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Research Paper

STUDY ON THE EFFECT OF GUST LOADS ON TALL BUILDINGS

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Multi-storeyed buildings have become common in the modern growing cities. As the height of the building increase for the given width, the building frame becomes flexible. Particularly in the case of frames with heights above 50 stories slenderness becomes more and the fundamental frequency of the frame becomes less. The wind pressures are fluctuating the nature and this is illustrated by the wind spectrum. There is a possibility of the fundamental frequency of the tall building structure machine with the wind frequency and this produces large displacements and critical effects on the frame. In the Gust Factor method the interaction between the fluctuating components of the wind with the structure is considered. The wind effects are expressed as equalling static loads. The approach is more rational compared to the ordinary static wind load approach. In the present project work, tall building frame 20 to 80 stories are considered for wind load analysis. Equivalent static wind loads are computed using the provisions of IS: 875-1987 PART-III. Analysis is conducted by using the package in two loading cases, i.e., vertical loads with or without wind loads. The resulting effects like beam moments, column moments, axial forces are compared. The criticality of the wind on tall building frames is examined and recommendations are given. The present study would lead to important and useful recommendations for the action of critical wind loads on tall building frames.

Keywords: Gust loads, Tall buildings, Wind pressure, Wind frequency, Static load

INTRODUCTION

High-rise buildings having very large number of stories are being constructed in urban towns and cities all over the world and India is also exception phenomenon. Tall buildings consisting of multi-storied framework are flexible in nature and they are susceptible to action of wind forces. In this introduction chapter the advent of multistoried buildings, the importance of wind loads, etc., are discussed here in.

Due to influx of heavy population the towns and cities are growing very rapidly. This phenomenon can be seen all over the world. The paucity of available land for construction particularly in major cities all over is a common problem.

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A tall building means which consists of 6 to 100 stories or more. But to construct these, enormous cost in involved. For middle level cities, the number of stories can range from 6 to 12 with an upper limit of 12. For middle level cities casting a frame with concrete, say M25 of M30 can be done through conventional methods and with better supervision.

LITERATURE REVIEW

The various structural systems adopted for the construction of tall buildings, the wind loads on tall buildings, wind effects on static and dynamic structures, etc., are reviewed. The nature of wind the computation of design wind pressure the various factors required for computing the design wind pressure, etc., are reviewed.

WIND LOADS ON TALL STRUCTURES

The development of modern materials and construction techniques as resulted in the emergence of new generation of structures

Table 1: 20 Storey Frame (Dl+Ll+Wl) Left End Column

Story Level	Height in m	Axial Load (x-axis)	Axial Load in KN for Hyderabad	Axial Load in KN Ahemadabad	Axial Load in KN Delhi
0	0	0	559.01	795.03	389.5
4	14	200	634.58	806.03	511.02
8	28	400	650.67	748.74	580.05
12	42	600	561.75	605.27	530.33
16	56	800	369.79	379.77	362.81
20	70	1000	71.37	71.86	71.04

Figure 1: Variation of Axial Load with Height for Left End Column for 20 Storied Frame

