Assessment of pre-fabricated bathrooms from the 1990s

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ABSTRACT

In Denmark many older dwellings have or had no proper bathroom. Therefore, a lot of dwellings have been refurbished with bathrooms over the past 40+ years. There is great focus on establishment of bathrooms for several reasons. One is that bathrooms are expensive; one of the most cost-intensive tasks when building or renovating dwellings. Moreover, bathrooms are vulnerable because of high moisture load combined with complex solutions. Many problems with bathrooms have been registered and unfortunately not only the bathroom itself is damaged but also often adjoining building elements.

In the 1990s a Danish project called Project Renovation focused on the development of cheap and durable pre-fabricated bathrooms. These bathrooms included light- and heavy-weight structures as well as assembly kit and whole cabins.

The aim of the current investigations of bathrooms from the Project Renovation was to evaluate the performance and durability of the developed pre-fabricated bathrooms after 15-20 years of use. A systematic condition assessment was developed for the bathrooms inspections. Three bathrooms were investigated for each bathrooms solution:

- Heavy-weight whole concrete cabins
- Heavy-weight assembly kit with fibre reinforced concrete bottoms
- Light-weight assembly kit of fibre reinforced concrete elements

The use of an inspection scheme implied that a consistent visual assessment of the bathrooms included constructions, installations and measurable conditions, e.g. moisture content and crack sizes, was obtained. Each parameter in the inspection scheme was judged on a 5 step ranking scale of conditions and interrelated degree of consequences.

The investigation of the 9 bathrooms indicated a generally high quality of the bathrooms. Many of the registered failures may be eliminated with increased maintenance. Specifically, mould growth on resilient silicone sealant was a problem in wet zones. More critically was the registered mould growth in the ceiling, where the mechanical ventilation was low. Both issues could to some degree be prevented by more focus on user habits and maintenance in the bathroom. Cracked tiles were also detected. For the heavy-weight assembly kit of fibre reinforced concrete bottoms this might have been caused by the underlying construction of the bottom with a plinth on top of which the walls were placed.

The non-destructive investigations revealed no causes for failures e.g. the above mentioned cracks. Therefore definitive conclusions are difficult to make based on the visual inspection, hence the methodology might be questioned if adequate for a durability assessment.

KEYWORDS: Pre-fabricate, bathroom, wet room, inspection methodology.

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1 INTRODUCTION

Bathrooms are construction wise perhaps the most complicated room to build. Many professions have to collaborate, thus functions, technical service installations, tiles, joints etc. must fit together. Constructing bathrooms in new buildings are easier compared to refurbishing bathrooms in existing buildings. Therefore, the bathroom is also the most expensive room per square meter to construct regardless of whether it is a new building or refurbishment of an existing building. Normally, in existing buildings there is very limited space available for establishment of a bathroom.
The many functions and installations require that special care is taken to minimise the risk for damages and especially water leakage. Given that bathrooms are exposed to high water impact on floor and walls and high relative humidity, it is normally necessary to install a water tight membrane in order to protect vulnerable materials. In general constructions of inorganic materials are considered as more resistant against moisture than organic materials. For instance, wood is vulnerable to decay and mould if leakages occurs in flooring, wall covering or installations. Worst case of leakages will be water ingress to neighbouring construction increasing the risk of water damages. Such water damages may lead to a costly repair if they are not detected and eliminated in reasonable time. Therefore, it is necessary to inspect constructions and installations on a regular basis e.g. as a part of maintenance dependent on performance measurements.

Eriksen *et al*. [1991] investigated 44 newer bathrooms and reported 205 failures related to the zone with highest water load. These 205 failures were divided into 7 typical groups, i.e.,

1. Leakage at pipes passing through wall, floor and ceiling (59 failures)
2. Joint defects (44)
3. Moisture accumulation (30)
4. Cracks (25)
5. Lack of adherence (20)
6. Depression and lump (16)
7. Subsidence (11)

The findings from the 44 investigations established a need for improving the quality of bathrooms. Hence, a development programme called Project Renovation was initiated with the intention of improving the quality of bathrooms and simultaneously limit the cost of construction.

