

# APEC-WW-2010 Country Report: Philippines

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**ABSTRACT:** This paper has two main parts, talking about recent developments in structural and environmental wind engineering in the Philippines. The first few sections discuss the new wind loading provisions of the 6<sup>th</sup> and latest edition of the National Structural Code of the Philippines, or the NSCP 2010, which are primarily based on those in the ASCE 7-05 provisions. Additional features of the NSCP 2010 that differentiate it from the ASCE7-05 provisions are discussed, namely: foregoing a wind zone map in favor of a wind zoning table, application of “rigid” and “flexible” structure classification to buildings only, and provision of a different set of gust effect factor formulations for “other,” non-building structures as well as guidelines for estimation of natural frequencies and damping ratios. The last section discusses current environmental wind engineering conditions and relevant policies.

**KEYWORDS:** Philippines, wind loads, codes, NSCP, wind environment.

## 1 INTRODUCTION

The current paper has two main parts, talking about recent developments in structural and environmental wind engineering in the Philippines. The first few sections introduce and discuss the new features of the wind loading provisions in the 6<sup>th</sup> and latest edition of the National Structural Code of the Philippines, Volume 1 (Buildings, Towers and Other Vertical Structures), or NSCP 2010. The last section discusses current environmental wind engineering conditions and relevant policies.

This paper is the 6<sup>th</sup> in a series of country reports from the Philippines that have been presented at the Workshop on Harmonization of Wind Loading and Wind Environmental Specifications in Asia-Pacific Economies (APEC-WW) that started in 2004 in Atsugi, Japan, and continued on in 2005 in Hong Kong, China, 2006 in New Delhi, India, 2007 in Shanghai, China, and 2009 in Taipei, Taiwan.

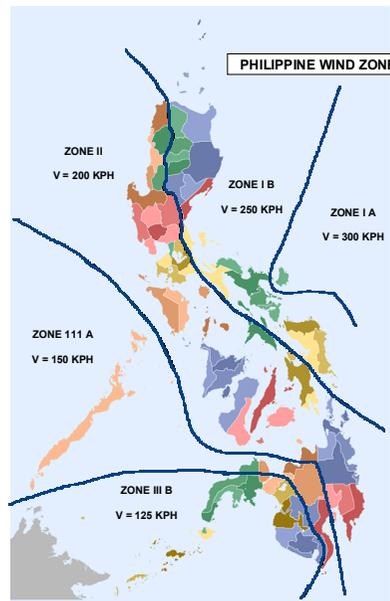
## 2 NEW WIND LOADING PROVISIONS

### 2.1 *Facts about the NSCP 2010*

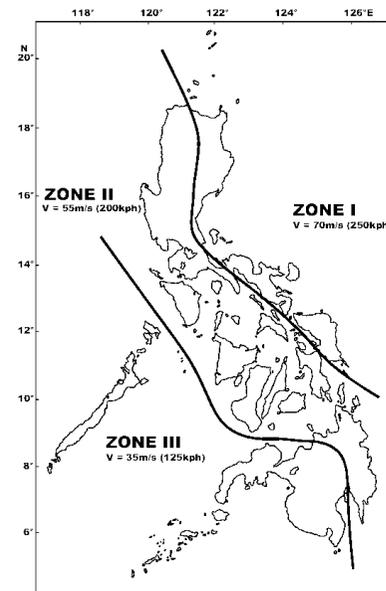
The Volume 1 of the NSCP 2010 has been launched in June 2010. A corresponding update of Volume 2 (for Roads, Highways, and Bridges) and release of new Volumes 3 (for Housing), 4 (Railways), and 5 (Ports and Harbors) are also planned in 2010. Updated editions of the NSCP are first reviewed and consequently approved by the Department of Public Works and Highways to become a referral code of Presidential Decree No. 1096, the National Building Code of the Philippines, which is the governing regulation for construction and design in the Philippines. The Association of Structural Engineers of the Philippines and specifically its Codes and Standards Committee (ASEP-CSC) prepares and publishes the NSCP.

Table 1. Historical basis of the NSCP wind loading provisions for buildings

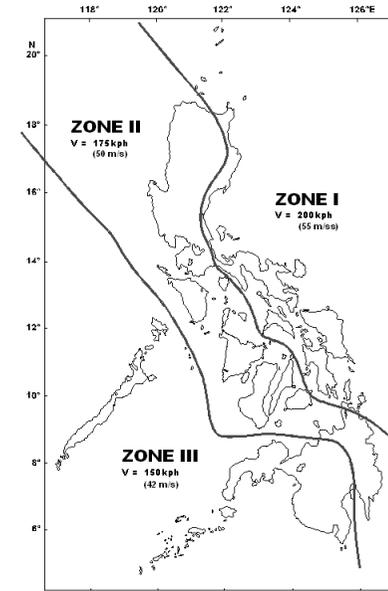
Edition / Volume / Printing	Year	Title	Short Name	Primary Code Basis
1st edition	1972	National Structural Code for Buildings	NSCB 1972	UBC 1970
1st edition, 2nd printing	1977	National Structural Code for Buildings	NSCB 1977	UBC 1970
2nd edition	1982	National Structural Code for Buildings	NSCB 1982	UBC 1978
3rd edition	1987	National Structural Code of the Philippines	NSCP 1987	UBC 1985
4th edition, Volume 1	1992	National Structural Code of the Philippines – Volume 1 (Buildings, Towers, and Other Vertical Structures)	NSCP 1992	UBC 1988
4th edition, Volume 1, 2nd printing	1996	National Structural Code of the Philippines Volume 1 (Buildings, Towers, and Other Vertical Structures)	NSCP 1992	UBC 1988
5th edition, Volume 1	2002	National Structural Code of the Philippines Volume 1 (Buildings, Towers, and Other Vertical Structures)	NSCP 2001	ASCE 7-95
6th edition, Volume 1	2010	National Structural Code of the Philippines Volume 1 (Buildings, Towers, and Other Vertical Structures)	NSCP 2010	ASCE 7-05
1st edition, Volume 3	2010	National Structural Code of the Philippines Volume 3 (Housing)	(NSCP 2010)	(The International Residential Code has been proposed as code basis.)



(a)



(b)



(c)

Figure 1. (a) Initially proposed wind zone map for the NSCP 2010, (b) wind zone map in NSCP 2001, and (c) wind zone map in the earlier, first four editions of the NSCP.

## 2.2 Historical basis of the NSCP

The NSCP wind loading provisions for buildings has been historically based on US-based codes, namely the Uniform Building Code or UBC, and the American Society of Civil Engineers' Standard 7, "Minimum Design Loads on Buildings and Other Structures," or ASCE7. (Aquino, 2005)

As seen from Table 1, there was a shift in code basis from the UBC to the ASCE7 in the previous NSCP edition, NSCP 2001. This was a major shift in the wind design philosophy from the earlier editions which disregarded dynamic effects for wind-sensitive or "flexible" structures, and which used a "fastest kilometer wind speed" as basic wind speed compared to today's "3-second gust" basic wind speed.

Also as seen from Table 1, the latest NSCP 2010 wind loading provisions are now based on ASCE 7-05 (2005 version of ASCE7) as opposed to the ASCE 7-95 (1995 version of ASCE7, released in 1996), which was the basis of the earlier NSCP 2001. There are improvements in the ASCE 7-05 (ASCE, 2005) over the ASCE 7-95 (ASCE, 1996) that has significant impacts in design wind loads, but overall, the design philosophy generally remains the same. (Refer to Pacheco et al, 2009.) However, the NSCP 2010 (ASEP, 2010) has additional wind load provisions that are not found in ASCE 7-05. The list of features of the ASCE 7-05 which have been used in NSCP 2010, particularly those new features not found in ASCE 7-95 or in the NSCP 2001 (ASEP, 2002), are left to the reader to find elsewhere. This paper primarily discusses the features of NSCP 2010 in addition to those in ASCE 7-05.