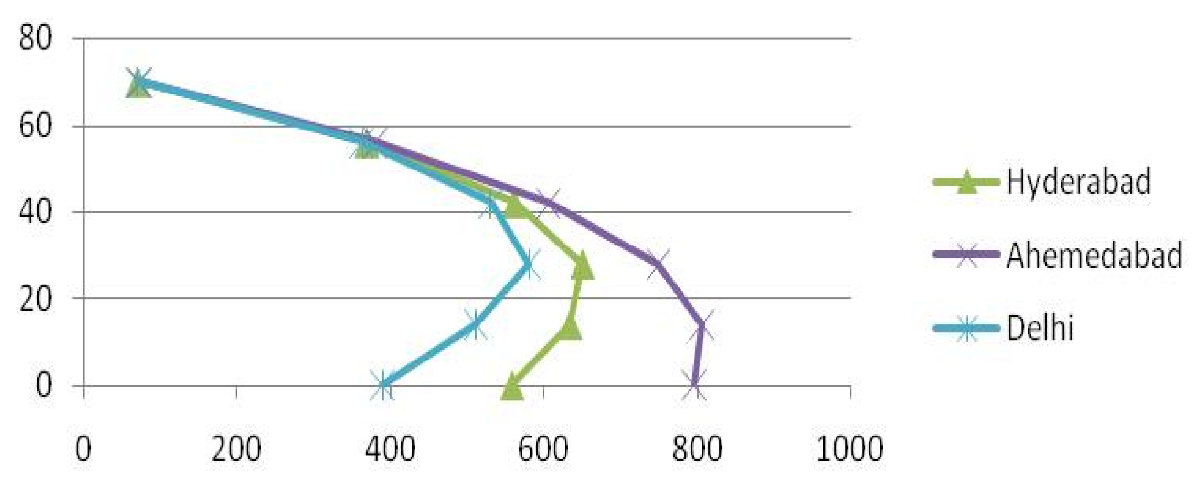
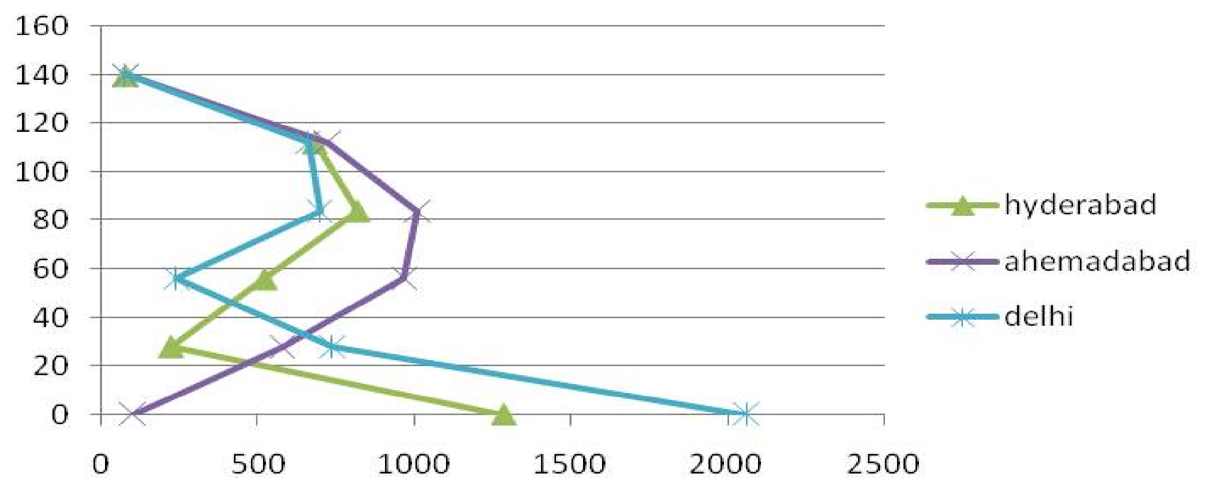


Table 2: 40 Storey Frame (DL+LL+WL) Left End Column

Story Level	Height in m	Axial Load in KN for Hyderabad	Axial Load in KN for Ahemadabad	Axial Load in KN for Delhi	Axial Loads (x-axis)
0	0	1286.5	99.8	2058.9	0
8	28	221.56	579.32	736.17	500
16	56	521.43	968.2	237.6	1000
24	84	818.64	1010.83	696.5	1500
32	112	681.95	721.61	657.56	2000
40	140	75.49	76.88	74.67	2500

Figure 2: Variation of Axial Load With Height for Left End Column for 40 Storied Frames



that are often, to degree unknown in the past, remarkably flexible, low in damping, and light in weight.

To achieve this end designer needs information regarding

- The wind Environment.
- The Relation between Environment and the forces induces on the structure.
- The Behavior of these structures under these forces.

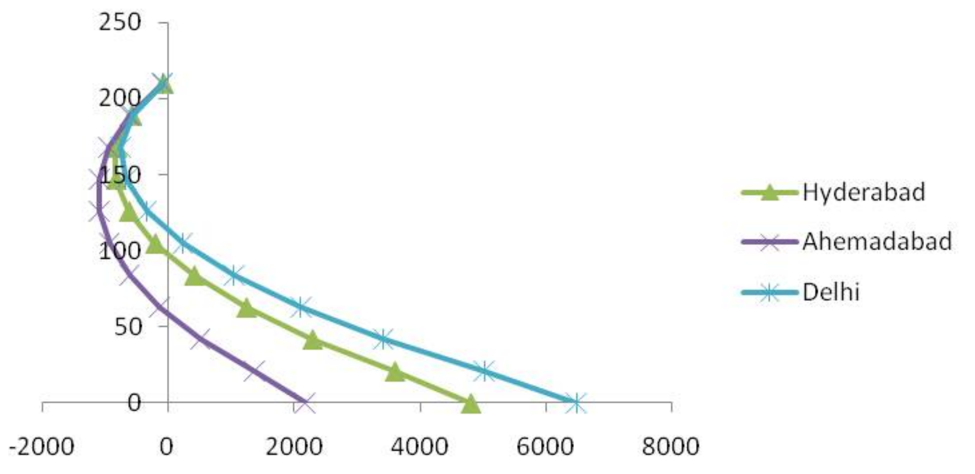
GUST EFFECTIVENESS FACTOR METHOD

The procedure outline under design of wind speed is applicable to static or rigid structures for the computation of wind loads. The code also (IS: 875 PART-III) has described the gust effectiveness factor method, which is more applicable to deal with tall, slender and flexible structures. The details of gust effectiveness factor method are discussed here in.

