Functional, Structural and Human Related Safety Measures in Multiple Use of Space

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Abstract

This paper will propose spatial safety measures for buildings above roads and railways during exploitation stage from a functional, structural and human related viewpoint.

1 Introduction

Multiple use of space, building above roads, railway tracks and existing buildings, becomes feasible if significant safety measures are implemented, particularly when buildings are realised above transport routes of hazardous materials. In general, these measures are drawn up to reach a certain level of safety. There are several measures that can be implemented in multiple use of space projects. These measures will reduce either the probability and / or the consequences of an incident in the building above the infrastructure, the vicinity or in the covered infrastructure. The measures that should be implemented should focus on hazards taking place on infrastructure; *traffic accidents* (mechanical load on the structure of the building), *fires*, *leaks of toxic substances*, and *explosions* [1]. This paper will give a quantitative overview of physical safety measures from *functional*, *structural* and *human related* viewpoint.

2 Functional Safety Measures

2.1 Logistic and proactive measures

A very traditional measure for multiple use of space projects is to implement a functional measure from a logistic point of view, in which one separates the transport of hazardous materials from the normal traffic [2]. Additionally, one may decide to prevent realising buildings above infrastructure on which the transport of such materials takes place. Other functional measures could be implementing uni- or bi-directional tubes on infrastructure below the building to prevent frontal collisions. However, mostly the transport of dangerous goods takes place through such transport routes, especially planned and designed for transport of hazardous goods [3]. Therefore, prohibiting transport of hazardous materials or urban development are controversial and almost not realisable measures. From this point, there is a strong need for measures which could stimulate the continuity of both the transport of hazardous material and the urban development above those transport routes. Given the fact that transport of hazardous materials is allowed in such areas, the building and infrastructure parameters can be influenced by their configuration. This will result in the variation of both the form of the (individual) risk contour and the group risk for the building above the infrastructure and for the surroundings. The main influencing (functional) building and infrastructure parameters are the width and height of the tunnel, possibly combined with the length of covering infrastructure, and the height level of the infrastructure. These influencing parameters form a main part of the functional measures. If one likes to implement functional measures, one may achieve effective results. It is clearly discussed by [4,5] that if ratio L/D - which is the length of the tunnel L divided by the average diameter of the covered infrastructure D - is more than 10, the probability of a detonation in the pipe/tunnel will increase rapidly. In this research, it is therefore assumed that if L/D of the covered infrastructure is more than 10, then it is proposed to be a possibility of a detonation may occur.

2.2 The effect of the width and height of the tunnel

The height of the covered infrastructure depends on the height of the lowest story of the building (h_o). The width of the covered infrastructure depends on the span (l) of the building. These two parameters form the basis for the possible scenarios at the infrastructure. Suppose h_o is designed at a minimum of 4 meters. This can initiate problems by truck drivers at roads, which can result in an accident [1]. So, if l = 12 m, than $D = (12 + 4) / 2 = 8$ m. Since $L/D < 10$, the limit for the covering length $L \leq$ 80 m (in order to prevent a detonation scenario).

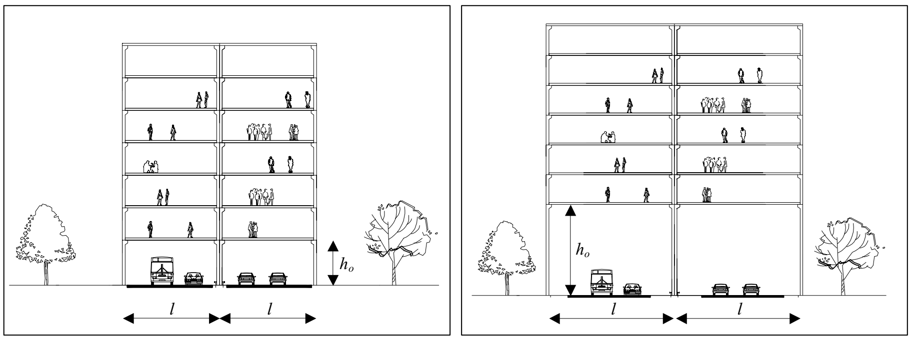

Figure 1: The height of the lowest story of the building and the width of the building: standard variant (left) and the variant with a higher lowest story and a bigger width (right).

In order to comply with the criterion of $L/D < 10$, one may decrease the covering length L or increase the section area D. Implementing a big diameter (a high level for the lowest story h_o and a bigger span l) in the design of the building leads to smaller probabilities for the detonation scenario and in case of fire the consequences are lower. Additionally, a large *L*/*D* provides also a better spatial contour against fires occurring on the infrastructure. An example of the lowest story h_o being high and a big span *l* being applied is the Gateway project at Schiphol Airport, Amsterdam (figure 2). However, this concept was based on architectural design rather than safety considerations.