The Project Renovation programme was initiated for promotion of trade and was implemented from 1994-1998, aiming at developing and testing models for industrialised renovation/refurbishment, which embraced products, methods and processes. In the framework of Project Renovation 9 categories of projects were identified, where bathrooms was one of them. Project Renovation was conducted during the period where a major urban renovation took place in Copenhagen. The urban renovation aimed at improving the quality of housing and thereby bringing toilets and showers from the back stairs or small broom cupboards and backyards into each apartment, see Fig. 1.

Common for Project Renovation was the use of pre-fabricated bathrooms and in total 19 different bathroom solutions were installed. The bathrooms can be grouped as light- or heavy-weight bathroom with further 3 subdivisions, i.e., in situ, assembly kit and whole cabins. The Project Renovation "*5 years inspection report*" [MHUR 2004] concluded that 90% of the bathroom solutions were implemented in practice. For some of the bathrooms the water tightness was investigated in laboratory before the bathroom was installed in buildings. Furthermore, an advantage of pre-fabricated bathrooms is that large parts of the quality control of the components are implemented at workshop production. Nevertheless, a follow up on the performance of these 19 bathrooms projects was never executed.

Figure 1. Example of a) a toilet placed in a small broom cupboard before urban renovation and b) an enlarged bathroom after urban renovation with the shower to the left of the door.

The present work is part of a research project that follows up on three different bathroom types installed during the 1990s and 2000s in apartment buildings. The results contribute to the future guideline on how to construct bathrooms in new and existing apartment buildings. The work reported, focuses on the methodology used to inspect the bathrooms and the outcome of these inspections of three different prefabricated bathrooms types. The conducted condition assessments aim at evaluating the general conditions and register damages of 15-20 years old bathrooms.

2 BATHROOMS

Today's requirements to water tightness of bathrooms are not necessarily fulfilled for bathrooms constructed during Project Renovation. However, many of these bathrooms have some sort of water tightness system. Figure 2 illustrates today's design requirements for a bathroom with shower unit; however, if the bathroom is smaller than 3.25 m^2 or 1.3 m wide the walls have to be treated as wet zone [Brandt 2001].

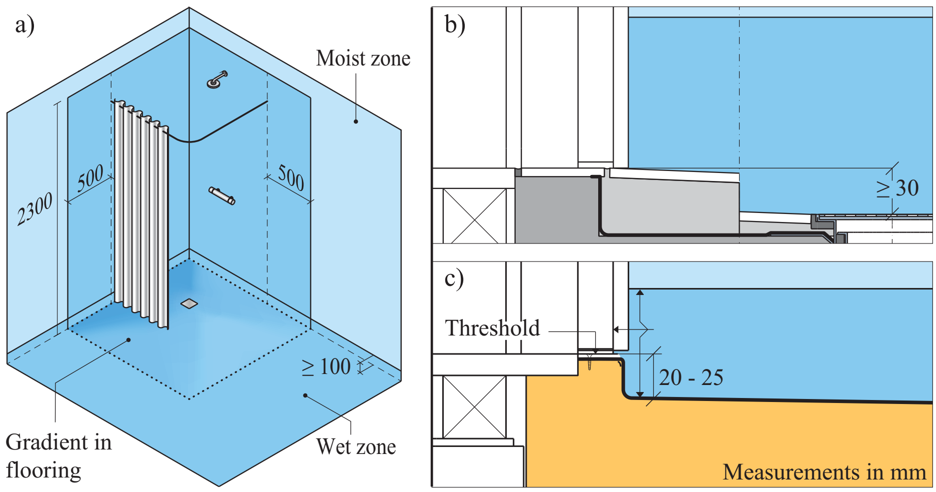

Figure 2. a) Moist and wet zone in a bathroom with a shower unit, where wet zone encompasses the entire floor and walls around the shower unit until 500 mm from its demarcation. Wet zone on walls are from floor to ceiling, however in tall rooms the area above normal room height can be considered as moist zone. No penetration of pipes is allowed in the area with a gradient in the flooring. A basin is required i.e. b) 30 mm height difference between the top of the drain and the floor at the door or alternatively c) 20 mm between top of floor and lower edge of threshold [Brandt 2001].

The bathrooms presented in this paper are all installed in typical apartment buildings from about the 1900. This signifies that the bathroom floors were installed on top of the existing floor divisions constructed of wooden beams with clay pugging.