Table 3: 60 Storey Frame (Dl+Ll+Wl) Left End Column

Story Level	Height in m	Axial Load in KN for Hyderabad	Axial Load in KN for Ahemadabad	Axial Load in KN for Delhi	Axial Loads (x-axis)
0	0	4805.5	2192.16	6486.2	0
6	21	3598.6	1375.43	5023.7	2000
12	42	2290.1	517.11	3419.2	4000
18	63	1238.7	-134.21	2106.4	6000
24	84	410.47	-611.29	1049.6	8000
30	105	-209.11	-927.24	234.76	-500
36	126	-624.69	-1087.3	-333.95	-1000
42	147	-829.64	-1089.5	-670.89	-1500
48	168	-822.08	-933.66	-755.18	-2000
54	**189**	**-583.36**	**-606**	**-570.89**	
60	**210**	**-81.21**	**-82.02**	**-80.85**	

Figure 3: Variation of Axial Load with Height for Left End Column for 60 Storied Frame

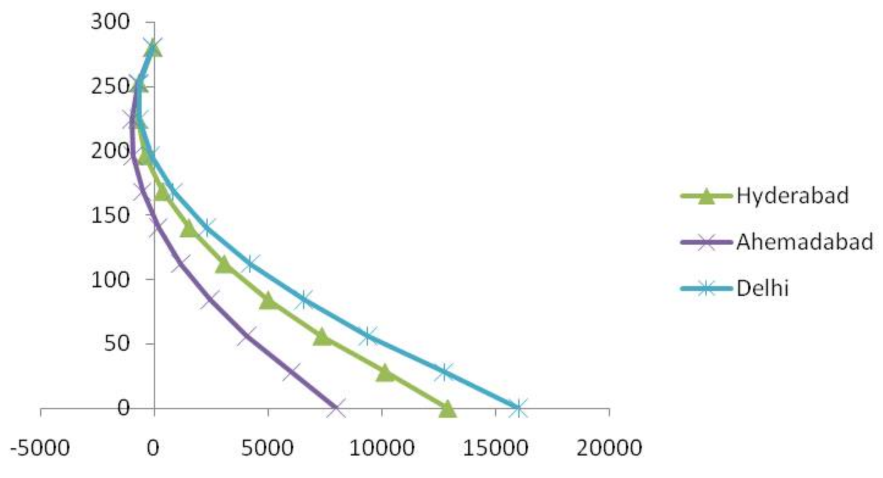


Only the method of calculation of load along wind or drag load by using gust factor method is given in the code since methods for calculating load across wind or other components are not fully matured for all types of structures. However it is permissible for a designer to use gust factor method to calculate all components of loads on a structure using any available theory. Use of existing theories of gust factor method requires knowledge of maximum wind speeds averaged over one hour at a particular location.

Table 4: 80 Storey Frame (Dl+Ll+Wl) Left End Column

Story Level	Height in m	Axial Load in KN for Hyderabad	Axial Load in KN for Ahemadabad	Axial Load in KN for Delhi	Axial Loads (x-axis)
0	0	12878	8000	15999	0
8	28	10119	6022	12720	5000
16	56	7351	4054	9370	10000
24	84	4988	2457	6567	15000
32	112	3057	1165	4218	20000
40	140	1507	165	2306	-5000
48	**168**	**347**	**-538**	**844**	
56	**196**	**-406**	**-932**	**-152**	
64	**224**	**-742**	**-1003**	**-663**	
72	**252**	**-688**	**-729**	**-655**	
80	**280**	**-79**	**-80**	**-77**	

Figure 4: Variation of Axial Load with Height for Left End Column for 80 Storied Frame

