5) RCC structure was analyzed for both static and dynamic loads. For the analysis the critical loading was obtained and the parameters like Story Drift, Displacement and Diaphragm Centre of Mass Displacement was compared in the RCC structure with and without dampers. Initially the structure was created in Autocad and for further analysis it was imported in E-tab.

Dimension of the G+5 RCC structure in X-direction is 13.17m & in Y-direction is 17.90m.The height of G+5 RCC structure is 18.70m having Floor to floor height is 2.9m from 1st floor onwards and 4.2m that of ground floor only. M30 grade of concrete is considered for the analysis and Fe 500 for steel.

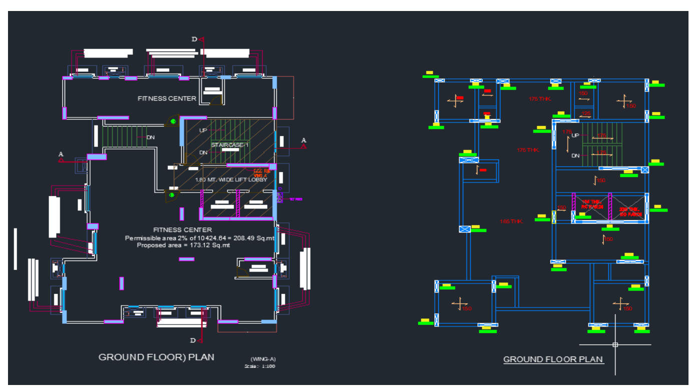


Fig 2: Ground Floor Plan

IV. LITERATURE REVIEW

A. Analytical Approach

Gavale G. et.al (2022) proposed "Base Isolation" which is important class of seismic protective system or device which has mechanical characteristics of being flexible horizontal direction is follow in succession. Elastomeric base isolation and sliding base isolation are basically used devices. They emphasized the mechanical flexibility of such systems, particularly in the horizontal direction. Elastomeric and sliding base isolations were identified as commonly used devices. Base isolation is designed to shield structures from the damaging effects of earthquakes by introducing supports that isolate them from the shaking ground. It's also referred to as seismic base isolation or a base isolation system, offering significant enhancements to a structure's seismic performance and sustainability in certain applications.

Tripathi S. et.al (2022) conducted a survey focusing on works related to base isolation, particularly in multistorey buildings. The paper summarizes various types of bearings used for base isolation in such structures and their performance characteristics. Both analytical and experimental studies comparing fixed base and isolated base structures were reviewed. Additionally, the study included shaking table and full-scale component tests of a proposed isolator known as the Multiple Friction Pendulum System (MFPS), assessing its effectiveness and durability. Results indicated that the MFPS isolator could significantly reduce acceleration responses, ranging from 70 to 90 percent, compared to fixed base structures under different ground motions.

B. Experimental Approach

Rathod K. et.al. (2020) conducted nonlinear time history analysis on a nine-story reinforced concrete structure using ETABS software. They utilized the historical Centro earthquake data from 1940 for this analysis. Key parameters assessed in seismic analysis included load carrying capacity, ductility, stiffness, damping, and mass. Various response parameters such as base shear, storey drift, and storey displacements were calculated. Storey drift values were compared against the minimum requirements specified in IS 1893:2002. Additionally, they determined the maximum displacements caused by base reactions in both X and Y directions due to the el Centro earthquake's ground motion**.**

Reddy K. et.al. (2019) experimented a high-rise building of 30 floors (G+30) by considering seismic, dead and live loads on ETABS 2016. determined the effects of lateral loads on moments, shear force, axial force, base shear, maximum displacement and tensile forces on structural system being subjected and also compared the results of seismic zones 2, 3, 4 and 5. It is found that the lateral displacements are more in zone 5 when compared to the zones 4, 3&2 and from the base reactions of structure obtained in zone 5, the story shear is higher in zone 5 than in zone 2. Better accuracy of the analysis can be obtained by ETABS.The members, which are not appropriate, will be obtained and the software recommends suitable sections.

