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Comparison of wind effect according to various codes

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Abstract
The wind is one of the important effects that should be considered during the design of structures. Wind is a phenomenon at least as destructive as an earthquake. It is known that the wind effect increases especially in high buildings. In structures, small cross sections and high such as minarets, the wind effect can be even more destructive. There are many minarets reported that were damaged from wind in Turkey. It is known that most of these structures were built without engineering services. Wind effect should be considered during design phases on structures such as minarets. The internal forces and behavior of the structure under wind effect should be well known. In order to apply the wind effect correctly, a code about wind design should exist in the country. Nevertheless, adequate measures are not taken about wind effect during design structures in Turkey. Design codes for wind load calculation are insufficient. In this study, a 6 - storey reinforced concrete building model was created. In order to examine the wind effect on the building, the wind load effect was applied according to various codes. The results were compared according to the codes. Advantages and disadvantages of wind load calculation method used in our country have been evaluated.

Keywords: w Wind effect; wind stress; TS-498; ASCE 7.05; EUROCODE 1-2005.

1. Introduction

Wind is one of the critical phenomenon effects due to its interaction with the structure. Wind contains many eddies in the air, acting on the surface of the earth [1]. These eddies cause the hurricane, stormy, and wind turbulent[2]. Wind load on the structure is considered during design to ensure its survivability [3]. It is known that the wind effect increases especially in high structure. Especially buildings with a natural vibration period over one second may interact with the wind [4]. The change in wind speed with height is given in figure 1. In structures, small cross sections, and high such as minarets, the wind effect can be even more destructive [5]. There are many minarets reported that were damaged from wind in Turkey [6,7].

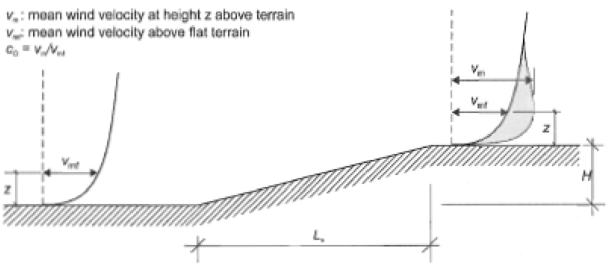

Figure 1. Variation of wind pressure with height [8].

It is known that structures in various parts of the world are damaged by high winds such as typhoons storms. The wind creates suction forces on the side surfaces and the rear surface while the wind creates pressure on the surface; it strikes on the structure. Wind effect distribution on the buildings is given in figure 2. According to the past researches, wind damage occurs generally in roof cladding of buildings [9]. Importance of wind calculation is happened due to damages in structures. In recent years, some methods have been developed for wind effect calculation. The gaussian estimation method is one of them. However, the measurement of environmental loads, such as strong winds, deviates significantly from the Gaussian method [10].

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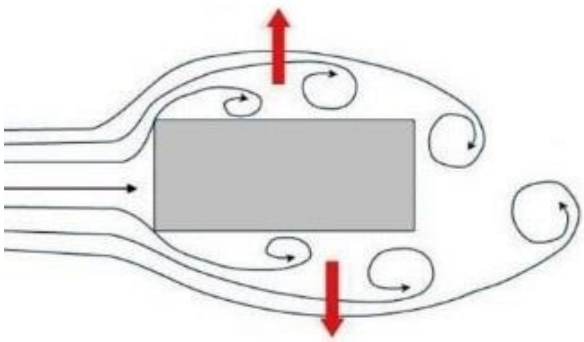


Figure 2. Wind effect distribution on the buildings.

There have been many studies due to the complex nature of the wind and the excess of parameters[11]. Many researchers focused on wind load effect on the tall buildings. Marukawa et al. (1992) studied the properties of crosswind for tall buildings [12]. Liu et al. (2019) studied effects of twisted wind flow on wind loads for tall buildings [3]. Tanaka et al. (2012) studied aerodynamic forces and wind pressures [13]. There are many other studies about tall structures such as Cheng et al. (2011), Kim et al. (2014), Sun et al. (2017) [14–16]. There are many studies on the parameters affecting wind load, such as terrain characteristics [17], extreme wind conditions [18,19]. In this study, a 6 - storey reinforced concrete building model was created. In order to examine the wind effect on the building, the wind load effect was applied according to various codes. The results were compared according to the codes. Advantages and disadvantages of wind load calculation method employed in our country have been evaluated.