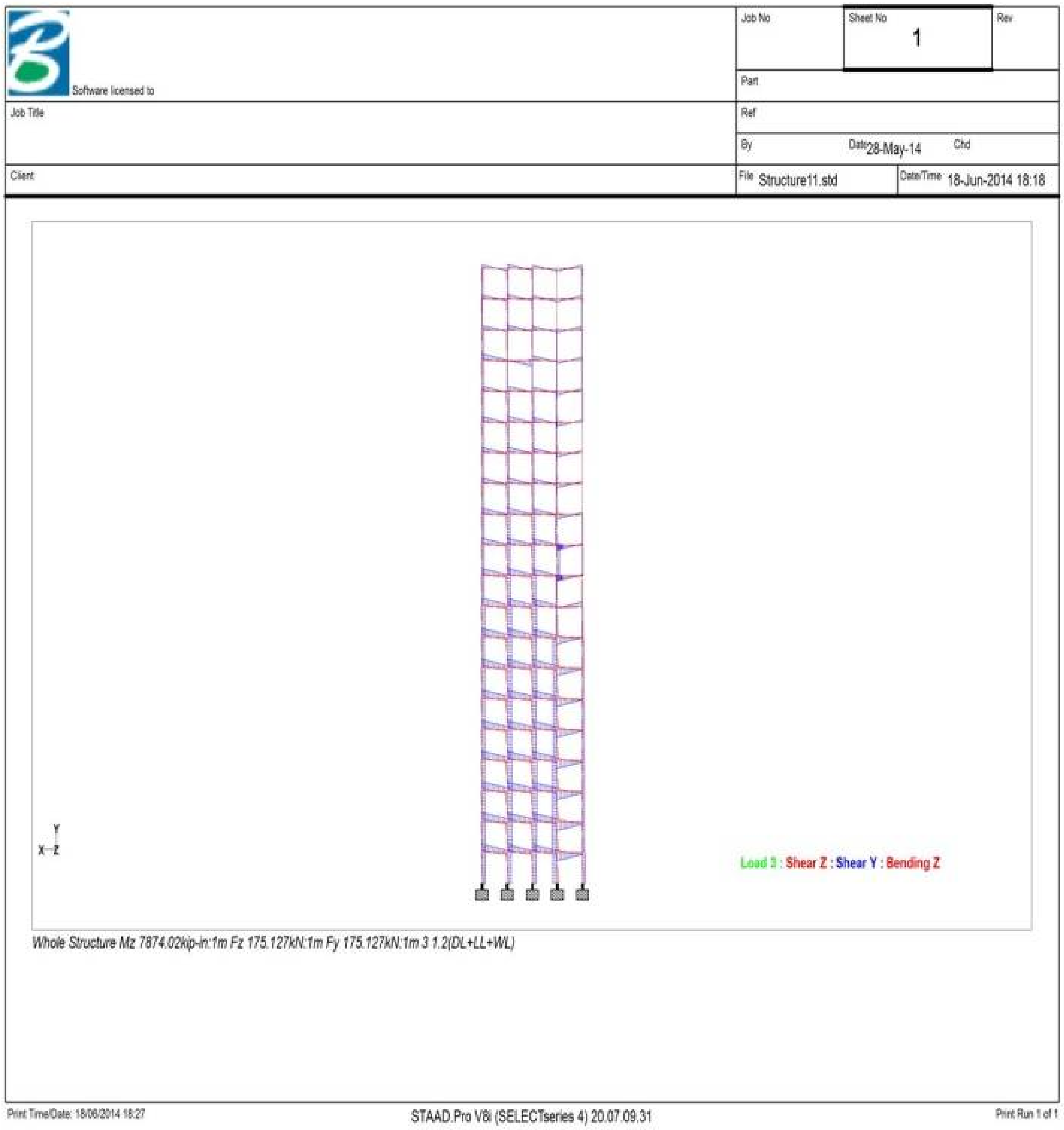


DETAILS OF FRAMES ANALYZED AND WINDLOAD COMPUTATIONS

The code of practice for design loads IS: 875 PART-III-1987 has given gust effectiveness factor method for estimating the wind load. To study the criticality of wind loads obtained by gust effectiveness factor method for the design of tall buildings.

In gust effectiveness factor method, wind

Figure 5: 20 Storey Frame Shear Force and Bending Momemt Diagram



pressures are obtained directly from wind velocity which depends on factors like terrain, topography, size and dynamic properties like stiffness, damping, fundamental frequency, background factor, etc., are taken into account for obtaining wind pressures. In the present project work, typical multi storied building ranging from 20 to 80 storeys are examined for criticality of wind loads in typical places like Hyderabad, Ahemadabad and Delhi.

DESCRIPTION OF STAAD-PRO

- Computer is a major invention of the 20th Century. Over the years, they have invaded

Figure 6: 20 Storey Frame Sway Momemt

all the walks of life. Computers have entered almost all the engineering field.

- Using STAAD-PRO software package we can do both static and dynamic analysis of structure. Earlier Civil engineers used flexibility and stiffness method for analysis and designing.

Analysis Facilities

Following Analysis facilities are available in STAAD-PRO

- Stiffness Analysis
- P-Delta Analysis
- Dynamic Analysis

Figure 7: 40 Storey Frame with Wind Load and Displacement (SWAY)

Salient feature of stiffness analysis, which is being used in this work, has been discussed in the following sections.