C. Findings from Literature Survey

- Base isolation reduces the response of structure due to earthquake loading.
- Fluid viscous dampers (FVD), has highly effective in controlling the structural deformations and forces during seismic events.
- For taller or unsymmetrical structures, response spectrum method is recommended.
- Base isolation reduces the response of structure due to earthquake loading.
- During the earthquake the dynamic responses of the structure will not be influenced significant by the soil properties and the structure can be analysed under the fixed base condition.
- The capacity of building to undergo in elastic deformations governs the structural behavior of building during seismic event.
- The use of dampers in the structure provides elastic movement to the building and dissipates seismic energy.
- The storey displacement is reduces significantly by the application of dampers in the structure.
- Use of dampers in the structure provides elastic movement to the building and

dissipates seismic energy.

- Found that among FVD, friction damper and TMD, FVD is effective to dissipate seismic energy. The addition of FVD in the structure provides damping up to 30% of critical.

V. BUILDING MATERIALS AND DAMPERS

The grade of steel taken for the G+5 RCC structure is 500N/mm^2 deformed bars with elongation not more than 16% confirming to IS 1786:2008. Modulus of Elasticity is taken as 2.1 x10^5 N/mm^2.Poisson's Ratio considered as 0.2.Unit weight of steel = 78.5 KN/m^3. Grade of Concrete for Floor Beams and Floor Slabs is analysed for 30N/mm^{2}and Grade of Concrete in Columns and Shear walls is 30N/mm^2.The table below Table 3.1 shows the various unit weight of the material used in this analysis.

Table I
Unit weight of the materials

Material	Unit weight (KN/m^3)
Saturated Soil	20
Conventional Bricks	20
Plain Concrete	24
Reinforced Concrete	25
Siporex walls or Light Weight Blocks	10

Dynamic analysis of structures refers to the process of studying and evaluating the behaviour of structures under dynamic loads such as earthquakes, wind, vibrations, and other external forces. It involves analysing the response of a structure to time-varying loads and understanding how it behaves and reacts to these dynamic forces. In structural dynamics, the focus is on the dynamic characteristics of a structure, including its natural frequencies, mode shapes, damping properties, and response to various types of dynamic loads. Types of dynamic analysis are as follows

- Modal Analysis

It is a fundamental technique used to identify the natural frequencies and mode shapes of a structure. It involves solving the eigen value problem of the structural system to determine its dynamic characteristics. Modal analysis provides crucial information about the dominant modes of vibration and their corresponding frequencies, aiding in the subsequent steps of analysis.

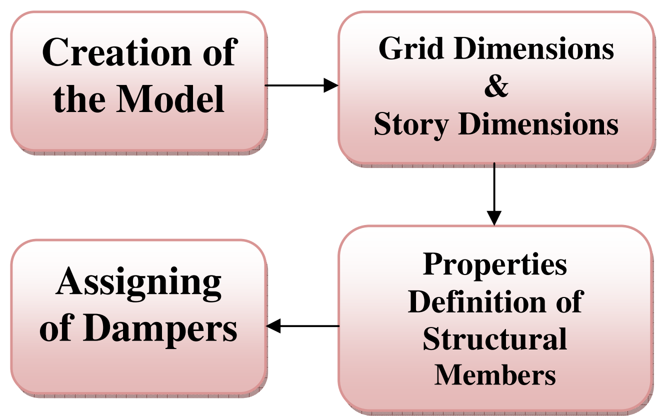
- Response Spectrum Analysis

It is widely employed for evaluating structures subjected to seismic loads. It uses a response spectrum, which represents the maximum response of a structure at different frequencies. By applying the response spectrum to the structure, engineers can assess its performance under earthquake-induced motions and design it to withstand the expected ground motions.

- Time History Analysis

Involves simulating the actual time-varying loads or ground motions that a structure may experience. It captures the dynamic response of the structure over time, considering the specific characteristics of the applied forces. Time history analysis is particularly useful when dealing with complex loading patterns or non-linear behaviour of the structure.

VI. MODELLING AND ANALYSIS



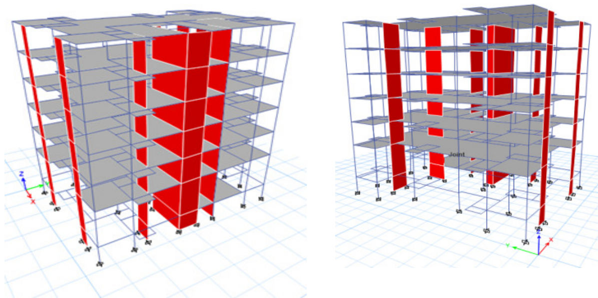


Fig 3: G+5 RCC Model

For this analysis the loads considered Dead load, Live load, Wind load and Earthquake load in both the type of structure i.e the structure with dampers and the structure without dampers. Along with the mentioned load other load combinations as per the codal provisions were applied to the structure and analysis was carried out.