2.1 Heavy-weight whole concrete cabins

The bathrooms are room size concrete bathroom cabins approx. 1.9 m^2. They are mounted on top of each other starting on a foundation for the cabins in the basement. The cabins were installed as two neighbouring bathrooms followed by concrete elements for construction of a new kitchen (Fig 3). The roof, façade and floor division was demolished to allow for the cabin bathroom and kitchen concrete deck. The bathrooms were fully equipped from factory with 150 x 150 mm tiles on floor and walls. The suspended ceiling could easily be removed giving access to installations. The service shaft is placed outside the bathroom with access from the living room. The bathrooms are ventilated by mechanical exhaust ventilation.

a) b)

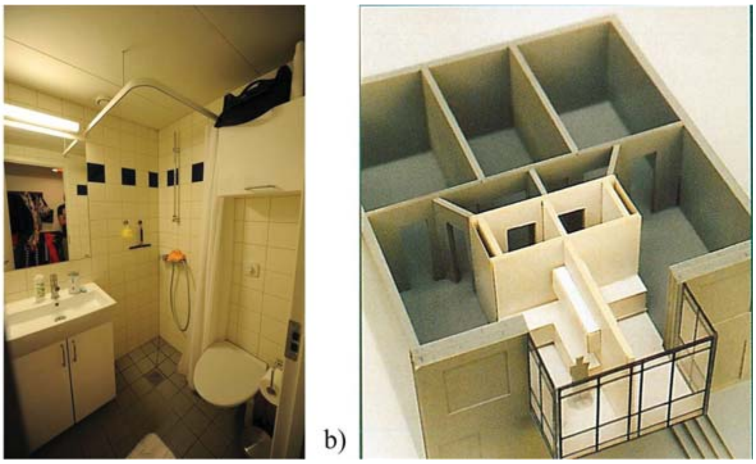

Figure 3. a) Bathrooms made as heavy-weight whole concrete cabins with dimension: 1.5 m x 1.4 m, and b) illustrates the bathroom cabins and kitchens given in light colours [MHUR 1999a].

2.2 Heavy-weight assembly kit with fibre reinforced concrete bottom

The sizes of the bathrooms are approx. 2.5 m^2, and the bathrooms are located inside the apartments, having only a door but no windows. The floor construction is of fibre reinforced concrete with a small plinth (Fig. 4), on which the wall elements made from aerated concrete are placed.

a) b)

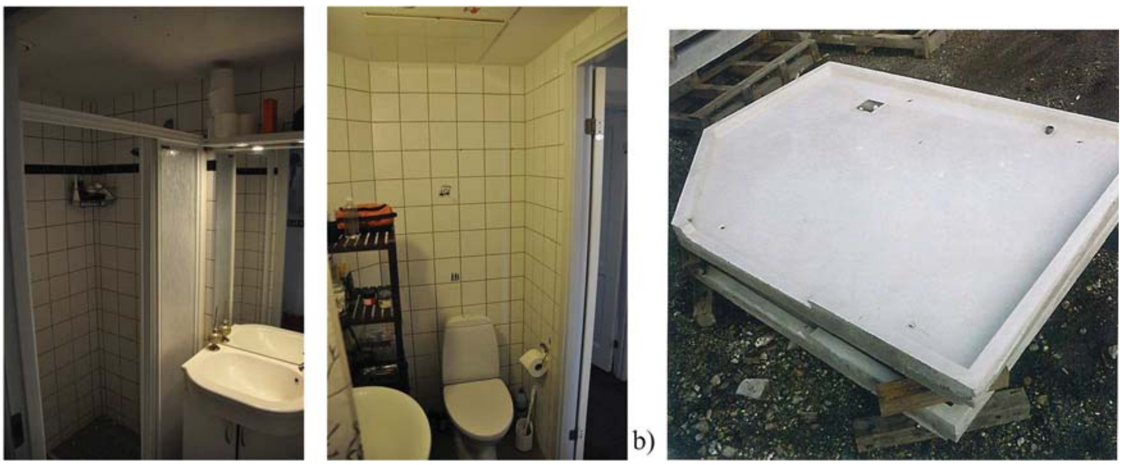

Figure 4. Heavy-weight assembly kit with fibre reinforced concrete bottom with dimension: 2.3 m x 1.2 m, and b) the fibre reinforced concrete bottom [MHUR 1999b].

