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Safety Evaluation of Billboards According to Some Random Factors in the Southwest of Vietnam

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SAFETY EVALUATION OF BILLBOARDS ACCORDING TO SOME RANDOM FACTORS IN THE SOUTHWEST OF VIETNAM

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ABSTRACT

Billboards are present in many localities of Vietnam, with typical structure of large surfaces, so wind load is one of the main loads during the design stage. In the Southwest region of Vietnam, during the rainy season, there are usually thunderstorms accompanied by strong winds, causing many billboards to be damaged. To avoid such damage, the structure of the billboard is simulated by random quantities such as wind load, material strength, geometric dimensions, resulting in the reliability of the structure was evaluated. The results show that there may be a high risk of the integrity of the billboards, even if the safety of these structures is implied by the design code. This study analyzed reliability index of billboard structure under wind speed, material, geometric characters by Monte Carclo simulation to indentify the reliability of billboard design.

Key words: Safety, billboard, reliability, probability, windload, Vietnam.

1 INTRODUCTION

The need for advertising is indispensable, especially in VietNam where is under strong economic development. Outdoor advertising has been researched and evaluated to bring good communication efficiency, strong growth momentum, and has increased of 6.4% from 2011. Four megacities, including, Hanoi, Ho Chi Minh City, Da Nang and Can Tho recently stand more than 17,000 billboards [1]. Outdoor large billboards are often placed on the main roads such as highways, national highways, provincial roads, etc., at bus stops, between intersections of streets, on buildings, skyscraper, etc.

Figure 1. *Damage of Billboard and partial damage building (Highway 1, Bac Lieu province, 3 August 2019) [2]*

Double-sided or three-sided panels and single or double columns are the major constructed of outdoor billboards design. A large billboard has a surface area over 40 m^2 [3], due to the large wind-receiving surface, the main load during the design stage of billboard is wind load. The impact of wind load is not only the effect of a static component but also the dynamic component, causing billboards to work more complexly such as oscillation, air turbulence, vibration types, etc. This study focuses on analysising billboard structure according to Vietnam standards and building codes especially simulates reliability of billboard design, and does not investigate the impact of dynamic components on the bearing capacity of the billboard structure. The scope is safety assessment for billboard works in the southern region, typically Ho Chi Minh City and neighboring provinces.

Table 1. *Statistics of typical storms in Ho Chi Minh and the Southwestern provinces [4]*

No.	Name of Storm	Characters
1	Linda, 31 October 1997, Ca Mau, Bac Lieu province	Wind speed 100km/h, gust grade of 8,9
2	Storm**,** 1 December 2006, Southwest	Wind speed 150km/h - 185km/h
3	Tembin, 25 December 2017, in Tien Giang, Ben Tre, Tra Vinh, Vinh Long, Can Thơ, Kiên Giang provinces	Wind grade of 6, gust grade of 8
4	Storm No 9, 23 November 2018	Wind grade of 7, gust grade of 9
5	Storm No 9 (Pabuk), 1 January 2019, Southern provinces	Wind grade of 8, gust grade of 10

According to statistics in recent years, to the rainy season, thunderstorms, Ho Chi Minh City and its neighboring provinces are the least affected by storms in the southern Viet Nam (Region IIA) [5], but the number of destructive advertising boards tends to increase. After typhoons or storms, there were many damaged or collapsed large billboards, no matter what they were costly elaborate.

It can be seen that the risk of losing safety in designing outdoor billboards is the cause of these incidents. The large surface billboards are affected by the weather, rain, sunshine that are the cause of steel rust, especially tornadoes that can collapse billboards at any time. Unsafety designed billboards potentially threat to lifes and residences, mainly in the rainy season. Ensuring safety is an urgent issue not only megaticiti such as Ho Chi Minh where is under a large number of billboards, but also the other provinces such as Vinh Long, where has only about 50 outdoor billboards, and many of which have been downgraded and influenced the beauty and safety, some pillars have built for a long time but have not been re-evaluated [6].

Figure 2. *Damage of Billboard and partial damage building (Highway 1A, Binh Tan distric, Ho Chi Minh city, 10 August 2018) [7]*

Figure 3. *Damage of Billboard and partial damage building (Dong An industrial area, Binh Duong province, 7 August 2013) [8]*

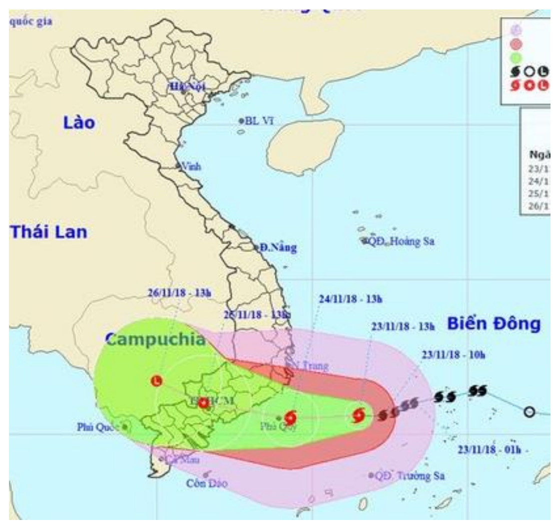

Figure 4. *The direction of the storm No. 9 [4]*

Table 2. *Statistics of damage to houses in Southern provinces [9] [10] [11]*

No	Date	Location in Map	Damages
1	18/11/2017	Ho Chi Minh City	82 houses were unroofed, 134 trees fell, due to the impact of the storm 14
2	3/7/2019	Lap Vo town, Dong Thap province	24 houses collapsed and unroofed
3	4/7/ 2019	Bac Lieu province	23 houses were unroofed due to tornado
4	15/7/2019	Tien Giang province, Long An province	100 houses were unroofed due to tornado, more than 300 houses were unroofed, damaged
5	23/7/2019	Tinh Biên town, An Giang province	604 houses collapsed and unroofed by tornado
6	1-3/8/2019	Soc Trang province	heavy rain with tornadoes collapsed, roof speed 194 homes
7	3/8/2019	Hau Giang province	more than 100 houses were unroofed due to tornadoes
8	4/8/2019	Can Tho province	83 houses were unroofed due to tornado
		Kien Giang province	200 houses were damaged, unroofed
9	9/8/ 2019	Bac Lieu province	60 houses collapsed, roofs were broken, 10 electric pylons fell
10	12/8/2019	An Giang province	96 houses were damaged, unroofed