2. Material and method

In this study, a 6 storey reinforced concrete frame building created on ETABS. The building analyzed for three different codes. The building plan is given in figure 3. The dimensions of the building in the plan were chosen as 40x30 m. Building cross section I-I is given in figure 4.

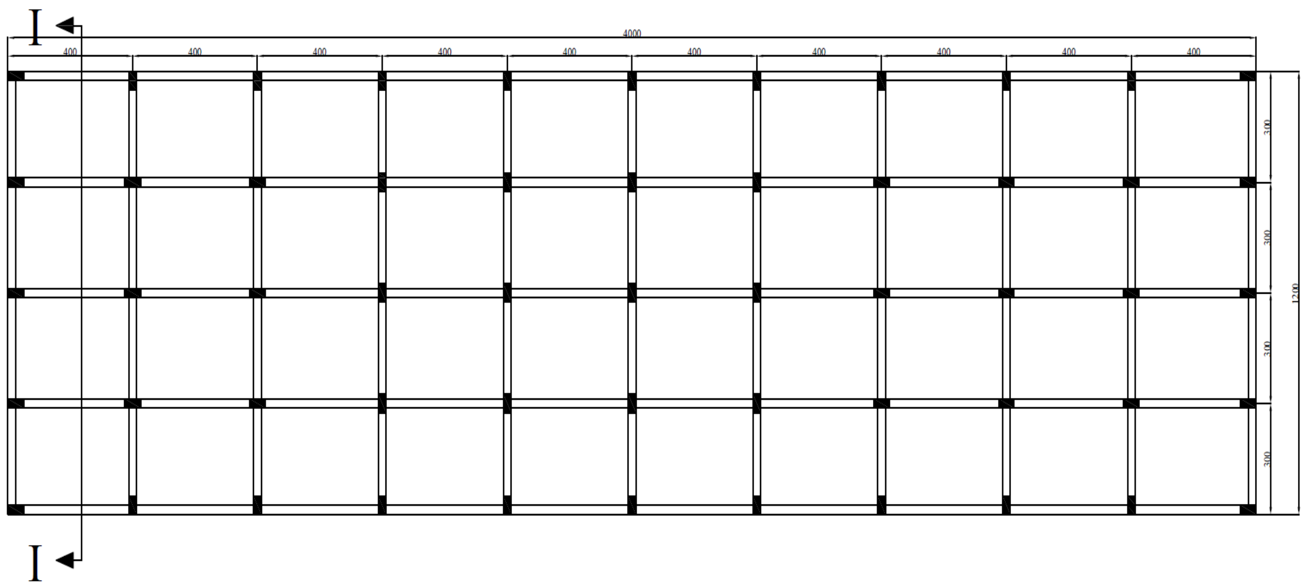


Figure 3. Building plan.

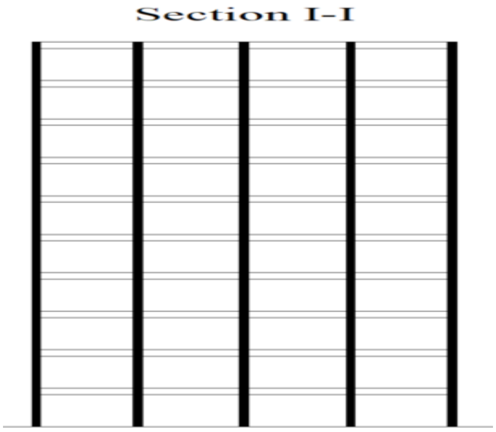


Figure 4. Building's cross section.

The dimensions of the building in the plan were chosen as 40x30 m. Building cross section I-I is given in figure 4. Column dimensions, beam dimensions, and slab thickness were selected as 25x50 cm, 25x50 cm, and 12 cm, respectively. Building height is chosen 3 m. The foundation connection of the building is accepted as fix support. 1.5 kN / m^2 dead load, including slabs' own weight and 5 kN / m^2 live load were applied to the slabs. Each storey is regarded as a rigid diaphragm in itself. The building's 3D model is given in figure 5.

