DESIGN OF FLOW AND HOLDING CAPACITY OF ESCAPE ROUTES IN BUILDINGS

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ABSTRACT

A method was developed to dimension escape routes in a multi-storey building, controlling both the flow capacity of egress elements and the holding capacity of floor sections. The method is an extension of a current more traditional approach that requires the staircases in a building to provide sufficient holding capacity on each storey to accommodate all occupants of the storey. The width of stairs and doors is governed by the requirement that the building can be evacuated in 15 minutes. The existing method, mandatory in the Netherlands for office buildings, is unsuitable for high density occupancies such as assembly and education.

The new method recognizes the protection offered by smoke and fire compartments on the same floor as where the fire originated. It allows using these other compartments to hold occupants for a limited time before they can move into the staircases, thus making the method practicable for high occupant density buildings.

A side benefit of the new method is that it forces the designer to consider the likely exit routes taken by escaping groups depending on the location of a fire, not only in the originating fire compartment but in all other parts of the building as well. This is valid not only for the average distribution of occupants over the various parts of the building, but also for any other foreseeable distribution of occupants. The new method was published in 2011 as a Dutch Standard NEN 6089, and was introduced in a modified form in the Dutch Building Decree in April 2012.

The paper describes the method, and compares it to popular methods in current use worldwide.

The authors argue that the new method overcomes some relevant limitations of the conventional methods, while remaining simple enough to be acceptable as a mandatory analysis for a building permit.

Key words: NEN 6089, escape routes, holding capacity

CONCEPTS AND PRACTICE RELATED TO EVACUATION ROUTE SIZING

In case of a fire in a multi-storey building, the evacuation routes should have sufficient capacity to allow occupants to evacuate the area close to the fire or the building as a whole before they are threatened by smoke and fire or collapse. Unfortunately, widely different ideas have developed worldwide over what constitutes ‘sufficient capacity’. These ideas have been translated into corresponding requirements in building codes to the size of egress elements such as doors, corridors, lobbies and stairways. The ideas reflect different answers to questions such as: which portion of the evacuation must be controlled? Which occupants need to be provided with egress capacity? How long? How much capacity do they need? How much safety margin is needed in the capacity? How fast are people assumed to move? How fast are fire and smoke assumed to grow? How do we account for delays between alarm and start of movement? Which routes are occupants assumed to take?

Also unfortunately, the concepts are in most cases not explicitly stated but have to be re-engineered from the codes themselves. (Bukowski, 2009) does that in a representative overview of international approaches, from which major elements are used in this paper. The discussion focuses on staircase dimensions, omitting doors, corridors and other floors outside staircases.

From a 1935 NBS report, Bukowski distinguishes several different concepts, including:

- Capacity method, where all occupants are stored within a protected staircase, and subsequently evacuate the building.
- Flow method, which regulates stair width by requiring that all occupants are able to leave the building within the time that it is safe to be in the building.
- Combined method, which means the flow method for lower buildings, shifting to the capacity method for taller buildings.
- Probability method, considering only the population of the six most densely populated floors, implying a phased evacuation.

Bukowski found that regulations worldwide are mostly based on the capacity method, with slight differences in the details.

US CODE REQUIREMENTS

In the US model building codes IBC and NFPA 5000, the required capacity of stairs and doors on any floor is related to the number of occupants served on that floor, with 7.6 mm (0.3 in) of stair width required per person for an unsprinklered building. IBC reduces the required capacity to 5.1 mm (0.2 in) per person where sprinklered. The minimum 1100 mm (44 in) wide stair thus accommodates 147 persons unsprinklered or 220 persons sprinklered.

Bukowski considers this a capacity approach. We note however that a staircase containing a 1100 mm wide stair and associated landings can store around 40 persons on every floor at 0.25 m^2 per person, far less than the 147 or 220 persons allowed. In a general and simultaneous evacuation of the whole building, assuming an occupant load close to maximum on most of the floors, most people will have to wait outside the staircase for a considerable time.