Table 1 shows that the quantity of storms tends to increase in quantity and intensity, and they often form the ocean and then move in to the land (Fig.4). During the cyclone storm in Ho Chi Minh City and the Southwest provinces, wind speed / pressure is still under the allowed limits in the standard, its level is approximately to the wind grade of 12 in Beaufort scale [12]. During the rainy season (June to December) in the Southern provinces, there are thunderstorms accompanied by heavy rain, strong wind gusts, that cause many damage residences, broken trees, and electricity poles. Table 2 indicates that although the wind speed grade of 13 [12], but the consequences were heavy, as house collapse, roof break, electric poles, fallen trees. Thus, if billboards are designed under the current Vietnamese standards [5] [13], they will have to resist being destroyed by wind loads. It can be results of environmental climate change; leading to the actual wind speed is higher than the current standards. With the wind load, other factors, such as, material strength, manufacturing dimensional errors, etc., were applied to analyze the risks of reliability index of billboard design in this study.

There are many studies related to analyzing the reliability of large-scale structures, such as, K. Ohdo analyzed Reliability of construction scaffoldings system under wind storms [14], Zhang and Zhou performed system reliability assessment of 3d steel frames designed under AISC specifications [15]; Le-Thuy Nguyen [16] studied about impact of wind load on large plate billboards in Vietnam, L. T. Giang [17] researched about damage caused by wind load standard for building in Vietnam, Huong Chu-Thi at el. studied about variations and trend of maximum wind speed in Vietnam during 1961-2007 [18], the report on zoning of wind pressure for use in construction industry over Vietnam was written by T.V. Lien [19]. However, there is no study about the reliability of billboard structure in Viet Nam.

2 MATERIALS AND METHODS

According to Vietnamese standards, outdoor billboards have been been mainly calculated by the limit state method, in which there are only general instructions, no specific instructions. In this study, first, the author presented a specific example to calculate the billboard structure according to Vietnamese Standard (TCVN) [20], then analyzed the safety of the billboard structure under some typical random variables.

2.1. Load and action

The load used to design billboard structure was from TCVN 2737–1995 Load and action- Design code [5], including:

a) Weight of load: Due to the weight of load–bearing and covering structures of the billboard.

b) Wind load: Due to the characteristics of large billboard constructions, often located in vacant areas, on national highways, the influence of wind load is significant. In [5], there are instructions for calculating wind loads for various types of buildings. In 2009 to supplement the changes due to environment The Vietnam building code (Natural physical & climatic data for construction) QCVN 02-2009 / BXD [13] was issued. However [13] has not been widely used since most engineers are still familiar with the standard [5]. This invisibly makes the design works inconsistently with the natural conditions and the provisions of law.

Table 3. *Criteria wind pressure depending locations [5]*

Loacation in Map	I		II		III		IV	V
	IA	IB	IIA	IIB	IIIA	IIIB	IVB	VB
W_o(kN/m^2)	0.55	0.65	0.83	0.95	1.1	1.25	1.55	1.85

For wind load design [13], mean-wind-speed V_o using in design depend on the 3-seconds mean wind speed of 10 m height in open-flat terrain (type B), with a return period of 20 years. For calculating of wind load, TCVN 2737-1995 is divided into 5 zone of wind pressure. Conversion factors to obtain wind speed/pressure at higher return periods, 50 to 100 year-return periods, also is given in the QCVN02: 2009/BXD.

Table 4. *The adjust- factor, a_t [5]*

Assumption life time of building (years)	5	10	20	30	40	50
a_t	0.61	0.72	0.83	0.91	0.96	1.0

According to [13], wind speed converted value from 10 minutes in 50 years (V_{10}^{50}) to 3 seconds in 20 years (V_3^{20}) is 37.21m/s, and a deviation changes from *3.1m/s - 6.6m/s ((0.084-0.18)V_0)* based on [5] and [18], respectively. Therefore, the mean and deviation of the wind load should be considered when designing the billboard structure

The standard value of wind load static component W at the height Z above the reference level is determined by the formula [5]:

$$W = W_o \times k \times c \tag{1}$$

where: W_o- the velocity pressure, according to the map in Appendix D and Article 6.4; k – factor of wind pressure variation height, from Table 5; c - aerodynamic factor, from Table 6; Coefficient of surplus load (reliability of wind load) is taken equal to 1.2.

2.2. Materials

The most advantages of steel structure applied for billboard are high material strength, convenient for transportation because of their small size, high reliability, easily to erect (steel structures are manufactured in factories, so their quality is controlled by advanced technology effectively, save time construction than the other structures, etc). However, the steel billboard structure is susceptible to corrosion due to moisture, resulting in structural failure. Therefore, measures must be taken to protect steel from corrosion. In Vietnam, low-intensity low-carbon steel *($f_y \leq 290Mpa$, $f_u \approx 380$ -400Mpa)* such as CT34, CT38, SS400, S235, Q235, A36, and quite high strength steel (a flow limit of 310-400Mpa, a durable limit of 450 - 540Mpa) such as Q345, A570 are popularly used, recently, [20].

2.3. Limit state design and System Reliability Evaluation

The limit state design method has been applied in Vietnam since 1965, this method is applied to the the Vietnamese steel structure design standard-TCVN 5575-2012 "Steel structures – Design standard" [20], originating mainly from the Soviet standard-SNIP II-23-81* [21]. The meaning of the method is that the structure will be reliable when the load effect U (expressed in a suitable unit) is less than the effect of the structural strength B. This condition may be written in any equality:

$$U < B \tag{2}$$

where: U denotes design force in a member caused by the action of all the design loads in their most unfavorable combination; B denotes the load capacity limit of the member, which is a function of the geometrical dimensions of the member and the design strength of their material.

Inequality (2) describes a desirable (satisfactory, safe) state of a considered structural component. It is assumed that structural failure occurs when the condition (2) is not satisfied. Thus, an assumed sharp (unambiguous) distinction between a desirable (safe) and undesirable (failure) state of the structure is given by the following equation:

$$B - U = 0 \tag{3}$$

Equation (3) is the fundamental form of the so-called limit state (performance) function.