Stiffness Analysis

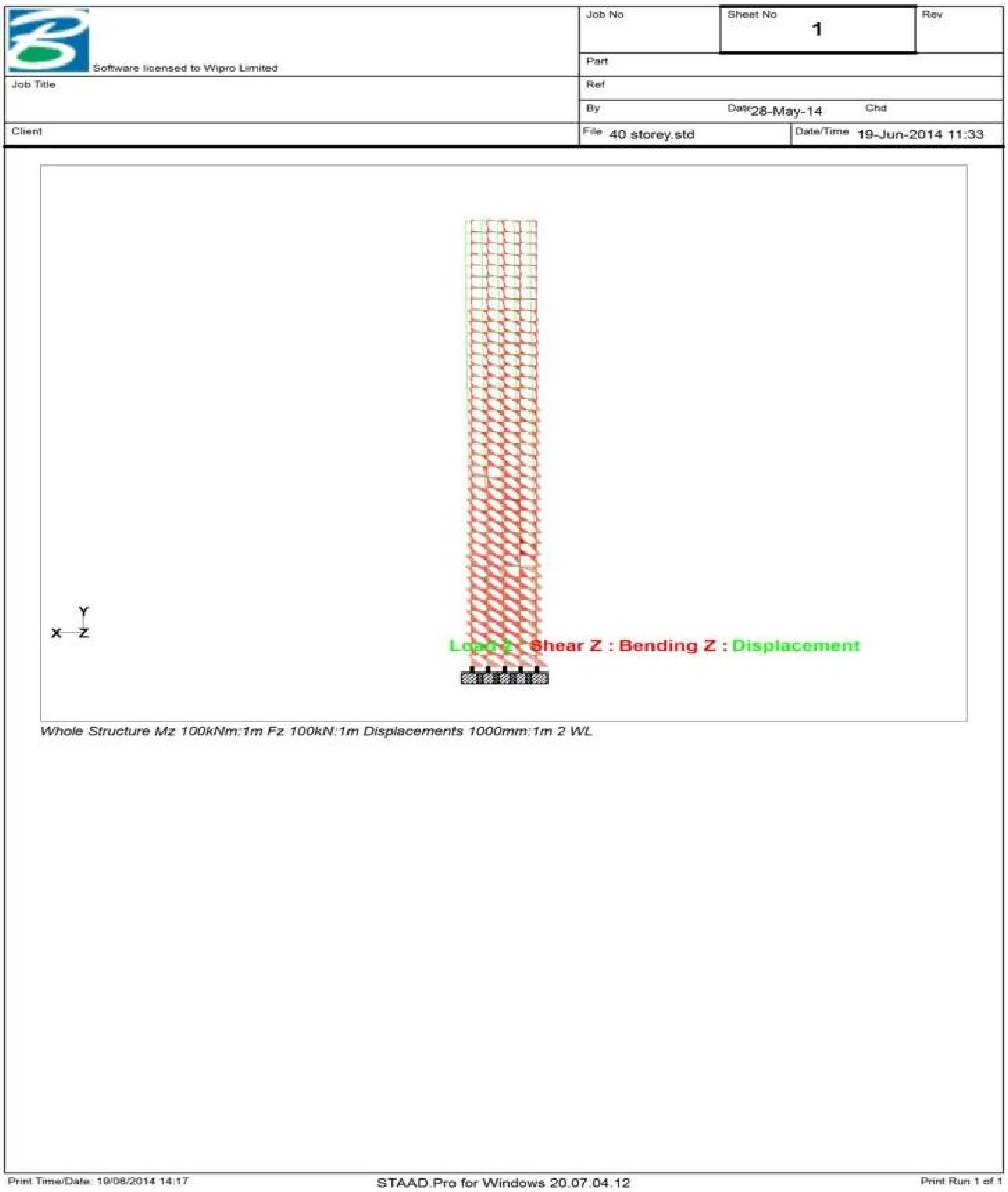
- The stiffness analysis implemented in STAAD-PRO is based on the matrix displacement method.
- In the matrix analysis of complex structures by the displacement method, the structure is first idealized into an assembly of discrete structural elements.
- Each element has an assumed form of displacements in a manner, which satisfies the force equilibrium and displacement compatibility at the joints.

Assumption of the Analysis

For a complete analysis of the structure, the necessary matrices are generated on the basis of the following assumptions:

- The structure is idealized into an assembly of beam and plate type elements jointed together at their vertices (nodes). The