It can be argued that this is not necessarily unsafe since some phasing will occur even if the alarm is activated on all floors at the same time. The fire floor would effectively respond to the alarm before the other floors, allowing its occupants to find shelter on the lower levels of the staircase. Occupants of the non-fire floors will take longer to enter the staircase, but since there is much less urgency for them, that is not a problem. This argument is clearly not very robust. If the non-fire floors start to evacuate at the same time as the fire floor, occupants of the fire floor will again find themselves blocked outside the staircase.

A phased evacuation, with sufficient delay to allow all occupants of the fire floor to enter the protected staircases before the other floors are alarmed, eliminates the above problem to a large degree. Measures should be taken to prevent occupants on other floors from noticing the alarm on the fire floor.

If unrestricted access to the stairs is guaranteed, objections can still be raised as to the safety of the dimensioning rules in the US code.

- Even with unrestricted access to the staircase, the occupants on the fire floor may take considerable time to enter the staircase since they must proceed down over the stairs in order to make place for others. Using Bukowski's recommended numbers, the flow rate over the 1100 mm stair is 52 or even only 32 persons per minute. Assuming the latter value, it takes almost 7 minutes before the last of 220 persons on a sprinklered fire floor can enter the staircase. If the fire floor is laid out as undivided office space and the staircases have no protected corridor or lobby, 7 minutes cannot be considered safe to stay in the room of fire origin.

  The danger of accidents is obviously greater if access to the staircase is restricted on the fire floor as discussed above.
- On the floors directly above and below the fire floor, the time delay before the last person can enter a protected staircase can be many minutes. The delay may be large enough to see smoke and heat propagating to these floors, causing persons to have to wait in rapidly deteriorating conditions;

A robust way to deal with the above discrepancy between the basic concept of the capacity method and the actual US implementation would be to provide storage area for all occupants of each floor on the flights and landings of the staircase or in a protected lobby or corridor, a provision apparently not required in the US building codes. Bukowski recommends this approach in his suggestions for performance objectives, with a specific escape for floors with assembly spaces: a refuge area next to the staircase, large enough to store all occupants of that floor, would exempt the staircase from the extremely large size requirement on the staircase on the floors below the floor in question.

The corresponding code requirements in the other countries Bukowski studied are actually very similar to those in the USA, so the same comments hold.

- Australia, deemed to satisfy solutions: a 1000 mm (between handrails) stair serves 100 persons; a storey accommodating between 100 and 200 persons requires an aggregate stair width of 1000 mm plus 250 mm for each 25 persons; over 200 persons, the required stair width increases less, 500 mm for each 60 persons.

  The approach is similar to the US. A stair serves on any storey more persons than it can store, but substantially less than the US rules allow: 100 instead of 147/220 persons on a 1100 mm clear width stair.
- The UK approved document B (ADB) follows the capacity approach more fully. For a simultaneous evacuation, a staircase must have sufficient capacity to store all persons it serves, with an allowance for the number of persons that can have left the staircase after 2.5 minutes given a flow capacity of 80 persons per minute per meter clear width. Each storey in a staircase is assumed to store 50 persons per meter of effective stair width (Bukowski and Kuligowski, 2004).

  The worked examples in ADB show that the rule can lead to rather strange and unsafe results in case of an uneven distribution over storeys: A staircase serving 50 persons on each storey but 100 persons on the upper two storeys, would need less stair width than serving 50 on all floors!

For phased evacuation, the required stair width is only determined by the number of persons on any storey, implying that only the persons on the fire floor need to find space in the staircase directly. A 1100 mm stair accommodates 120 people per floor, each additional person requiring 10 mm more. The 120 persons having unrestricted access, and the 1100 mm allowing a flow rate of 88 persons/minute, the fire floor is emptied in 1,4 minutes.

Bukowski's less optimistic assumption of 32 persons/minute leads to 3.8 minutes, lower than the US value.

In addition, the UK assumes one person for every 6 m^2 of office area. Whether this represents a substantial safety margin taken in the UK egress capacity requirements, or simply a more Spartan use of space in Britain is not known.

DISCUSSION

The various approaches discussed appear to deal quite differently with buildings with high occupant densities above the ground floor. The UK effectively requires that the stairways accommodate everyone in the building (Communities and Local Government, 2006). That is a quite safe requirement, far more constricting than other countries that allow smaller staircases; countries such as Australia and the USA apparently rely on unspecified safety factors that make it acceptable if people on the fire floor take several minutes before they can enter a protected staircase. These countries have adopted that margin since their industries consider strict application of the capacity concept too burdensome.

