BÁNKI KÖZLEMÉNYEK
1. ÉVFOLYAM 2. SZÁM

Reliability of critical infrastructure elements

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Abstract — The present paper is focused the reliability of critical infrastructure elements. Possible threats on the critical infrastructure elements are described. Next the extreme load which the critical elements have to resist are defined. Paper gives an overview on the problems and shows on the gaps in the current standards and their approach**.**

Keywords: critical infrastructure, reliability, safety, extreme loading

1 INTRODUCTION.

In the last years critical infrastructure elements were defined. Mainly after the terrorist attacks and the damages of important buildings and life loses a new concept of critical infrastructure protection was adopted in United States of America and in Europe.

European council directive defines the term of 'critical infrastructures' only, not clearly defines the term of 'critical infrastructure element'. National Council of the Slovak republic on February 8th 2001 adopted law N° 45/2001 Coll. Where 'Critical infrastructure element' is defined as mainly engineering structure, public service or informational system in the critical information sector. According to sectoral and cross-cutting criteria the disruption or the destruction of them could have negative consequences on the function of society and economy and to life quality of inhabitants from the view of their life protection, health, security, property and environment. According to the law 'Civil engineering law' engineering structure is defined as roads, highways, bridges, tunnels, airports etc.

Critical infrastructure elements vary from intangible thinks as services, systems, network to tangible ones as bridge, tunnels water dam etc.

The concept of critical infrastructure was set mainly because of the occurrence of unexpected events. To identify its elements for efficient managing security, it is necessary to define the types of attacks as well as to estimate the probability of occurrence and their expected consequences.

When we speak about Critical Infrastructure Protection, we are regarding under the influence of the entire spectrum of possible threats, which are classified into three types:

1. Natural events,
2. Technical failure/human error, and
3. Intentional acts such as terrorism, crime or war [1].

2 EXTREME LOADS

All types of threats defined above could be considered as extreme loads for critical infrastructure element, which can cause their failure or damage. If the structure has to be safe and functional have to resist to the external loads.

According to the standard valid for the design of structures in Europe (Eurocode 1), actions (loads) are divided into different classes [8]:

Table 1 Classification of actions

Permanent action	**Variable action**	**Accidental action**
Self-weight of structures, fittings and fixed equipment	Imposed floor loads	Explosion
Prestressing force	Snow loads	Fire
Water and soil pressure	Wind loads	Impact from vehicles
Indirect action, e.g. settlement of supports	Indirect action, e.g. temperature effects	

Generally, as an extreme load is a considered load which are not commonly considered. EN 1991-1-7 (Eurocode 1 – Actions on structures-Part 1-7: General Actions-Accidental actions), some of theme describes with the name "Accidental actions". The following actions included (i) impact forces from vehicles, rail traffic, ships and helicopters, (ii) actions due to internal (only!) explosion and (iii) actions due to local failure from an unspecified cause. Accidental actions can be caused by:

2.1 Impact

a) road vehicles

Design values for action due to the impact on the supporting structures are defined according to the category of traffic (see Table 2).

Table 2 Indicative equivalent static design forces due to vehicular impact on members supporting structures

Category of traffic	Force $F_{dx}{}^{a}$ [KN]	Force $F_{dy}{}^{a}$ [KN]
Motorways and country national and main roads	1000	500
Country roads in rural area	750	375
Roads in urban area	500	250
Countryyards parking garages with access to: - Cars - Lorries[b]	 50 150	 25 75
[a] x=direction of normal travel, y=perpendicular to the direction of normal travel [b] The term "lorry" refers to vehicles with the maximum gross weight greater than 3,5 tonnes.		

b) forklift trucks

Design values for accidental actions due to the impact from forklift trucks should be determined taking into account the dynamic behaviour of the forklift truck and the structure. The structural response may allow for nonlinear deformation. As an alternative to a dynamic analysis an equivalent static design force F may be applied. F may be taken as 5W, where W is the sum of the net weight and hoisting load of a loaded truck.

