

Ignacy Jakubowicz
Torbjörn Klaesson

Influence of Wet Concrete and Some Specific Components on the Durability of PE-films

Abstract

In certain constructions PE-films commonly used in buildings are in contact with wet concrete during their service life. The alkaline environment created by wet concrete accelerates the degradation of films. In the previous investigation it was shown how low-density polyethylene (LDPE) films, stabilised with common stabilisers, are affected by prolonged action of wet concrete. In the present work, the influence of some components in concrete on durability of LDPE-films was investigated, e. g. iron sulphate, various alkaline solutions and deionised water. The investigation shows that high alkalinity of the fresh concrete is of significant importance for the ageing time. The t₅₀-values corresponding to the exposure with "old" concrete as top prism were of the same magnitude as the values from the moist air exposure. The same result was also achieved using sheets of glass instead of old concrete prism on the top.

Furthermore, the ageing time in some aquatic solutions was in the range between ageing in contact with fresh wet concrete and in moist air exempt for solutions containing iron sulphate. Our conclusion is that there are components in concrete that accelerate degradation of PE-film while iron sulphate seems to prevent PE-film from degradation.

The most aggressive aquatic solution was constitute by deionised water which seems to be even more aggressive than alkaline solutions like NaOH and CaO. Elongation at break of individual test specimens nearest to the water surface show up the lowest values. This is probably due to a bigger supply of oxygen in the uppermost part of water which causes strongest oxidation.

Key words: polyethylene, accelerated ageing, wet concrete, aquatic solution, durability

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**Swedish National Testing and
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Postal address:
P.O. Box 857, SE-501 15 BORÅS,
Sweden
Telephone +46 33 16 50 00
Telefax +46 33 13 55 02

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1 Introduction

Polymer materials are oxidised by atmospheric oxygen like most other organic compounds. This process is called autooxidation. Antioxidants are used to minimise the rate of oxidation. The addition of antioxidants such as hindered phenols and amines is widely used, which retards oxidation and thus the ageing. The main mechanism of the oxidation reactions and stabilisation in air is well known and described [1, 2, 3]. The problem with physical depletion of the stabilisers by migration, extraction, etc. has also been investigated [4, 5, 6].

PE-films, foils and sheets are commonly used in buildings as construction films, vapour barriers, damp-proof membranes, safety sheets, parquet floor underlay, ground sill insulation, etc. In certain constructions, these products are in contact with wet concrete during their service life. The alkaline environment created by wet concrete accelerates the degradation due to chemical or physical depletion of stabilisers which leave the material unprotected against autooxidation (7). In the previous investigation it was shown how low-density polyethylene (LDPE) films, stabilised with common stabilisers are affected by prolonged action of wet concrete.

In this work, the influence of some components in concrete on durability of LDPE-films is investigated, e. g. metal ions, various alkaline solutions and deionised water.

2 Experimental

2.1 Materials - PE-films

The material used in this study was based on low density polyethylene (LDPE) from Neste Oy - NCPE 6600 with melt flow rate $MFR_2 = 0,3$ g/min and density 922 kg/m³. Two films were manufactured by Neste Oy in Finland. One film contained only a little amount of a process stabiliser and is designated F2. The second film was additionally stabilised with 0,1 % Tinuvin 622 LD from Ciba-Geigy - a polymeric light stabiliser of the hindered amine type (HALS) and is designated F3. One film was also manufactured by Statoil A.S and contained only a little amount of a process stabiliser and is designated F1. All films were approx. 200 μ m thick.

2.2 Materials - Concrete

The raw materials used in manufacturing of concrete (stones, sand, gravel, and water) contained varying amounts of metal ions. It is known that transition metal ions and many metal complexes increase the rate of both thermal and photo-oxidation by catalytic action. The most active catalysts are such metals which form two ions of similar stability and whose oxidation numbers differ by one (e.g. ions of Fe, Co, Mn, Cu, Cr, Al, Ni, Ti). The ions catalyse the decomposition of hydroperoxides to free radicals. One of the tasks which was investigated in this work was the influence of iron in concrete, on the degradation of PE.

