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Study of Ductile Detailing for Vertical Urbanization using STAAD Pro

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Abstract: Srinagar city - known as the heart of Kashmir, is one of the growing city in the northern part of India. With the population increment by 12 times from 1901 to 2011, there is a need to manage the growing population of the city to prevent the overburdening of resources and amenities in the city. The city falls in Zone V [Indian Standard 1893 (Part 1) 2002], the highest-risk earthquake zone, leading to many restrictions in construction as the city is more vulnerable to frequent earthquakes. The land resources are limited, and to fit in the population in this limited land resource, vertical construction is very necessary. Therefore, to make vertical housing or vertical construction workable in Kashmir, keeping in mind the increasing urbanization as well as the seismicity, ductile detailing is a very important and a good idea. Ductile detailing approach aims at fulfilling the Earthquake safety requirement demands of a reinforced concrete structure as per IS 13920. For this reason, ductile detailing is an appropriate solution wherein standard code clauses are being applied to beams, columns, slabs and spans. This changes the dimensions and quantity of material required for construction.This study attempts to visualize the population growth pattern and redesign a reinforced concrete structure considering ductile detailing. The study of the Displacement of floor and nodes is noted and found to be less in case where ductile detailing is done which makes it favourable in terms of strength and capacity and helps to save lives during the times of earthquakes. In this study, we have introduced this technique and applied this idea in the vertical construction, as a result of which we can handle the problem of increasing urbanization technically as well as economically. The study concludes at Ductile Detailing to be a good and an adequate process for the construction and an alternative to the current scenario.

Keywords: Earthquake, Seismicity, STAAD Pro, AutoCAD, ductile detailing, Urbanization