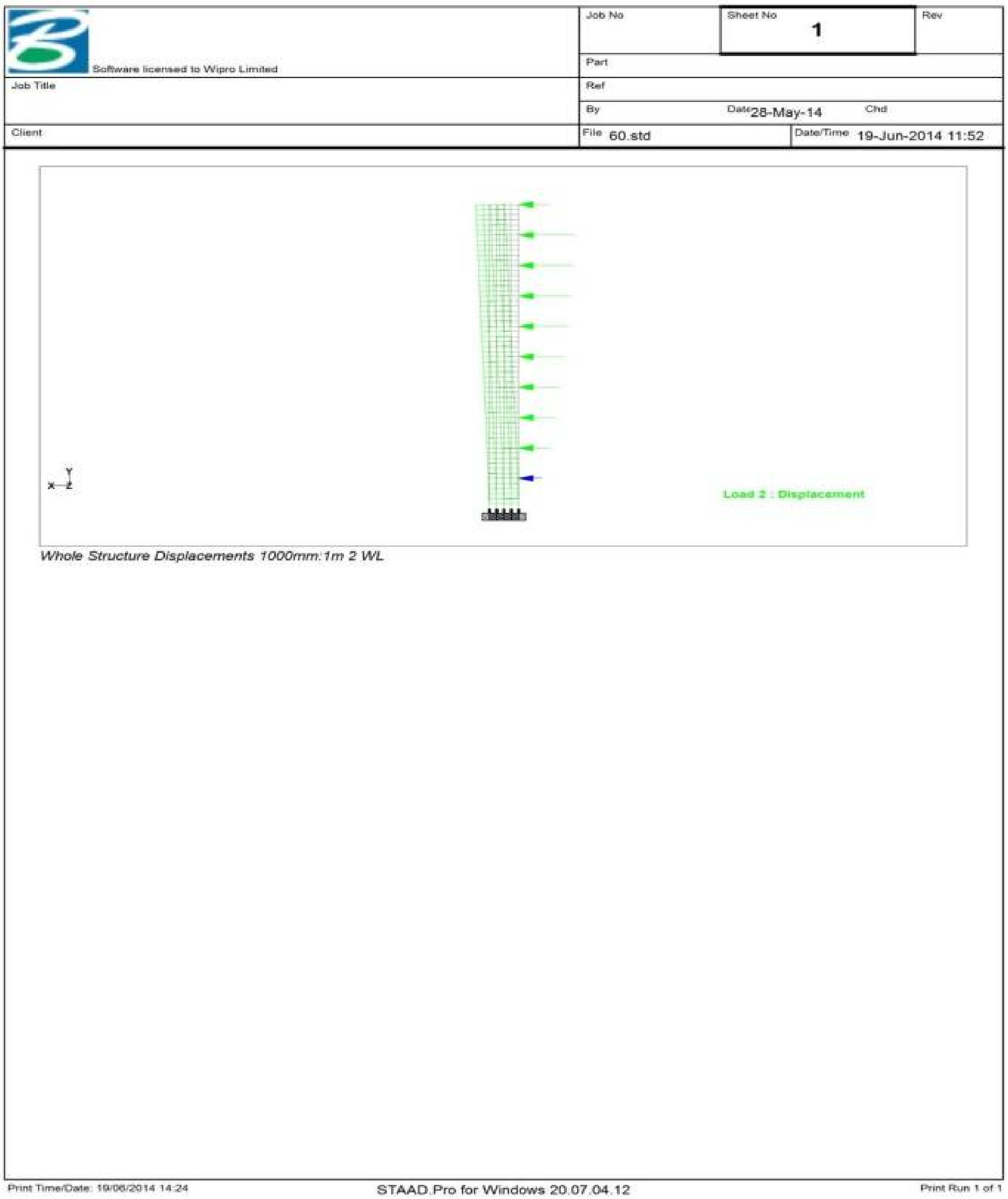
Figure 8: 40 Storey Frame with Shear, Bending and Displacement



assemblage is loaded and reacted by concentrated acting at the nodes. These loads may be both forces and moments, which may act, in any specified directions.

- A beam member is a longitudinal structure member having a constant, doubly symmetric near-doubly symmetric along its length. Beam members always carry axial forces.

Figure 9: 60 Storey Frame with Wind Loads and SWAY Moment



- A plane element is a three of four nodded element having constant thickness. These plate elements are referred to as "elements" in the manual.
- Internal and external loads are acting on each node are in equilibrium. If torsional or bending properties are defined for any member, six, degree of freedom are