The concrete material used in the experiments was partially of the standard quality K 25 with compression strength 25 MPa and partially concrete manufactured using small stones and cement with various amount of iron sulphate.

The cement used in K 25 contained about two weight percent iron oxide, Fe_2O_3 which is included in the mineral tetra-calcium-aluminium-ferrit. The material also contained between 0,3 and 0,4 weight percent iron sulphate, $FeSO_4 \cdot 2H_2O$ which is normally used in order to reduce Cr^{6+} (allergyforming) to Cr^{3+} . The qualitative X-ray analysis showed that besides iron, small amounts of Al, Ti and Mn could also be identified. The other concrete materials contained the same sort of cement as K25 and iron sulphate as follows: no iron sulphate designated C1, 0,5 % - C2 and 1,0 % - C3.

2.3 Materials - Solutions

The influence of various aquatic solutions on PE has also been investigated. Following solutions were used:

Table 1 Aquatic solutions used for the immersion tests

Solution	Content
1	De-ionised water
2	Saturated CaO solution
3	0,5 weight-% $FeSO_4$
4	Saturated CaO solution + 3,0 weight-% $FeSO_4$
5	"Synthetic cement": 2,81 % KOH, 0,40 % NaOH, 0,26 % Ca SO_4 , 0,10 % Ca (OH) ₂
6	0,5 % KOH, 0,5 % NaOH

2.4 Accelerated ageing

Concrete prisms with dimensions 130 x 110 x 50 mm were placed in glass containers with the dimensions 350 x 200 x 150 mm. The containers were filled with deionized water to a level of roughly 15 mm under the upper edge of the concrete prisms. Test pieces of the PE-films were placed on the top of each of the submerged prism and another concrete prism was placed over the film in order to create a good contact between the wet concrete and the PE-film. An additional test piece of PE-film was placed on the top of each of the uppermost concrete prism. The glass containers were covered with cover sheets of glass and placed in the heating cabinets at 70, 80, and 90 °C. Throughout the tests, the water level was adjusted by refilling with deionized water.

The durability of the PE-films in aquatic solutions has been tested by simple immersion at 90 °C. Glass containers were filled with respective solution, test pieces were placed vertically without any contact to each other and containers were covered with cover sheets of glass and placed in the heating cabinets.

2.5 Elongation at break

A tensile test was carried out in accordance with the Swedish standard SS 24 10 20 with the aid of an Instron 1122 Universal Testing Machine. Five strips of 15 mm width were taken out of each test piece. The speed of elongation was 500 mm/min and the clamping length was 100 mm. The elongation at break values presented are the arithmetic mean value of five measurements if nothing else is mentioned.

3 Results and discussion

Evaluation of changes in the films due to ageing was performed by measurements of elongation at break. From diagrams of elongation at break vs. ageing time, the time needed for the materials to reach 50 % retention of elongation at break (t_{50}) and 0 % retention of elongation at break (t_{100}) was determined.

3.1 Influence of wet concrete

All submerged concrete prisms contained fresh concrete. Pieces of PE-film were placed on top of each submerged prism and another prism (top prism) was placed over the film. Results of accelerated ageing in contact with wet concrete are summarised in table 2.