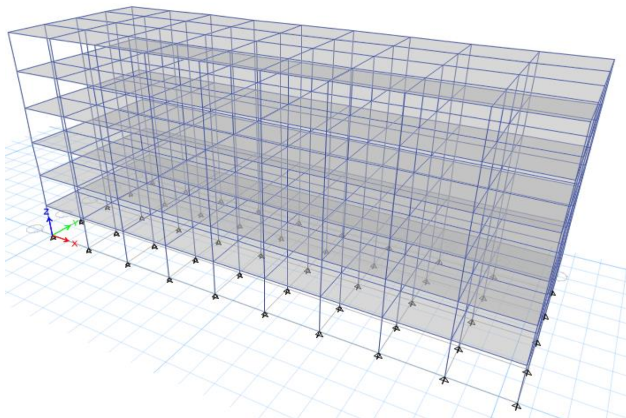


Figure 5. Building's 3D model.

ASCE 7.05, TS498, EUROCODE 1-2005 were used for analyzing.

2.1. ASCE 7.05

Wind speed was considered as 85 mph for ASCE 7.05. Exposure type for the building was chosen as B due to the ground surface roughness condition. Building classification was chosen II according to table 1.

Table 1. Building classification [20].

Nature of Occupancy	Occupancy Category
Buildings and other structures that represent a low hazard to human life in the event of failure.	I
All buildings and other structures except those listed in Occupancy Categories I, III, and IV.	II
Buildings and other structures that represent a substantial hazard to human life in the event of failure.	III
Buildings and other structures designated as essential facilities.	IV

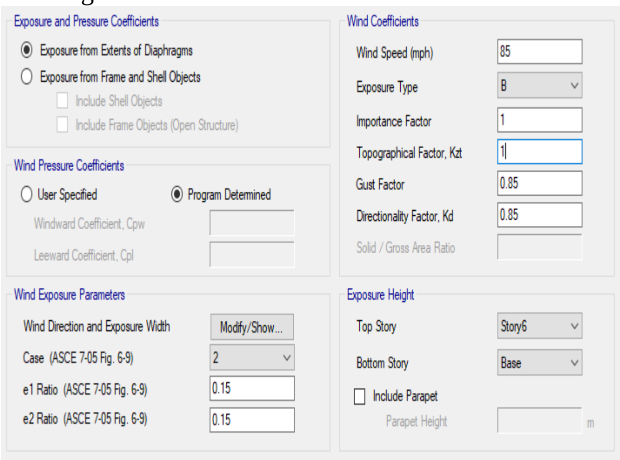
Importance factor was chosen as 1 according to table 2.

Table 2. Importance factor [20].

Category	Non-Hurricane Prone Regions and Hurricane Prone Regions with V=85-100 mph and Alaska	Hurricane Prone Regions with V>100 mph
I	0.87	0.77
II	1.00	1.00
III	1.15	1.15
IV	1.15	1.15

Topographical factor, Kzt, was considered 1. All values are considered for ASCE 7.05 are given in figure 6.

Figure 6. All values considered for ASCE 7.05.



2.2. EUROCODE 1-2005

Wind velocity was considered as 35 m/s for EUROCODE 1-2005. Terrain category was chosen as IV according to table 3.

Table 3. Terrain category [8].

Terrain Classification	Category
Sea, a coastal area exposed to the open sea.	0
Lakes or area with negligible vegetation and without obstacles.	I
An area with low vegetation such as grass and isolated obtacles (trees, buildings) with seperations of at least 20 obstacle heights.	II
An area with the regular cover of vegetation or buildings or with isolated obstacles with seperations of maximum 20 obstacle heights (such as villages, suburban terrain, permanent forest).	III
An area in which at least 15% of the surface is covered with buildings and their average heights exceeds 15 m.	IV

Orography factor, turbulence factor, and structural factor were taken as 1. All values taken for EUROCODE 1-2005 is given in figure 7.

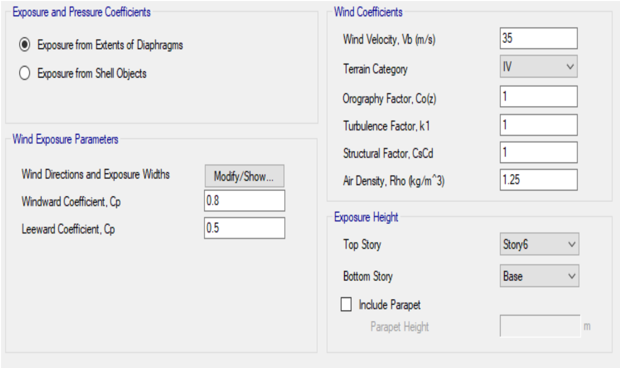


Figure 7. All values taken for EUROCODE 1-2005.