The following basic load combinations for the structural design of members were carried out in the software

i) 1.5DL+1.5LL
ii) 1.2 DL +1.2L L±1.2EQX/SPECX
iii) 1.2 DL +1.2LL±1.2EQY/SPECY
iv) 1.5 DL ±1.5EQX/SPECX
v) 1.5 DL ±1.5EQY/SPECY
vi) 0.9 DL ±1.5EQX/SPECX
vii) 0.9 DL ±1.5EQY/SPECY
viii) 1.2 DL +1.2LL±1.2WINDX
ix) 1.2 DL +1.2LL±1.2WINDY
x) 1.5 DL ±1.5WINDX
xi) 1.5 DL ±1.5WINDY
xii) 0.9 DL ±1.5WINDX
xiii) 0.9 DL±1.5WINDY

VII. RESULTS & DISCUSSIONS

The figure below Fig 4 shows the earthquake load when applied in the Y direction and its respective displacement in X directions, where we can observe that when the structure is applied with dampers the amount of displacement at 4th floor is 2.94mm and the same without dampers is 9.131mm.

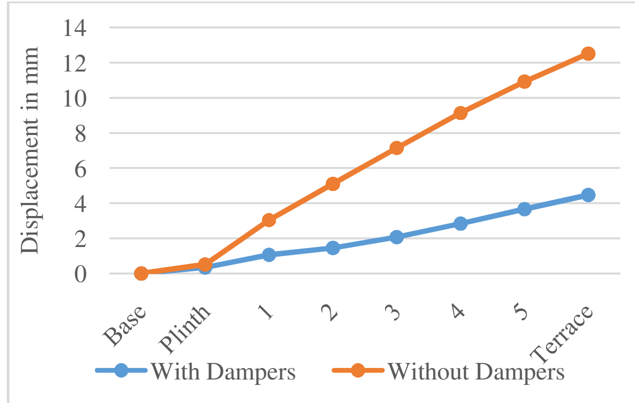


Fig 4: Earthquake load in Y-Direction & Displacement in X-Direction

The figure below Fig 5 shows that the Earthquake load is applied in Y direction and displacement obtain in Y direction. Where we can see that structure is applied with dampers the maximum displacement value reached at 23.455mm on terrace and without dampers the maximum value reached 41.52mm on terrace.