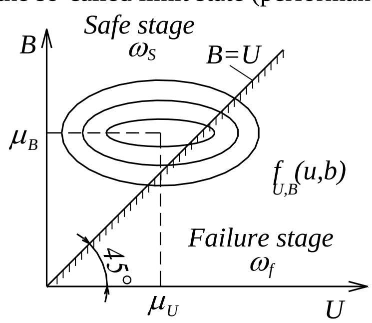

Figure 5. *The limit state function*

Both U and B are generally random variables and the validity of inequality (2) cannot be guaranteed absolutely, i.e. with the probability equal to 1. Therefore, it is necessary to accept the fact that the limit state described by equation (3) may be exceeded and failure may occur with a certain probability. The essential objective of reliability theory is to assess the probability of failure p_f and to find the necessary conditions for its limited magnitude. For the simple condition in the form of inequality (2), the probability of failure may be formally written as

$$p_f = P(U > B) \tag{4}$$

To analyze reliability, A.R. Rzannhitsun [22] and V.D. Raizer [23] assumed that both basic variables, the action effect U and resistance B, are random variables. It is then more complicated to assess the probability of failure defined by equation (4). Then, the difference M, called the reliability margin, has a normal distribution.

$$M = B - U \tag{5}$$

Distribution of M has mean value of $\mu_M = \mu_B - \mu_U$, and Fig. 6 presents the details of calculating its standard deviation (σ_M) and probability density (*$f(m)$*).

When B and U are independent random variables, we have:

$$f(m) = \int_{-\infty}^{\infty} g(m+u)f(u)du, \tag{6}$$

When: $g(m+u)$ – probability density of strength, the variable is $m+u$; $f(u)$ – probability density of load effect.

Probability of failure

$$R = P(M > 0) = \int_0^{\infty} f(m)dm = \int_0^{\infty}\int_0^{\infty} g(m+u)f(u)dudm \tag{7}$$

And probability of failure is then given as:

$$P_f = P(M < 0) = 1 - R = \int_{-\infty}^{0} f(m)dm \tag{8}$$

In reality, there are often not enough statistical data to determine the multi-dimensional density function or the specific density function of each variable. To obtain an analytical solution of probability of destruction or safety is determined by the expression (6) (7), FORM and SORM proposed the reliability approximate approach method (V.D. Raizer [23], Rackwitz và Fissler [24], Holický [25]), that can be used to evaluate integrals in Eq.(6). However, the disadvantage of this method is the complex state function when the number of variables is large.