Figure 2: Impression Gateway, Amsterdam (Source: Benthem & Crouwel).

2.3 The effect of the length of covering infrastructure

Multiple use of space begins to be interesting if the infrastructure is covered for long distances [1]. This is, however, not always realisable because of urban and spatial limits and safety considerations, i.e. detonation scenario. In order to comply with *L*/*D* < 10, one may realise individual buildings with a short covering length. Note that the space between two buildings should be more than the covering length of one building, because then the speed of the flame cannot spread to the next building. The probability of an accident on the infrastructure is related with the covering length of the infrastructure, while the consequences of an explosion increase rapidly with the length of the tunnel, as discussed by Berg *et al*. [4]. The effect of the covering length of infrastructure for the main scenarios is presented in table 1. One can read that a small covering length of infrastructure is positive regarding the explosion scenario. The advantages on toxic gasses are however not achieved.

Table 1: The effect of the covering length of infrastructure on the damage to the building above the infrastructure and the vicinity.

COVERING LENGTH	Explosive materials	Release of toxic gasses	Traffic accidents towards the building structure	Fires
Large	- -	+	-	+
Small	0	0	0	0

In case of prohibiting the transport of explosive materials, one can cover infrastructure for longer distances. When the infrastructure is covered for long distances with a building, some hazards can be enclosed into the infrastructure. In this regard, both the individual and the group risk for the surroundings can decrease in comparison to the building built above infrastructure. Both the individual and group risk increase for the surrounding area at both ends of the building. This increase and decrease must be compared in order to determine whether the risk increases by building over infrastructure. An example of the shield that is formed by a covering of the infrastructure for toxic gasses, is shown in figure 3. This is not valid for small coverings.

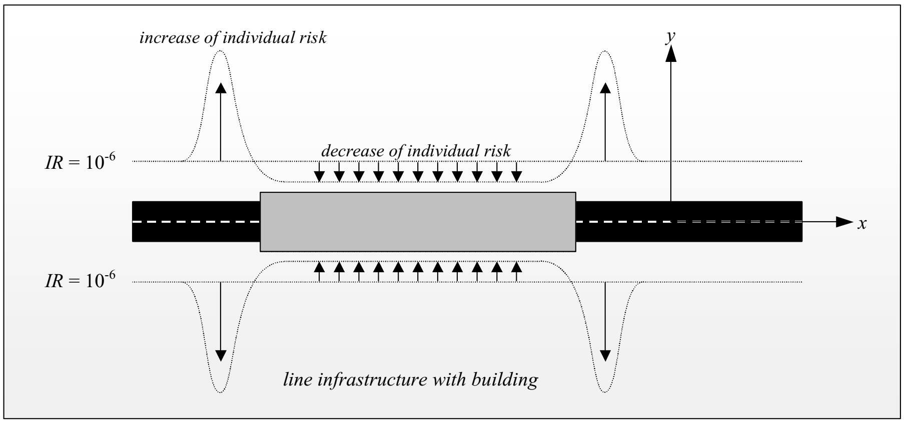

Figure 3: Local decrease and increase of individual risk by enclosing infrastructure for toxic gasses.

2.3 The effect of the length of covering infrastructure

There are four different levels of height for infrastructure that can be distinguished: underground, subsurface, ground level and elevated. In figure 4, these different positions in height are drawn for railway infrastructure.

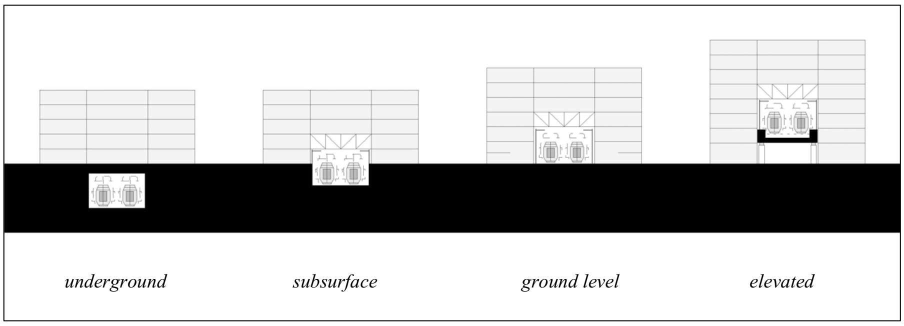

Figure 4: Different positions in height of railway infrastructure.