## 3 WIND ZONING AND BASIC WIND SPEEDS

### 3.1 Wind zone table instead of wind zone map

The new NSCP 2010 has foregone the use of a wind zone map that has been used in all earlier editions of the NSCP.

Pacheco et al (2009) showed a wind zone map (Fig. 1a) as the initially proposed replacement for the existing one in NSCP 2001 (Fig. 1b). Certain new features of this initially proposed map, namely the introduction of wind sub-zones (i.e. Zone 1A & 1B within the existing Zone 1, and Zones 3A & 3B within the existing Zone 3) and basic wind speeds of 300 kph or 80 m/s (in Zone 1A) were rejected by the ASEP-CSC during one of its deliberation meetings related to the code update.

However, one improvement of the initially proposed map over the existing one in NSCP 2001 was the delineation of wind zones according to political boundaries, and particularly at the provincial level (or equivalent to a county level). This has been a recommendation by Pacheco et al (2007), and its intention was to make it easier for structural engineers to more properly interpret and use the code. The ASEP-CSC also then deliberated that for even more clarity, a table that assigns each province in one zone should be provided. However, the ASEP-CSC concluded that a table and a map give redundant information and it was decided that the table communicates the wind zoning more clearly to engineers. Thus, in lieu of a wind zone map, a wind zone table (Table 2) has been included instead in the NSCP 2010. As mentioned the table contains information that is essentially the same as the initially proposed map, except that the sub-zones have been removed and the basic wind speeds are the same as the NSCP 2001 map except for Zone 3, which now has  $V = 150$  kph versus 125 kph previously.

Table 2 Wind zone assignments for different provinces of the Philippines (ASEP, 2010)

Zone Classification (Basic Wind Speed)	Provinces
Zone 1 ( $V = 250$ kph)	Albay, Aurora, Batanes, Cagayan, Camarines Norte, Camarines Sur, Catanduanes, Eastern Samar, Isabela, Northern Samar, Quezon, Quirino, Samar, Sorsogon
Zone 2 ( $V = 200$ kph)	Abra, Agusan del Norte, Agusan del Sur, Aklan, Antique, Apayao, Bataan, Batangas, Benguet, Biliran, Bohol, Bulacan, Camiguin, Capiz, Cavite, Cebu, Compostela Valley, Davao Oriental, Guimaras, Ifugao, Ilocos Norte, Ilocos Sur, Iloilo, Kalinga, La Union, Laguna, Leyte, Marinduque, Masbate, Misamis Oriental, Mountain Province, National Capital Region, Negros Occidental, Negros Oriental, Nueva Ecija, Nueva Vizcaya, Occidental Mindoro, Oriental Mindoro, Pampanga, Pangasinan, Rizal, Romblon, Siquijor, Southern Leyte, Surigao del Norte, Surigao del Sur, Tarlac, Zambales
Zone 3 ( $V = 150$ kph)	Basilan, Bukidnon, Davao del Norte, Davao del Sur, Lanao del Norte, Lanao del Sur, Maguindanao, Misamis Occidental, North Cotabato, Palawan, Sarangani, South Cotabato, Sultan Kudarat, Sulu, Tawi-tawi, Zamboanga del Norte, Zamboanga del Sur, Zamboanga Sibugay

### 3.2 Comparison of basic wind speeds

Table 3 shows a comparison of the basic wind speeds between the 3 groups of wind zoning systems used in different editions of the NSCP, namely the NSCP 2010 zoning (consisting of the initially proposed wind zone map, and the zoning according to Table 2, above), the NSCP 2001 zoning, and the NSCP 1992 zoning (representing the NSCP 1992 and earlier editions).

Table 3 Comparison of basic wind speeds, in kilometers per hour (and in m/s, rounded off to the nearest 5 m/s)

Zone <sup>(2)</sup>	NSCP 1992 and earlier (fastest-km)	NSCP 1992 and earlier (equiv. 3-sec gust)	NSCP 2001 (3-sec gust)	Initial proposal <sup>(1)</sup> for NSCP 2010 (3-sec gust)	NSCP 2010 (3-sec gust)
1	200 (55)	220 (60)	250 (70)	300 & 250 (80 & 70)	250 (70)
2	175 (45)	195 (55)	200 (55)	200 (55)	200 (55)
3	150 (40)	165 (45)	125 (35)	150 & 125 (40 & 35)	150 (40)

(1) The zoning in the initial proposal for the NSCP 2001 have further sub-divided Zones 1 and 3 into two sub-zones, namely Zones 1A, 1B, 3A, & 3B. The two numbers shown in the table above correspond to sub-zones A & B (i.e. 250 & 300 kph, and so on, correspond to Zones 1A & 1B respectively, and so on).

(2) Note that zone boundaries between the two NSCP 2010 zoning systems (Fig. 1a, Table 2), the NSCP 2001 zoning (Fig. 1b), and the NSCP 1992 and earlier zoning (Fig. 1c) do not perfectly match each other. However, the initial proposed zoning for NSCP 2010 (Fig. 1a) and the final NSCP 2010 zoning (Table 2) have similar boundaries between major wind zones (e.g. between Zones 1 and 2).

Between the NSCP 2001 and NSCP 1992 groups of wind zoning systems, it has already been pointed out by Pacheco et al (2005) that the basic wind speeds according to NSCP 1992 over-estimate the more rationally obtained basic wind speeds of NSCP 2001 in the low wind zone (Zone 3), and under-estimate those in the high wind zone (Zone 1), both as seen from Table 3. In terms of zone boundaries, the main difference is the inclusion into Zone 1 of some eastern provinces formerly in Zone 2. (See Figure 1b & 1c.)

Between the NSCP 2010 and NSCP 2001 groups of zoning systems, the boundaries between major zones are essentially the same except, as mentioned earlier, the zone boundaries now correspond to political boundaries. As for any change in any wind zone boundary, obviously the most affected with potentially significant changes in design wind loads are those areas close to the boundaries. These areas are usually certain portions of provinces that have been assigned across-the-board to one wind zone.

Those areas that were formerly in Zone 2 and now in Zone 1 would have a 25% increase in basic wind speeds, or around a 50% increase in basic wind pressures. Most areas that were and now still are in Zone 3, as mentioned below, would have a 15% increase in basic wind speeds or around a 30% increase in basic wind pressures. Some areas formerly in Zone 3 and now in Zone 2 would have basic wind speeds that are nearly 60% larger than before, with nearly a 150% increase in basic wind pressures.

### 3.3 Basic wind speeds in the new NSCP 2010 wind zoning system

The initially proposed zoning for the NSCP 2010 has assigned the Catanduanes island province to a new sub-zone (Zone 1A) within the existing Zone 1, with a basic wind speed of 300 kph (approx. 80 m/s). This is approximately 20% larger than the previous basic wind speed assigned to the same area, hence representing around 40% larger design wind loads under the new code. As mentioned earlier and also as illustrated in Table 3, this proposal has been rejected for the NSCP 2010. Catanduanes still has a basic wind speed of 250 kph, as seen from Table 1.