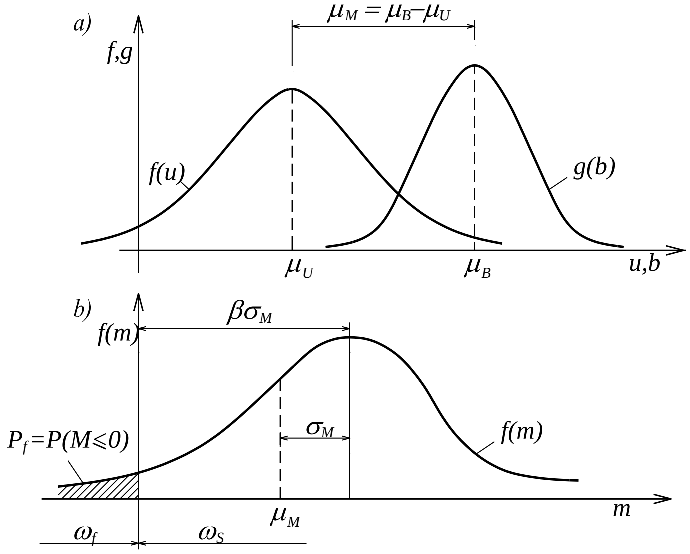

Figure 6. *Safety margin and reliability index*

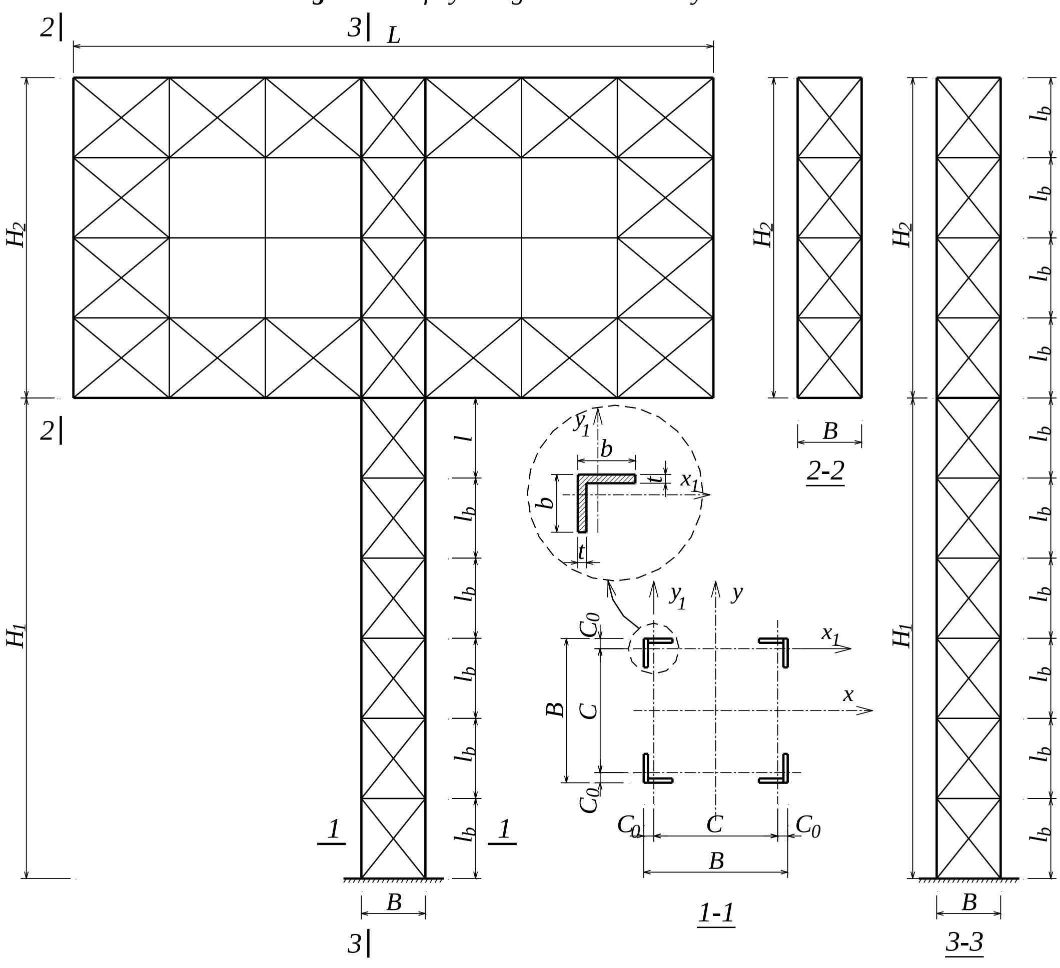

Figure 7. *Type of Billboard structure*

Simulation methods (direct, adaptive and allocated) are very popular and attractive for their simplicity and transparency. All the simulation methods are based on the generation of random variables of given distribution (uniform, normal, log-normal, Gumbel etc.) [25]. Monte Carlo simulation is a precise and powerful technique to analyze this problem. Thus, the Monte Carlo simulation is described briefly in this study, and the other information concerning sophisticated simulation methods are available in a number of specialised references.

In fact, U and B often do not know in advance or have no clear mathematical expressions, or maybe they are not independent variables. In that case, it is best to represent the basic variables $x_i, i = 1,2,\ldots,n$, which are statistically independent and have known distribution functions. Monte Carlo method aims to create a set of values for independent representations of x_i for each basic variable and thereby determine the corresponding values of the safety interval M.

$$m = f(x_1, x_2, \ldots x_n) = f(\overline{x}) \tag{9}$$

By generating random numbers, this process is repeated many times to create a large set of m values, from which the probability distribution of the quantity M can be simulated. So, the probability of failure is then given as:

$$P_f = P(M \leq 0) = lim_{n\to\infty} \frac{k}{n} \tag{10}$$

In which: n - the total number of tests, k - the number of trials with $f(\overline{x}) \leq 0$

3. NUMERICAL EXAMPLE

3.1 Example Description

Consider a typical billboard built in the HCM city. Bearing structure consists of an open-web column lattice, each branch is a angle steel welded from two plates, the ties are made of hot-rolled steel (L). Impact load: self load (structure system, shroud, technical equipment ...); Wind load is calculated with HCMC area (region IIA). All the billboard parameters are presented in Table 5, Table 7.

Table 5. *Input parameters of the billboard analysis*

Parameters of Billboard (m)						Column shape branch (mm)		Material (MPa)	
H_1	H_2	L	B	l_b	d_1	b	t	E	f_y
15	10	20	2	2.5	L75x5	250	12	2.1E5	275

3.2 Statistic Properties of Random Variables

Figure 8 describes the billboard structure, deterministic and random input are presented in Table 5, respectively. The random variables of reliability analysis include the yield strength of steel, elastic modulus, cross-sectional area, geometric dimensions, and wind load. Density distributions parameters of these variables are mean (μ), standard deviation (σ) and coefficient of variation $= \sigma/\mu$, and displayed in Table 6.

Table 6. *Statistic parameters of random variables*

No	Property	Random variables	Mean/Nominal, μ	Standard Deviation, σ	CV	Probability Distribution
1	Material property	Yield strength, f_y (MPa)	270	0.05 μ_{fy}	0.05	Lognormal [26]
2	Geometric property	Leg size, b (cm)	25	0.05 μ_B	0.05	Normal [27]
		Leg thickness, *t* (cm)	1.6	0.05 μ_{tf}	0.05	Normal [27]
3	Load	Wind speed, V_o(m/s)	36.8	(0.084-0.18) μ_V	0.084-0.18	Gumbel [22]

3.3 Structural design case and reliability estimation

With a life of 20 years, the billboard constructions designs have a wind speed of V_o *= 36.8m/s*. So, according to the formula [5], the wind pressure $W_o(kN/m^2)$ is determined as $W_o = 0.613V^{20}x10^{-3} = 0.83kN/m^2$. Analysis internal force results indicated that the column foot section is the most dangerous, the internal force (M) has the torque value of *5515.39 kNm*, and the vertical force (N) of *-154.52kN*.

Table 7. *Geometric characteristics*

Geometric characteristics	*One branch of column*	*Sum of area*
Area, A	45.8cm^2	234.24cm^2
Momen of inertia, I	3637.86cm^4	2054391.05cm^4
Radius of gyration, r	7.88cm	93.65cm
Equivalent slenderness ratio, λ_o	31.71	26.69
Conventional slenderness ratio, $\overline{\lambda}$	1.25	1.52

For billboards, the following conditions must be checked:

- Check the buckling of branch columns, $\sigma_1 = 20.15MPa < f.\gamma c = 24.43MPa$, *OK*
- Check local buckling of the column: $\sigma_c = 18.07MPa < \sigma_{lim} = 40.46MPa$, *OK*
- Check the global stability of the column (compressive strength): $\sigma_f = 21.02MPa < fx\gamma c = 24.43MPa$, *OK.*
- Horizontal transfer conditions guaranteed.

For effective design, the stress limit $\sigma \approx 0.9f_y/(\gamma_m.\gamma_c)$. The analysis results show that the most dangerous of billboard is the loss of general stability of its column (maximum normal stress). Therefore, this study focus on the global stability of column structure under of random factors (steel strength, geometric dimensions, wind load, etc.). The limit state function of the overall stability of the column of billboard has the form:

$$g(X) = f\gamma_c - \sigma = f\gamma_c - \frac{N_1}{\varphi_{min} A_1} > 0, \tag{11}$$

In which: N_1 denotes total vertical force on one side of compression; A denotes the area of 2 branches on the side of the compressive surface; φ_{min} denotes determined from the conventional slenderness $\overline{\lambda}$, equivalent slenderness λ_0.