In this pilot project the floor elements were placed on a new floor division of steel and gypsum, and a change in the floor division for this type of bathroom was expected in future projects. Also the façade must be partly demolished to render possible the access of the floor construction. The floor and the wall are covered with 150 x 150 mm tiles. Installations above the suspended ceiling are accessible through two hatches of approx. 500 x 500 mm. The service shaft is placed outside the bathroom with access from the kitchen. The bathroom is with mechanical exhaust ventilation. Ventilation and other piping is lead through the walls. In the pilot project the kitchen was enlarged entailing the possibility of making larger bathrooms.

2.3 Light-weight assembly kit of fibre reinforced concrete elements

The bathroom size is approx. 1.8 m^2 and the bathrooms are located inside the apartments; hence no windows or doors to the outside were present. The bathroom is constructed of glass fibre reinforced concrete elements for floor, walls, corners and ceiling. The many components are assembled in the apartments as shown in Fig. 5. The elements could be brought up the stairs and into the apartments without destructive action of the building envelope. The wall surfaces are covered with tiles ca. 150 x 150 mm contrary to the small ca. 50 x 50 mm tiles on the bathroom floor. The ceiling was not treated and can easily be disassembled by loosening a few screws. Mechanical exhaust ventilation was installed in the ceiling and other piping were lead on the outside of the elements to a service shaft that was accessible from the kitchen.

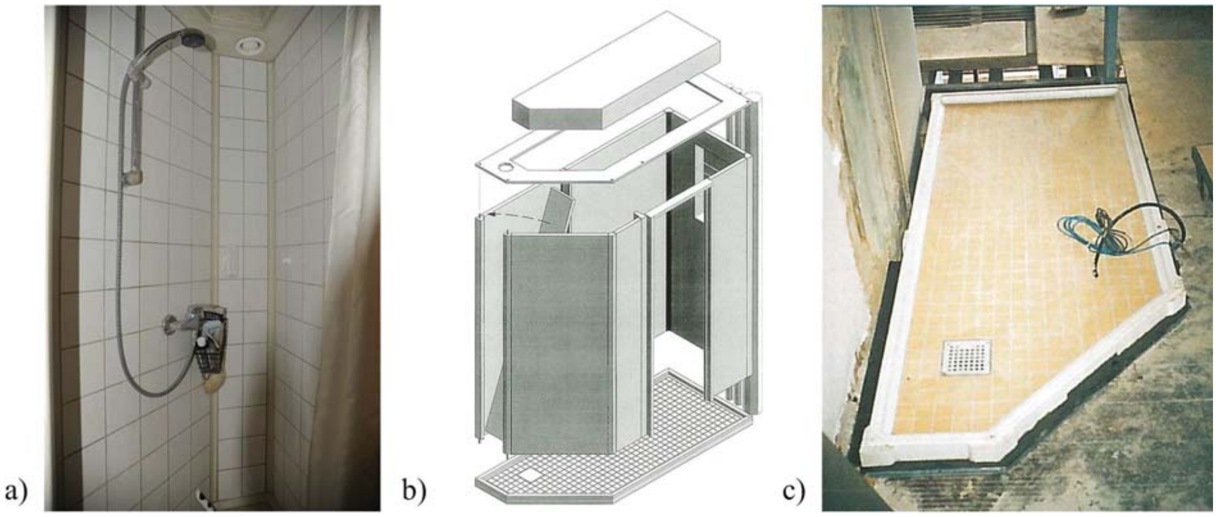

Figure 5. a) View in the shower area of the bathroom with dimension: 2.1 m x 0.9 m. b) Illustration of the assembly part for the bathroom and c) the bathroom floor [MHUR 2002].

3 METHODOLOGY

A systematic condition assessment was developed for inspection of the bathrooms. The condition assessment relates to damage investigation and describes the procedure used for field investigation of bathrooms. An inspection scheme was developed based on the Nordtest Report [Brandt 1997], thus a consistent evaluation of each bathroom was achieved independent of the investigator. By means of the scheme, visual inspections are performed systematically to register the conditions and damages of several predefined items.