Table 2 Results of accelerated ageing in contact with wet concrete

Film	Concrete	80 °C, t_{50}	80 °C, t_{100}	90 °C, t_{50}	90 °C, t_{100}	Note
F2	K25	72	100	18	30	1 st investigation fresh concrete in top prism
F2	C1	150	250	45	75	Old concrete in top prism
F2	C2	150	250	45	75	Old concrete in top prism
F2	C3	150	250	45	75	Old concrete in top prism
F2	K25			50	70	Sheet of glass on top
F2	K25			15-20	30-50	Fresh concrete in top prism
F1	C1			70	80	Old concrete in top prism
F1	C2			70	80	Old concrete in top prism
F1	C3			>70	>80	Old concrete in top prism
F3	K25	180	250	58	80	Fresh concrete in top prism
F3	K25			100	200	Old concrete in top prism
F3	C1			100	200	Old concrete in top prism
F3	C3			100	200	Old concrete in top prism

The first investigation (see SP Report 1992:31) shows that the rate of degradation of PE-films in the environment of fresh wet concrete at ambient temperatures was much higher than in moist air. Only fresh concrete was used in the submerged prisms as well as in the top prisms. The importance of having fresh concrete even in the top prisms was not realised at this stage and in the following investigation, old prisms were used as top prisms. The results (t_{50} -values) from exposures with old top prisms are of the same magnitude as for the material aged on the top of the uppermost concrete prisms (moist air). The use of sheets of glass on top instead of concrete prisms gave the same effect as the use of old concrete prisms.

Accelerated ageing in contact with concrete manufactured with small stones and various amount of iron sulphate (C1, C2, C3), and with old top prisms gave the same results as K25 with old top prisms. Otherwise, there were no differences concerning effects of concrete containing various amount of iron sulphate.

3.2 Influence of some aquatic solutions

In order to investigate the importance of some components existing in concrete on the rate of degradation of PE-films, some water based solutions were used. The durability was measured by simple immersion of film F2 in various solutions at 90 °C. Following estimated t_{50} -values were received :

Table 3 Time to 50 % retention of elongation at break in aquatic solutions

Solution	Ageing time in days (t_{50})
Deionised water	21
Saturated CaO solution	28
5 % NaOH solution	32
Synthetic cement	41
0,5 % FeSO_4 solution	>100

All values are in the range between the t_{50} values from exposures in contact with fresh wet concrete (18 days) and in moist air (42 days) with exemption for solutions containing iron sulphate (FeSO_4), see figure 1. Consequently, the conclusion must be that some components in concrete interact to increase the rate of degradation (synergistic effects) or there are some other components in concrete which can accelerate the degradation (e. g. metal ions).