This does raise the question of whether the UK does construct the very substantial staircase dimensions that the rule prescribes for high occupant densities; or have they adopted other, more practical ways to ensure safety, without changing the rule accordingly?

The methods described do not appear to explicitly value some of the factors that have been used in developing the Dutch standard, notably:

- A distinction between the need for rapid evacuation by persons in the compartment of fire origin, and those in an adjacent fire compartment. By controlling the flow capacity and the storage capacity of a storey as a whole, the rules make no such distinction. Thus, an open plan office storey requires identical staircase capacity as the same storey divided in fire compartments. From a point of view of hazard, significant differences exist. As discussed above, occupants of the open plan fire floor may have to wait 7 minutes before the last person is in a staircase. The same storey divided in two equal fire compartments connected by wide doors offers a different view: occupants of the compartment where the fire starts now have a high capacity additional exit to the safety of the second fire compartment.
- The capacity of a staircase is mostly coupled to the width of the stair. Actually, a standard staircase stores more persons on the landings than on the stair, and the size of the landing on floor levels is often relatively easy to enlarge without resorting to adding lobbies.
- No direct control of the overall evacuation time of the staircase.

DUTCH CODE REQUIREMENTS

The Dutch Building Decree up to April 2012 specified a rule similar to the UK, but more restrictive (van de Leur et. al, 2009). It is a combination of:

- full capacity method, requiring that protected staircases provide room on every floor for all occupants of that floor;
- flow method, which states that the flow capacity of the stairs must allow all staircases to be evacuated within 15 minutes (20 minutes in staircases with additional protection by a smoke proof lobby, 30 minutes in 'safety staircases' that can only be accessed from the outside).

A less strict interpretation of the rule allows for storage in a protected staircase lobby.

The requirements to the capacity of stairs come on top of a basic rule that governs the total door width of rooms and smoke compartments. Sufficient door width must be available to allow occupants to leave the room or compartment in not more than 1.5 minutes.

Basic parameters of calculations are prescribed as follows. Flow capacity: 90 persons per min per m clear width for doors and passageways, 45 persons per min per m clear width for stairs. Storage capacity is set at 4 persons per m^2 on floors, 0.9 persons per m stair width on each tread on stairs.

The Dutch code requirements are set in addition to a set of basic rules:

- Fire compartments are limited to 1000 m^2, separated by 60 minutes fire resistant constructions (EI60 according to the European standard EN 13501-2);
- Each fire compartment must be divided in smoke compartments such that the maximum walking distance to the nearest compartment exit does not exceed a limiting value varying between 30 m high occupant densities down to 1 person per 8 m^2 usable floor area, and 60 m for occupant densities lower than 1 person per 20 m^2 usable floor area. Smoke compartments are separated by 20 minutes fire resistant constructions (E20 or Sa by NEN-EN 1634-3).

NEED FOR ADVANCED EVACUATION MODELLING

A discussion of the hazards mentioned above in this chapter does not need advanced calculation models such as Building EXODUS, Steps and similar to quantify them. As long as cases simplified to their essential core are discussed, the simple calculation rules in the prescriptive and deemed-to-satisfy methods are sufficient to discuss the value and safety issues of the different approaches. The modern evacuation models can make their analysis simpler, and they become essential when the added effects of varying occupant number and density, mobility issues and the like need to be addressed. Most literature on application of these models seems to consider these 'building regulations' cases less interesting than, e.g., complex structures and crowd management issues. The authors disagree.

THE NEED FOR AN ALTERNATIVE MODEL

The formal implementation of the Dutch code method for dimensioning of stairs is applicable only up to 15 floors, offering no guidance for higher buildings.

The strict application of the capacity concept makes it very restrictive, and completely impractical even for relatively low buildings with high occupant loads such as assembly or education. Building owners strongly object against the excessive loss of rentable space that must be reserved for staircases and protected lobbies, and in practice the method is rarely applied in full except for less densely occupied buildings such as offices and hotels.