To assess the system reliability of the billboard frame, Matlab program is used to implement Monte Carlo simulation, with N = 10^5 samples (Fig. 10), and the distributions variables were presented in Table 6.

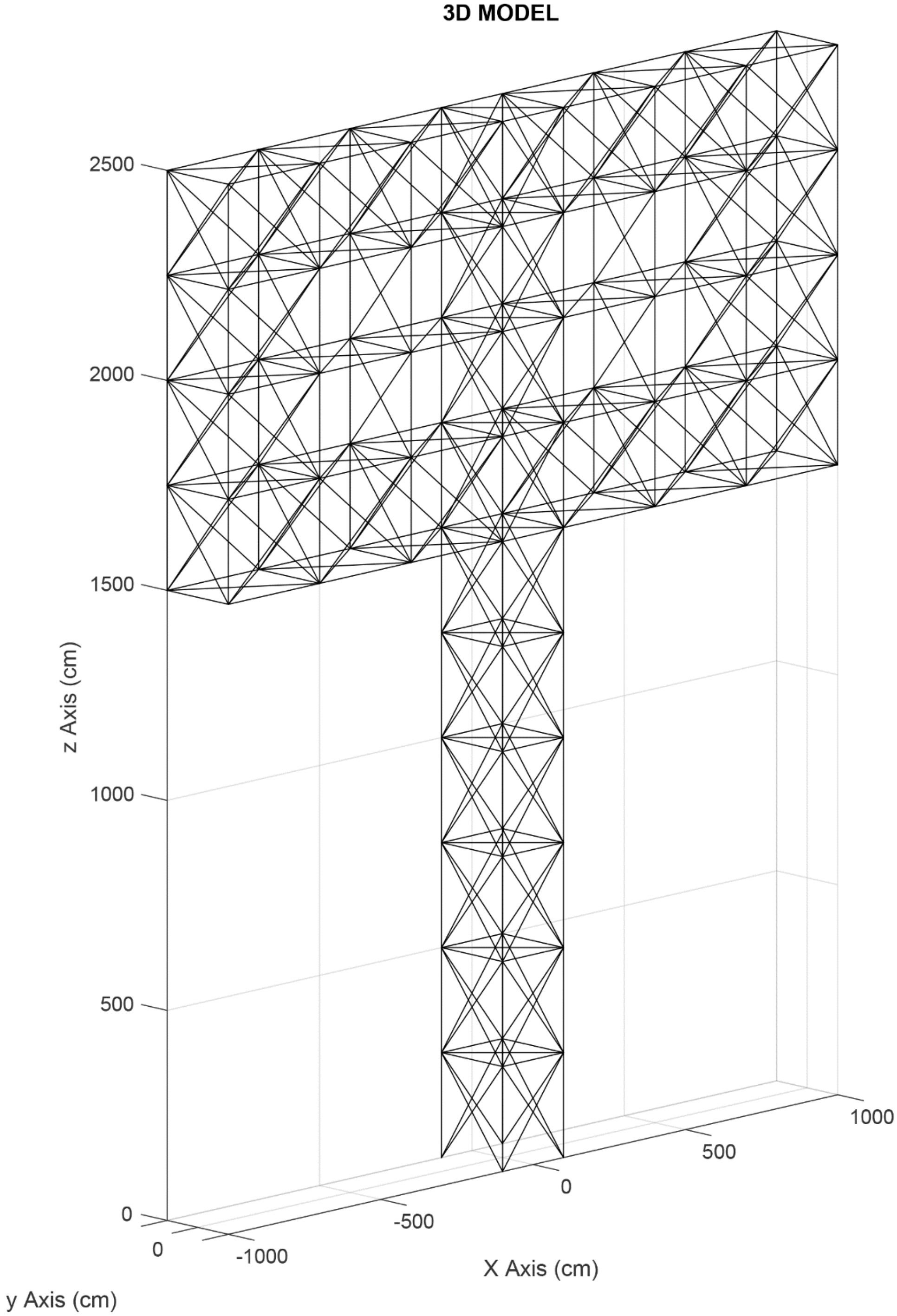

Figure 8. *Design of the billboard and its deformation under the wind load*

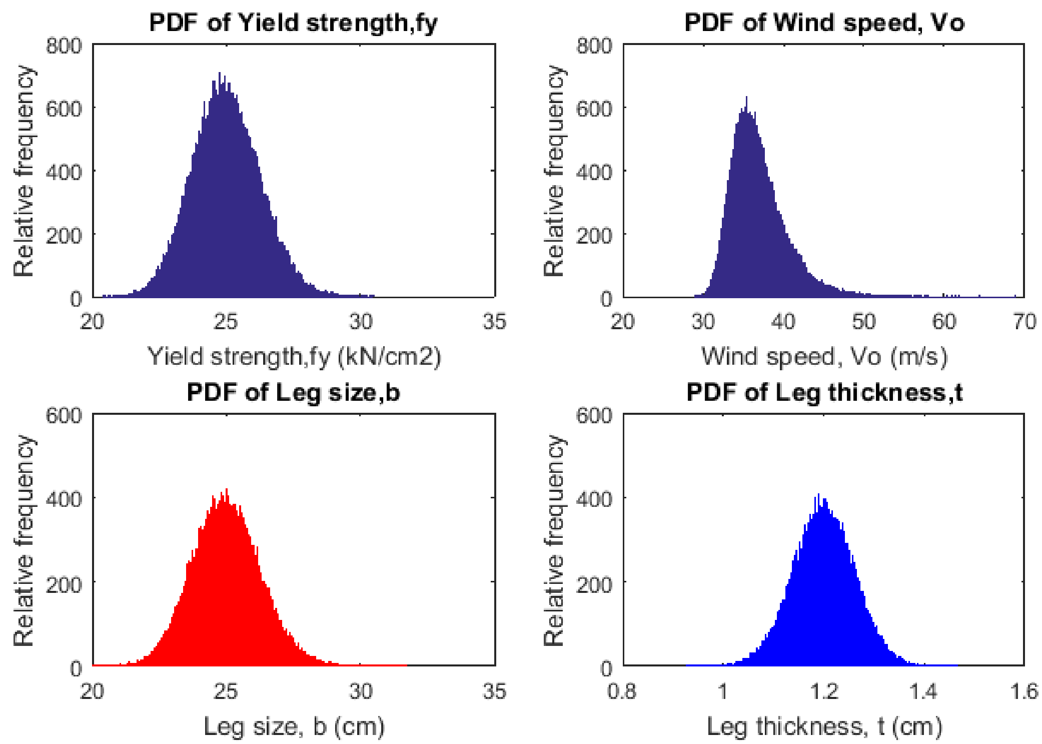

Figure 9. *Probability density function (PDF)of Yield strength (fy), Wind speed (Vo), Leg size (b), Leg thickness (t)*