Figure 10: 60 Storey Frame with Shear and Bending Moment

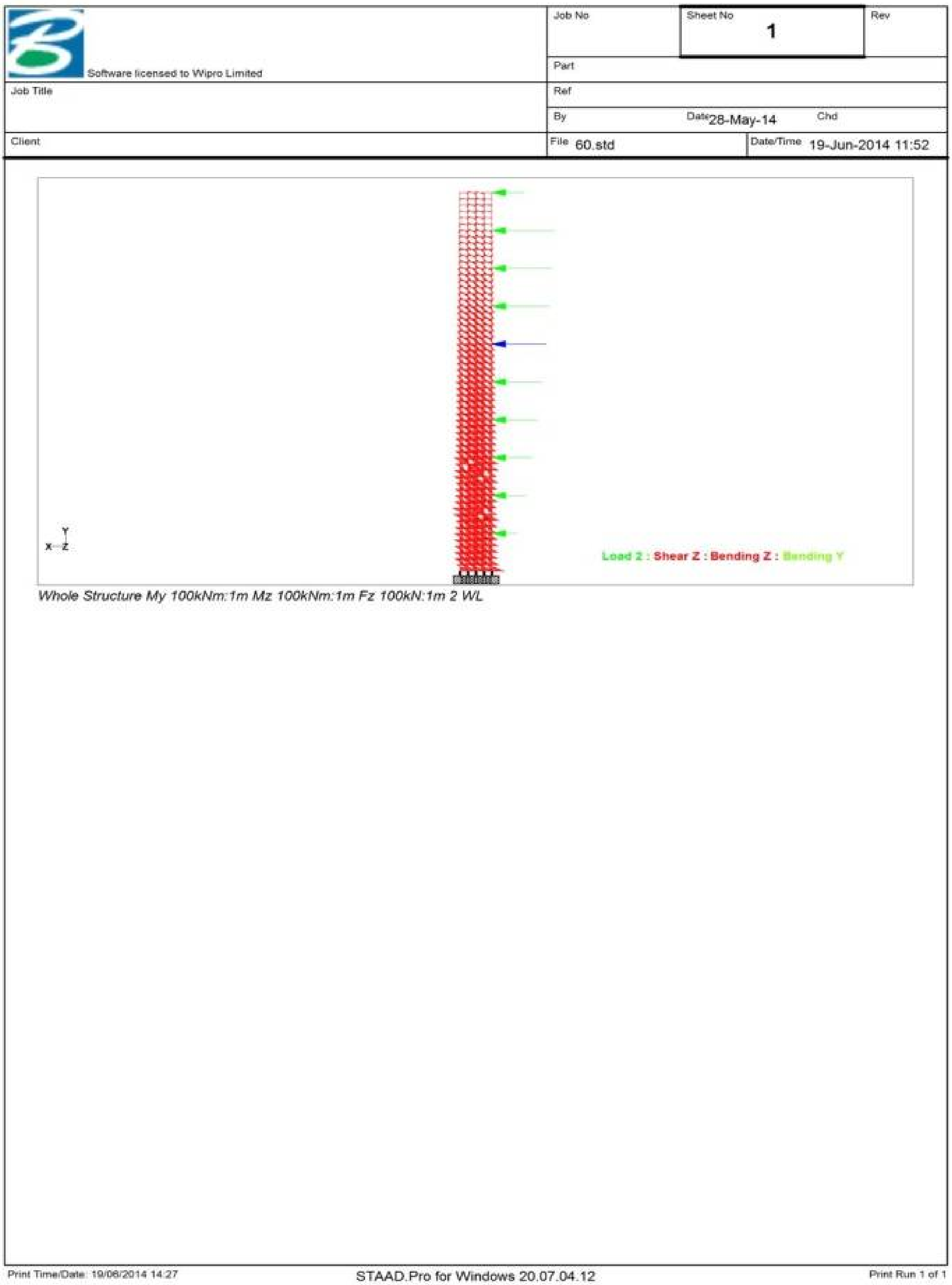


Figure 11: 80 Storey Frame with Wind Loads and SWAY Moment

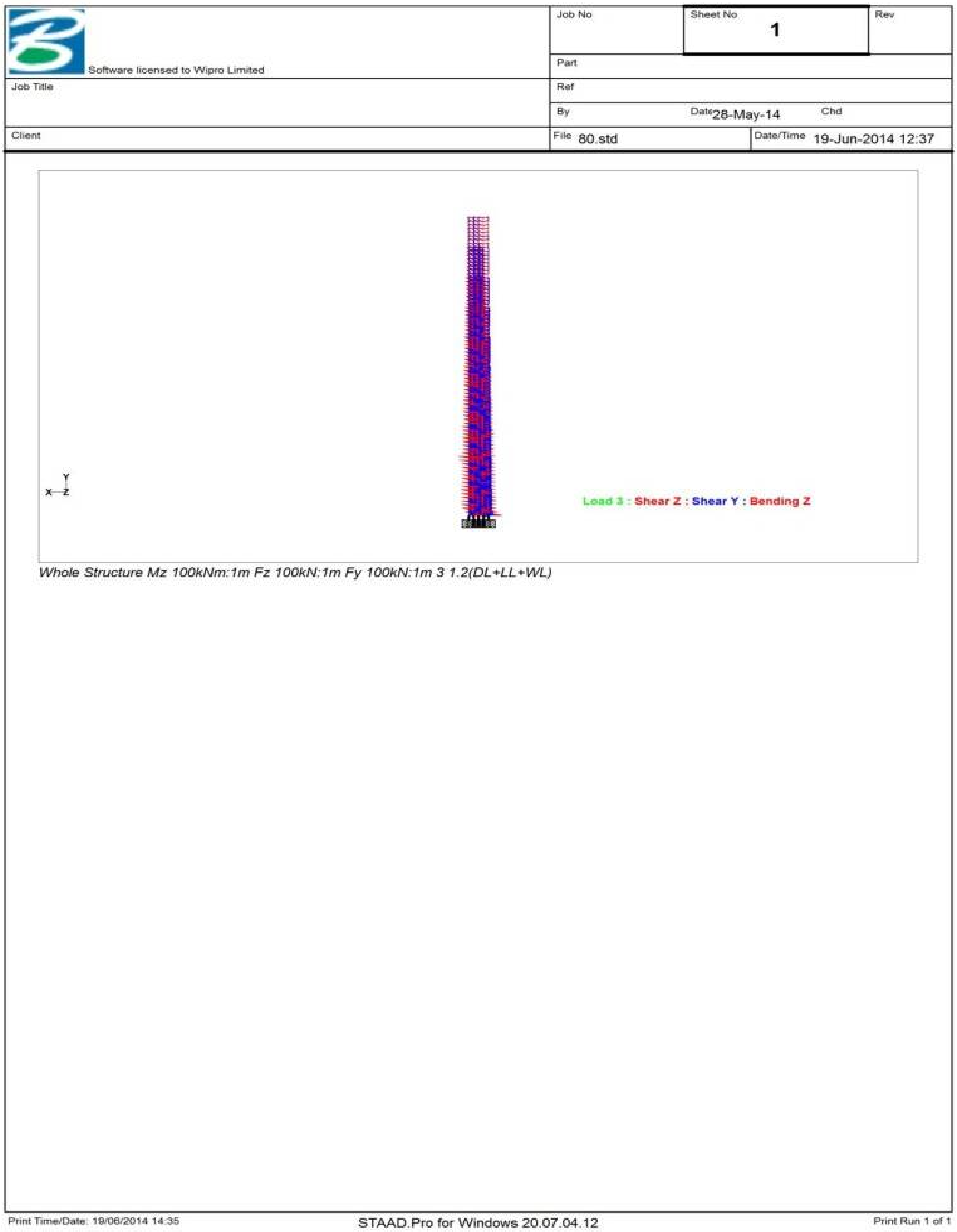
considered on each node (Le. Three transnational and three rational) in the generation of relevant matrices.

PRESENTATION OF RESULT ANALYSIS

Results Presented

The present thesis covers the study of variation of gust pressures in tall multi storied frames and their effects on the members of the frames. The various results of columns moments, column axial forces, beam moments, etc., are tabulated for three different wind climates of the country. Multi storied frames with height varying from 20 to 80 stories are covered in this analysis. For the analysis in tall cases, gust

Figure 12: 80 Storey Frame with Shear and Bending Moment



loads computed by using gust effectiveness Factor method as per IS: 875 PART-3.

DISCUSSION

- As the number of stories of a multi storied building frame increases the slenderness of the frame also increases. The building frame becomes more and more flexible with height.
- If the height of building frame id limited with larger aspect ratio, the frame tense to be rigid.
- In the case of rigid structures the natural frequency of building frame is very high and hence it does not dynamically interact with the fluctuating wind component.
- The frame dynamically interacts with the fluctuating wind component and as a result critical wind effects is more appropriate and realistic for computation of equivalent static wind loads on the structure.

CONCLUSION

- Gust effectiveness factor method, which is rational and realistic, should be considered for the computation of wind loads in the case of very tall frames and structures. It becomes necessary to study the criticality of wind forces in the case of multi-storied frames particularly on more serve wind zones.