Practitioners realized that where a floor is subdivided in fire or smoke compartments, the protected staircase is not the only safe place on the floor. In case of fire in one compartment, the other compartments on the same floor provide a safe place, at least for a short time. That eliminates or at least reduces the need for the provision of storage area in protected staircases or lobbies.

DEVELOPMENT OF NEN 6089

This idea has lead to the development of a model that allowed for temporary storage in smoke compartments or fire compartments adjacent to a protected staircase. Phased evacuation was to be introduced at the same time. For all other parts of the model the objective was to stay as close as possible to the existing Dutch building code. That included keeping the model as simple as possible, a prerequisite for getting a mandatory role in building permit procedures.

In the discussions over the development, new problems were identified that required additional features in the method.

- Limits needed to be set to the time that people are forced to wait in the 'holding space' adjacent to the protected staircase. Consensus was reached over maximum waiting times of 3.5 minutes in a smoke compartment (E20 protection), and 6 minutes in a fire compartment (EI30 protection).
- A scenario with no fire is checked for compliance of the overall evacuation time of the building with the standard 15/20/30 minutes, depending on staircase protection.
- A fire can start in the compartment adjacent to a protected staircase. In that case, it is not reasonable to allow an extended waiting time, the directly threatened compartment must allow evacuation in 1.5 minutes as per the building code (or: the building construction must allow evacuation in 1.5 minutes).
- It was found necessary to introduce fire scenarios, at least by making a distinction between the compartment where the fire starts and all others. The latter are protected from the fire by E20 or EI30 constructions and can serve as waiting space. Since a fire can start in any compartment, this means that the analysis of a building involves many calculations, one for each scenario.
- No further specification of the fire location within the compartment is required. Effects of exits being blocked by the fire are not treated.
- Further scenarios are introduced if different major occupant distributions can be distinguished, each offering a different challenge to the egress system. An example is an educational building; at ordinary school hours virtually everyone is in the classrooms, but at specific times the whole school may be assembled in a main hall. By treating each as a different scenario, a common problem is avoided that arises when the maximum occupant load is assumed in all areas.
- The previous allows for a rather straightforward prediction of the distribution of persons over the exit doors of the compartments on the fire floor and on other floors.
    - In the 'directly threatened compartment' where the fire starts, occupants may be assumed to use all exits available to the compartment, since in the very first phase of fire development blockage of exits by fire or smoke is improbable. The assumption is moreover in line with the code requirement governing only the total exit door width.
    - In a compartment on another floor, occupants are likely to evacuate all taking the same 'normal' route, since there is no immediate threat that would cause them to look for the closest possible exit of their compartment. They are also unlikely

to have information as to the exact location of the fire, so they have no reason to deviate from their designed evacuation route. They will obviously take longer to evacuate their compartment than 1.5 minutes, but that does not threaten their safety.
    - In other compartments on the fire floor, the situation for occupants is more complex. Their normal evacuation route may lead through the compartment of fire origin; occupants trying that route are likely to track back as soon as they see smoke or fire, or people fleeing towards them. A reasonable assumption is that they avoid all escape routes running through the directly threatened compartment, and choose another available route. This other route is then taken by a) occupants for whom this is the normal escape route, b) occupants of other compartments avoiding the directly threatened compartment, and c) a fraction of the occupants of the directly threatened compartment, who used a 'non-standard' exit. These numbers can normally be estimated in a simple way, easily defended when reviewed.
- It is to be expected that on the fire floor, the distribution of persons over staircases is different from the standard, whereas the distribution remains unchanged on other floors. In an extreme case, with a fire in the compartment adjacent to a staircase, almost all occupants of the fire floor must be expected to use the only other staircase. The waiting time to enter that staircase on the fire floor could be critical.
- It is the responsibility of the applicant to propose reasonable distributions of occupants over compartment exits and staircases in the various scenarios. The above principles may serve as starting points, but the specific situation of the building may lead to modified distributions.
- Apart from fire scenarios, the model allows for treatment of varying occupation of the building. The same population could be distributed over classrooms during working hours, but concentrated in an assembly hall at another time. Treating every relevant distribution as a separate scenario avoids the problems of designing for simultaneous maximum occupancy for all spaces.
- An important simplification is the assumption that walking distances and walking times are negligible, and that the evacuation process is governed by flow and storage capacity. This assumption loses its validity with extremely low occupant densities, a situation rarely found in buildings where stairway dimensioning is a relevant issue.
- In order to deal with waiting times and uneven distributions of persons, the model was cast in the form of a time development, tracing numbers of persons along their egress paths. To keep the model reasonably simple, a fixed time step of 30 s is imposed;
- A consequence of the assumption of negligible walking times is that walking speeds do not pose a limit on the vertical distance over which persons can move within a time step. A specific rule limits that distance;
- Waiting times outside the staircases are strongly influenced by the assumptions regarding the process of mixing the stream from a storey with the stream from the storeys above in the staircase. A local 50% - 50% mixing on each storey is assumed. This does have rather important consequences in that high occupant loads are far easier to handle on the lowest storeys than high in a building.