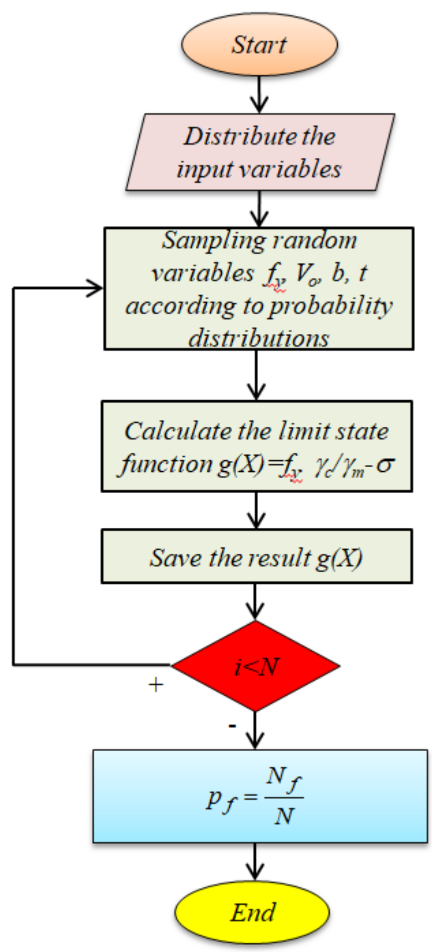

Figure 10. *Flowchart of Monte Carlo simulation. In wich: N_f - as the number of simulations where the limit state function g(X) <0, P_f – probability of failure*

Table 8. *Relation between Mean and standard deviation of winload*

μ_{Vo} *(m/s)*	36.8	36.8	36.8	36.8	36.8	36.8
σ_{Vo}*(m/s)*	0.9	1.8	2.7	4.4	5.3	6.1
CV_{Vo}	0.024	0.049	0.073	0.120	0.144	0.166
μ_{Wo} *(kN/m²)*	0.838	0.8388	0.8452	0.8577	0.8667	0.8765
σ_{Wo} *(kN/m²)*	0.0414	0.084	0.128	0.2133	0.2612	0.3072
CV_{Wo}	0.05	0.100	0.15	0.20	0.25	0.30

By the Gumbel density distribution of the wind speed, the mean, standard deviation, and coefficient of variations of wind pressure obtained from the results from Eq (1) are presented in Table 8 and Fig.11 indicate that the coefficient of variation of wind pressure is 2 to 2.2 times those of wind speed.