The items included in the conditions assessment are

- *Constructions* – flooring, wall covering and ceiling as well as construction configuration
- *Installations* – water and drainage, electrical, ventilation, service shafts
- *Measureable conditions* – e.g. moisture content in wooden items and cracks in tiles

The systematic condition assessment includes a 5 step ranking of condition and interrelated degree of consequence for the structures and installations, as shown in Table 1. The ranking was conducted for floor, walls, ceiling, doors/windows, building services in bathrooms and service shaft. Furthermore, the inspection scheme included a plan drawing of the bathroom.

Table 1. Ranking of condition and interrelated degree of consequence for the inspected structures and installations.

Condition N/A	Not applicable or it is not possible to do the inspection
Condition 0	Very good: No signs of abnormal wear or damages
Condition 1	Good: Need for minor maintenance
Condition 2	Bad: Need for maintenance and minor repair
Condition 3	Very bad: Evident symptom of failure or damage repair needed

3.2 Field investigation

The bathroom inspections were conducted in randomly chosen apartments, where the only criterion was that the bathrooms were constructed during Project Renovation. The investigator had no interest in the property and apartments, hence no destructive investigation were conducted. However, moisture content in wood and cracks were measured if appropriate.
Inspections were conducted in 3 bathrooms for every type of bathroom design and the chosen bathrooms were chosen based on the occupant’s willingness to participate in the project. This random selection was considered as sufficient to obtain bathrooms with different use patterns and damages.

Prior to the on-site inspections supplementary information was collected. The information included location, addresses, information regarding refurbishment and repair, drawings and descriptions. Additional information was gathered from interview of occupants, executive committees and administrators.

The visual inspection was conducted according to the inspection scheme with associated ranking of the conditions, see example in Table 2. The field investigation were conducted systematic comprising floor, walls, ceiling, doors and windows, drainage, pipe penetrations in floor and walls, sanitary equipment, fixtures, visible pipes, ventilation, electrical installations and access above ceiling and in service shafts. Furthermore, the bathroom layout was sketched with the general installation and photos were taken for documentation of the bathroom and its possible damages.

Table 2. Excerpt of an inspection scheme for a flooring assessment.

Subject	**Condition**	**Assessment/Observation**
Flooring		Tiles, small
Surface material condition	2	1 tile cracked at gully
Water tightness of floor and wall	0	
Basin	0	5 cm, ca. 3 cm resilient silicone sealant
Joints/welded joints	0	Resilient silicone sealant at arc-corner and floor/wall
Resilient silicone sealant	0	
Surface easy to clean	0	Small tiles

4 RESULTS

The inspections lead to the conclusion that in general the conditions of the bathrooms were good e.g. all bathrooms had a basin and shower unit without moisture sensitive materials. However, the resilient silicone sealants were often attacked by mould especially in the wet zone, loss of adherence and cracks, as shown in Figs 6a and 6c. Mould growth was also detected in the ceiling and mortar joints in the wall of one bathroom as shown in Fig 6b. The mechanical ventilation was judged very low in this particular bathroom contrary to many other bathrooms. Other failures registered in the wet zone were holes that were not repaired after removal of hooks etc. Cracked tiles were registered close to the gully (Fig 6a) and for the heavy-weight assembly kit with fibre reinforced concrete bottom on the wall about 30 mm above the floor (Fig 6d). This bathroom floor was constructed with a small plinth and the cracks were observed at different locations in each bathroom.