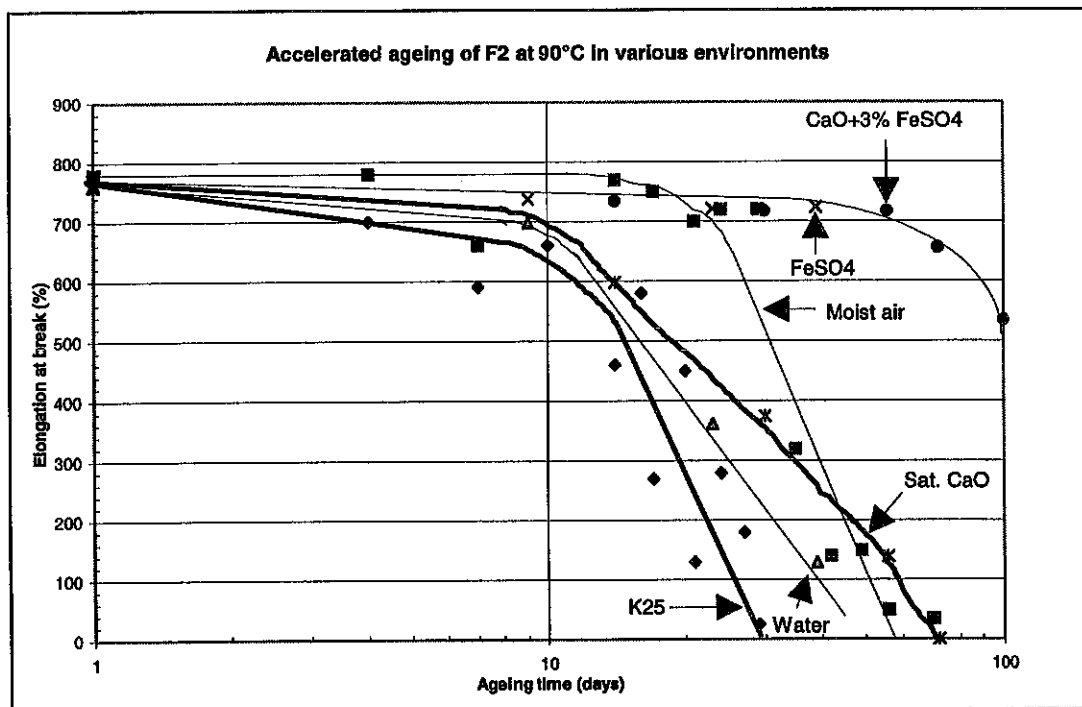


Figure 1 Elongation at break as a function of ageing time in various environments

The most aggressive aquatic environment was constituted by deionised water. In figure 2 comparison is made between effects of exposure in deionised water and in 5 % NaOH-solution.

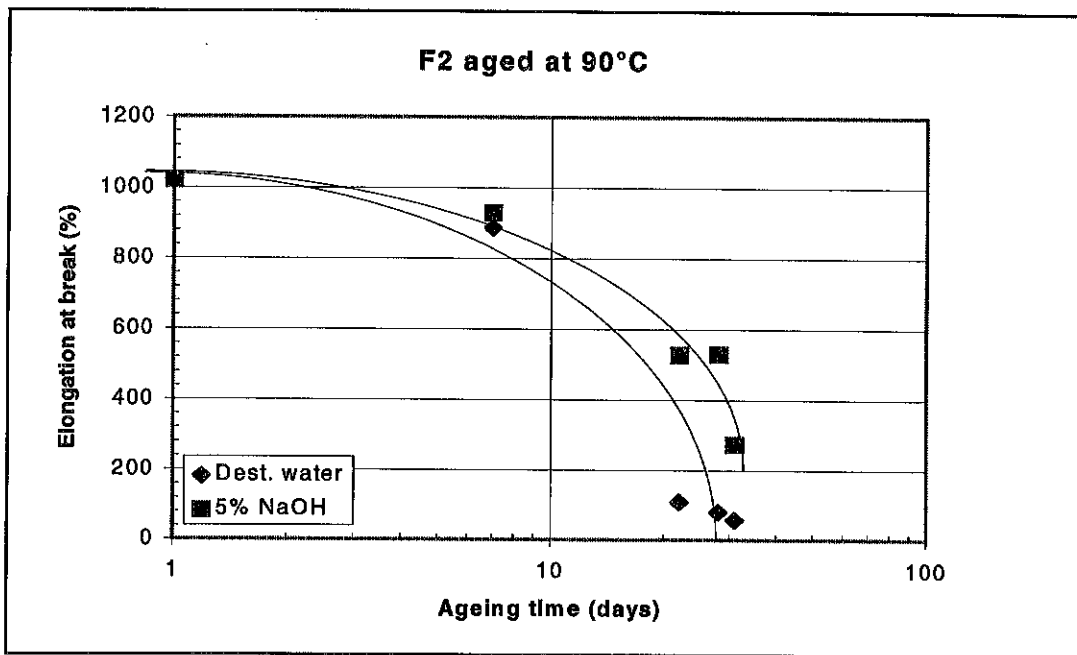


Figure 2 Elongation at break as a function of ageing time in deionised water and in 5 % NaOH-solution

3.3 Influence of deionised water

Accelerated ageing was performed at 90 °C in deionised water using various types of test pieces as shown in figure 3. The purpose was to determine whether there is a correlation between depth of water and rate of degradation. Test specimens were cut and numbered as shown in figure 3.