Likewise, the initially proposed zoning for the NSCP 2010 has also assigned another group of provinces within the existing Zone 3 to a new sub-zone (Zone 3A) that has a basic wind speed of 150 kph (approx. 40 m/s). This is approximately 15% larger than the previous basic wind speed assigned to the same area, hence representing around 30% larger design wind pressures under the new code. Yet, this proposal has been accepted by the ASEP-CSC, and have even been adopted for the whole Zone 3. (See Table 3.) The main four reasons for this are as follows:

- a. Typhoon risk coming from the South China Sea justifies a 150 kph basic wind speed for certain areas within Zone 3 as shown in the initially proposed map.
- b. Retaining the previous number of zones (three) and thus having one uniform basic wind speed within Zone 3 is still desired.
- c. The use of 150 kph is a decision favoring safety, and yet it is not as much an overestimate as the 165 kph effectively assumed in the early editions of the code (Table 3).
- d. The wind speed interval between zones is now uniformly consistent at 50 kph.

### 3.4 Further improvement

The NSCP 2010 wind speed information is now contained in a table, as opposed to being in a map as in older editions of the NSCP. It has adopted one of the recommendations in Pacheco et al (2007) in terms of aligning wind zone boundaries with political ones, and it has slightly increased the basic wind speed for the low wind zone (Zone 3) given the four reasons as stated above. However, as identified by Pacheco et al (2007), there are still more work in terms of data conditioning and statistical analysis that needs to be done to even further improve what is essentially a wind hazard information in the NSCP that could be used for other purposes as well, such as wind-related disaster risk reduction.

## 4 CLASSIFICATION OF “RIGID” AND “FLEXIBLE” STRUCTURES

### 4.1 Background

The concept of “rigid” and “flexible” structures was introduced first in ASCE 7-95 and consequently in NSCP 2001. A “flexible” or dynamically wind-sensitive structure was defined as those with natural frequencies less than 1 Hz or those with an aspect ratio greater than 4. A “rigid” structure was defined as one that is not considered to be a “flexible” structure.

It is important to correctly classify whether a structure is “rigid” or “flexible” because this dictates the procedure to be used for estimating the gust effect factor (GEF), also known as “dynamic response factor” in other codes, which accounts for dynamic amplification effects due to wind gusts. These definitions are still used in NSCP 2010 except for the specific aspect ratio definition for “flexible” structures. A qualitative word, “slender,” is used instead.

For “rigid” structures according to the new ASCE 7-05, the GEF may be taken as 0.85 or calculated using the given formula with resonant effects neglected. The GEF for “flexible” structures uses a similar formula but this time with resonant effects considered. Resonant effects are calculated using vibration properties of the structure (i.e. natural frequency, damping ratio). Obviously the GEF values for “flexible” structures are larger than for “rigid” ones of

the same size and under the same wind conditions, the two other factors that affect the GEF. In general, structures that are smaller or those under stronger wind conditions have higher GEF than if otherwise.

Note that the said GEF formulas did not appear in the ASCE 7-95 provisions. Instead they appeared only in the ASCE 7-95 commentary and thus were not reflected in NSCP 2001. They are now in the ASCE 7-05 provisions, and thus are now contained in NSCP 2010.

#### 4.2 *Classification assigned to buildings only*

The ASEP-CSC has deliberated to apply the “rigid” and “flexible” structure classification to buildings only, as opposed to being applied generally to “buildings and other structures” in ASCE 7-05. “Other” structures, defined in the NSCP 2010 as poles, masts, signs, trussed towers, billboards, and the like that are rarely occupied by humans, are effectively always considered as “flexible.” The main reasons for this direction are as follows:

- a. The ASCE 7-05 GEF value for “rigid” structures, and GEF formulas for both “rigid” and “flexible” structures have been calibrated for buildings.
- b. Most other structures have aspect ratios typically greater than 4, and are more like 1D (line-like) or 2D (planar) structures as opposed to buildings which are more like 3D (volume) structures. The GEF would be closer to 1.0 than 0.85 for such structures.
- c. Classification of “flexible” non-building structures as “rigid” is prevented, and meanwhile a “flexible” structure assumption requires using the more general and more rational procedure that is actually the basis of the simplified “rigid” design procedure.
- d. GEF or similar formulas different from those given in the ASCE 7-05 and deemed more appropriate for such other structures are used in other standards that are specifically for these other structures, such as transmission towers and antenna towers.

## 5 GEF FORMULATIONS FOR “OTHER” STRUCTURES

### 5.1 *Background*

Complementary to the discussion above, it is therefore necessary to include GEF formulations for such “other” structures. Aquino et al (2007) has offered 5 justifications for such:

- a. *The NSCP-2001 requires a flexible design for structures with aspect ratios over 4.* Transmission towers and antenna towers in the Philippines typically have aspect ratios around 7. Poles, masts, and signs certainly have aspect ratios much greater than 4. Most billboards are generally flat, 2D-like structures.
- b. *The “rigid” structure GEF value of 0.85 is calibrated for buildings in the USA.* As mentioned, spatial correlation effects for “other,” non-building structures are smaller and thus the GEF value even for “rigid” “other” structures should be generally larger than 0.85. Also, such prescribed “rigid” structure GEF values are applicable to non-hurricane prone regions in the USA, and hurricane-level wind speeds in the Philippines generally tend to be larger than those in hurricane-prone areas in the US. Both arguments suggest that the “rigid” structure GEF value may need to be larger for non-building structures in the Philippines.
- c. *A “flexible” structure GEF is more appropriate for such other structures.* Again as mentioned, this is evidenced by the fact that GEF formulas exist in standards specifically for such non-building structures. A study (Aquino, 2006) has also shown that such structures even with natural frequency much greater than 1 Hz could have higher GEF values than if the “flexible” structure GEF intended for buildings were even used. Consequently, and also as already mentioned, “flexible” structure GEF formulations are more general and more rational than their “rigid” structure counterparts.

- d. *Strict deflection criteria for other structures such as antenna towers could not compensate for non-consideration of dynamic wind effects.* If dynamic effects were not considered or the GEF was under-estimated, increase in member sizes to meet strict deflection criteria are still under-designed.
- e. *Use of “rigid” structure assumption is one of many possible causes of structural collapse during recent typhoons.* During typhoons that passed through Naga City, Bicol Province in 2004 and Metro Manila itself in 2006, many non-building structures such as those mentioned collapsed. (Pacheco et al, 2006)

On the basis of these justifications, supplementary material based on work by Aquino (2006) was proposed as supplement to the NSCP 2001. They have since been slightly modified and incorporated into the new NSCP 2010 to complement the ASCE 7-05 wind loading provisions. These are discussed in this section and the next.

## 5.2 Gust effect factor for poles, masts, and towers

For other structures such as poles, masts, trussed towers, and the like, that function as communication towers or antenna-supporting structures, electrical transmission towers and poles, structures supporting lighting equipment, and the like, the gust effect factor shall be calculated based on Davenport’s gust response factor (GRF) formula found in the ASCE Manual of Practice No. 74, “Guidelines for Electrical Transmission Line Structural Loading” or ASCE MOP 74 (ASCE, 1991) as modified by Aquino (2006) for compatibility with the current wind design philosophy in the NSCP. The modified GRF formula is now a GEF formula of the following form:

$$G_f = (1 + 0.85g_e \rho \sqrt{Q^2 + R^2}) / (1 + 0.85g_p) \quad (1)$$

where

$$\rho = 4.9 \sqrt{D_0} (10 / \bar{z})^{1/\alpha} \quad (2)$$

$$Q = 1 / \sqrt{1 + 0.27h/l} \quad (3)$$

and

$$R = \sqrt{0.017/\beta} (n_1 \bar{z} / \bar{V}_{\bar{z}})^{-5/6} \quad (4)$$

The peak factor  $g$  is to be taken as 4.0. The value of  $e$  shall be 0.75 for electrical transmission towers and poles with cables, to account for spatial effects, or 1.0 for all other cases. The parameters that define the wind field characteristics, specifically  $D_0$ ,  $\alpha$ , and  $l$  are obtained from Table 4. The effective height  $\bar{z}$  shall be taken as two-thirds the height of the tower ( $2/3h$ ), but not less than  $z_{min}$  which is also listed in Table 4. The hourly mean wind speed at the effective height  $\bar{V}_{\bar{z}}$  is calculated as per the formulas from ASCE 7-05.