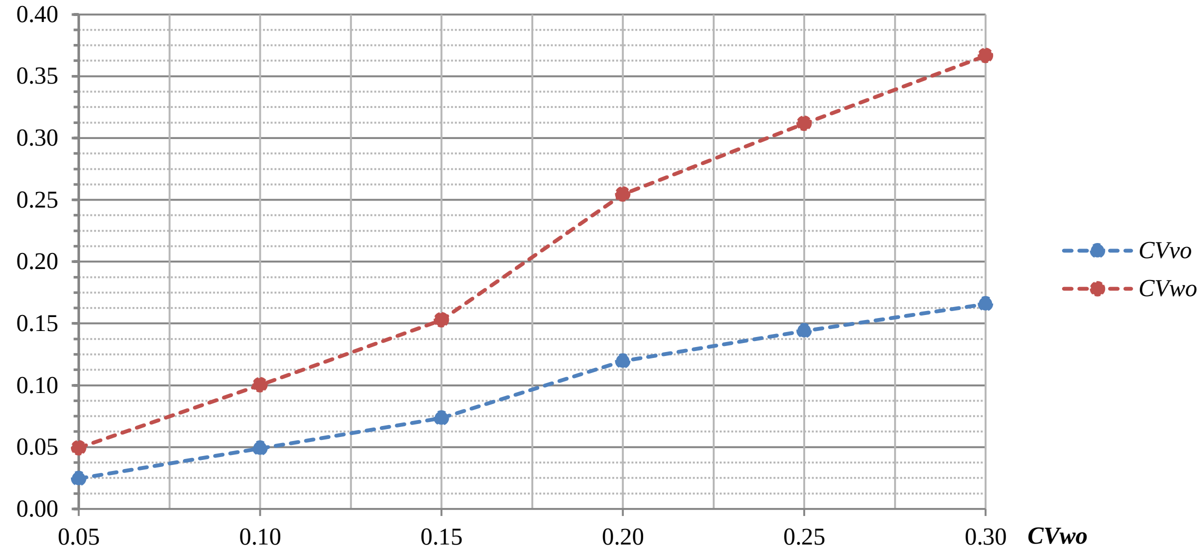

Figure 11. *Relation of coefficient variation of wind speed and win pressure*

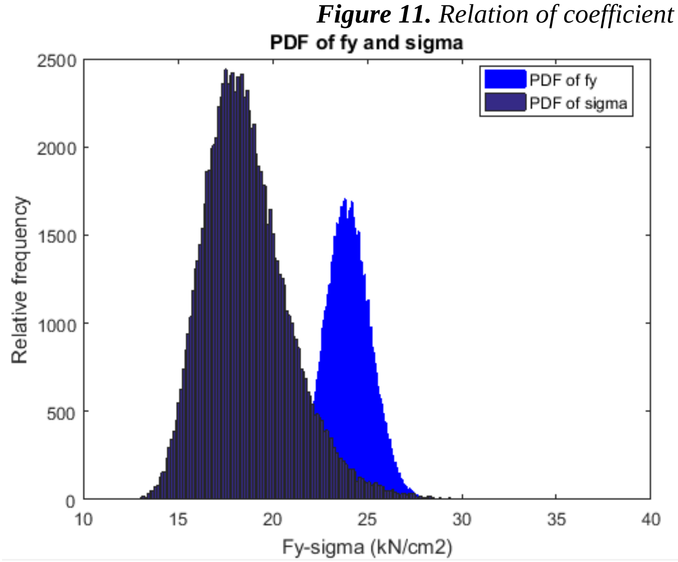

Figure 12*. PDF of Yield strength (fy) and stress (σ)*

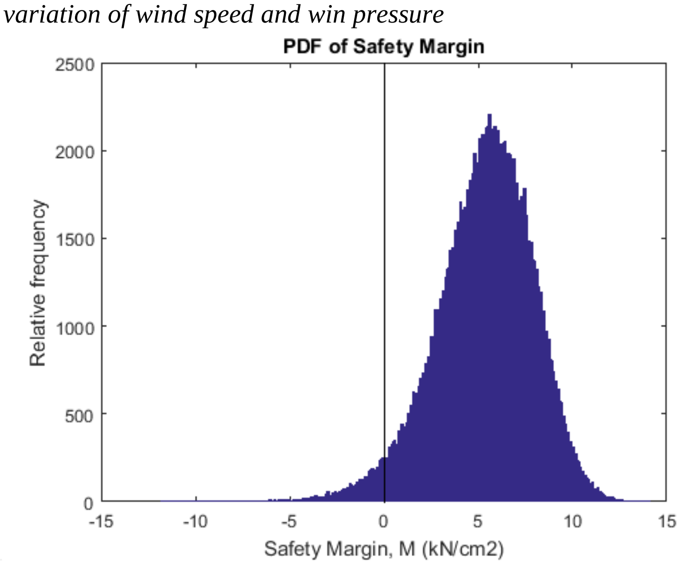

Figure 13*. PDF of Safety margin, M*

4 RESULTS

Analyzing the reliability of the billboard structure in the 5 different cases, are displayed in Table 9. The failure probability distribution of case 3 and the reliability margin M are presented in Fig.12 and Fig.13, respectively.

Table 9. *Case of analysis*

N^o	*Case*		*coefficient of variation, CV*			
			CV_{Wo}	CV_{fy}	CV_b	CV_{tf}
1	Case 1:	$\gamma_1 \approx 0{,}1$	$0{,}05 \rightarrow 0{,}3$	0,05	0,05	0,05
2	Case 2:	$\gamma_2 \approx 0{,}15$	$0{,}05 \rightarrow 0{,}3$	0,05	0,05	0,05
3	Case 3:	$\gamma_3 \approx 0{,}2$	$0{,}05 \rightarrow 0{,}3$	0,05	0,05	0,05

4	Case 4:	$\gamma_4 \approx 0{,}25$	0,05 →0,3	0,05	0,05	0,05
5	Case 5:	$\gamma_5 \approx 0{,}3$	0,05 →0,35	0,05	0,05	0,05

In which: cases considered on the relationship between the safety margin of the structure and the strength of materials: case(i): $\gamma i=\mu_{Mi}/(f_y \gamma_M \gamma_c)$, *i=1..5.*

Reliability-based design has found wide application in structural engineering [28], for example as the basis of the partial safety factors applied in the Standards [29] [30], the target reliability index (β) is given for the working life and related not only to the consequences but also to the relative costs of safety measures, see Table 10, Table 11.

Table 10. *Target β-values for elements (lifetime), ISO 2394:1998 [31]*

Relative costs of safety measures	Consequences of failure: small	some	moderate	great
High	0	1.5	2.3	3.1
Moderate	1.3	2.3	3.1	3.8
Low	2.3	3.1	3.8	4.3

Table 11. *Classification of reliability for different periods according to (EN 1990 2002). [29]*

Reliability classes	Failure consequences	Reliability ind.		Examples
	small	1 year	50 years	
RC3	0	5.2	4.3	Bridges, public buildings
RC2	1.3	4.7	3.8	Residences, offices
RC1	2.3	4.2	3.3	Agricultural builidings

According to EN 1990 [29], billboards can be classified into the third class (RC1), in which the target of structure reliability value (β) is select of 4.2 for one year. Then, based on [29], the reliability level corresponding to arbitrary remaining working life can be expressed as follows:

$$\beta_{tref} = \Phi^{-1}\{[\Phi(\beta_1)]^{tr}\} \quad (12)$$

where β_1 denotes target reliability index, which is taken from Table 10 for a relevant reliability class with the reference period t_{ref} = *1 year*. Thus, *β≈3.34* should be considered for t_{ref} = *20 years* of the billboard structure.

5 DISCUSSION

Based on analyzed results, in which, the reliability index (*β*), reliability (P_s), probability of failure (P_f) of 05 cases are displayed in Table 12, the resulted are ploted to present the relation between reliability (P_s) and the deviation std. of wind load in 5 cases of safety margin (Fig.14).

Table 12. *Characteristic reliability*

No	Cases	Characteristic reliability	Variable coefficients of wind pressure, CV_{Wo}: 0.05	0.1	0.15	0.2	0.25	0.3
1	Case 1:	P_s=	0.98295	0.94382	0.89887	0.85632	0.81977	0.79462
	γ_1=0.1	P_f=	0.01705	0.05618	0.10113	0.14368	0.18023	0.20538
		β=	2.12	1.59	1.28	1.06	0.91	0.82
2	Case 2:	P_s=	0.99324	0.96594	0.92869	0.88985	0.85325	0.82708
	γ_2=0.15	P_f=	0.00676	0.03406	0.07131	0.11015	0.14675	0.17292
		β=	2.47	1.82	1.47	1.23	1.05	0.94
3	Case 3:	P_s=	0.99849	0.98486	0.95674	0.92735	0.89473	0.86777
	γ_3=0.2	P_f=	0.00151	0.01514	0.04326	0.07265	0.10527	0.13223
		β=	2.97	2.17	1.71	1.46	1.25	1.12
4	Case 4:	P_s=	0.99968	0.99374	0.9774	0.95387	0.92577	0.90285
	γ_4=0.25	P_f=	0.00032	0.00626	0.0226	0.04613	0.07423	0.09715
		β=	3.41	2.50	2.00	1.68	1.44	1.30
5	Case 5:	P_s=	0.99994	0.99739	0.98751	0.96953	0.95089	0.92638
	γ_5=0.3	P_f=	0.00006	0.00261	0.01249	0.03047	0.04911	0.07362
		β=	3.85	2.79	2.24	1.87	1.65	1.45