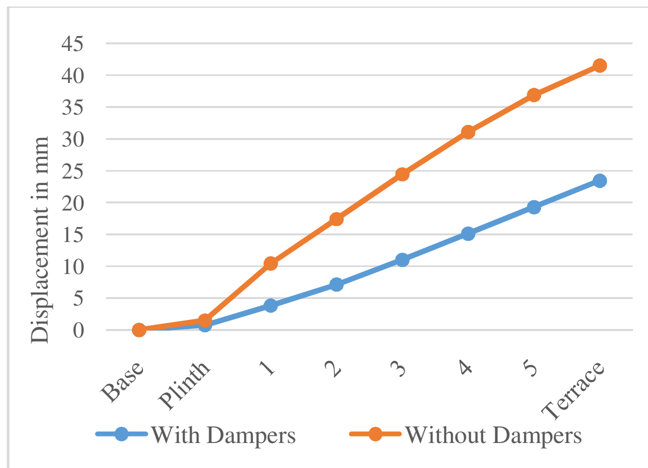


Fig 5: Earthquake load in Y-Direction & Displacement in Y-Direction

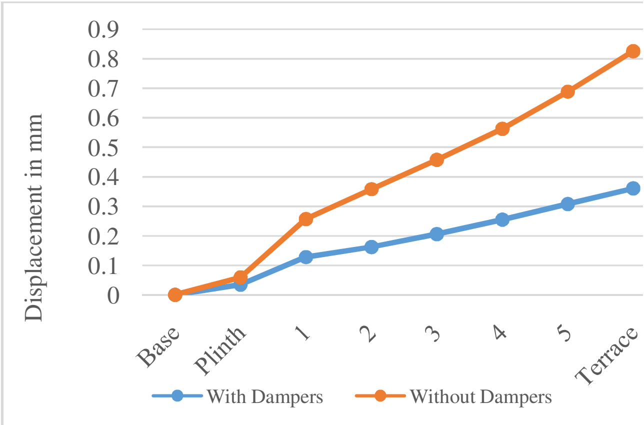


Fig 6: Wind load in X-Direction & Displacement in Y-Direction

The above Fig 6 shows the wind load applied in X direction and respective displacement obtain in Y direction. The displacement in without dampers the displacement happen in Y direction of structure the reading will increase from 1st floor to terrace, where applying dampers the displacement in Y direction will effectively decrease from 1st floor the displacement was 0.128mm to terrace floor the displacement was 0.361mm.

The figure below Fig 7 and Fig 8 shows the wind load are applied in the Y direction and its respective displacement obtained in both X and Y directions, the displacements we see that the without dampers structure have more displacements. After assigning dampers in the structure the displacement will reduce extensively.

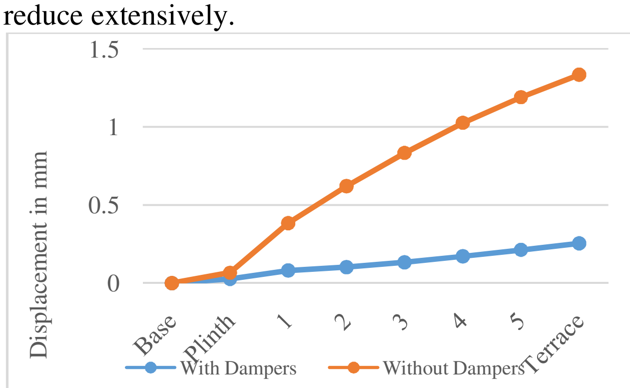


Fig 7: Wind load in Y-Direction & Displacement in X-Direction

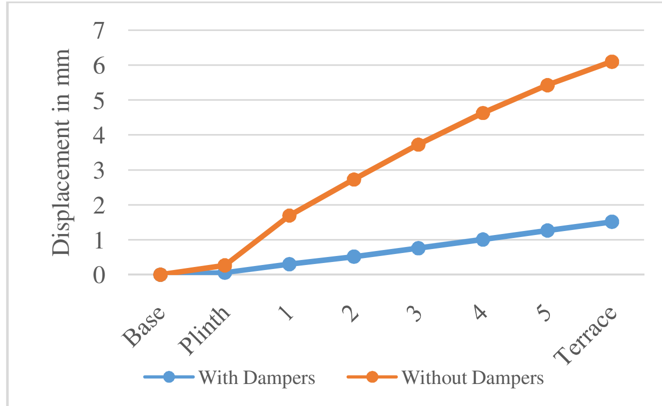


Fig 8: Wind load in Y-Direction & Displacement in Y-Direction

Below Fig 9 shows the story drift in the X direction when the load is applied in the X direction. The story drifts in the with dampers structure reduce the story drifts efficaciously as compare to the without dampers structure.