Table 4 Combined terrain exposure constants from ASCE 7-05 and ASCE MOP 74 (ASCE, 1991)

Exposure	$\alpha$	$z_g$ (m)	$\hat{a}$	$\hat{b}$	$\hat{a}$	$b$	$c$	$D_0$	$l$ (m)	$\epsilon$	$z_{min}$ (m)
B (Urban/suburban)	7.0	365	1/7	0.84	1/4	0.45	0.30	0.010	100	1/3	9
C (Open country)	9.5	275	1/9.5	1.00	1/6.5	0.65	0.20	0.005	150	1/5	4.5
D (Seaside)	11.5	215	1/11.5	1.07	1/9	0.80	0.15	0.003	200	1/8	2

\* $z_{min}$  = minimum height used to ensure that the equivalent height  $z$  is the greater of  $z_{min}$  or  $2/3h$  for trussed towers, the height of the transmission cable above ground, or 0.6h for buildings and all other structures. For  $h \leq z_{min}$ ,  $\bar{z}$  shall be taken as  $z_{min}$ .

The equations above were obtained to meet the following criteria (Aquino, 2006):

- a. It is an appropriate GEF formulation that, (a) is found in recognized literature, (b) is intended for the structure to which it is applied to, e.g. it does not incorporate a reduction

factor that may have been calibrated for buildings, (c) accounts for dynamic properties, and (d) accounts for wind field characteristics at the site.

- b. It is an NSCP-compatible GEF formulation, following the procedure by Solari & Kareem (1998) used for arriving at the ASCE 7-95 GEF formulation starting from a GRF formulation where applicable.
- c. It uses NSCP-compatible wind characterization, i.e. among others, the averaging time of basic wind speed is 3 seconds, and the duration of storm considered is 1 hour.
- d. It uses NSCP-compatible units, i.e. it uses kph for the basic wind speed, among others.

Additionally, it was intended that the resulting formulation was simple enough for use by structural engineers in the Philippines. Eight (8) different GEF or GRF formulations and procedures were evaluated according to these criteria and in the end, as mentioned, a modified version of Davenport's GRF formulation for latticed towers that appeared in ASCE MOP 74 (1991) was selected. However, there are still some limitations in this formulation that are to be considered for future development, namely:

- e. It accounts for directionality and topographic effects in the wind field characterization.
- f. It accounts for non-linear mode shapes (in the case of trussed towers).
- g. It uses the von Karman gust spectrum model.

### 5.3 *Billboard structures, free-standing walls, and solid signs*

For billboard structures, free-standing walls, and solid signs with height-to-least-horizontal dimension greater than 4, the procedures as shown above in Section 4.2 is to be used. Otherwise, the procedures for "flexible" buildings may be used.

### 5.4 *Cables supported on vertical structures*

For cables, Equations 1, 2, and 4 shall be used together with  $z_h$  taken as the height of the cable above ground, and:

$$Q = 1/\sqrt{1+0.4B/l} \quad (5)$$

where  $B$  is the total length of the cable.

### 5.5 *Structures Supporting Antennas, Cables, and Other Attachments and Appurtenances*

A section on all structures supporting attachments and appurtenances including antenna- and cable-supporting structures have been added, mostly to consider wind loads on such attachments that transfer to their supporting structures, the standards for which are in documents separate from the ASCE 7-05. The aim for the inclusion of this section is to caution the structural engineer, and to point them to the existence and the use of the appropriate standards. Unless sufficient supporting evidence can be obtained from recognized literature or from wind tunnel tests, guidance on wind loads on supported antennas is to be obtained from the ANSI/TIA-222-G-2005 standard ("Structural Standard for Antenna Supporting Structures and Antennas;" TIA, 2005) and guidance on wind and other loads on supported transmission cables is to be obtained from ASCE MOP 74, except that the gust effect factor for cables is to be obtained as in Section 4.4 above. Obviously, the wind loads on such supported antennas, cables, attachments, and appurtenances shall be applied at the location of support on the structure.

### 5.6 *Comparison with other gust effect factors*

The GEF formula intended for masts, poles, trussed towers, billboards/signs/free-standing walls with high aspect ratios, and transmission cables that is shown in Sections 4.2 and 4.4

above are compared with GEF formulas or recommendations from the ASCE 7-05, TIA-222-G-2005, and the new ASCE MOP 74 (ASCE, 2010a).

### 5.6.1 ASCE MOP 74

Note that the formulas shown in Sections 4.2 and 4.4 were developed in 2006 based on the 1991 version of the ASCE MOP 74 (Aquino, 2006), and the original intention was to have an updated NSCP by 2009. The NSCP update has since been delayed to 2010 as mentioned, and the new ASCE MOP 74 and ASCE 7-10 have now been published. While there is no change in the ASCE 7-10 from the ASCE 7-05 that has a significant effect on these additional provisions in the NSCP 2010, it is noted that the formulas in the new ASCE MOP 74 have been also made compatible with the ASCE 7-05 and are somewhat different from those by Aquino (2006) that has appeared in slightly revised form in the new NSCP. The following new ASCE MOP 74 GEF formula is the equivalent of Equation 1:

$$G_f = (1 + 2.7\rho Q) / k_v^2 \quad (6)$$

where  $k_v = 1.43$ , considered as “the ratio of the 3-sec gust wind speed to the 10-min average wind speed.”

The features of Equation 6 that are different from Equation 1 are as follows:

- a. The resonant response component was neglected (i.e.  $R$  is assumed as zero; transmission towers and cables are considered “rigid” and not dynamically wind-sensitive).
- b. The factor  $0.85ge$  was generalized into a factor 2.7. According to the procedure in NSCP 2010,  $0.85ge$  becomes 3.4 for 4-legged or square-in-plan towers and 2.55 for 3-legged or triangular-in-plan towers.
- c. A constant,  $k_v^2$ , equal to around 2.04, and that is independent of the wind field characteristics, is used in the denominator whereas according to the NSCP 2010 (e.g. Eqn. 1), this denominator would be around 2.09, 1.86, and 1.70 for Exposures B, C, and D, respectively, for a 30-meter high tower. These values decrease with an increase in the tower height, and vice versa.

Furthermore, the 2010 ASCE MOP 74 definition of  $Q$  is slightly different from that in the NSCP 2010, although the impact is not significant. Considering that towers in the Philippines typically range from 30m to 60m in height (Aquino, 2006), are typically square in plan, and that they are usually located in Exposure B or C, the above-mentioned 3 features however all generally lead to lower GEF values for most towers in the Philippines, according to the ASCE MOP 74 than if the NSCP 2010 procedure were used. This applies for most towers in the Philippines even if their resonant components are actually negligible. However, the NSCP 2010 GEF calculation procedure is still considered more rational and more appropriate precisely because of these factors that are already illustrated above:

- a. it does not neglect the resonant response component,
- b. its factor for conversion from the 3-second gust speed to the mean wind speed is not a single, generalized value but instead is dependent on the wind characteristics,
- c. it accounts for some effects of the overall structural shape,
- d. it allows engineers with more advanced wind engineering knowledge to modify some parameters such as the peak factor  $g$  or the gust spectrum used, or to add parameters to account for mode shape corrections, and so on, and
- e. additionally, the NSCP 2010 formula truly uses the new gust basic wind speed concept and the corresponding wind field characterization parameters of the ASCE 7-05 that has been introduced since ASCE 7-95 whereas the new, 2010 ASCE MOP 74 somewhat has roots still heavily pinned on the fastest mile basic wind speed concept that was used in ASCE7 versions before 1995 and in the 1991 ASCE MOP 74 (ASCE, 1991). In fact, the 2010 ASCE MOP 74 still calls the formula a “gust response factor,” although later it is used together with the 3-second gust basic wind speeds of ASCE 7-05.