2.3. TS-498

Wind velocity was taken as 36 m/s. Coefficient of dynamic, Cr, was taken as 1.2 [21]. All values taken for TS 498 is given in figure 8.

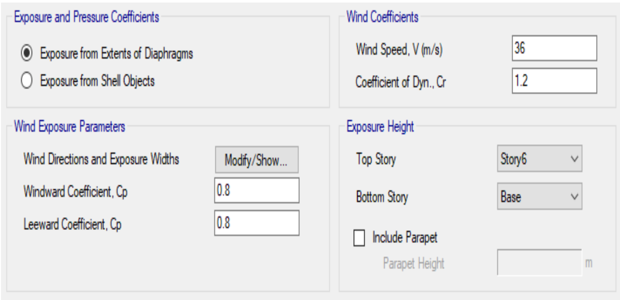


Figure 8. All values are taken for TS 498

3. Results and discussions

Base shear forces obtained as a result of the analysis is given in table 4.

Table 4. Base shear forces

Code	Base Shear Force (kN)
TS-498	307.93
ASCE 7.05	73.75
EUROCODE 1-2005	252.12

As seen in table 4, the highest base shear force was obtained with TS-498. As there are very few parameters defined in TS-498 code, the results are not realistic. Story forces are given in figure 9. Story moment is given also in figure 10.

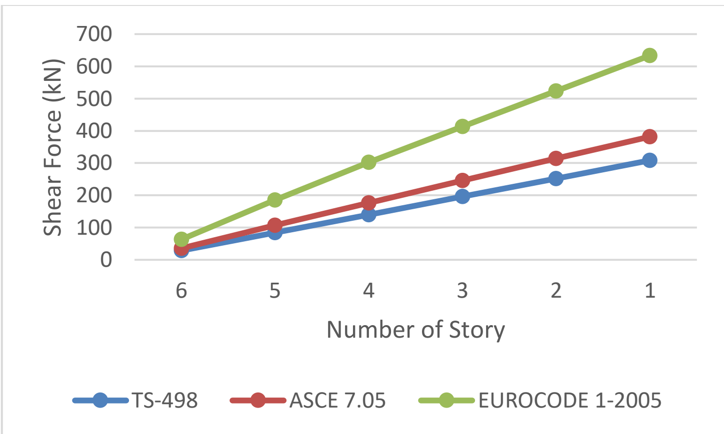


Figure 9. Story forces

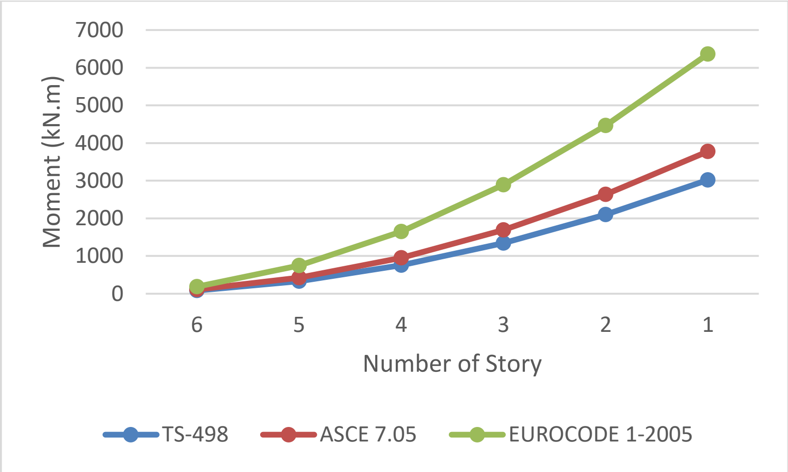


Figure 10. Story moment

As seen in figure 10, the story moment increases towards the base story. Increasing in shear force between stories is higher for EUROCODE 1-2005. Story displacement is given in figure 11.