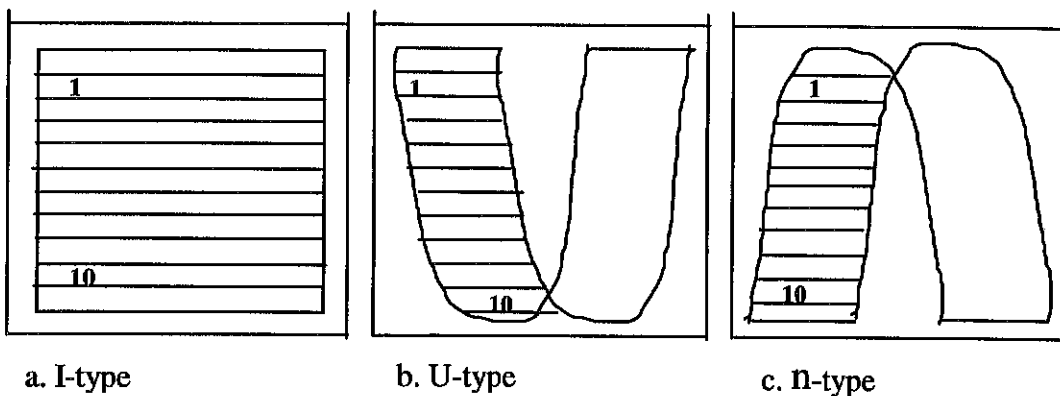


Figure 3 Various types of test pieces of PE-film (F2) used for ageing in deionised water

Time needed for the material (F2) to reach 50 % retention of elongation at break (t₅₀) in deionised water at 90 °C was determined to about 20 days. The results after ageing in deionised water for 28 days show a big fluctuation. Mean values of elongation at break ranges between 90 and 800 %, see table 4. This is probably due to the circumstance that 28 days of ageing constitutes a point on the steep part of the lifetime curve which gives fluctuating results. In figures 4, 5, and 6 it is shown the variation of elongation at break of individual test specimens as a function of the distance from water surface for different types of test pieces (as shown in figure 3).