2.2 Internal explosion

Eurocode 1 consider only internal explosion, no external. Explosive material such as explosive gases, or liquids forming explosive vapour or gas are taken into account. Effects due to the explosives are outside the scope of the Eurocode 1. The most significant aspects of the design and the assessment of the buildings are the blast wave propagation (dependence of pressure to time) and the maximal blast pressure. The blast wave propagates outward in all directions from the source in the form of sphere at supersonic speed. The magnitude and the shape depends on the nature of the energy release and on the distance from the explosion epicentre. We recognise two type of blast wave. The first one, has a sudden rise in pressure above ambient atmospheric conditions to a peak overpressure, the pressure returns to ambient value. In the second phase the pressure takes the negative values and gradually return to ambient. [3]

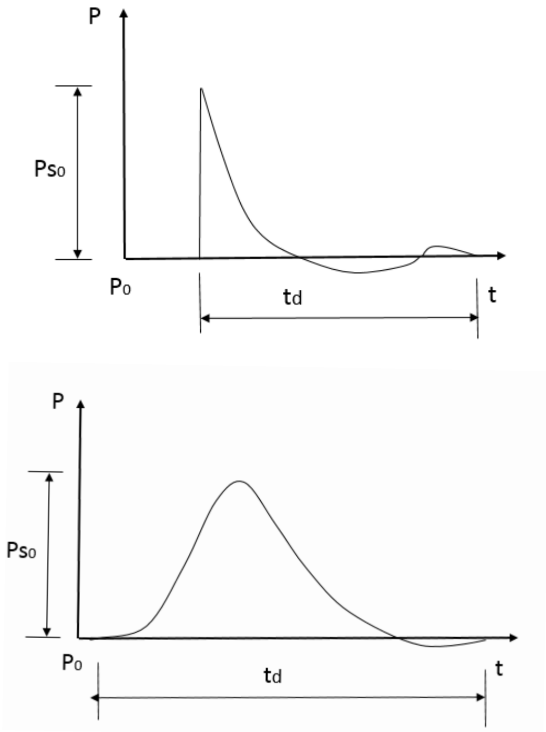

Fig. 1 Specific history of blast wave according to the type of explosive substances

Eurocode 1 recognise dust explosion and natural gas explosion. For the dust explosion defines so called venting area A depending on the material parameter of various type of dust, maximum pressure of the dust, the deflagration index of a dust cloud, volumes and pressures as static activation pressure and anticipated maximum reduced pressure.

For natural gas explosions is internal natural gas explosion defined using a nominal equivalent static pressure depending on the uniformly distributed static pressure, or the ratio of area of venting components and the volume of rectangle enclosure can be taken into consideration.

Extreme loads are not anymore only those described above but with the significant climate change and increasingly more unpredictable weather patterns is about the freezing precipitation, snowfall, snow loading and snow storms, windstorms and heavy precipitation causing the extreme loads for the structures.

2.2 Extreme clime load

a) wind

To climate load, Eurocode 1 part 1-4 (Wind load) is focused. But the norm does not give guidance on local thermal effects on the characteristic wind, e.g. strong arctic thermal surface inversion or funnelling or tornadoes.

Numerous past cases of extreme weather point out of the deficiency of such guidance, the maximal design value for wind is less than values measured in the past cases. From the past notable event are windstorms Lothar and Martin, Western Europe, December 1999 with the maximum 10m wind speeds in m/s. The data [4] shows that in many regions of Europe the 5-year and the 50-year return levels are exceeded by the 10m wind speeds.

Lotar was carried across the Atlantic at speeds that reached 130 km/h. Next, with winds at times gusting above 210 km/h, Lothar crossed the Normandy coast in the early hours of December 26th. In less than 12 hours it raged across northern France, battered Belgium, tore through Germany, and only when nearly half-way across Poland, finally weakened. Just 300 kilometres in diameter, Lothar's compact internal pressure gradients were comparable to those of a Category 2 hurricane. Lothar brought wind gusts of 170 km/h to Paris and 150 km/h to Karlsruhe, Germany, some 450 km from landfall. One day later, in the mid-afternoon of December 27th, winter stormMartin nevertheless brought gust wind speeds of 190 km/h to the French coast, and as high as 160 km/h to Vichy and 140 km/h to Carcassonne, far to the south. Bordeaux, where gusts reached 144 km/h, was especially hard hit. [5]

Windstorm Kyrill in West, Central and East Europe, January 2007, where windstorm Kyrill reached the Irish coast in the morning of the 18 January, where it caused wind speeds of up to 120 km/h. Consequently, strong pressure gradients occur and it led to widespread hurricane force wind gusts up to 150 km/h throughout Central Europe. [4].