The standard NEN 6089 was published in 2011, accompanied by a practical instrument NPR 6080 in the form of a computer program that practitioners can use to carry out the necessary calculations (NEN 6069, 2011). The software was developed by DGMR for the Dutch Standards organisation NEN. The example calculations below were made using the software.

Within the Building Decree 2012 rules for different flow capacities are giving depending on the maximum openings angle of a door. These figures are not well validated and suggest an accuracy that cannot be proved. Within NEN 6089 in case of a fire people are directly projected in front of the exit doors of a compartment. The distance to be walked or differences in floor levels within a compartment are ignored. The Building Decree 2013 takes these effects in account which suggest accuracy that is not important at all but influence the outcome highly in some premises.

Also the time to evacuate the smoke compartment were the fire started is returned to 1 minute instead of 1,5 minute. In international perspective there is no reason for such a severe requirement.

The outcomes of the Building Decree 2012 calculations are much more severe than that of calculations by NEN 6089. In practise this lead to a lot of discussions and to unnecessary building costs and pressure on the income of a company because of diminishing the amount of people that is permitted in the premises.

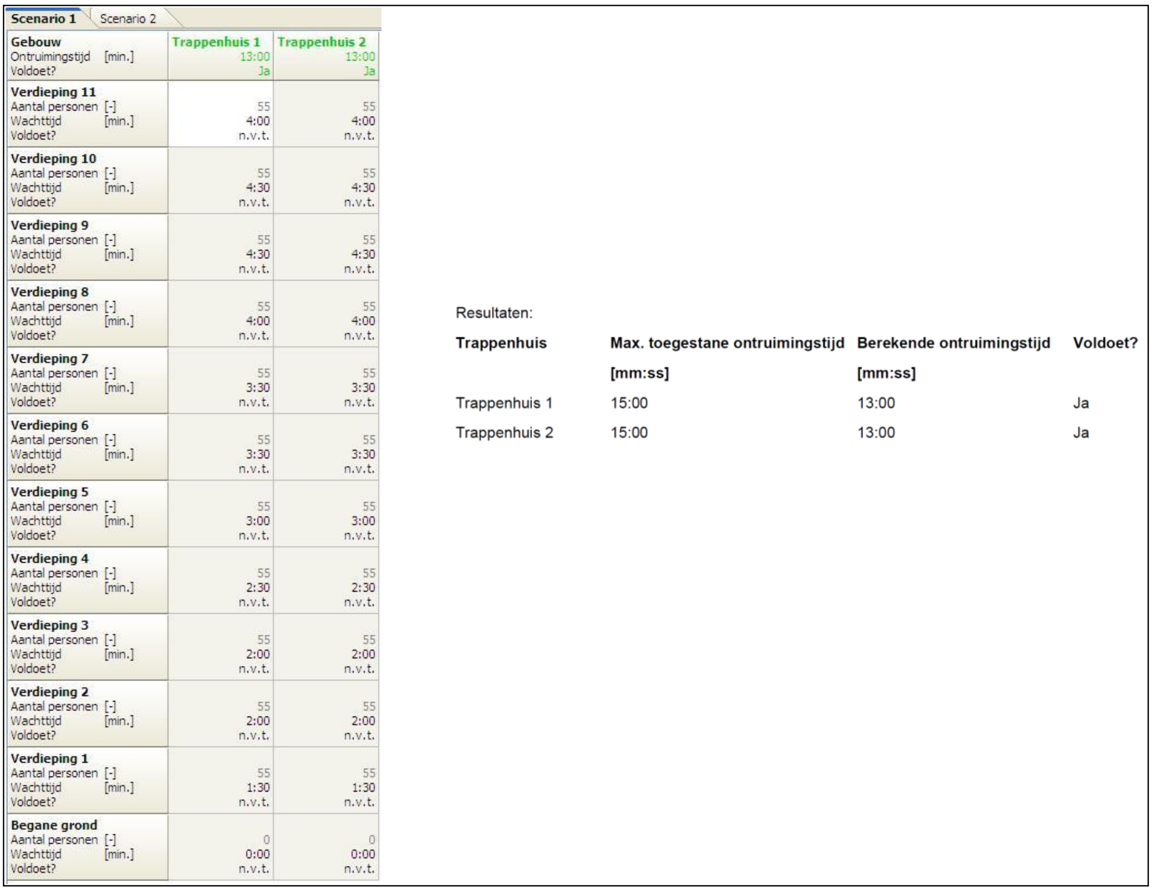
EXAMPLES

Example calculations are presented that correspond to a worked example in ADB par. 4.25, an office building designed for simultaneous evacuation. The

building has 11 office storeys above the ground floor, each of two stairs serving 600 persons, distributed evenly over the storeys. The required stair width according to ADB is 1100 mm.
For the purpose of this paper, two scenarios are selected to illustrate the method. In an actual building project permit application, the applicant must make plausible that all relevant scenarios have been tackled, and that all show compliance.
