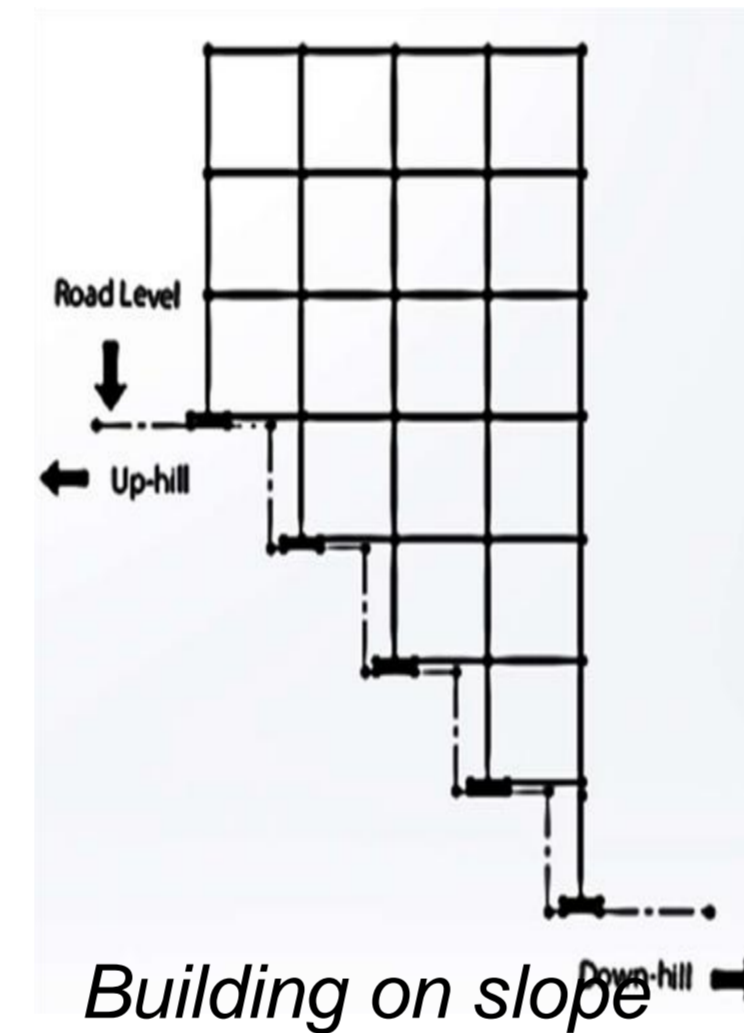




# Earthquake behaviour of Buildings on Slopes

## Introduction

- The construction in hilly regions is generally constrained by local topography resulting in vertical as well as horizontal irregularities in the buildings.
  - Dynamic properties of such buildings vary significantly.
  - Fundamental Natural Period of a building is one such important dynamic property.
- Ambient Vibrations of certain buildings constructed on hill slopes of Mussoorie were recorded to obtain respective Natural periods of certain buildings.
- Observed that the existing code provisions for estimating the approximate period of a building are not efficient enough in the case of such buildings.
- An empirical relation to estimate natural period of buildings constructed on slopes was derived using regression analysis.



## Regression Analysis

- Obtained data set is not sufficient to yield an efficient relation.
- A total of 270 buildings were modelled using SAP 2000, based on the above data.
- Relation to estimate natural period has been derived using regression analysis

$$T = \alpha (f(H_{avg}))^{\beta_1} (g(\theta))^{\beta_2} (h(D))^{\beta_3}$$

Regression Analysis results (Constant values and Regression coefficients R<sup>2</sup>, S<sub>e</sub>)