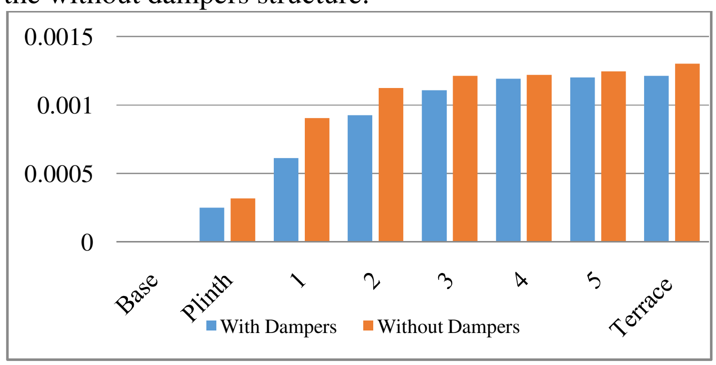


Fig 9: Earthquake load in X-Direction and Story Drifts in X-Direction

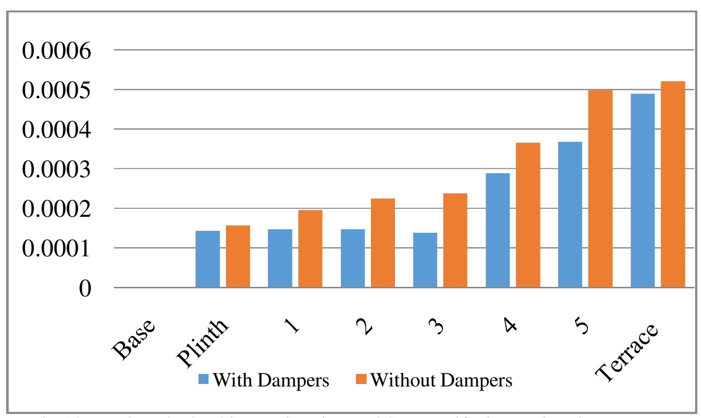


Fig 10: Earthquake load in Y-Direction and Story Drifts in Y-Direction

The above Fig 10 shows the story drift in the Y direction when the load is applied in the Y direction. In this case at 5th floor level there is a maximum difference story drift observed of 0.00013.

The Fig11 and Fig 12 below depict the result of Diaphragm Centre of mass Displacement. Here the results of Earthquake load applied in X and Y directions and diaphragm centre of mass displacement recorded in both the type of structure i.e with and without dampers are done.

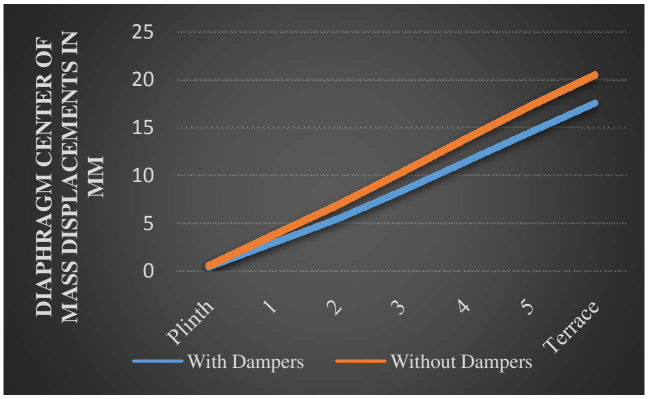


Fig 11: Earthquake load in X-Direction

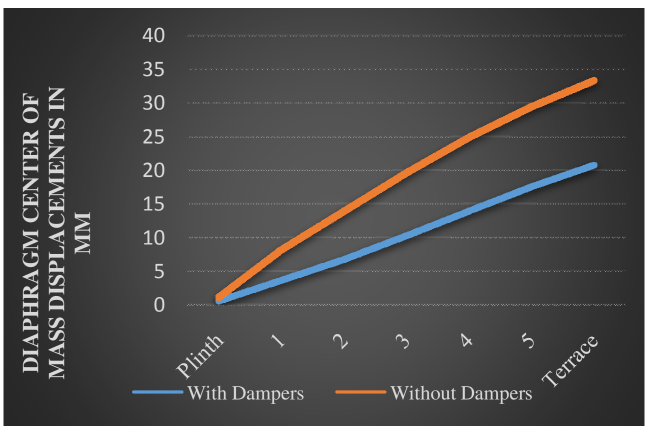


Fig 12: Earthquake load in Y-Direction

VIII. CONCLUSIONS

When earthquake load is applied in the Y direction and the displacement recorded in the X direction there is a reduction in the displacement by 64.28% when dampers are used. Similarly the displacement drops by 43.50% in the Y direction of the similar loading condition. Seen from the results when wind load is applied, the maximum reduction in the displacement is observed in the X direction of 80.89%.

The next structural parameter that was considered for this study was the story drift, in this the maximum difference observed when the earthquake load applied in the X direction and its drift was in X direction was 32.37% at the 1st floor level. When the same earthquake load applied in Y direction maximum difference in story drift was observed in Y direction at 3rd floor level of 42.07%.

Diaphragm Centre of mass Displacement was also studied and the maximum reduction in this structural parameter was observed at the plinth level in both X and Y direction by 30.74% and 50.34% respectively.

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