- In the very tall frames it is necessary to combine the effect of lateral wind Load to examine the net axial force in the extreme end column to know its stability. In a place Hyderabad there is a reduction by 71% in the left end column axial force for a 20-storey frame. Similarly the reduction increases further for 40, 60 and 80 stories frames. In a place like Ahemadabad there is a reduction by 59% in the left hand column axial force for a 20-storey frame. Similarly the reduction increases further for 40, 60 and 80 stories frames. In a place like Delhi there is a reduction by 80% in the left hand column axial force for a 20-storey frame.
- For the design of columns both axial loads moments critical for design when wind effects are included.
- The values of beam moments increase by 20 to 35% bottom to top for different multi-storied frames from 20 to 80 stories for dead load and live load combination. Large criticality is being caused in the design of beams in multi-storied frame when wind effects are included.
- There is need to considered the wind effects in the case of frames having more than 20 storey particularly in serve wind climate to arrive at the critical values for design.

SUGGESTIONS FOR FUTURE WORK

- It has been established that wind causes criticality in the design of tall frames and structures, which are flexible in nature. The present project work covers the tall multi-storied frames.
- Further work may be carried out on tall structure like steel towers, chimneys, cooling towers, etc., for wind effects. Frequency analysis may be carried out to know their dynamic behavior.
- Criticality between wind and earthquake may be examined.

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