### 5.6.2 ANSI/TIA-222-G-2005

The ANSI/TIA-222-G-2005 presents this as its gust effect factor formula for trussed towers supporting antennas:

$$0.85 \leq G_f = 0.85 + 0.15(h/45.7 - 3.0) \quad (6)$$

where  $0.85 \leq G_f \leq 1.00$ . Aquino (2006) also raised issues in using the above formula for trussed towers:

- a. The formula is independent of wind field characteristics, which is contrary to the definition of the GEF. For the same height of structure, the same value will be used for those located in an area with  $V = 250$  kph near the ocean, and for an area with  $V = 100$  kph in urban terrain.
- b. The formula is independent of dynamic properties of the structure, which is again contrary to the definition of the GEF. Granted that the natural frequency is generally inversely proportional to the height, and the GEF generally increases with lower natural frequencies, this still means that if additional damping sources are present, or if the damping is very low, benefits or otherwise, respectively, could not be accounted for.
- c. The formula is independent of spatial correlation (size reduction) properties, which is yet again contrary to the definition of the GEF. The height of course is an indicator of size, but with the upper bound limit of 1.0, lower wind correlation effects are effectively neglected.

These all essentially suggest that the ANSI/TIA-222-G-2005 GEF formula is a “rigid” structure formulation that ranges in value only between 0.85 and 1.00. Later in the numerical comparison, the difference between the results using this formula and the other mentioned formulas here is shown to be significant. On these bases, it is considered much less appropriate than “flexible” structure formulations such as that in the NSCP 2010.

### 5.6.3 Modified ASCE 7-05 procedure

Simiu & Scanlan (1996) suggested a group of techniques to be able to use the ASCE 7-05 GEF formula for buildings to other structures such as trussed towers. These are as follows:

- a. Assume effective height as  $2/3h$  (compared to  $0.6h$ ).
- b. Set the along- and across-wind face widths,  $B$  and  $L$  respectively, equal to the width at the effective height for wind loads on the face of square towers.
- c. Set  $B$  equal to the width at the effective height times  $\sqrt{2}$ , and  $L$  equal to zero for wind loads along the diagonal of square towers.
- d. Set  $B$  equal to the width at the effective height and  $L$  equal to zero for wind loads on triangular towers.

Solari (1993) suggested a similar set of techniques, specifically setting both  $B$  and  $L$  to zero, but additionally suggested that the same rules could apply to other vertical line structures such as poles and masts.

## 6 ESTIMATES OF STRUCTURE DYNAMIC PROPERTIES

When values for natural frequency and damping ratio are required input parameters in the calculation of the gust effect factor for buildings and other structures, procedural information on estimating dynamic properties are not readily available to all structural engineers in the Philippines. In ASCE 7-05, some recommendations are given in the accompanying commentary. The NSCP 2010 does not come with such a commentary. The NSCP 2010 essentially recommends using values of dynamic properties from full-scale measurements of the actual structure or from computer simulation models first. Otherwise, the estimation formulas as shown in this section are prescribed.

### 6.1 Approximate fundamental natural frequency

For buildings, the fundamental natural frequency  $n_1$  may be estimated using the following general formulas (where  $h$  is the total height in meters):

Table 5 Fundamental natural frequency estimates for buildings

Building Type	Service-level	Strength-level
Concrete	$67/h$	$56/h$
Steel	$50/h$	$42/h$

The above are based on the recommendations for the Architectural Institute of Japan (e.g. Tamura et al, 2000), and are likewise recommended in the ASCE 7-05 commentary (ASCE, 2005) and in Kwok (2006).

For free-standing trussed towers, and billboard truss structures,  $n_1$  may be estimated using the following formula, which is based on the study by Aquino (2006) of data from full-scale measurements of 34 trussed towers from other countries, mostly from Japan, and from other empirical formulas in literature:

$$n_1 = 107/h M_a R_{a0} P_a A_a D_a \quad (7)$$

where

$$R_{a0} = 1.25(h/B_0)^{-0.2} \quad (8)$$

$$M_a = 1/\text{sqrt}(k_m m_r) \quad (9)$$

and

$$k_m = 3/((B_{0h}/B_0)^3 + 0.15). \quad (10)$$

The plan-shape factor,  $P_a$  is taken as 0.9 for triangular (in plan, or 3-legged) towers, and 1.0 for other conditions. The amplitude-dependence factor  $A_a$  is taken as 1.0 for service-level condition, and 0.83 for strength-level condition. The 0.83 value is based on a value recommended for buildings (i.e. see Tamura et al, 2000) and possibly conservative for trussed towers, but for lack of better information and while it errs on the side of safety, it has been accepted in the code.  $B_{0h}$  is the average tower width, or average of the base and top widths, or  $B_0$  and  $B_h$  respectively, for tapered towers. The factor  $k_m$  is actually a constant taken as 2.6 for billboards, poles, masts, and non-tapering towers and other structures. This and the mass factor  $M_a$  were derived by Aquino (2006) from a 1DOF simplified assumption but also appear in ANSI/TIA-222-G-2005 and in an Australian Standard for lattice towers (SA, 1994).  $D_a$  is a design-dependence factor that could affect the solidity ratio of the trussed structures. In general, it is expected that, for example, antenna towers of the same height and carrying the same weight of antennas but in different zones of seismicity would have larger solidity ratios and generally be stiffer and have higher natural frequencies. For lack of better information, this is left as 1.0 in Equation 7.

The above procedure is able to predict all “flexible” structure cases from the available data, i.e. when the frequency is less than 1 Hz. It may also be generally conservative, which is the penalty for being a relatively simplified procedure. Certainly for natural frequency estimates, modal analysis of finite element models or actual full-scale measurements, which are the recommended procedures by the NSCP, would yield more accurate results.

Alternatively, for free-standing trussed towers or billboard truss structures in the Philippines without attached antennas, cables, or other major appurtenances, the following even simpler formulas based on Equations 7–10 are used:

Table 6 Simple natural frequency estimates for free-standing trussed towers or billboard truss structures in the Philippines without attached antennas, cables, or other major appurtenances

Plan-shape	Service-level	Strength-level
Triangular	81/h	68/h
Others	91/h	75/h

For most other antenna towers or electrical transmission towers in the Philippines with mass ratio  $m_r$  as 5% (or approximately 3 attached antennas):

Table 7 Simple natural frequency estimates for antenna towers or electrical transmission towers in the Philippines with mass ratio  $m_r$  as 5% (or approximately 3 attached antennas)

Plan-shape	Service-level	Strength-level
Triangular	73/h	61/h
Others	81/h	68/h

It can be observed that while Equations 7–10 and Tables 6 and 7 above give conservative estimates compared to the recommended procedures using computer simulation or full-scale measurements, these are not too conservative in that they still yield much higher natural frequency estimates than those for steel buildings as shown in Table 5.