According to the Erocode EN 1991-1-4 the stricter has to resist to the wind estimated as a fundamental value of the basic wind velocity vb,0. The wind climate for different regions/countries in Europe is described by values related to the characteristic 10 minutes mean wind velocity at 10 m above ground of a terrain with low vegetation (terrain category II). These characteristic values correspond to annual probabilities of exceedance of 0,02 which corresponds to a return period of 50 years.

Fig. 2 Basic wind velocities for Europe [2]

From the Figure 2 is obvious that the structure is designed generally for the wind velocity range from 20 to 31 km/h. As we mentioned above extreme loading in the case of hurricanes and storms, which are more and more common are is significantly different from the standard design values.

b) Flash and river floods

The other extreme load, which are in last days present but the structures are not design for them effects are flash and river floods. The hydro-meteorological event is of a type that can be observed several times in Europe each year, in different mountainous locations, that is quasi stationary or so-called back-building storms punching heavy rain for several hours over the same area, resulting in flash floods that destroy local streets and bridges. The maximum rain is rarely directly measured in such events, but seems often to be well above 100 mm within one or two hours. [4]

c) Extreme snow load

Heavy snow loading is other extreme loads. Winters and climate during winters have been changed. It is no more about the regular constant snow load, but snow fluctuations occur. The value of snow load is exceeded. This year 2017 snow occurs in many places of south Europe (mainly in Spain, Italy and Turkey) after years and in some places the snow cover reached 40 cm of heavy snow with the rain. In Slovakia, town of Čadca the snow record was measured, when 104 cm of new snow was reached in one day.

Because of heavy snow load, the glass roof of Prague theatre (Prague, Czech Republic) were damaged and fragments injured three peoples in the hall in 2010. More than 100 people were injured and 10 killed because of roof collapse of university hall in South Korea under the heavy snow.

Fig. 3 Roof collapse due to the snow [(a) Theatre in Czech Republic (b) University hall in South Korea]

Eurocode 1 EN 1991-1-3 provides guidance for the determination of the snow load to be used for the structural design of buildings and civil engineering works for sites at altitudes under 1500m. In the case of altitudes above 1500m advice may be found in the appropriate National Annex. EN 1991-1-3 does not give guidance on the following specialist aspects of snow loading: impact loads" due to snow sliding off or falling from a higher roof; (ii) additional wind loads resulting from changes in shape or size of the roof profile due to presence of snow or to the accretion of ice; (iii) loads in areas where snow is present all the year; (iv) loads due to ice; (v) lateral loading due to snow (e.g. lateral loads due to drifts); and (vi) snow loads on bridges.

According to prEN 1991-1-3 the snow load on the roof is described by the characteristic value of the ground snow load for the relevant altitude s_k. Ground snow load map of 10 Climatic Regions with homogeneous climatic features is defined (see Fig.4) Different zones are defined for each climatic region. Each zone is given a Zone number Z, which is used in the load altitude correction formula.

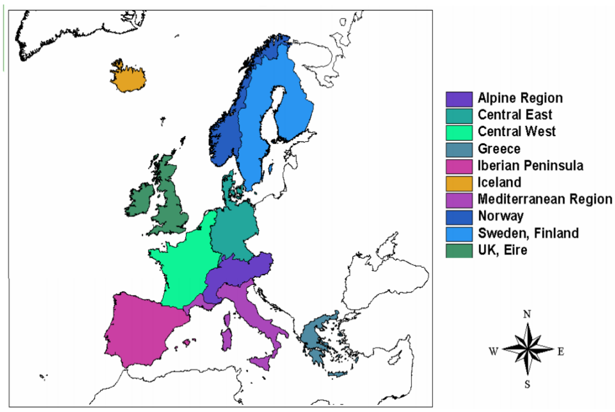

Fig.4 Ground snow load map of 10 Climatic Regions according to Eurocodes

If we consider the mentioned case above in Slovakia, town of Čadca where the snow record was measured, when 104 cm of new snow was reached in one day, we can make a comparison. According to the Slovak snow map, the value of ground snow load for this reagion is 2,25 KN/m^2. This value corispond to he height of snow equal 22,5 cm. so we can conclude that the snow load was exceded about 77%.