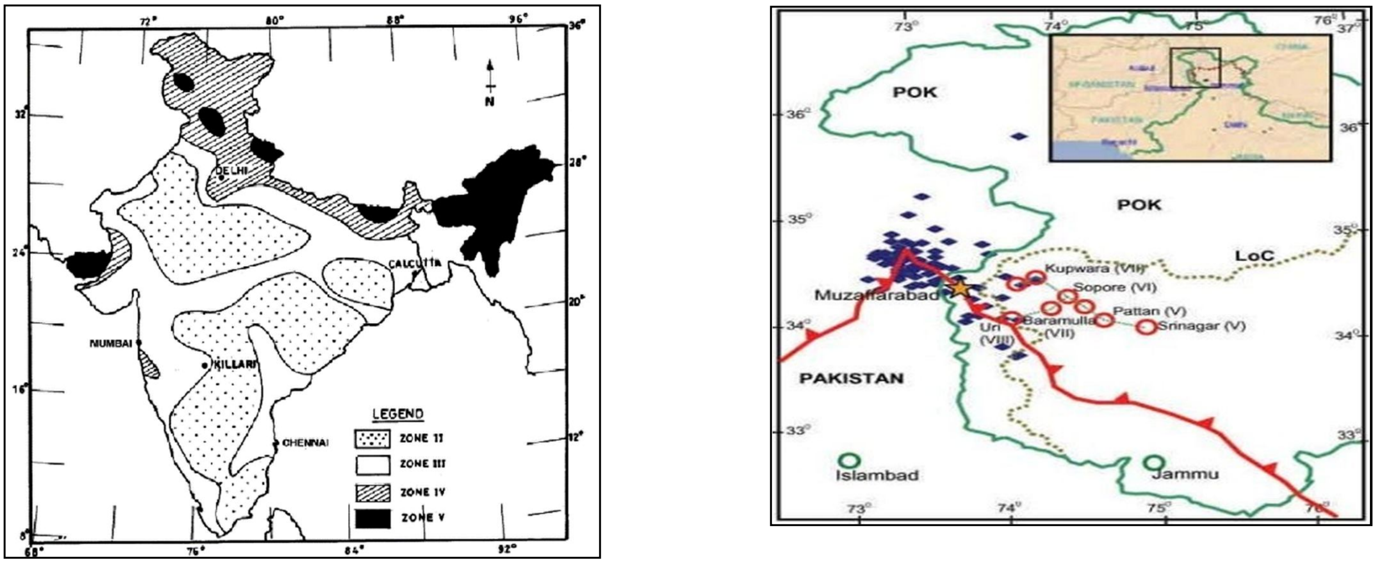
I. INTRODUCTION

India is counted among the top populated countries in the world. The rapid urbanization and growth in India are evident from the population growth of 12 times, from 1901 to 2011 [1, 2].Urbanization as such, is not perceived as a threat to the environment and development but it is the unplanned urban sprawl that affects the accessibility to amenities and land-use of any region. Srinagar is also prone to earthquakes and lies in the most vulnerable earthquake zones(seismic map of India).The Muzaffarabad earthquake of 8 October 2005 which caused major devastation on both sides of the Line of Control (LoC) in Kashmir, presented another opportunity to further our understanding of earthquake risk in the region. The earthquake claimed many lives and made the study and planning of the major economy in Kashmir i.e., Srinagar City, a valid study [3].

Our Study aims at the design and analysis of a residential building for the Srinagar City and calculating the results. Design of buildings wherein there is no damage during the strong but rare earthquake is called earthquake proof design. The aim of the earthquake resistant design is to have structures that will behave elastically and survive without collapse under major earthquakes that might occur during the life of the structure. To avoid collapse during a major earthquake, structural members must be ductile enough to absorb and dissipate energy by post elastic deformation. For earthquake resistant structures, ductility provides enough scope in making the structure more resistant. If ductile members are used to form a structure, the structure can undergo large deformations before failure. This is beneficial to the users of the structures, as in case of overloading, if the structure is to collapse, it will undergo large deformations before failure and thus provides warning to the occupants. This gives a notice to the occupants and provides sufficient time for taking preventive measures; this will reduce loss of life. This project is proposed to critically study provision of the IS 13920- 1993, analyze the structure with and without ductile detailing and to study implications of ductile detailing [4]. Ductile detailing is a process of providing reinforcement to concrete to be able to sustain earthquakes. It does not mean earthquake proof. It just means, for a building in said zone of earthquake, will stand (without major structural collapse), an earthquake that has a return period of a definite time. Ductile detailing approach aims at fulfilling the Earthquake safety requirement demands of a reinforced concrete structure as per IS 13920. For this reason, ductile detailing is an appropriate solution wherein standard code clauses are being applied.

II. STUDY AREA

The building is designed for Srinagar city, which is the summer capital of the state of Jammu and Kashmir. The city falls in Zone V [Indian Standard 1893 (Part 1) 2002], the highest-risk earthquake zone. According to the 2011 census, the city has a population of 12.2 lacs. Considering the fact that the population of the city has grown 12 times and the built up area 24 times from 1901 to 2011 and the frequent earthquakes, the study of better approach for construction to minimize the damage and increase the deformation before failure of the structure is quite significant.



(a) (b)

Fig 1.

(a) Seismic mapping of India as per IS 1893 [Part 1(2002)]

(b) Prone areas to frequent Earthquakes which includes Srinagar [Study after 2005 Earthquake]

A. Building Data

1) Live Load : As per IS 875 (Part - 1)
2) Dead Load : As per IS 875 (Part - 2)
3) Thickness of slab : 120 mm
4) Location of the site : Srinagar (Seismic Zone – V)
5) Type of Soil : Medium Soil, (Type-II as per IS: 1893 (Part-1))
6) Each Storey Height : 3.4 m
7) No of Floors : Ground+5
8) External Wall Thickness : 230 mm
9) Internal Wall Thickness : 120 mm
10) Column Size : 300x300 mm (Outer Columns)
: 450x450 mm (Centre Columns)
11) Beam Size : 250x500 mm (G+2 Floors)
: 400x230 mm (G+3 and G+4)
: 400x200 mm (Top Floor)
12) Wind Load : This building is located in seismic zone V, therefore the lateral loading of earthquake is predominant to the effect of wind load. Hence wind loads are not considered.
13) Seismic Load : As Per IS: 1893-2002 (Part-1)

Note: The Beam Size and the Column sizes are changed to make the construction economical referring the standard IS-Codes for safe design.