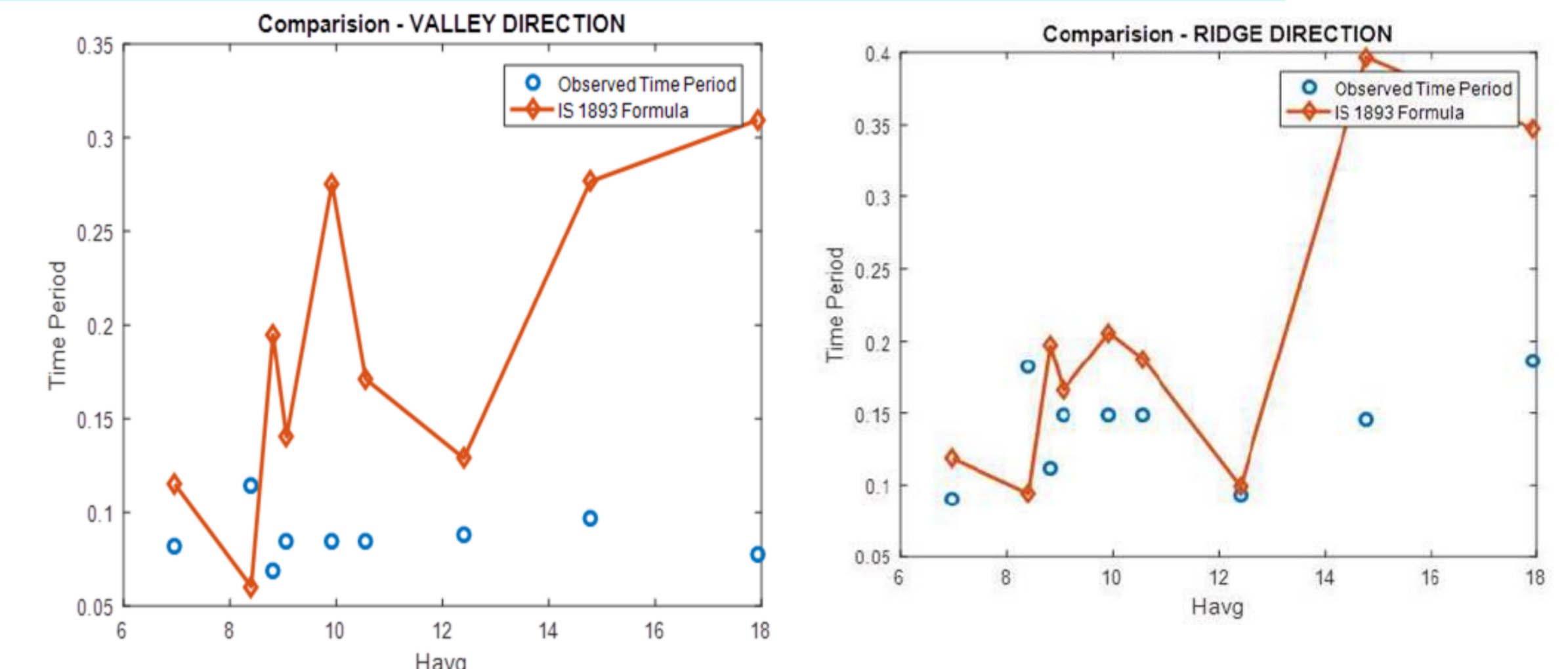
M No	f	g	h	α	β <sub>1</sub>	β <sub>2</sub>	β <sub>3</sub>	R <sup>2</sup>	S <sub>e</sub>
<b>VALLEY Direction</b>									
V1	H	1	D	0.004	1.37	N/A	-0.61	0.914	0.123
V2	H	1+sinθ	D	0.013	1.40	-0.48	-0.63	0.972	0.070
V3	H	1+sinθ	A	0.013	1.38	-0.46	-0.62	0.941	0.091
<b>RIDGE Direction</b>									
R1	H	1	D	0.007	1.24	N/A	-0.59	0.939	0.093
R2	H	1+sinθ	D	0.015	1.24	-0.3	-0.59	0.965	0.070
R3	H	1+sinθ	A	0.016	1.25	-0.32	-0.6	0.949	0.087

## Conclusions

- The obtained empirical relations to estimate the Natural period of a building constructed on hilly region along Valley and Ridge directions respectively.

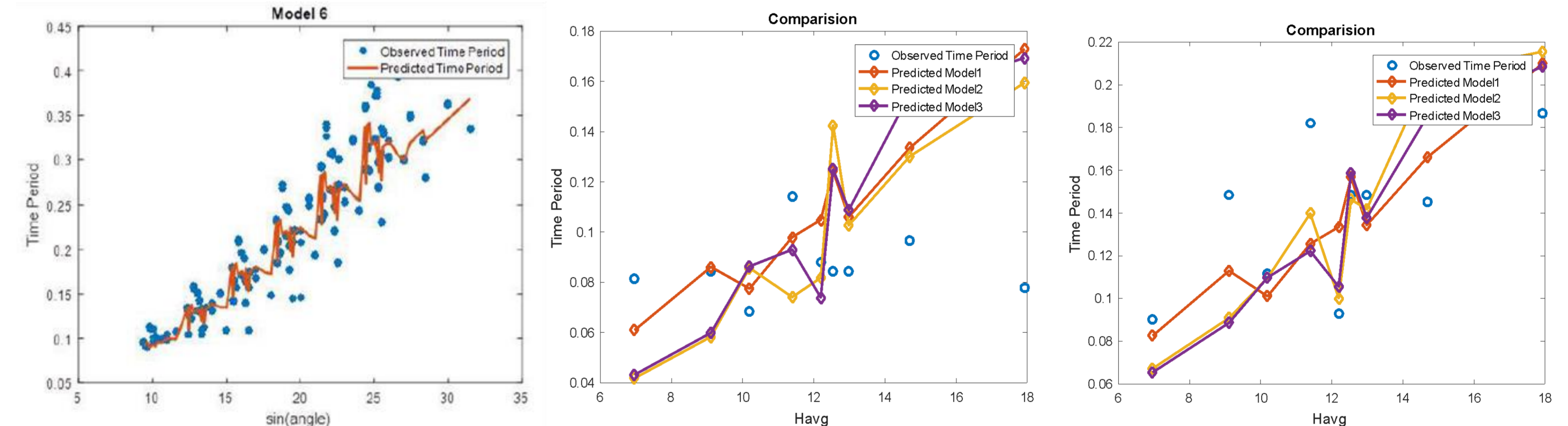
## Ambient Vibration Test - Mussoorie vs. IS 1893:2016

- Buildings constructed on hill slopes were tested for their ambient vibrations in Mussoorie, Uttaranchal.
- The data was further processed to obtain their respective Fundamental Natural Period.
- Obtained values were compared with the existing IS codal provisions.  $T = \frac{0.09h}{\sqrt{D}}$



Natural period obtained from ambient vibration test observations V/S IS 1893:2016 provisions;

## Validation of derived relations



Sample regression results

Comparison of Natural period of buildings tested calculated using predicted model's vs. actual experimental value; Along Valley, Ridge directions respectively

$$T = 0.0132(H_{avg})^{1.4} (1 + \sin\theta)^{-0.63} (D)^{-0.48}$$

$$T = 0.0156(H_{avg})^{1.24} (1 + \sin\theta)^{-0.59} (D)^{-0.29}$$

VALLEY direction

RIDGE direction