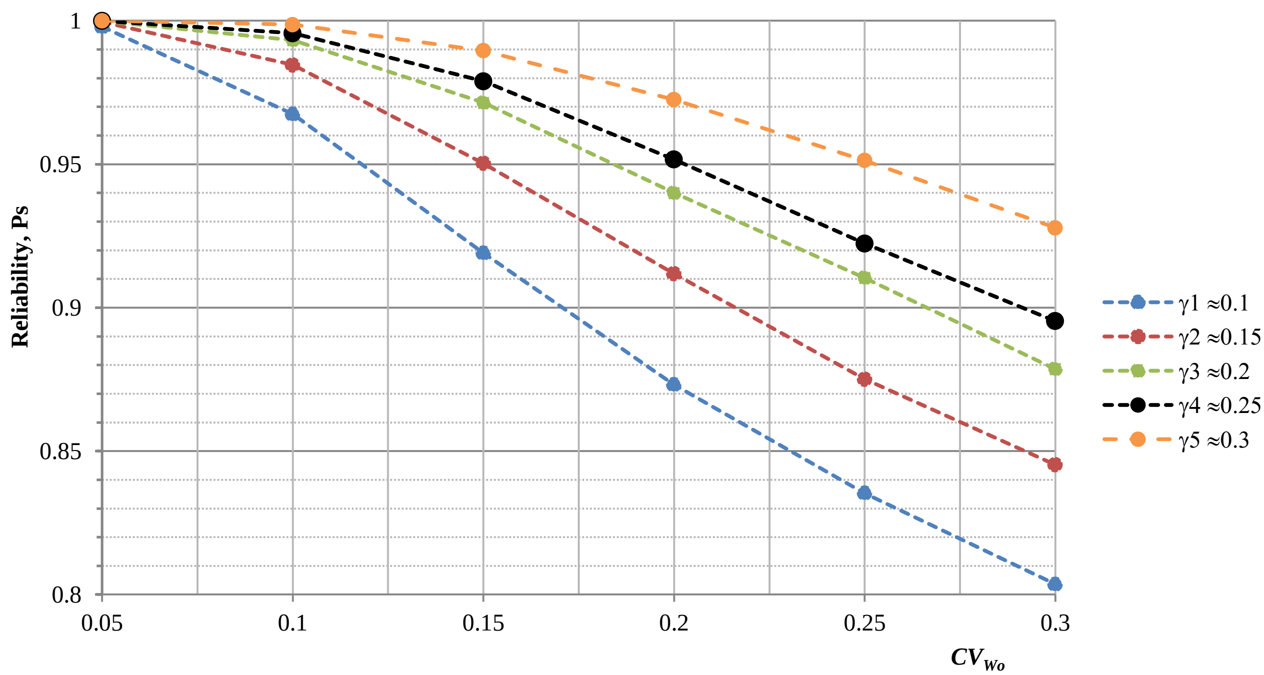

Figure 14. *Reliability analysis following to the cases*

Form Table 12 and Fig. 14 shows that the increase in the difference in wind speed, the decrease of reliability index. Specifically:

- When the mean of safety margin (μ_M) is *(10%)*μ_{fy}, and σ_{Wo}*=5-30%*, β value decreases rapidly from 2.12 down to 0.82 and P_s value declines slowly from 98% →79%, the reliability is very low.
- When the mean of safety margin (μ_M) is *(15%)*μ_{fy}, and σ_{Wo}*=5-30%*, β value decreases from 2.47 down to 1,82 , and P_s value is from 99.3% →96.5% when σ_{Wo} *=10%→30%* , P_s value decreases rapidly to 82.7% and β=0,94, reliability is very low.
- When the mean of safety margin (μ_M) is *(20%)*μ_{fy}, and σ_{Wo}*=5-10%*, β value decrease from 2.97 down to 2.17, and P_s value is from 99.8% →98.0%, reliability is low when σ_{Wo} *=10%→30%*, P_s value decreases rapidly to 87.7% and β=1.12, reliability is very low.
- When the mean of safety margin (μ_M) is *(25%)*μ_{fy}, and σ_{Wo}*=5-10%*, β value decrease from 3.41 down to 2.5, and P_s value is from 99.96% →99.3%, reliability is low when σ_{Wo} *=10%→30%* , P_s value decreases rapidly to 90% and β=1.12, reliability is very low.
- When the mean of safety margin (μ_M) is *(30%)*μ_{fy}, and σ_{Wo}*=10%*, β value is 3.85, the avergage of reliability index- P_s value is 99.99%, σ_{Wo} *=5%→10%*, then β = 2.79, P_s value reliability is low, when σ_{Wo}*=10%→30%*, Ps value decreases rapidly to 92.63%, and β=1.45, reliability is very low.

6 CONCLUSIONS

This study investigated the damage of billboards in the Southwest provinces under storms and cyclones, the variation between wind speed and wind pressure are from TCVN [5], QCVN 02-2009 [13] and QCVN 17 [3]. Based on the results of the studies in section 3, 4, density charts of random quantities such as wind speed, steel strength, and section shape dimension were built.

Monte Carlo simulation was used to analysis the reliability of billboards, especially the relationship between random variables (wind speed, steel strength, section parameters) with safety margin. The results indicated that the small change of wind speed leads to a large change in wind pressure in unpredictable climate change conditions. Thus, consider of wind load value should be carefully considered for designer.

The article only investigated the reliability of the global stability condition of the billboard (04 branches) by 04 random variables. In addition, analyzation of many types of column (2 branches, 3 branches), types of load (dynamic component of the wind, due to the subsidence of knee, etc.), and dimension factors (distance between column branches, branch length ...) will do in next research.

The state management agencies need to have regulations and instructions on assessing the quality of outdoor billboards by the time to ensure safety for society.

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