For poles, masts, solid signs, guyed structures, cables, and other structures, the natural frequency is recommended to be estimated from full-scale measurements or mathematical models and computer simulations taking into account the effect of tension-only element properties and other attachments.

## 6.2 Approximate damping ratio

For general wind loading purposes, the total damping ratio may be taken as 0.015 for concrete structures, and 0.010 for steel and other structures. This is based on recommendations in the ASCE 7-05 commentary, as well as the AIJ recommendations. In the NSCP, this is deemed to account for all sources of damping in the structure: structural, non-structural, and aerodynamic damping. For some cases, these values may under-estimate the total damping ratio and thus possibly result in an over-estimate of the design wind loads and response. The stand of the NSCP 2010 again is that these conservative values shall be accepted, somewhat as a penalty when more rational bases like full-scale test results and so on are not used.

Based on work by Aquino (2006), the following structural damping ratio estimation formulas for poles, masts, trussed towers, billboards, and similar structures have been presented by Pacheco et al (2006). However the original equations where the natural frequency is the main parameter were modified following the recommendation in Tamura (2006) where it is thought to be more appropriate that the damping is affected more by soil-structure interaction (with lower height structures being affected more than taller ones) instead of the natural frequency. For estimates of the structural damping ratio  $\beta_s$  at service- and strength-level condition, the formulas are:

$$\beta_s = 0.16/h \geq 0.003, \text{ and} \quad (11)$$

$$\beta_s = 0.23/h \geq 0.004, \text{ respectively.} \quad (12)$$

The aerodynamic damping ratio  $\beta_a$  at service-level condition for trussed towers, billboards, and the like, may be taken as:

$$\beta_a = 0.007/n_1 \geq 0.007 \quad (13)$$

where  $n_1$  is the service-level natural frequency.

The aerodynamic damping ratio  $\beta_a$  at strength-level condition for trussed towers, billboards, and the like, may be taken as

$$\beta_a = 0.011/n_1 \geq 0.007 \text{ for Wind Zone 1 or 2 or for } V > 162 \text{ kph, and} \quad (14)$$

$$\beta_a = 0.009/n_1 \geq 0.007 \text{ for Wind Zone 3 or for } V \leq 162 \text{ kph} \quad (15)$$

where  $n_1$  is the strength-level natural frequency.

The aerodynamic damping ratio  $\beta_a$  may be obtained from a more detailed analysis, e.g. after Holmes (1996), with the appropriate basic wind speed  $V$  as parameter, the hourly mean wind speed as calculated according to the NSCP, a mode shape exponent of 3.0, unit mass at the base, and solidity ratio  $\varepsilon$  and drag force coefficient  $C_f$  evaluated at the effective height.

The total damping ratio  $\beta$  shall then be taken as

$$\beta = \beta_s + \beta_a \leq 0.06 \quad (16)$$

The basis for the minimum values in the above structural damping ratio estimation formulas is the minima from the full-scale measurement data. The basis for the minimum values in the above aerodynamic damping ratio estimation formulas is as recommended in literature (i.e. Wyatt, 1984). It is certainly believed that there is a minimum level of structural damping inherent in the material, and that a certain level of aerodynamic damping is always present for such types of structures.

The aerodynamic estimate from the simple formula presented above in Equations 13–15 in fact generally result in more conservative wind load estimates than if the detailed equation by Holmes (1996) were used (assuming a mode shape exponent factor of 3 is used, as recommended by the NSCP), which is again a penalty for preferring to use simpler methods than more rational but more detailed methods.

Meanwhile, a limit is placed such that the total damping ratio does not become too high, and this maximum limit is based likewise on the maxima from the full-scale measurement data. Lastly, it is not explicitly stated in the above, but the minimum total damping ratio that a designer of such structures would then use according to the NSCP is 0.01 at service-level condition and 0.011 at strength-level condition, which corresponds to the general recommendation for steel structures. These alternative procedures thus somewhat enable structural engineers to refine further their designs of such structures if they so desire; otherwise they can settle with the general damping ratio assumptions that result in the most conservative wind load and response estimates.

## 7 NUMERICAL EXAMPLE FOR NEW WIND LOADING PROVISIONS

### 7.1 *Structural properties*

Consider the wind conditions and structural and geometric properties in Table 8 for a given self-supporting antenna tower in the Philippines for which we need along-wind loads on one tower face at strength-level conditions.

The next step is to compute the dynamic properties. For the natural frequency, the parameters shown in Table 9 are obtained. Multiplying all factors in Table 9, we obtain a natural frequency coefficient of 67, and thus the natural frequency is  $67/h$ , which is nearly equal to the corresponding value listed in Table 7. This is again yielding in a much higher natural frequency than the corresponding  $42/h$  as estimate for steel buildings under the same conditions. The natural frequency estimate for our example tower is thus 1.11 Hz.

Table 8 Wind, structural, and geometric properties of example antenna towers in the Philippines

Description	Symbol (units)	Value
Wind Zone		2
Basic wind speed	$V$ (kph)	250
Exposure category		D
Height	$h$ (m)	60
Base width (at elevation $z = 0$ )	$B_0$ (m)	8.6
Top width (at elevation $z = h$ )	$B_h$ (m)	2.0
Average width (of top and base widths)	$B_{0h}$ (m)	5.3
Ratio of average width to base width	$B_{0h}/B_0$	0.617
Aspect ratio	$h/B_0$	7.0
Mass distribution parameter	$k_m$	5.657
Plan shape		square
Effective height	$\bar{z}$ (m)	40
Equivalent along-wind face width (at $z = \bar{z}$ )	$B$	6.4
Equivalent across-wind face width (at $z = \bar{z}$ )	$L$	6.4
Mass ratio	$m_r$	0.05

Table 9 Natural frequency parameters

Description	Symbol (units)	Value
Basic natural frequency coefficient		107
Aspect ratio factor	$R_{a0}$	0.85
Mass factor	$M_a$	0.88
Plan-shape factor	$M_a$	0.88
Amplitude-dependence factor	$A_a$	0.83
Design-dependence factor	$D_a$	1.00

We can readily estimate the structural damping ratio, which is taken as the minimum value, 0.004, and the aerodynamic damping ratio, which is 0.010. The total damping ratio is thus taken as 0.014. For comparison purposes, the aerodynamic damping ratio for the same structure using Holmes' (1994) detailed estimation formula would be around 0.020, and the total damping ratio would have been 0.024. As mentioned earlier in the text, the NSCP results in more conservative estimates than if detailed methods were used, but still they are not considered to be too conservative when compared with just using direct recommendations of around 0.01 for steel structures. Note also that the aerodynamic damping ratio in this case is larger than the structural damping ratio, and it is found true for tower heights over 30 meters (Aquino, 2006). For our example in this paper, we will use the NSCP estimate of 0.014.

## 7.2 Calculation of the GEF according to various procedures

Using the ANSI/TIA-222-G-2005 formula, the GEF estimate would be 0.85.

Using the ASCE 7-05 formula together with assumptions recommended by Simiu & Scanlan (1996), our calculation trail would be as shown in Table 10.

Assuming a "rigid" structure assumption as per the NSCP or ASCE 7-05, we would use 0.85 as well, or 0.87 if we used the detailed formula with the resonant component  $R$  set to zero (i.e. resonant effects neglected) as seen in Table 10. The above also uses a factor 0.925, which is believed to calibrate the GEF estimate for buildings. If this was removed, our resulting "rigid" and "flexible" structure GEF values would be 0.939 and 1.050, respectively. Taking the "flexible" structure GEF as the more rational and more appropriate value, 1.050 or even 0.972 (with the additional 0.925 factor) is 12%~24% larger than the "rigid" structure values of the NSCP (for buildings), the ASCE 7-05, or of ANSI/TIA-222-G-2005.