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III. METHOD

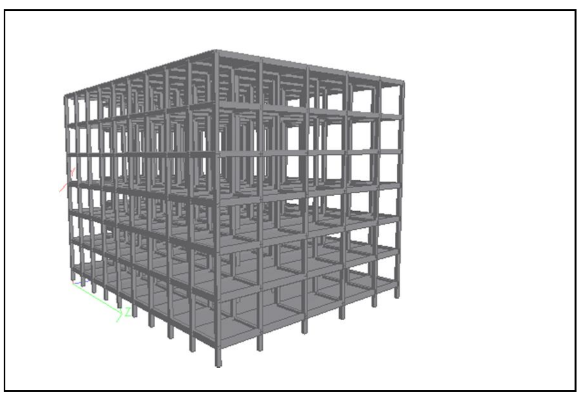
AutoCAD plan of the structure is used to frame the proposed building in STAAD Pro. The proposed building is designed for Srinagar City as per the IS codes. The building is analysed and designed as per IS 456 and IS 13920 with seismic loads applied on it.Seismic load parameters for proposed building in Srinagar City location taken as per IS 1893- 2002 are as under:

Importance factor	1
Soil Factor	2
Damping ratio	.25
Seismic zone factor	.36
Time period	.71
Soil type	Medium

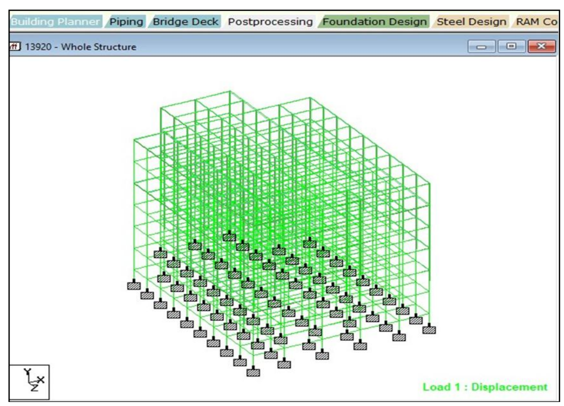
Ductile detailing aims at the increased ductility, it is provided in structures so as to give them adequate toughness and ductility to resist severe earthquake shocks without collapse. It is provided for the structures located in seismic zone IV and V with height of the structure more than 15m.The minimum grade of structural concrete is kept to be M 20 as per the standard requirements. Similar Clauses are being applied to beams, columns, slabs and spans as per the standard IS code that changes the dimensions and material required for construction. Furthermore after designing, required data which includes the displacement, load distribution, Shear force and bending moment differences of the structure after application of seismic force designed as per the two different IS codes[456 & 13920] are noted from both the design output STAAD Pro files and then compared.

IV. DESIGN AND COMPARISON

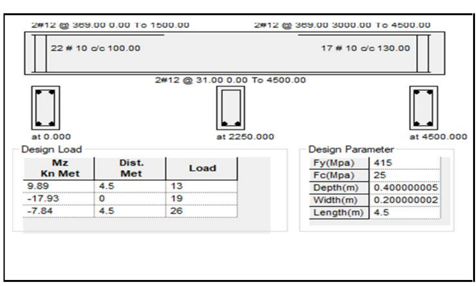
We have used STAAD Pro Software for the safe Seismic Design of the proposed structure. Equivalent static analysis approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. The Equivalent static analysis is been done on the building designed as per standard IS 456[Plain and Reinforced Concrete] and then with IS 13920[Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces] for a comparison in ductility and earthquake performance of the structure in seismic zone V.