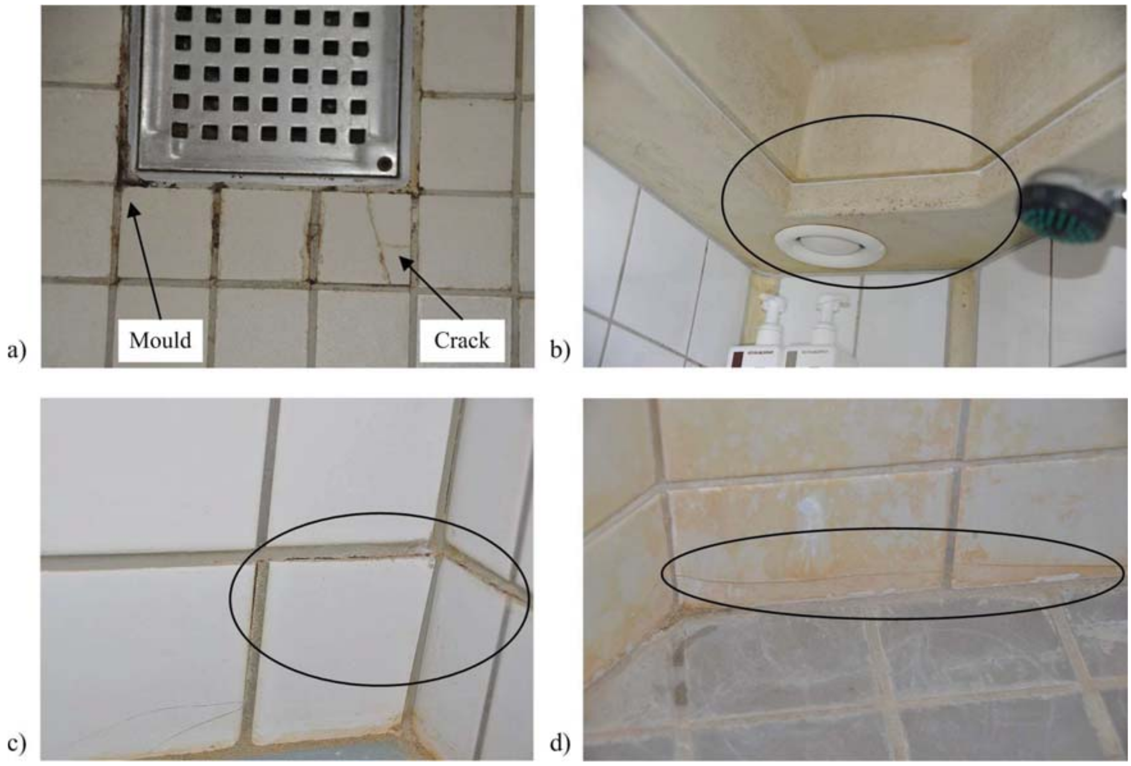

Figure 6. a) Black discolouration in resilient silicone sealant around floor gully due to extensive mould growth; and cracks in tiles on floor. b) Mould growth in a ceiling made from fibre reinforced concrete due to low ventilation (high relative humidity). c) Loss of adherence and crack in resilient silicone sealant. d) Cracks in wall tiles in the height of the plinth.

A variation of the design of the service shafts was registered i.e. size of hatches, accessibility and space for future installations. Not all service shafts had an alarm system to report if leakages were present. For the heavy-weight whole concrete cabins drain pipes were lead from each shaft to the basement but still without an alarm system other than water penetrating will be visible in the basement.

5 DISCUSSION AND CONCLUSION

In general the quality of the bathrooms is high considering their age of 15-20 years. Many of the failures registered could have been avoided with increased maintenance, e.g. replacement of tiles with cracks and silicone sealant with mould growth. One reason for the high quality of the bathrooms relates to their layout, where the wet zone is separated from critical assemblies and moisture sensitive materials such as wooden panels are kept in the moist zone. The influence of mechanical ventilation is important to the indoor environment in these small bathrooms without venting opportunities to the outside. This is assessed to be the reason for mould growth in the ceiling of one bathroom with reduced ventilation as compared to the other bathrooms. Again this might be related to the occupant's ability of maintaining the bathroom and the ventilation system i.e. the fan.

Perhaps the most critical failure was registered in the heavy-weight assembly kit of fibre reinforced concrete bottom with a plinth. As the crack was observed on different walls but in the same height in

the three inspected bathrooms, the crack might be related to the plinth on the bottom element (Figs. 4b and 6c). However, the cracks could also be related to movement in the building. As no destructive inspections were conducted, the correct reason for the crack cannot be stated.
The visual inspections can be questioned if adequate for an evaluation of the construction of bathrooms. The inspection did not reveal any underlying failure in the construction of the building, which could have a high economic impact for the occupant or building owner. However, the inspections of the bathrooms are conducted on a uniform basis with a pre-defined rating system. The developed scheme encompasses the most important items for a conditions assessment of bathrooms.

The concluding remarks are that the nine inspected bathrooms after 15-20 years in general are in good condition. However, as it only has been visual inspections a need for destructive investigation might be needed in (a few) certain cases where the reason for damages is not clear.

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