Using the ASCE 7-05 or NSCP "flexible" structure procedure and using Solari's (1993) suggested assumptions expectedly yield in even larger GEF estimates, as shown in Table 11.

Table 10 ASCE 7-05 (or NSCP for buildings) GEF calculation trail using Simiu & Scanlan (1996) assumptions

Description	Symbol (units)	Value
Peak factor for background component	$g_Q$	3.4
Peak factor for mean velocity component	$g_R$	3.4
Turbulence intensity at effective height	$I_{zbar}$	0.16
Turbulence length scale at effective height	$L_{zbar}$ (m)	200.6
Background response factor	$Q$	0.872
Hourly mean speed at effective height	$Vbar_{zbar}$ (m/s)	52
Resonant response parameter for $h$	$\eta_h$	5.90
Resonant response parameter for $B$	$\eta_b$	0.63
Resonant response parameter for $L$	$\eta_d$	2.10
Resonant component factor for $h$	$R_h$	0.16
Resonant component factor for $B$	$R_b$	0.69
Resonant component factor for $L$	$R_d$	0.36
Reduced frequency parameter	$N_1$	4.29
Gust energy factor	$E$ or $R_n$	0.06
(Spatial correlation or size reduction factor)	$S$	0.14
Resonant response factor	$R$	0.52
“Rigid” structure GEF	$G$	0.869
GEF denominator	$G_{vp}$	1.918
“Flexible” structure GEF	$G_f$	0.972

Table 11 ASCE 7-05 (or NSCP for buildings) GEF calculation trail using Solari’s (1993) assumptions

Description	Symbol (units)	Value
Equivalent along-wind face width (at $z = \bar{z}$ )	$B$	0
Equivalent across-wind face width (at $z = \bar{z}$ )	$L$	0
Background response factor	$Q$	0.872
Resonant response parameter for $h$	$\eta_h$	5.90
Resonant response parameter for $B$ or $L$	$\eta_b$ or $\eta_d$	0
Resonant component factor for $h$	$R_h$	0.16
Resonant component factor for $B$ or $L$	$R_b$ or $R_d$	0
Resonant response factor	$R$	0.789
“Rigid” structure GEF	$G$	0.942
“Flexible” structure GEF	$G_f$	1.151

Table 12 ASCE MOP 74 (2010) GEF calculation trail

Description	Symbol (units)	Value
Background response factor	$Q$	0.905
Resonant response factor	$R$	1.260
Turbulence factor	$\rho$	0.280
GEF	$G$	0.824
GEF denominator	$k_v^2$	2.045
“Flexible” structure GEF	$G_f$	1.063

Table 13 NSCP 2010 GEF calculation trail

Description	Symbol (units)	Value
Peak factor	$g$	4.0
Background response factor	$Q$	0.951
Resonant response factor	$R$	1.260
“Rigid” structure GEF	$G$	0.976
GEF denominator	$k_v^2$	1.952

When using the new ASCE MOP 74 (2010) and NSCP 2010 procedures, our calculation trails are as shown in Tables 12 and 13, respectively.

For illustration purposes, if different peak factors were used for each component (i.e.  $g_Q$ ,  $g_R$ , and  $g_V$  instead of a single  $g$ ), the NSCP 2010 would result in even higher GEF values of 0.976 and 1.397 for “rigid” and “flexible” cases, respectively.

Note that the GEF denominator according to the ASCE 7-05 and NSCP procedures is 1.918 and 1.952, respectively, which is lower than the 2.045 according to the ASCE MOP 74 procedure. The ASCE 7-05 and NSCP procedures would yield a similar value only for towers between 30 and 35 meters in height in Exposure C. If the tower was in Exposure D or B, the ASCE 7-05 procedure would yield a similar value only for towers less than 10 meters or towers around 300 meters in height – not typically used tower heights in the Philippines. If the tower was in Exposure D or B, the NSCP procedure would yield a similar value only for towers less than 10 meters or towers around 100 meters in height. This illustrates a limitation of the new ASCE MOP 74 procedure.

### 7.3 Discussion

Table 14 summarizes all calculated GEF values as per the different procedures:

Table 14 Summary of GEF values for example 60-meter tower

Procedure	“Rigid”	“Flexible”
ASCE MOP 74 (2010) (1.063)	0.82	
ASCE 7-05 default	0.85	---
NSCP 2010 default for buildings	0.85	---
ANSI/TIA-222-G-2005	0.85	0.85
ASCE 7-05 with Simiu & Scanlan (1996) assumptions	0.87	0.97
ASCE 7-05, modified, with Simiu & Scanlan (1996) assumptions 1.05	0.94	
ASCE 7-05, modified, with Solari (1993) assumptions	0.94	1.15
NSCP 2010	(0.98)	1.28
NSCP 2010, modified	(0.98)	1.40

The values in the table above are arranged according to the “rigid” structure GEF value. As observed, the NSCP 2010 results in the largest values. It is believed that it is the most appropriate among all the listed procedures, and it has been selected again on the basis of penalizing the use of this relatively “simple” procedure, with the “detailed” procedure being carefully carried out wind tunnel tests or full-scale measurements.

Alternatively, a “rigid” structure value of 1.0 could have been recommended as minimum, and the “modified” ASCE 7-05 (i.e. without the 0.925 factor believed to be to calibrate the GEF estimate for buildings) together with either of the Simiu & Scanlan (1996) or Solari (1993) assumptions may have also been considered by the ASEP-CSC. This would have made the NSCP 2010 wind loading provisions a little bit simpler than it is now. But another intention for the departures from ASCE 7-05 particularly the application of “rigid” or “flexible” structure classification only to buildings and the separate set of GEF formulas for non-building structures, aside from the fact that there are other existing standards for such, is to caution the structural engineer that the treatment of the two sets of structures (buildings and non-buildings) are slightly different. The NSCP, after all, also serves as an educational tool for engineers in the Philippines, considering that most of them do not have access to the ASCE 7-05 itself, or even its newer version, the ASCE 7-10, particularly the accompanying commentaries, as well as all other reference materials.

## 8 WIND ENVIRONMENT IN THE PHILIPPINES

This section covers three aspects of the wind environment: outdoor air quality, indoor air quality, and greenhouse gases emissions. Current conditions, including relevant policies, are briefly described.

### 8.1 Outdoor Air Quality

Air pollution from stationary and mobile sources is one of the pressing environmental problems in many urban centers in the world. In the Philippines, it is a major issue in the big cities such as Metro Manila as the country experiences economic growth coupled with a steady increase in population. It is estimated that by 2050, 84% of its 140 million population will be living in the cities. The country's demand for energy grew as its GDP increased. Between 1990 and 2005, there was an increase in energy demand of 0.73 quadrillion BTU to 1.34 quadrillion BTU (Clean Air Initiatives, 2008). Likewise, the number of motor vehicles is increasing. From 1.6 million in 1990, it grew to 5.5 million in 2007.

The Clean Air Act of 1999 (or Republic Act 8749) is the Philippine government's regulation to manage air quality. The primary pollutants as defined from the Clean Air Act include the following: SO<sub>2</sub>, NO<sub>2</sub>, PM<sub>2.5</sub>, ozone, CO, lead, and VOCs. Based on the inventory conducted by the Department of Environment and Natural Resources (DENR) as reported in its 2005 – 2007 Monitoring Report, it was shown that half of the pollutants is Carbon Monoxide (Fig. 2).