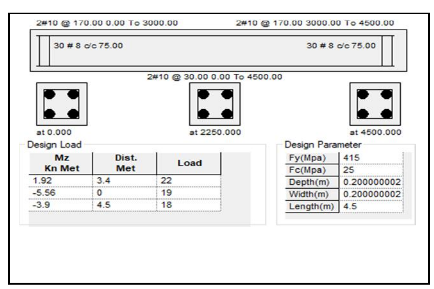
Rendered 3D view



Post processing window



(a)



(b)

A. Loads Considered

1) LIVE LOAD
2) DEAD LOAD

Reinforcement Details of Beam No.1444

a) Designed as per IS – 13920
b) Designed as per IS – 456

3) EQ +X[Earthquake load in +x direction]
4) EQ -X[Earthquake load in -x direction]
5) EQ +Z [Earthquake load in +z direction]
6) EQ -Z [Earthquake load in -z direction]

Comparison of displacement is done from the data in post processing window of STAAD Pro software from where the readings are noted.We have considered Node no. 549 for the comparison of the node displacement for all different laods and combinations. For Storey Displacement corner column was choosen and the data was comapared as per the result data from the software.

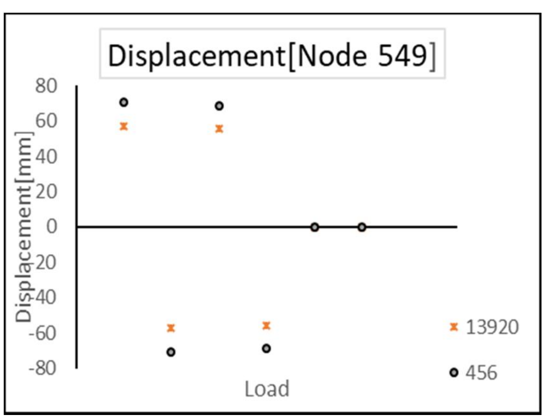
LOADS	IS-13920	IS-456
EQ+X	57.095 mm	70.6 mm
EQ-X	-57.095 mm	-70.6 mm
EQ+Z	55.9 mm	68.951 mm
EQ-Z	-55.9 mm	-68.951 mm
DEAD	.003 mm	.004 mm
LIVE	.001 mm	.002 mm

(a)

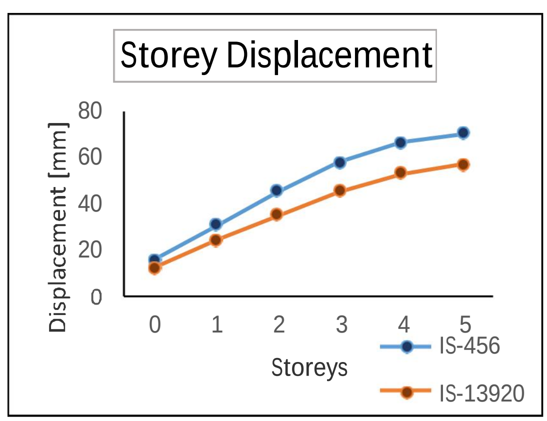
STOREY	IS-13920	IS-456
G	12.371 mm	15.593 mm
1	24.144 mm	31.018 mm
2	35.182 mm	45.485 mm
3	45.410 mm	57.884 mm
4	53.409 mm	66.679 mm
5	57.095 mm	70.682 mm

(b)

(a) Tabular results of displacement due to the respective loads on Node no 549.
(b) Tabular results of Storey displacement due to the EQ+X load on corner column on different storeys.



(a) +



(b)

(a) Graphical representation of displacement due to the respective loads on Node no 549.
(b) Graphical representation of Storey displacement due to the EQ+X load on corner column at different storeys.

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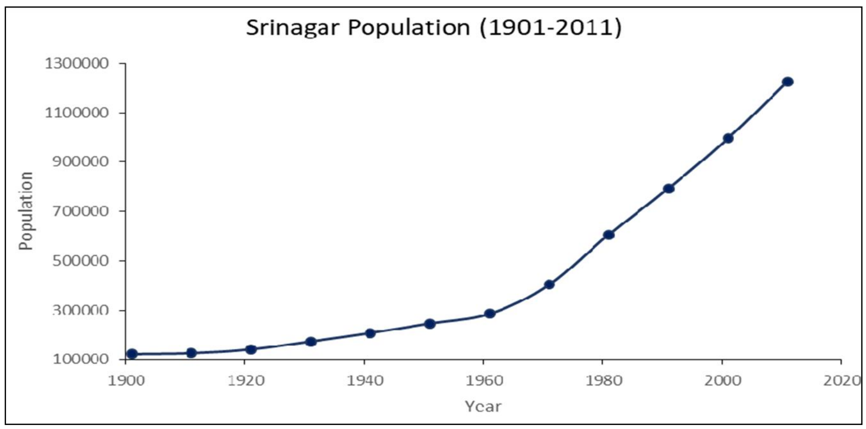
V. RESULT AND DISCUSSION