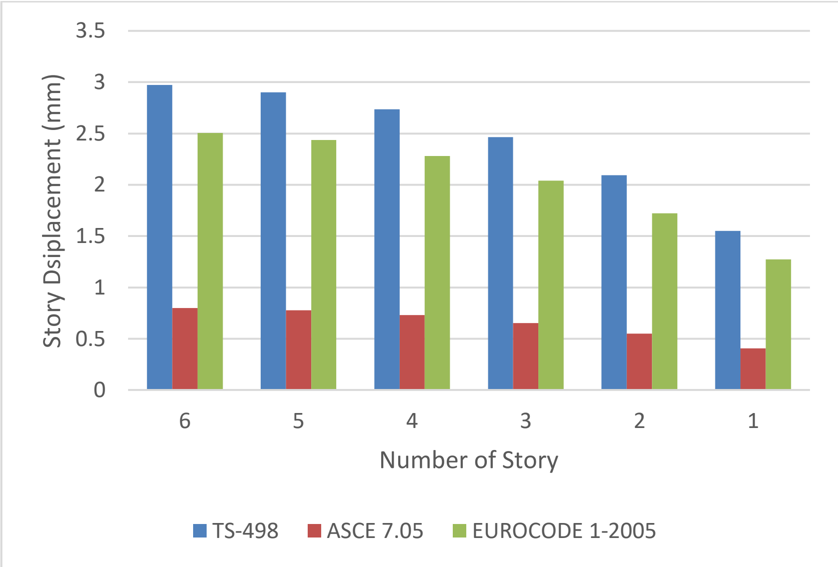


Figure 11. Story displacement.

As seen in table 5, torsional irregularity doesn't occur in the building.Maximum story drift, average story drift, and max. drift/avg. drift is given in table 6.

Table 5. Torsional irregularity coefficient

Code	Number of Story	Max. Displacement (mm)	Average Displacement (mm)	Ratio
TS-498 1	6	2.974	2.971	1.001
	5	2.901	2.899	1.001
	4	2.734	2.732	1.001
	3	2.465	2.463	1.001
	2	2.093	2.091	1.001
	1	1.55	1.55	1.001
ASCE 7.05	6	0.8	0.733	1.092
	5	0.779	0.714	1.091
	4	0.73	0.669	1.091
	3	0.654	0.599	1.091
	2	0.551	0.505	1.092
	1	0.407	0.372	1.093
EUROCODE 1 2005 1	6	2.505	2.503	1.001
	5	2.436	2.434	1.001
	4	2.281	2.279	1.001
	3	2.041	2.04	1.001
	2	1.723	1.721	1.001
	1	1.272	1.271	1.001

Table 6. Story drift

Code	Number of Story	Max. Drift (mm)	Average Drift (mm)	Ratio
TS-498 1	6	0.073	0.073	1
	5	0.167	0.167	1.001
	4	0.269	0.269	1.001
	3	0.372	0.372	1.001
	2	0.542	0.541	1.001
	1	1.55	1.55	1.001
ASCE 7.05	6	0.021	0.019	1.1
	5	0.048	0.044	1.093
	4	0.076	0.07	1.091
	3	0.103	0.094	1.089
	2	0.145	0.133	1.088
	1	0.407	0.372	1.093
EUROCODE 1 2005 1	6	0.069	0.069	1
	5	0.155	0.155	1.001
	4	0.24	0.24	1.001
	3	0.319	0.318	1.001
	2	0.451	0.45	1.001
	1	1.272	1.271	1.001

4. Conclusions

The following results obtained from the wind load analysis according to three different codes are given :

- The highest base shear force was obtained with TS-498.
- Wind load did not cause torsion in the building due to the building's uniform geometry.
- The TS-498 code is inadequate in terms of wind load parameters. Therefore the base shear force is highest in this code.
- While wind load has a static effect on low-rise buildings, the impact on high-rise buildings should be examined.
- The TS-498 code should be revised and made as comprehensive as other codes.
- In particular, parameters such as terrain category, building importance factor, turbulence factor should be included in TS-498.
- For the single structures such as minarets, towers, a separate section should be established in the code.
- Wind behavior of minarets should not be ignored in countries which have many mosques such as Turkey.
- With the development of structure design according to the wind load, damage to the buildings due to wind load will be prevented to a great extent.

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