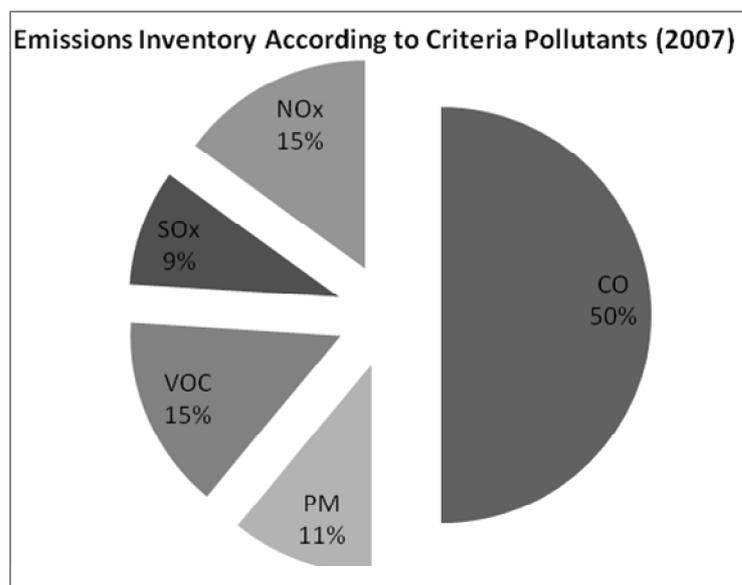


Figure 2. Criteria Pollutants Emissions Inventory in 2007.

In terms of the sources of the pollutants, the report showed that:

- more than 50% of PM emissions come from area sources, 31% from mobile sources, and 14% from industrial sources,
- SO<sub>2</sub> comes mostly from stationary sources (97%),
- area and mobile sources contribute about the same level to NO<sub>2</sub> emissions,
- mobile sources contributes the largest to CO emissions (85%), and
- VOCs are attributable mostly to mobile sources (87%).

In September 2010, the Secretary of the DENR admitted that the air quality in Metro Manila is not within the standards set by the government ([www.denr.gov.ph/section-news](http://www.denr.gov.ph/section-news)), attributing the major source of pollutants to mobile sources. Total Suspended Particulates (TSP) in Metro Manila were measured in 2009 as 130 micrograms per normal cubic meter (µg/Ncm), exceeding the standard of 90 µg/Ncm.

## 8.2 *Indoor Air Quality*

Since indoor air quality can be one of the causes of illnesses among workers, it is one of the issues that is covered by the Occupational Safety and Health Center (OSHC), under the Department of Labor and Employment (DOLE). The agency has released the Occupational Safety and Health Standards in 1978, a section of which tackles indoor air quality. The agency has conducted specific studies to evaluate working conditions including parameters such as temperature, ventilation and humidity.

In 1998, there was a study to investigate the effect of heat stress among Filipino workers. The level of exposure of Filipino workers to heat stress in different manufacturing industries was measured. The survey consisted of 110 companies, which undertake different manufacturing processes such as foundries/metal industries, glass, batteries, cement, etc. The study revealed that heat levels in most areas measured showed that workers are exposed to very high environmental temperature, and thus may be suffering from different levels of heat stresses. Recommendations and control measures were presented to protect workers from risks arising from such conditions.

With the prevalence of call centers in the country, the OSHC conducted a study in 2003 to examine health and safety in contact centers. Apart from the psychosocial stresses that are pervasive in a job which is in constant touch with customers with complaints and the added effect of working during the night, the physical hazards were also determined and measured. The noise, air velocity, temperature and relative humidity in the vicinity of the selected employee's workstation were measured.

Another study conducted by the OSHC in 2008 was to assess the health, safety and environmental conditions in basement parking areas in Metro Manila shopping centers. The results showed that the exposure of the workers to dust and gases such as nitrogen dioxide and sulfur dioxide were within threshold limit values. However, carbon monoxide concentrations in some of those which were tested were elevated, indicating poor ventilation. Similarly, most of the ventilation air exchange measured failed to meet eight air changes per hour as set by the OSHS standard and twelve air changes per hour which was set by international standard.

## 8.3 *Reduction of Greenhouse Gases*

In response to the global concern for climate change, the Philippine government is targetting a reduction of approximately 51 million tons of CO<sub>2</sub> emissions from 2005 – 2014 (Department of Energy). According to the DOE, this can be achieved through the following strategies:

- a. the aggressive promotion of energy conservation and energy efficient technology to effect higher energy savings both for the consumer and producer through information, education and communication campaigns
- b. intensify collaboration effort with the private sector in implementing energy efficiency programs through voluntary agreements
- c. continuous implementation and expansion of the appliance and equipment energy standards and labeling implementation of building energy usage standards
- d. integration of energy efficiency concepts in the procurement practices of the government
- e. the provision of technical assistance in identifying, implementing and evaluating effective measures to improve energy use efficiency
- f. the use of alternative fuel to reduce dependence on imported oil and
- g. periodic program monitoring and evaluation to assess the effectiveness of the energy efficiency and conservation plan.

The Department of Energy developed the “Guidelines for the Energy Conserving Design of Building and Utility System” which contain a set of standards pertaining to building envelope, lighting, HVAC, water heating systems, and others.

The Biofuels Fuels Act (Republic Act 9637) was signed into law in 2007. It mandates that all fuels sold in the country contain locally-sourced biofuels components. Bio-ethanol blend of 10% (or E10) is now available and being sold by some of the oil companies. Additionally, there is also a Natural Gas Vehicle Program for Public Transport in place.

The Philippine government very recently passed the Renewable Energy Bill to give incentives to investors and energy producers to build power plants based on renewable energy. The government targets to have at least 3000MW additional energy from renewable sources by 2016.

In the building industry, building professionals are currently working on developing energy efficiency ratings of buildings nationwide. A few major buildings being constructed are adapting the LEEDS standards.

#### 8.4 *On-going Researches/Projects*

With the recent passage of the Renewable Energy Bill, there are a lot of projects lined up to take advantage of the incentives for those investing on renewable energy. As of 2008, there were six wind farms in the country producing from 10 to 140 MW. There at least 16 more sites which have been identified by the DOE as ideal sites for wind farms.

#### 8.5 *Recommendations*

The issue of wind environment as it affects people's safety and comfort is not being addressed in the country. There is a need to study the role of wind current not only on transport/dispersion of pollutants, but also on its effect on heat dissipation and comfort of pedestrians.

### 9 CONCLUDING REMARKS

The NSCP 2010 has been released as an update to its predecessor, the NSCP 2001. Its wind loading provisions is primarily based on ASCE 7-05, which has a number of improvements over ASCE 7-95, the basis of NSCP 2001. However, the NSCP 2010 has additional features not found in ASCE 7-05, namely: the foregoing of a wind zone map in favor of a wind zone table, the applicability of "rigid" or "flexible" structure classification only to buildings, different gust effect factor calculation procedures for non-building structures, and recommendations for estimates of structural dynamic properties. Detailed discussions as well as a numerical example for such have been presented in this paper.

In general, the additional NSCP 2010 wind loading provisions provide additional margins of safety for engineers using it, but of course allow engineers to use other, more detailed procedures with rational bases to further optimize their designs. These new NSCP 2010 wind loading provisions also aim to educate structural engineers on the different treatment of building and non-building structures.

Issues on the wind environment in the Philippines, in the areas of outdoor and indoor air quality and greenhouse gas emissions, were identified and discussed. It has been pointed out that such issues are not being addressed in the country, and that studies on heat dissipation and pedestrian comfort are also necessary in addition to pollutant dispersion/transport.

### 10 REFERENCES

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