We design the same structure using IS 456 followed by IS 13920 and take the results from the respective output files. The results show that after the application of seismic load in Zone V [Indian Standard 1893 (Part 1) 2002], the highest-risk earthquake zone, there is a significant change in shear force diagram, bending moment diagram, displacement and base shear values of the structure. As we are aiming for ductility and deformation before failure we compared the displacement by different forces at a single node and displacement at different storeys due to a single load. When compared to IS- 456,in IS-13920 the node displacement taken for node no. 549 is decreased by 13.505mm and 13.05mm (+ as well as -) X and Z directions respectively. For the storey displacement the readings are taken from the same output STAAD Pro file at each storey due to EQ+X load that shows a decrease of 3.222mm ,6.874mm,10.303mm,12.474mm,13.27mm and 13.587mm from G to G+5 storeys respectively. Given that the displacement of the node as well as the storey has decreased to a significant level when compared at all G to G+5 levels, it can be concluded that ductility of the structure has increased. The storey displacement has decreased and the deformation at the time of earthquake.

A. Population Growth Rate

TABLE POPULATION – SRINAGAR CITY FROM 1901 -2011 [CENSUS OF INDIA]

YEAR	POPULATION
1901	122618
1911	126344
1921	141735
1931	173573
1941	207787
1951	246522
1961	285257
1971	403413
1981	606002
1991	793500
2001	995806
2011	1225837



With increase in population and built up density from past many years as shown in the graph plotted as per the census of India, it is clear that the population is increasing with a good rate. The increase in the population has occurred due to the migration of people from rural areas in search of better opportunities and lifestyle .The urbanization taking the agricultural and horticultural land area, has led to rapid increase in built-up area of the city. The wetlands of the city are also facing huge crisis due to encroachment coupled with siltation. Due to the shrinking of the wetlands, the city is at greater risk of flooding as well. Expansion of residential, industrial and commercial areas has put greater stress on the environment, as is evident from the increasing levels of pollution of the world-famous Dal Lake and the Jhelum river that are at the heart of the city. Due to the unplanned urbanization, the least vulnerable earthquake regions have also seen increasing cases of earthquake and post-earthquake damage. If the urbanization continues to increase at such a pace without planning, monitoring and management, the development of the city would prove to be unsustainable and increase the threat due to aftershocks to small scale constructions as well.

VI. CONCLUSIONS

The Urbanisation in the city of Srinagar is increasing rapidly. This has adversely affected the natural assets resulting in the shrinkage of the famous Dal Lake and Siltation in Jhelum River. Seismically, Srinagar is among the most vulnerable cities to earthquakes in India which has led the authorities to vertically restrict the construction till now. Keeping the population growth in the past decade and earthquake vulnerability of the structures in mind there is a need to redesign the structure and expand it vertically. Ductile detailing approach aims at fulfilling the Earthquake safety requirement demands of a reinforced concrete structure as per IS 13920.It is a process of providing reinforcement in concrete for the structure to sustain earthquakes. Results from STAAD Pro software design and analysis makes it clear that on performing the seismic analysis of the earthquake resistant G+5 building as per IS 13920, the story drift and node displacements have decreased considerably. The shear walls, braced columns are not necessary to be provided as the structure is safely checked under drift condition. The structure is earthquake resistant as per IS 13920 and makes the consideration of vertical expansion a valid project towards improvement of unplanned urban planning in Srinagar City.

VII. ACKNOWLEDGMENT

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