The main parameters used to make the calculations according to NEN 6089 are reproduced in Table 1.

Table 1
Calculation parameters, simultaneous evacuation

Parameter	Value
Scenario	No fire
Stair width	1100 mm
Landing dimensions	2500 mm x 1100 mm
Number of treads per storey	18
Number of persons on each storey	110
Total number of persons	990
Distribution of persons over staircases	55/55 on all floors
Protection level	EI30
Evacuation type	simultaneous



Scenario 1 | Scenario 2

	Trappenhuis 1	Trappenhuis 2
Gebouw		
Ontruimingstijd [min.]	13:00	13:00
Voldoet?	Ja	Ja
Verdieping 11		
Aantal personen [-]	55	55
Wachttijd [min.]	4:00	4:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 10		
Aantal personen [-]	55	55
Wachttijd [min.]	4:30	4:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 9		
Aantal personen [-]	55	55
Wachttijd [min.]	4:30	4:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 8		
Aantal personen [-]	55	55
Wachttijd [min.]	4:00	4:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 7		
Aantal personen [-]	55	55
Wachttijd [min.]	3:30	3:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 6		
Aantal personen [-]	55	55
Wachttijd [min.]	3:30	3:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 5		
Aantal personen [-]	55	55
Wachttijd [min.]	3:00	3:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 4		
Aantal personen [-]	55	55
Wachttijd [min.]	2:30	2:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 3		
Aantal personen [-]	55	55
Wachttijd [min.]	2:00	2:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 2		
Aantal personen [-]	55	55
Wachttijd [min.]	2:00	2:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 1		
Aantal personen [-]	55	55
Wachttijd [min.]	1:30	1:30
Voldoet?	n.v.t.	n.v.t.
Begane grond		
Aantal personen [-]	0	0
Wachttijd [min.]	0:00	0:00
Voldoet?	n.v.t.	n.v.t.

Resultaten:

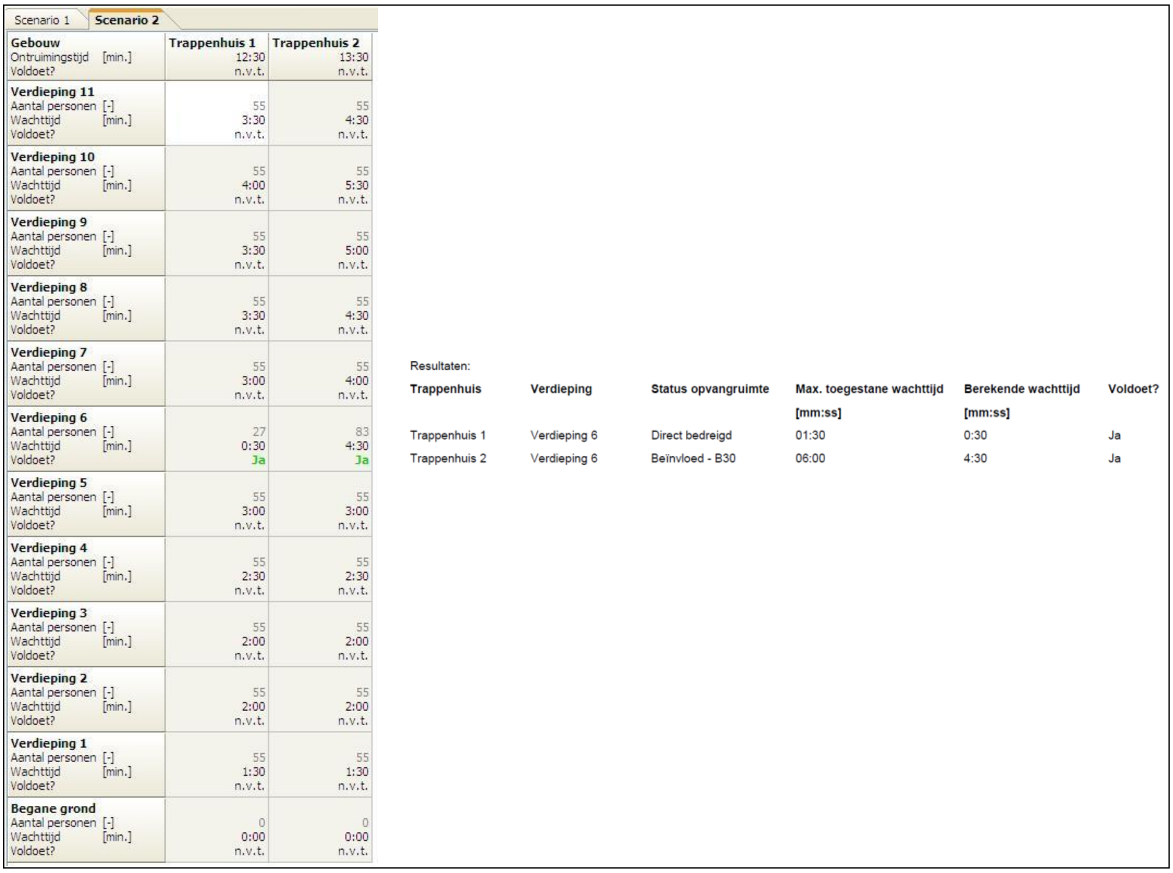
Trappenhuis	Max. toegestane ontruimingstijd [mm:ss]	Berekende ontruimingstijd [mm:ss]	Voldoet?
Trappenhuis 1	15:00	13:00	Ja
Trappenhuis 2	15:00	13:00	Ja

Explanation: gebouw: building; Verdieping: floor; wachttijd: waiting time; trappenhuis: staircase; aantal personen: amount of people; begane grond: ground floor; voldoet: satisfied; max. toegestane ontruimingstijd: maximum permitted egress time of the building; berekende onrruimingstijd: calculates egress time; ja: yes.

Figure 3. Results for scenario 1, simultaneous evacuation

The results for the ‘no fire’ scenario 1 are presented below. The screen dump shows the results for both staircases. Waiting times before the last of the 55 persons assigned to each staircase has entered the staircase increase from 1.5 min on the first floor, to 4 minutes on the highest floor. The overall evacuation time is 13 minutes. In the no fire scenario, waiting times are considered irrelevant. The report section reproduced to the right of the screen dump checks only the staircase evacuation times against the 15 minutes limit.

Scenario 2 introduces a fire in an area served by staircase 1 on storey 6. The storey is assumed to be separated in two smoke or fire compartments. Half of the occupants of the directly threatened compartment served by staircase 1 now evacuate to staircase 2, bringing the distribution on that storey to 27/83. allowed 1.5 minutes. The waiting time at staircase 2 is 4.5 minutes. Because this is higher than the allowed 1.5 minutes for the directly threatened compartment, an open plan configuration is not acceptable. The waiting time is also higher than 3.5 minutes, and as a consequence a smoke resistant (E20) separation is not sufficient. With a EI30 fire resistant separation the maximum waiting time increases to 6 minutes, which is not exceeded The overall evacuation time is slightly reduced for staircase 1 and slightly increased for staircase 2, but since no limit is set to evacuation time in a fire scenario these are irrelevant for the overall judgment. The report section reproduced to the right of the screen dump checks only the waiting times on the fire storey times against the 1.5 minute limit for the directly threatened compartment, and against 6 minutes for an EI30 protected 'influenced' compartment.