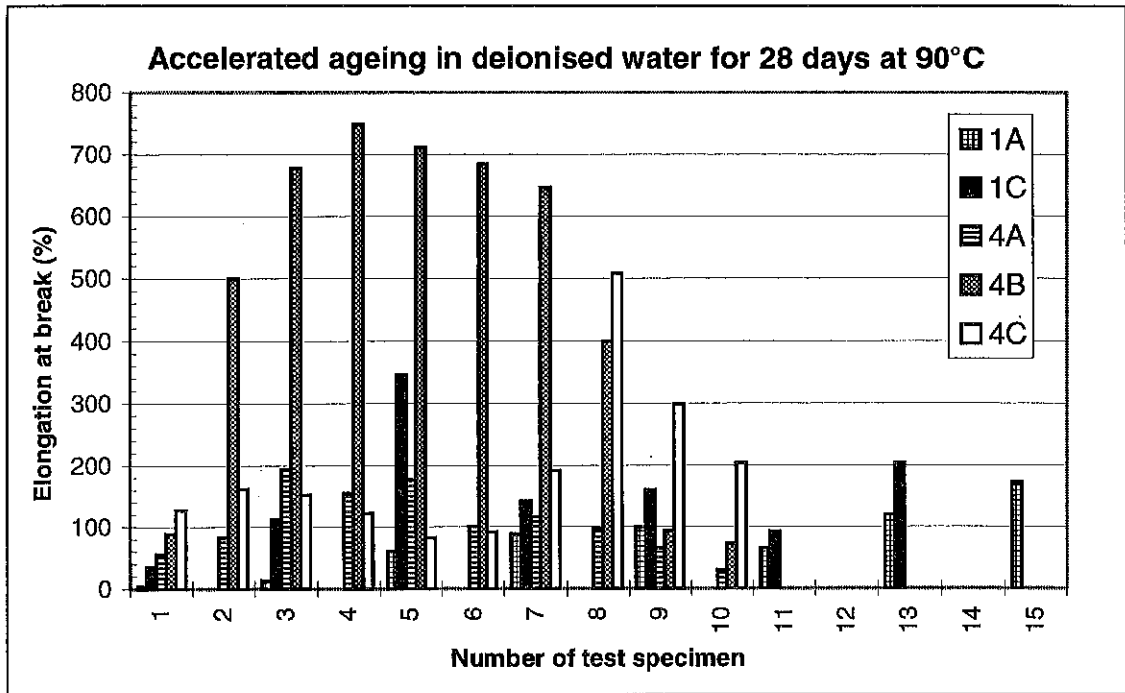


Figure 4 I-type of test pieces of PE-film (F2) aged in deionised water. Test pieces 1A and 1C were immersed in large glass containers, test pieces 4A, 4B and 4C were immersed in small glass containers.

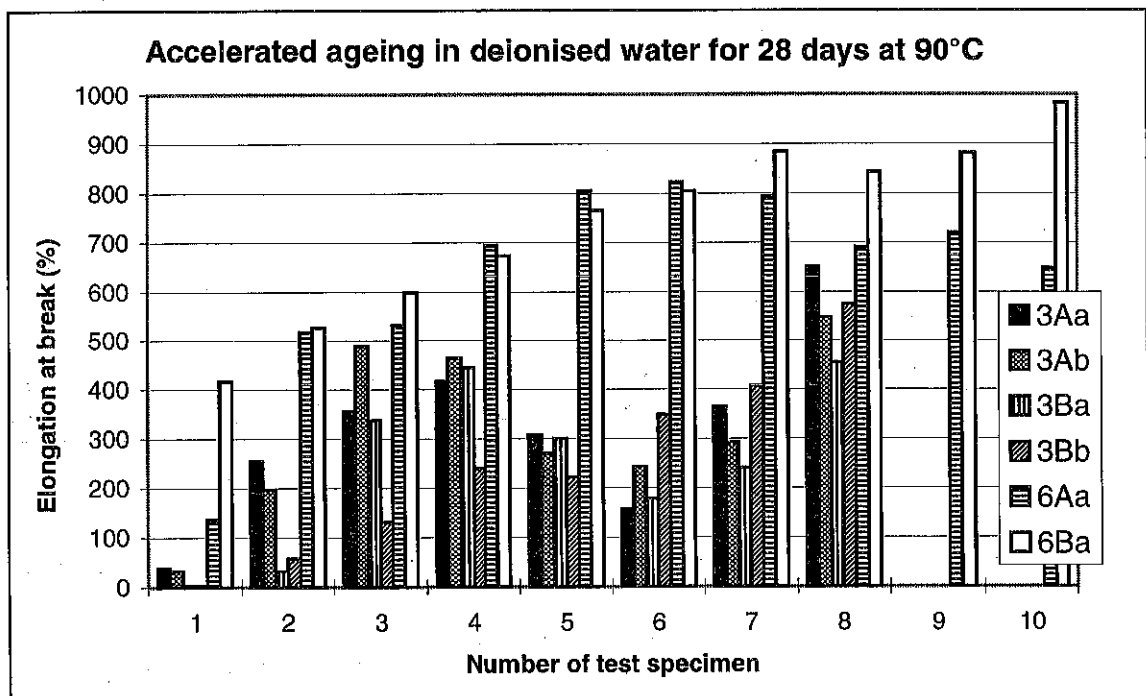


Figure 5 U-type of test pieces of PE-film (F2) aged in deionised water. Test pieces 3 were immersed in large glass containers, test pieces 6 were immersed in small glass containers.