3 REALIABILITY OF CRITICAL INFRASTRUCTURE ELEMENTS

Generally, buildings for the purposes of differentiate their reliability are categorised according to the supposed consequences classes [9]:

Table 3 Definition of consequence classes

Consequences Class	Description	Examples of buildings and civil engineering works
CC3	High consequence for loss of human life, or economic, social or environmental consequences very great	Grandstands, public buildings where consequences of failure are high
CC2	Medium consequence for loss of human life, economic, social or environmental consequences considerable	Residential and office buildings, public buildings where consequences of failure are medium
CC1	Low consequence for loss of human life, and economic, social or environmental consequences small or negligible	Agricultural buildings where people do not normally enter (e.g. storage buildings), greenhouses

The aim of prevent and security measurements is to decrease of the possibility of building failure or collapse. There is possible to categorize the selected element into the higher consequence class and done the exact analysis of considered loading. Table 4 shows recommended minimum values for reliability index β (ultimate limit states). For the increase of reliability of critical infrastructure element is required to done a risk analysis, where or risk will be considered.

Table 4: Recommended minimum values for reliability index β (ultimate limit states)

Reliability Class	Minimum values for β	
	1 year reference period	50 years reference period
RC3	5,2	4,3
RC2	4,7	3,8
RC1	4,2	3,3

CONCLUSIONS

To predict damage and safety hazard risks of critical infrastructure element a probabilistic risk assessment procedure has be taken into account in the form of structural reliability analysis. For structural reliability analysis, maximal load had to be set arising from the treat scenarios and geometric and mechanical characteristic of the critical infrastructure element have to be know. Problem is that the load characteristic for such extreme load can be applied from the Eurocodes, because in major part Eurocodes (or valid standard for Europe) do not count with such extreme loading. For example, only actions due to internal explosion arising from explosion of dust and gas are considered. Flood wave effect is not considered too. Risk assessment procedure is interdisciplinary problem where the knowledge of risk analysis, structural behaviour, and dynamic of structure have to be involved.

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REFERENCES

[1] Christine Eismann, Trends in Critical Infrastructure Protection in Germany. Transactions of the VŠB - Technical university of Ostrava Safety Engineering Series, ISSN 1805-3238 Vol. IX, No. 2, 2014. p. 26 - 31, DOI 10.2478/tvsbses-2014-0008

[2] Implementation of Eurocodes Handbook 3 Action Effects for Buildings. Aachen. 2005

[3] Figuli, F., Jangl, Š., Picot, S. (2017) Different Approaches to Setting the Blast Load of Structure. In: Kravcov A., Cherepetskaya E., Pospichal V. (eds) Durability of Critical Infrastructure, Monitoring and Testing. Lecture Notes in Mechanical Engineering. Springer, Singapore

[4] Groenemeijer, P. (2017) Past cases of Extreme Weather Impact on Critical Infrastructure in Europe. http://rain-project.eu/wp-content/uploads/2015/11/D2.2-Past-Cases-final.compressed.pdf

[5] Tatge, Y. (2090) Looking Back, Looking Forward: Anatol, Lothar and Martin Ten Years Later. http://www.air-worldwide.com/Publications/AIR-Currents/Looking-Back,-Looking-Forward--Anatol,-Lothar-and-Martin-Ten-Years-Later/

[6] http://www.ceskatelevize.cz/ivysilani/10118379000-udalosti-v-regionech-praha/210411000141207-udalosti-v-regionech/obsah/137532-v-divadle-v-dlouhe-se-pod-snehem-propadla-strecha

[7] http://zpravy.idnes.cz/v-koreji-se-zritila-strecha-haly-zemrelo-nejmene-10-lidi-p1b-/zahranicni.aspx?c=A140218_074148_zahranicni_vez

[8] Designers' Handbook to Eurocode 1: Basis of design, H. Gulvanessian, Milan Holický, Thomas Telford, 1996 - 123 p

[9] Mynarz, M.. Mimořádná zatížení staveb. Edice SPBI Spektrum. Ostrava 2015 ISBN978-80-7385-174-3