The effect of the height of infrastructure for the main scenarios is shown in table 2. The higher the level of the infrastructure, the higher the risks for the building. If the infrastructure is located in the underground, the effect of the hazards on the building and surroundings is much smaller than when the infrastructure is elevated.

Table 2: The effect of the level of infrastructure on the damage to the building above the infrastructure and the vicinity.

LEVEL OF INFRA-STRUCTURE	Explosive materials	Release of toxic gasses	Traffic accidents towards the building structure	Fires
Underground	0	+	+ +	+
Subsurface	-	0	+	0
Ground level	-	0	-	0
Elevated	-	-	-	-

2 Structural Safety Measures

Structural measures can be implemented towards (boundaries) the building above the infrastructure or the infrastructure itself. If one likes, one can design a building or a structure of the building from the shape of a risk contour as well. This is illustrated in figure 5. This is of course no general design solution and mostly the result of architectural considerations. Note that if one can utilize independent foundations for the infrastructure, one can reach safety advantages.

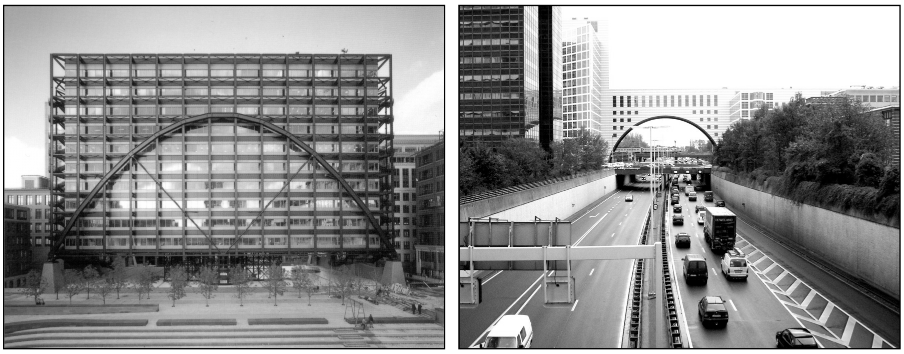

Figure 5: Examples of structural measures towards the building; Exchange House in London, UK (left) and the Haagse Poort in The Hague, The Netherlands.

The advantage of such a big span is that there can no columns be found on the infrastructure. By this, the probability of a collision of a train towards the main structure of the building will decrease. An example of structural measures towards the infrastructure is to encase the infrastructure e.g. in a steel tube, to minimise the effects during and after an explosion. When the tunnel is made strong enough, it may not collapse during a fire or an explosion in the tunnel. However, the realisation of a steel tube may reach limits of structural reliability and thus enlarge the costs of implementing such measure. Heat resistant lining is an effective measure preventing the fire spread from one area to another as discussed by Both [6]. Therefore, such a measure should be implemented on the boundary of the infrastructure and the building.

3 Human Related Safety Measures

The origin of safety measures aiming on evacuation of human beings are mostly based upon the escape opportunities for people in an emergency situation and the availability and accessibility of emergency response, such as fire brigade and ambulances. In essence, these measures are mostly measures of the repression class of the safety chain and should be implemented towards buildings on the top of the infrastructure or towards the infrastructure itself. An example of a measure, in which there should be enough escape possibilities in the building above the infrastructure, is presented in figure 6.

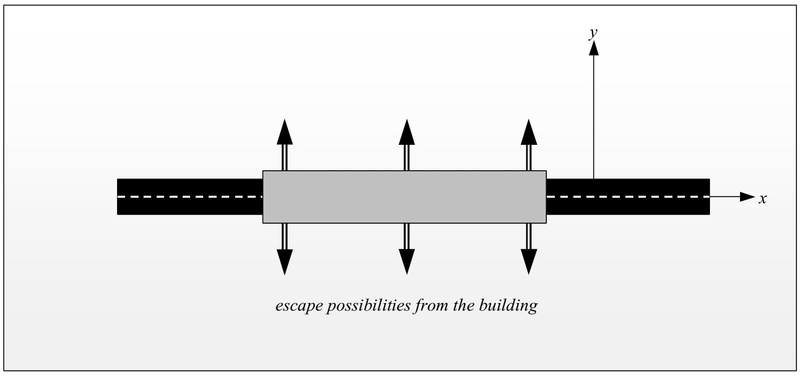

Figure 6: Escape possibilities should be considered during design stage.

4 Conclusions

This paper clearly showed that spatial safety measures for buildings above roads and railways could be implemented from a functional, structural and human point of view. However, the effect and the costs of these measures should be compared with each other.

References

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