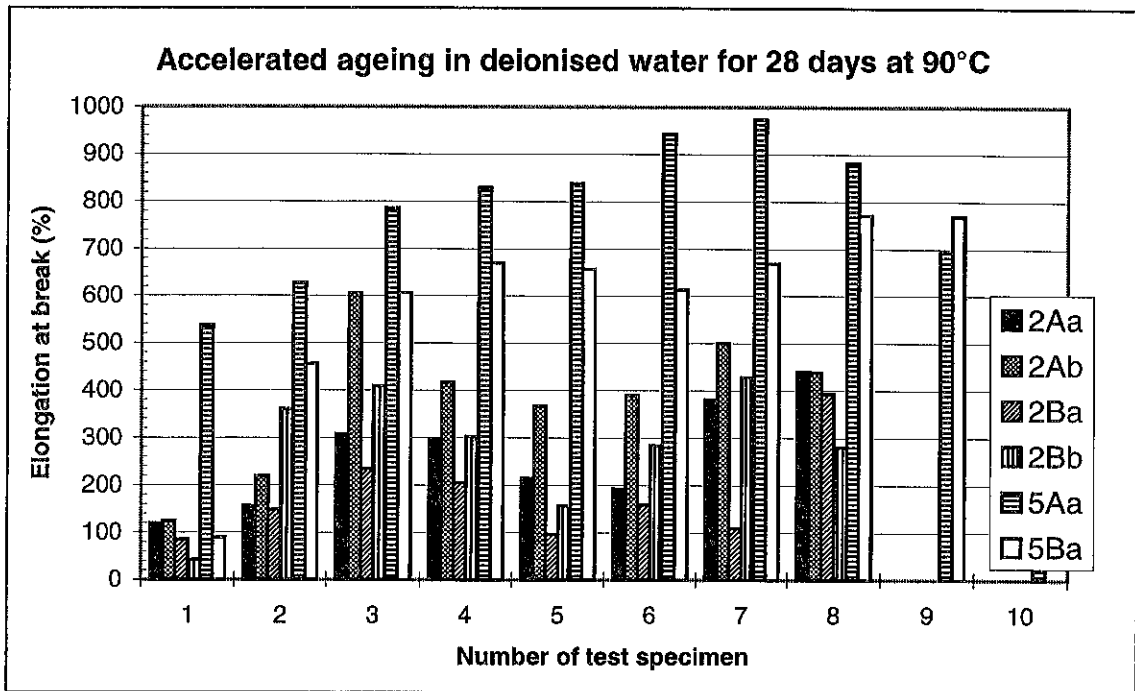


Figure 6 n-type of test pieces of PE-film (F2) aged in deionised water. Test pieces 2 were immersed in large glass containers, test pieces 5 were immersed in small glass containers.

Table 4 Mean values for various types of test pieces after ageing in deionised water for 28 days at 90°C

I-type	Elongation at break (%)	U-type	Elongation at break (%)	n-type	Elongation at break (%)
1A	88	3Aa	358	2Aa	284
1C	176	3Ab	357	2Ab	419
4A	113	3Ba	284	2Ba	192
4B	201	3Bb	283	2Bb	317
4C	504	6Aa	691	5Aa	796
		6Ba	773	5Ba	651

Looking at elongation at break of individual test specimens as a function of the distance from water surface it is clear that test specimens nearest to the water surface show up the lowest values. This is probably due to a bigger supply of oxygen in the uppermost part of water which causes strongest oxidation.

4 Conclusions

High alkalinity of the fresh concrete is of significant importance for the ageing time. The t_{50} -values corresponding to the exposure with "old" concrete as top prism were of the same magnitude as the values from the moist air exposure. The same result was also achieved using sheets of glass instead of old concrete prism on the top.

The ageing time in some aquatic solutions was in the range between ageing in contact with fresh wet concrete and in moist air exempt for solutions containing iron sulphate. The conclusion must be that there are components in concrete that accelerate degradation of PE-film while iron sulphate seems to prevent PE-film from degradation.

The most aggressive aquatic solution was constitute by deionised water which seems to be even more aggressive than alkaline solutions like NaOH and CaO. Elongation at break of individual test specimens nearest to the water surface shows up the lowest values. This is probably due to a bigger supply of oxygen in the uppermost part of water which causes strongest oxidation.

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