Scenario 1 | Scenario 2

	Trappenhuis 1	Trappenhuis 2
Gebouw		
Ontruimingstijd [min.]	12:30	13:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 11		
Aantal personen [-]	55	55
Wachttijd [min.]	3:30	4:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 10		
Aantal personen [-]	55	55
Wachttijd [min.]	4:00	5:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 9		
Aantal personen [-]	55	55
Wachttijd [min.]	3:30	5:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 8		
Aantal personen [-]	55	55
Wachttijd [min.]	3:30	4:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 7		
Aantal personen [-]	55	55
Wachttijd [min.]	3:00	4:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 6		
Aantal personen [-]	27	83
Wachttijd [min.]	0:30	4:30
Voldoet?	Ja	Ja
Verdieping 5		
Aantal personen [-]	55	55
Wachttijd [min.]	3:00	3:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 4		
Aantal personen [-]	55	55
Wachttijd [min.]	2:30	2:30
Voldoet?	n.v.t.	n.v.t.
Verdieping 3		
Aantal personen [-]	55	55
Wachttijd [min.]	2:00	2:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 2		
Aantal personen [-]	55	55
Wachttijd [min.]	2:00	2:00
Voldoet?	n.v.t.	n.v.t.
Verdieping 1		
Aantal personen [-]	55	55
Wachttijd [min.]	1:30	1:30
Voldoet?	n.v.t.	n.v.t.
Begane grond		
Aantal personen [-]	0	0
Wachttijd [min.]	0:00	0:00
Voldoet?	n.v.t.	n.v.t.

Resultaten:

Trappenhuis	Verdieping	Status opvangruimte	Max. toegestane wachttijd [mm:ss]	Berekende wachttijd [mm:ss]	Voldoet?
Trappenhuis 1	Verdieping 6	Direct bedreigd	01:30	0:30	Ja
Trappenhuis 2	Verdieping 6	Beïnvloed - B30	06:00	4:30	Ja

Explanation: gebouw: building; Verdieping: floor; wachttijd: waiting time; trappenhuis: staircase; aantal personen: amount of people; begane grond: ground floor; voldoet: satisfied; max. toegestane ontruimingstijd: maximum permitted egress time of the building; berekende onrruimingstijd: calculates egress time; ja: yes.

Figure 4 Results for scenario 2, fire on storey 6

ANALYSIS

These examples illustrate how the model values alternative egress paths in specific scenarios if they are protected from the location of the fire source. This makes it possible to go beyond the strict capacity method without losing sense of the safety of the design. The examples illustrate that the method does not sanction occupant loads far above the strict capacity of the staircases. Even if the directly threatened compartment can then evacuate within the limit of 1.5 minutes, the other compartments on the fire storey will easily slip beyond the maximum of 6 minutes.

Some relief of this is offered in situations with very uneven occupant load (a heavily loaded storey with almost empty storeys directly below and above can evacuate very fast). Phased evacuation is also very efficient in guaranteeing free staircases.

The recently published standard has gone through only a limited testing period. As practical results become available from building projects with its introduction in the building regulations, the model and its parameters will face a first large scale reality check. It should be expected that modifications are needed to satisfy both safety targets and economy.

CONCLUSIONS

The newly published Dutch standard NEN 6089 was developed to fill the need for a more practical design rule for staircase sizing than the strict capacity method that has been mandatory in the Netherlands until April 2012.

This paper discusses its design, and analyses how it compares to approaches in other countries. The new method offers a distinct advantage over the existing methods in dealing explicitly with the time that people have to wait before they can enter a protected staircase, applying limits dependent on the level of protection offered by smoke resistant or fire resistant separating structures.

Practical experience with the method is growing because the standard can be used from the end of 2011.

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